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Preparation of cotton knitted fabric by gamma radiation: A new approach

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ABSTRACT

This study attempts to introduce the exploitation of gamma radiation for the processing of cotton knitted fabric. A systematic investigation into the situations suitable for eco-friendly preparation (scouring and bleaching) of cotton fabric was carried out. Fabric used in this experiment includes cotton knitted single jersey structure of 160 gsm. The grey cotton knitted fabric was immersed in different (0 – 30 g/L) amount of hydrogen peroxide solution for 10 min. Subsequently, the samples were irradiated under Co-60 gamma radiation of absorbed dose (5–20 kGy) at a dose rate 5 kGy/h. Water absorbency, whiteness index (WI), weight loss, bursting strength, elongation at burst and dye uptake were taken as the measure of extent of scouring and bleaching performance of the intended fabric. The new technology yielded product with acceptable whiteness and water absorbency which is suitable for pale shade dyeing. The optimum results were achieved for the sample irradiated at a total dose 5 kGy treated with 10 g/L H_2O_2 solution. The water absorbency and WI value were 2.4 s and 39.43, respectively, as well as 82.2% dye exhaustion was obtained having the bursting strength 203.20 kPa for this option. But higher dose of radiation was found responsible for lowering the bursting strength of the fabric. However, the irradiated samples demonstrated the good dye-ability indicating the excellent level dyeing with Bezaktive Red S-3B and Novacron Yellow ST-3R reactive dyes.

1. Introduction

Cotton is considered as the purest form of cellulose in nature. It contains 88–96% α-cellulose (Karmakar, 1999). Even with this cotton fiber exhibits some noncellulosic materials such as protein (1–1.9%), wax (0.4–1.2%), ash as inorganic salts (0.7–1.6%), pectin (0.4–1.2%) and others substances which include natural resins, pigments, hemi-cellulose, sugars, organic acids and incrusted ligneous substances (0.5–8%) and the share of these impurities ranges from 4 to 12% (Hebeish et al., 2009; Lewin & Mark, 2007). Among them wax is very difficult to remove from the fiber surface. The cotton wax is composed of wax ester, phytosterol, polyterpenes, hydrocarbons, free wax alcohol, soapnifiable, nonsoapnifiable and inert wax. The melting point of cotton wax varies from 68 to 80 °C depending on the geographical position of cotton cultivation. The wax links with cellulose by phosphatides, amino acids, glucose and wax acid linkage. The pectin of cotton remains as insoluble salts of calcium, magnesium and ferrous of poly-D-galacturonic acid. On the other hand, most of the proteins are located in the cavity or in the lumen of cotton fiber and their contribution in the primary wall is around 14% on dry weight basis. The protein components are generally leucine, valine, proline, alanine, oxyprotein, threonine, glutamic acid, glycine, serine, aspartic acid, aspergine, lysine and arginine (Karmakar, 1999). The yellowish and brown discoloration of cotton fiber is due to the protoplasmic residues of proteins (Carr, 1995; Lewin & Sello, 1984) and the flavones pigments of cotton flowers. Natural cotton fiber becomes hydrophobic due to the presence of these non-cellulosic impurities which is attached mostly in the cuticle or in the outer layer of cotton fiber (Degani, Gepstein, & Dosoretz, 2004).

Cotton fiber has some unique properties such as it is soft, comfortable, high moisture absorbent, hygienic and biodegradable. It is predominantly consumed in the apparel industries due to these reasons. As a result the share of cotton fiber is about 48% in the global fiber consumption market (Bashar & Khan, 2013). But the processing of cotton fiber is hazardous and deploys toxic pollution load to the environment. The conventional preparation of cotton demands high alkaline condition at an elevated temperature (Calafell & Garriga, 2004). In addition, huge amount of fresh

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water is required for this preparation of cotton and hence creating soaring problem converting valuable water into toxic effluent. On the contrary, the source of water used in the textile industries is very commonly the ground water in a rapid industry growing country like Bangladesh. As a result the water layer is going down day by day which would create severe fresh water scarcity in future. This detrimental impact of conventional processing of cotton textiles and stringent environmental legislation are fostering the researchers around the world to innovate a cleaner technology and ecological supporting techniques. Several researchers around the globe has tried to modify the conventional method by using various specialized chemicals and methods and thus reported improved properties with less pollution load and economical possibility (Abdel-Halim, 2012a,b; Abdel-Halim & Al-Deyab, 2011; Öner & Sahinbaskan, 2011; Preša & Tavčer, 2009; Lim, Lee, Hinks, & Hauser, 2005). But they had applied substituted chemicals which had still some harmful impact on environment. Various workers had tried enzymatic preparation in search for an eco-friendly cotton processing (Flitsch et al., 2013; Shafie, Fouda, & Hashem, 2009; Hebeish et al., 2009; Wang et al., 2008; Wang, Fan, Hua, & Chen, 2007; Calafell & Garriga, 2004; Choe, Nam, Kook, Chung, & Cavaco-Paulo, 2004; Aly, Moustafa, & Hebeish, 2004; Buschle-Diller, Yang, & Yamamoto, 2001; Lin & Hsieh, 2001; Tzanov, Calafell, Guebitz, & Cavaco-Paulo, 2001; Etters, 1999; Csiszar, Szakács, & Rusznak, 1998; Sawada, Tokino, Ueda, & Wang, 1998). However some researchers have reported the application of ultrasonic energy in combination with enzymes to accelerate the process efficiency and performance (Wang, Yu, & Zhong, 2012; Condon et al., 2009; Yachmenev, Blanchard, & Lambert, 2004; Yachmenev, Bertoniere, & Blanchard, 2001). But most of the researchers concluded that only a single enzyme cannot efficiently be applied in scouring and bleaching of cotton fibers. On the other hand, an enzymatic method of preparing cotton goods is not universally applied for all types of shade because the degree of whiteness obtained by this method is not similar with the conventional technique. The fabric treated by enzymes can be used proficiently for dark shades such as black, navy etc. but not suitable for light or pale shade. Moreover, a color produced on enzymatic scoured fabric is not as bright as conventional one. Some researchers have tried to show a proficient and cleaner process of cotton preparation other than enzymes. Eren and Ozturk (2011) had tried ozonation technique for the pretreatment of cotton fabric. They concluded that the sample prepared through ozonation technique has sufficient water absorbency, whiteness index without severe damage of the fiber. Some other workers had also reported the application ozone for the preparation of cotton textiles (Perincek, Duran, Korlu, & Bahtiyari, 2007; Prabaharan, Nayar, Kumar, & Rao, 2000). Meanwhile Sun and Stylios (2004) tried low temperature plasma for the processing of natural fiber such as cotton and wool. But within our review studies none of the researchers have tried radiation technology for the preparation of cotton fiber. Ionizing radiation has been successfully applied in the management of industrial effluent for many years (Bhuiyan, Rahman, Shaid, & Khan, 2014; Rauf & Ashraf, 2009; Duarte et al., 2004; Shin et al., 2002; Han et al., 2002; Duarte et al., 2000; Sampa et al., 1995). Radiation technology could efficiently replace the hazardous and toxic cotton fabric preparation as virtually there is no demand any additional chemicals in this process. Gamma radiation is one of the strongest ionization radiations that can produce free radicals in presence of water. This free radicals generation is further intensified in presence of H_2O_2. Thus the free radicals would effectively destroy or converted any natural impurities in cotton fiber. The goal of the study was to discover the feasibility of gamma radiation in preparation of cotton fiber for the replacement of hazardous conventional processing technique. In this study gamma radiation was applied on hydrogen peroxide treated grey cotton fabric. After irradiation the fabric was washed at 60 °C for 10 min. The performance evaluated are water absorbency, whiteness index (WI), bursting strength, and dye-ability. The surface morphology of treated and untreated fabric and FT-IR analysis were also studied. The properties achieved through this technique were compared with the commercial conventional alkaline scoured bleached fabric.

Table 1
Identification of the various samples for irradiation and treatment with H_2O_2.

Identification	Concentration of H_2O_2 (g/L)	Total dose (kGy)
A_1	0	5
A_2	10	
A_3	20	
A_4	30	
B_1	0	10
B_2	10	
B_3	20	
B_4	30	
C_1	0	15
C_2	10	
C_3	20	
C_4	30	
D_1	0	20
D_2	10	
D_3	20	
D_4	30	

2. Experimental

2.1. Materials

One hundred percent cotton 22.7 tex combed yarn was used to manufacture the fabric. The fabric was knitted in single jersey structure of 160 grams per square meter (gsm) at knitting laboratory of Department of Textile Engineering of Mawlana Bhashani Science and Technology University, Santosh, Tangail, Bangladesh. The fabric has the following geometrical properties: course per inch (CPI) = 48, Wales per inch (WPI) = 37, stitch length = 2.75 mm. The color of the grey cotton fabric was creamy white. The detergent (Felson NOF), stabilizer and Bezaktive Red S-3B reactive dye were collected from CHT BEZEMA group, Germany. On the other hand Novacron Yellow ST-3R was obtained from Huntsman, Switzerland. These chemicals are commercial grade and some basic chemicals such as acetic acid, hydrogen peroxide, caustic soda, gluber salt and soda ash were collected from Merck Germany and were analytical grade. All the chemicals/reagents were used as received without any further treatment or purification.

2.2. Sampling

Grey cotton fabric was cut into 12 cm × 12 cm dimension. The samples were immersed in 0, 10, 20 and 30 g/L·H_2O_2 solution for 10 min. The samples are then sealed in polyethylene bag and were ready for irradiation. The prepared samples were divided into A, B, C and D group on the basis of total dose 5, 10, 15 and 20 kGy, respectively. Each of the above group was subdivided into four (e.g, A_1 = 0, A_2 = 10, A_3 = 20 and A_4 = 30 g/L) groups according to the treatment with H_2O_2. Therefore the samples were identified as follows (Table 1).

2.3. Irradiation

The prepared samples were irradiated under Co-60 gamma radiation at Institute of Radiation and Polymer Technology (IRPT), in Bangladesh Atomic Energy Commission, Dhaka, Bangladesh. The total absorbed doses were 5, 10, 15 and 20 kGy at a dose rate 5 kGy/h.

Table 2
Recipe for conventional scouring and bleaching.

Reagents (parameters)	Amount
Sodium hydroxide (NaOH)	2 g/L
Hydrogen peroxide (50%)	2 g/L
Detergent (Felson NOF)	1 g/L
Stabilizer	0.5 g/L
M:L	1:10
Temperature	95 °C
Time	1 h

2.4. Conventional scouring

Five grams of gray cotton fabric was scoured and bleached according to the following recipe (Table 2).

The scoured and bleached fabrics were rinsed twice with water and neutralized with 0.1% acetic acid solution and the samples were air dried.

2.5. Scanning electron microscopy (SEM)

Surface morphology of cotton fabric was probed by FEI Inspect (Material Research Laboratory, USA) at Atomic Energy Centre, Bangladesh Atomic Energy Commission, Dhaka, Bangladesh at the magnification up to 1000×.

2.6. FT-IR spectra of cotton knit fabric

FT-IR spectra of different specimens were measured by IR Affinity (Shimadzu Corporation, Japan) at Mawlana Bhashani Science and Technology University, Bangladesh. The raw cotton fabric was extracted by chloroform and left for evaporation. The residue of the raw cotton was mixed with KBr pellets and formed into disc. On the contrary, differently treated cotton fabrics were cut and ground and mixed with KBr pellet to produce disc.

2.7. Determination of weight loss

The samples were dried in oven at 105 °C for 1 h and conditioned at 55% relative humidity and at a temperature 20 °C for 30 min. Afterwards, the weight of the each sample was measured and the percentage weight loss of the sample was calculated.

2.8. Determination of water absorbency

The water absorbency of different fabric samples was measured according to AATCC test method 79–2000 (AATCC, 2000a,b). Fabric was mounted on an embroidery hoop with the diameter of 5 in. and distilled water was taken in a burette. The tip of the burette was adjusted 2 cm high from the fabric surface. The water drop was allowed to fall on the fabric. During this time a stopwatch was started and recorded the time until the water drop was absorbed. Five drops in different place of the fabric surface were taken and the average time was recorded as the water absorbency.

2.9. Determination of whiteness index (WI)

The whiteness index was measured according to AATCC test method 110-1995 (AATCC, 1995; Lim et al., 2005). The CIE whiteness was measured on a Datacolor Spectroflash SF 650X with the following settings: illuminant D65, large area view (LUV), specular excluded and CIE 1964 supplemental standard observer (10° observer). Each sample was folded twice to give an opaque view with four plies and the whiteness was measured four times at different fabric surface. The CIE whiteness value was then recorded automatically.

2.10. Determination of bursting strength and elongation at burst

The bursting strength and the elongation at burst were measured according to BSEN ISO 13938-2: 1999 (BSENISO, 1999). According to this method a test specimen of 50 cm^2 diameter was clamped over an expansive diaphragm by means of a circular clamping ring. Increasing compressed air is applied to the underside of the diaphragm causing distension of the diaphragm and the fabric. The pressure increased smoothly until the test specimen bursts. The bursting strength and bursting distension were determined. The pressure of the machine was adjusted so that it would burst the sample in 20 ± 3 s. Three tests were carried out and the mean of the bursting strength in kPa and distension in mm were recorded.

2.11. Dyeing of irradiated and conventional prepared fabric

The conventional prepared and irradiated samples were dyed with reactive dyes such as Bezaktive Red S-3B and Novacron Yellow ST-3R in 0.1% (on the weight of fabric) shade with liquor to goods ratio 10:1. In the dye bath 10 g/L gluber salt and 5 g/L sodium carbonate were used for dye exhaustion and fixation reaction, respectively. The dyeing was carried out 30 min at 60 °C. The unreacted dyes were removed from the dyed fabric surface with 0.5 g/L anionic detergent (Felson NOF) for 10 min at 70 °C. After that the fabric had been air dried.

2.12. Determination of exhaustion and color strength

The exhaustion of the dyed samples was measured by UV–visible spectrophotometer. The dye solution of before dyeing was diluted several times and different concentrations were run into the machine and subsequently measure the λ_{max}. The λ_{max} of Bezaktive Red S-3B and Novacron Yellow ST-3R dye was recorded 542 and 430 nm, respectively. Now the absorbance of the different sample after dyeing was measured and %E was calculated according to the following equation (Sun & Stylios, 2004).

$$\text{Exhaustion\%} = \frac{A_0 - A_t}{A_t} \times 100$$

where A_0 and A_t represent the absorbence of dye bath before and after dyeing, respectively.

The color strength of the dyed samples was measured by Datacolor Spectroflash SF 650X with the following settings: illuminant D65, large area view (LUV), specular included and CIE 1964 supplemental standard observer (10° observer). Each sample was folded twice to give an opaque view with four plies and the K/S value was measured automatically.

3. Results and discussion

3.1. SEM analysis of untreated and treated cotton fabric

Fig. 1 shows the SEM photograph of grey cotton knit fabric at 100, 200, 500 and 1000× magnification. The result showed that grey cotton fiber has natural convolution and having some adhering particulate at the surface of the fiber. These particulates resembles to natural impurities such as oil, wax, natural color etc. On the other hand Fig. 2 shows the SEM image of irradiated cotton knit fabric soaked with 10 g/L·H_2O_2 solution. It is indicative from the SEM photograph that irradiated cotton fiber is clean, free from particulate matter and smooth due to the synergistic action of gamma radiation and H_2O_2.

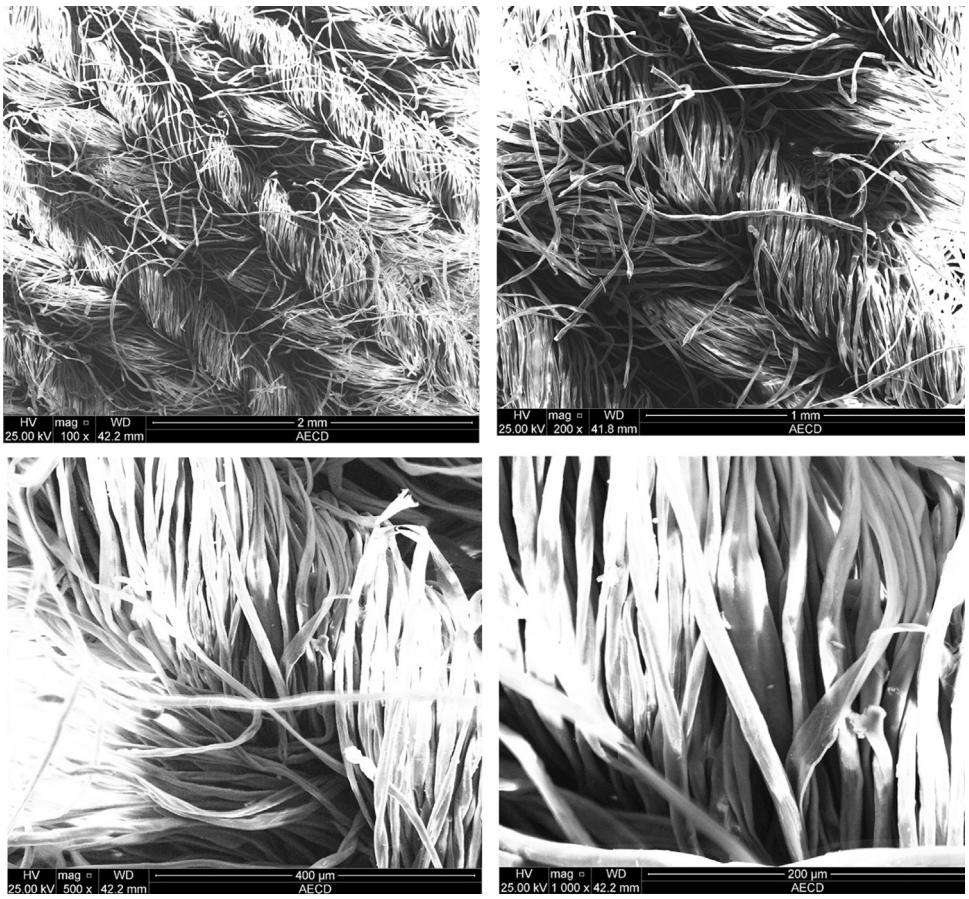

Fig. 1. SEM photograph of grey cotton knit fabric.

3.2. FT-IR spectra of cotton knitted fabric

FT-IR transmission spectra of raw cotton, raw cotton extract, irradiated cotton and dyed cotton was studied. In transmission mode the spectra were measured by KBr pellets made of finely cut and ground fabric. As a result the spectra showed only characteristic peaks of cellulose which is the major component of cotton fiber. But raw cotton also contains some impurities such as waxes, pectins etc. which are not detectable by transmission mode (Chung, Lee, & Choe, 2004) (Fig. 3).

The spectrum of raw cotton extract showed peaks at 2918 and 2849 cm^{-1} corresponding to the asymmetric and the symmetric stretching of methylene (—CH_2—) groups in long alkyl chains. This finding supports the work done by Chung et al. (2004).These peaks are responsible for the presence of waxes. Other impurities such as pectins showed characteristic peak in the region 1600–1800 cm^{-1}. On the other hand dyed cotton showed many weak peaks in 1100–1400 cm^{-1} regions which may be for ether bond with reactive dye and cellulose. These are not clearly detectable in IR transmission spectra (Figs. 4 and 5).

3.3. Analysis of water absorbency

The water absorbency of irradiated samples varied with total absorbed dose and concentration of H_2O_2. Fig. 6 describes the absorbency at 5, 10, 15 and 20 kGy against 0, 10, 20 and 30 g/L hydrogen peroxide concentration. The time required to absorb the water drop from the fabric surface was recorded 1.17, 2.4, 1, 1.4 and 1.4, 3, 2, 2 and 3, 2, 1, 1 and 1.5, 2, 1 and 1 s for A_1, A_2, A_3, A_4, and B_1, B_2, B_3, B_4 and C_1, C_2, C_3, C_4 and D_1, D_2, D_3, D_4, respectively. In general the water absorbency of the irradiated samples was higher for higher concentration of hydrogen peroxide for the same total absorbed dose. The water absorbency of all irradiated samples was uniform and regular on the fabric surface. The water absorption time for B_2 and C_1 was found 3 s and for B_3, B_4, C_2 and D_2 is 2 s. Other combination of treatment showed water absorbency of around 1 s. Even some treatment combinations absorbed water in less than 1 s. Thus all the irradiated samples absorbed water readily and were suitable enough to absorb the dye solution or finish liquors.

3.4. Analysis of whiteness index

The CIE whiteness index (WI) of the treated samples increased with the increase of total absorbed dose and concentration of H_2O_2. Fig. 7 demonstrates the WI values for different treatment options. The lowest WI values were obtained for A_1, B_1, C_1 and D_1 options whose corresponding values were 11.35, 12.42, 14.65 and 16.08 accordingly. These samples are not suitable for pale shade dyeing as they contained significant amount of natural colors even after irradiation. Higher whiteness index values were found for higher total absorbed dose. But the effect of total absorbed dose was little on WI values. Meanwhile the amount of hydrogen peroxide has significant impact for increasing the whiteness of the sample. The maximum whiteness was achieved for D_4, C_4, B_4 and A_4 for 20, 15, 10 and 5 kGy absorbed dose whose values stood 53.98, 53.23, 52.89 and 45.46, respectively. These results explained that hydrogen peroxide induced the free radical generation to a great extent which triggered accelerated free radical generation while irradiation and consequently the natural color destruction was also much pronounced.

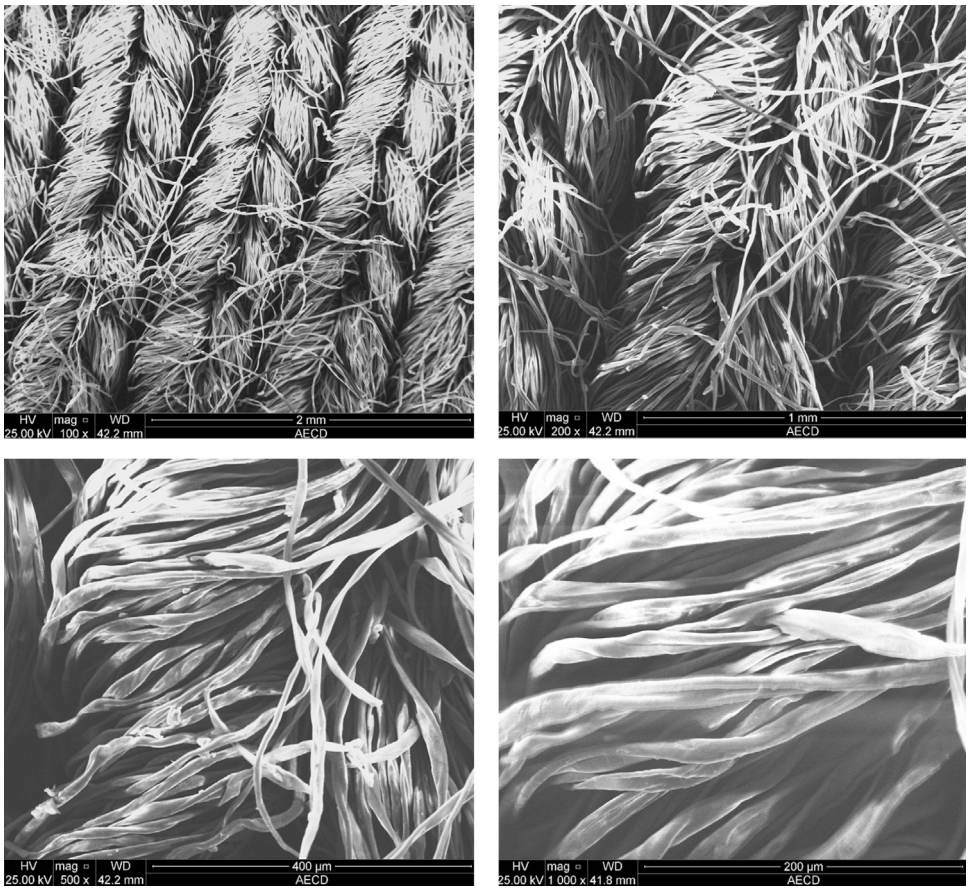

Fig. 2. SEM photograph of irradiated cotton knit fabric at 5 kGy soaked with 10 g/L H_2O_2 solution.

The lowest WI value but suitable for pale shade dyeing was found against A_2 option which was treated under 5 kGy total dose and soaked with 10 g/L H_2O_2. This sample was equally competent with conventional scoured fabric in respect to color brilliance and depth of shade.

3.5. Analysis of weight loss

The weight loss of grey cotton is the result of loss of non-cellulosic materials from the fabric. Generally conventional alkaline scouring with hydrogen peroxide accompanied with 5–10% weight loss (William, 1995). This is for the removal of several hydrocarbons, pectins, wax etc. In irradiated samples the weight loss ranged from 1.084 to 2.85 for different doses and different hydrogen peroxide concentration. Four different doses 5, 10, 15 and 20 kGy with four concentration of H_2O_2 such as 0, 10, 20 and 30 g/L were used to investigate the scouring and bleaching effect of cotton knitted fabric. When the total absorbed dose was intensified the weight loss was increased as well. This is true for increasing the concentration of H_2O_2 also. From Fig. 8, it is observed that the weight loss is lower for A_1, B_1, and C_1 and D_1. These samples were irradiated without H_2O_2. The highest weight loss obtained for C_3, B_3, D_4 and A_4 options whose corresponding value is about 2.85, 2.65, 2.58 and 2.5%. The weight loss is higher for higher absorbed dose and higher concentration of H_2O_2 with some exceptions.

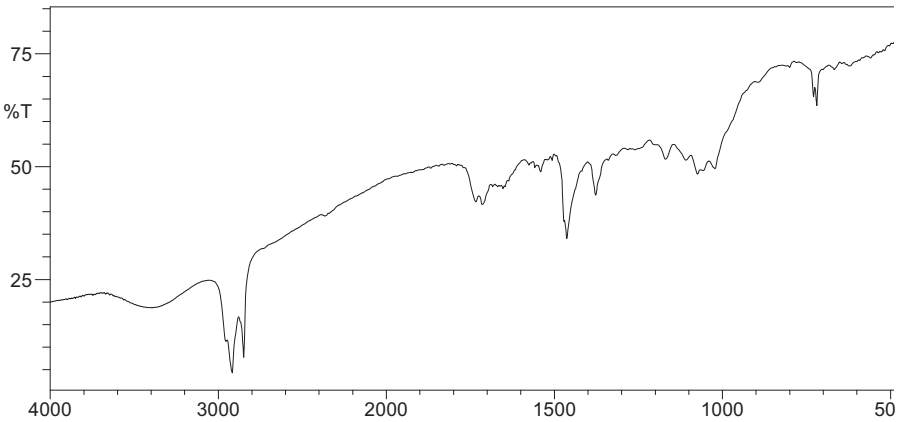

Fig. 3. Transmission mode spectra of raw cotton extract.

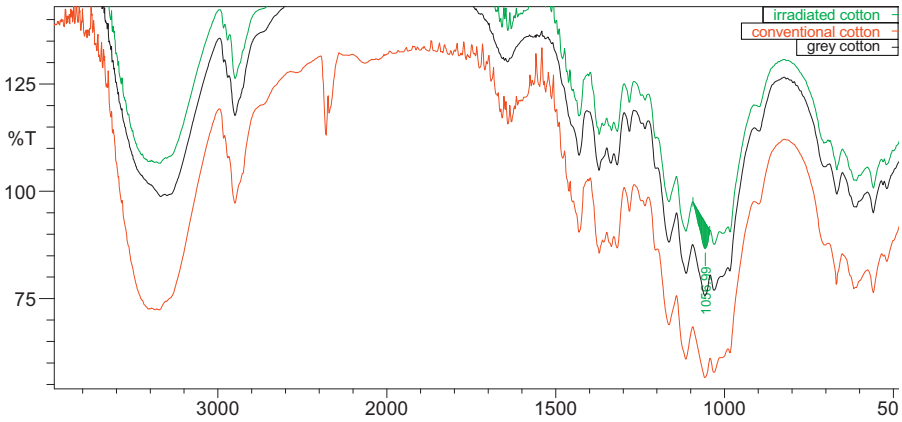

Fig. 4. Transmission spectra of grey, conventional scoured and irradiated cotton fabric.

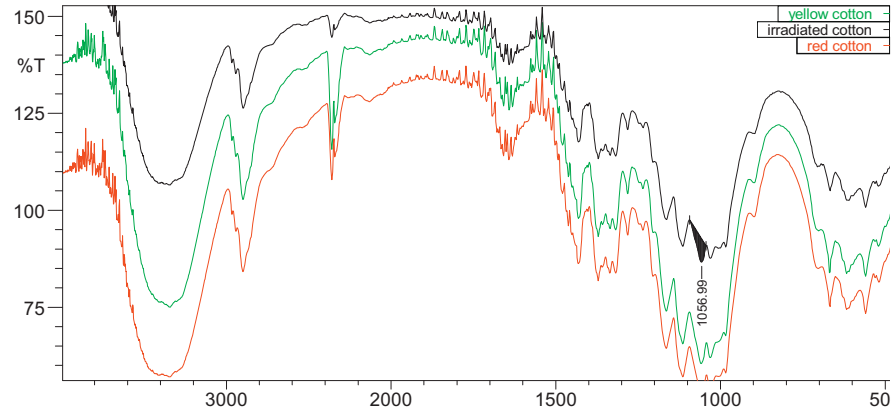

Fig. 5. Transmission spectra of irradiated dyed cotton fabric.

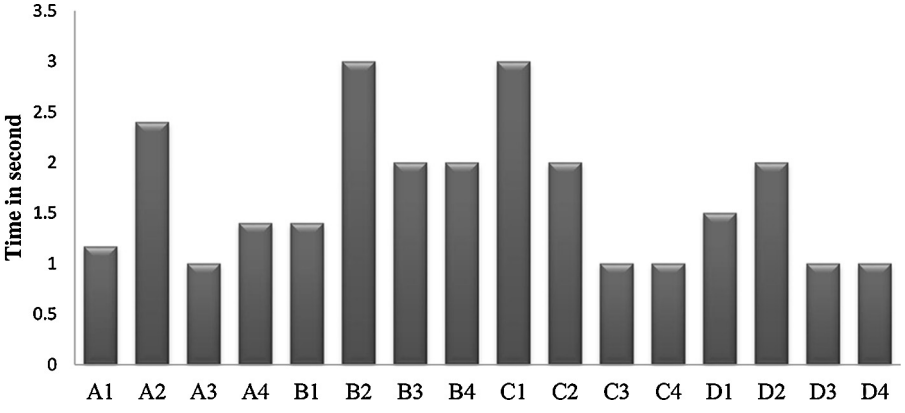

Fig. 6. The water absorbency of irradiated samples treated with hydrogen peroxide.

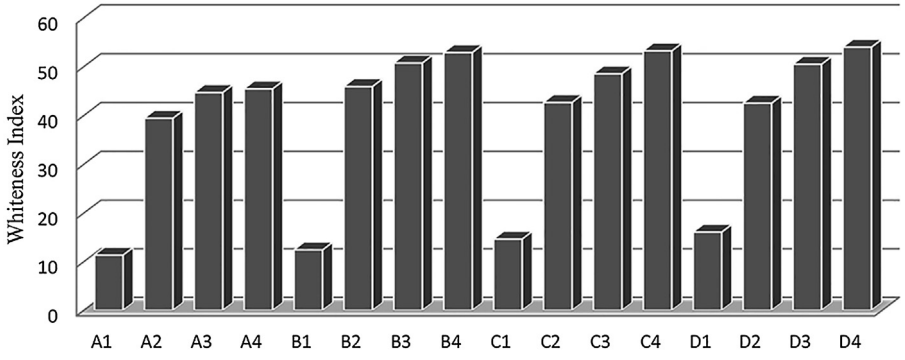

Fig. 7. CIE whiteness index of irradiated samples.

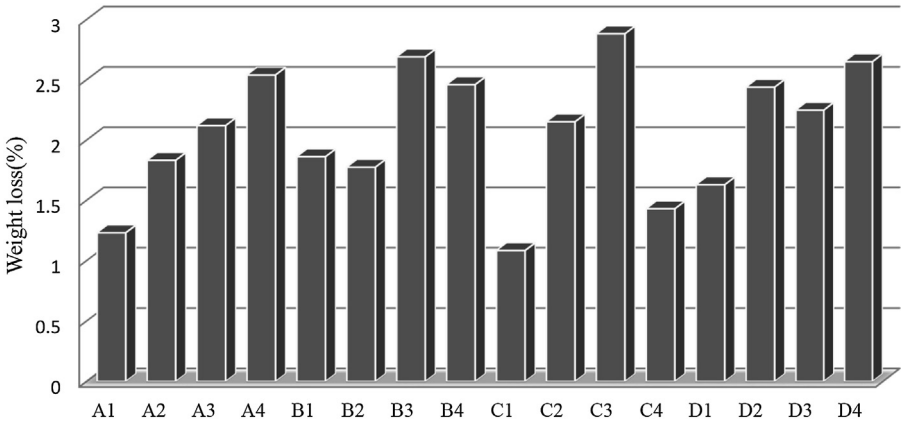

Fig. 8. Effect of total absorbed dose and H_2O_2 concentration on weight loss for irradiated samples.

3.6. Analysis of bursting strength and extension

The strength of the samples were measured by bursting strength tester and expressed in kPa with equivalent extension value in mm. Generally bursting strength correlates with the weight loss. Higher weight loss indicates the higher strength loss. Fig. 9 expressed the bursting strength of the irradiated samples. The bursting strength decreased with the increase of total absorbed dose and concentration of hydrogen peroxide. The strength of the irradiated sample found 210.4, 203.2, 181.7, 177.3 kPa for A_1, A_2, A_3, A_4, and 191.2, 184, 181.8, 179.4 kPa for B_1, B_2, B_3, B_4, and 188.5, 183.4, 181.7, 177.3 kPa for C_1, C_2, C_3, C_4 and 182.7, 176.7, 155.4, 160.1 kPa for D_1, D_2, D_3, D_4 options, respectively.

The lowest bursting strength was obtained for D_3 and maximum strength was recorded for A_1 option where D_3 was treated with 20 g/L H_2O_2 and A_1 was treated with 0 g/L·H_2O_2 and irradiated at 20 and 5 kGy dose, respectively. In each option the sample which was not soaked with hydrogen peroxide showed comparatively higher bursting strength and lower strength are found for higher doses and higher amount of hydrogen peroxide concentrations. For instance, the bursting strength for 10 kGy against 0, 10, 20 and 30 g/L hydrogen peroxide concentration was achieved 191.12, 184, 181.8 and 179.4 kPa which were in decreasing fashion. This phenomenon was progressively observed for all treatment combinations. This can be explained that for the higher doses in presence of higher H_2O_2 concentrations the generation of free radicals was also higher which attacked the polymer chain molecule more vigorously.

Fig. 10 shows the extension manner of irradiated samples. From the figure it is obvious that higher extension of the fabric was recorded for the samples which exhibit higher strength and vice-versa.

3.7. Exhaustion and color strength analysis

The exhaustion and color strength of a shade indicate the dyeability of a fabric. The exhaustion of irradiated sample showed variable phenomena for different doses and different hydrogen peroxide concentrations. Though the shade produced in the irradiated fabric shows excellent uniformity in color as the dyed samples were visually assessed under D65 light box. Figs. 11 and 12 indicate the exhaustion and color strength (K/S) of Bezaktive Red S-3B (Dye_1) and Novacron Yellow ST-3R (Dye_2) reactive dyes. The exhaustion of Dye_2 is higher than that of Dye_1. This may be due to the molecular structure and substantivity of the dyes. The exhaustion of Dye_1 is 27.0, 82.20, 46.29, 71.82 for A_1, A_2, A_3, A_4, and 21.0, 73.80, 59.76, 63.96 for B_1, B_2, B_3, B_4 and 27.0, 44.04, 46.56, 62.85 for C_1, C_2, C_3, C_4 and 24.0, 44.61, 39.00, 98.49 for D_1, D_2, D_3, and D_4, respectively. On the contrary color exhaustion of Dye_2 was obtained 75.86, 79, 84.24, 75.86% for A_1, A_2, A_3, A_4 and 83, 78, 81.77, 75.12% for B_1, B_2, B_3, B_4 and 77, 76.85, 75.86, 72.17% for C_1, C_2, C_3, C_4 and 71.18, 69.70, 70.20, 80.79% for D_1, D_2, D_3, D_4 treatment options correspondingly. From this result it clear that the exhaustion of Dye_1 is higher than that of Dye_2 for every treatment option. Another fact is that the exhaustion pattern of Dye_2 is more regular than for Dye_1. The value of color exhaustion is lower for higher absorbed doses and higher concentration of hydrogen peroxide without some exceptions. This manner of dye exhaustion can be hypothesized that due to higher dose in presence of higher peroxide concentration the

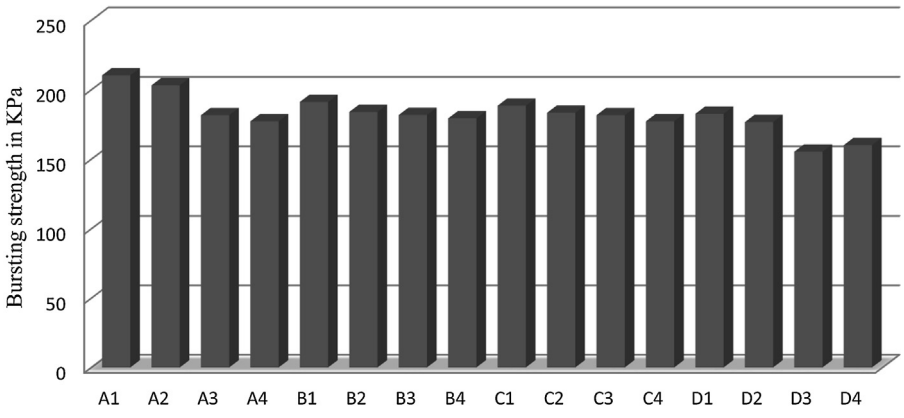

Fig. 9. Effect of total absorbed dose on busting strengths of samples treated with hydrogen peroxide.

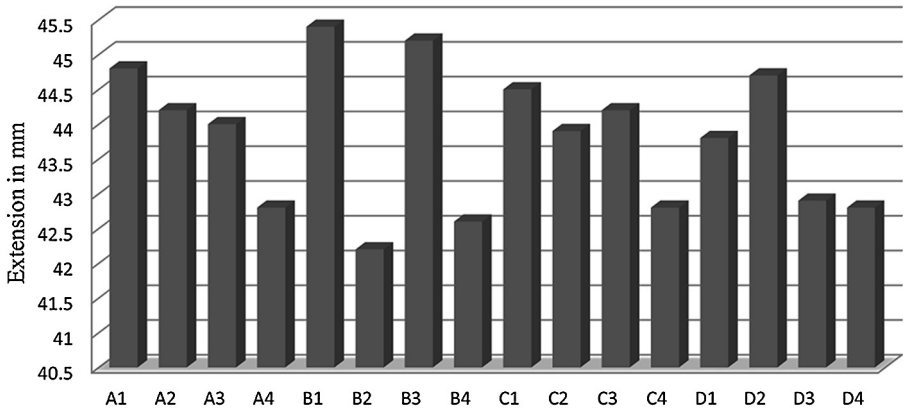

Fig. 10. Elongation properties of irradiated sample at burst.

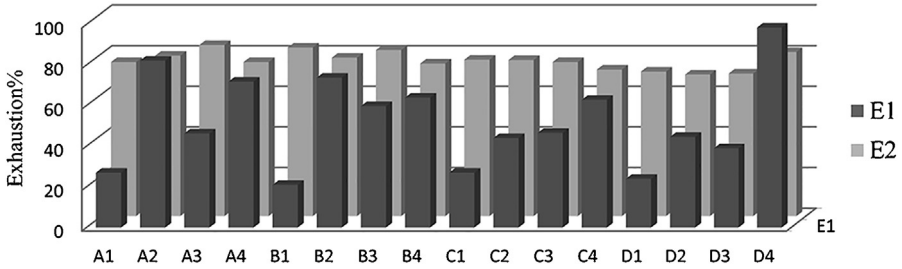

Fig. 11. Color exhaustion pattern of irradiated fabric for Bezaktive Red S-3B and Novacron Yellow ST-3R reactive dyes.

change of cellulose structural morphology is much pronounced that can adversely affect the substantivity of cellulose to dyes.

The color strength (K/S) value of the treated samples was in the range of 1.22 to 1.29 for Dye_1. This data support that all the samples treated with different variation of absorbed dose and hydrogen peroxide concentration are suitable to produce light shade with sufficient brilliance. The lowest dose and lowest hydrogen peroxide concentration are 5 kGy and 10 g/L, respectively. The sample treated with this combination is also competent for light color dyeing.

The color strength for A_1, B_1, C_1 and D_1 is not detectable. These treatment option stand for 5, 10, 15 and 20 kGy absorbed dose without hydrogen peroxide. Because these samples were not sufficiently bleached and some natural colors are remaining in the fabric surface. These samples exhibited lowest WI values also (Fig. 7). As a result the natural color interferes with the applied dyes. But these samples exhibit exhaustion to a certain level as the non-cellulosic hydrophobic materials may be removed or converted into water soluble materials for which these samples showed better exhaustion.

3.8. Comparative analysis of irradiated and conventional scoured and bleached fabric

Table 3 shows the comparative data of conventionally scoured bleached and irradiated fabric. It is noteworthy that all the samples with variable absorbency are suitable to absorb dyes solution and finishing chemicals. Some irradiated sample such A_3 and C_4 show better absorbency. In this case the time required was less than 1 s. The samples exhibit higher absorbency showed more bleaching effect (higher value for whiteness index) and higher strength loss. The whiteness index directly correlates the bleaching performance. The WI value for conventional scoured and bleached fabric is 68. On the other hand the highest WI value for irradiated sample was recorded 53.98 against D_4 treatment option. Though the WI of irradiated samples is lower than the conventional scoured fabric it is

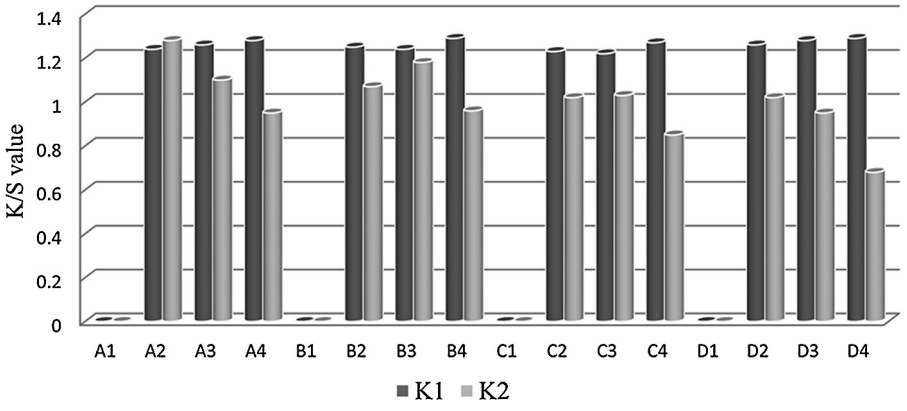

Fig. 12. Color strength of irradiated dyed fabric for Bezaktive Red S-3B and Novacron Yellow ST-3R reactive dyes.

Table 3
Comparative results of conventional prepared and irradiated fabric.

Sample identification	Absorbency (S)	WI	W. Loss (%)	Strength (kPa)	Exhaustion (%)		Color strength (*K*/*S*)	
					E_1	E_2	K_1	K_2
A_1	1.17	11.35	1.231	210.4	27	75.86	*	*
A_2	2.4	39.43	1.832	203.2	82.20	79.0	1.28	1.28
A_3	<1	44.71	2.12	181.7	46.29	84.24	1.25	1.10
A_4	1.4	45.46	2.54	177.3	71.82	75.86	1.26	0.95
B_1	1.4	12.42	1.862	191.2	21	83.0	*	*
B_2	3	45.93	1.775	184.0	73.80	78.0	1.25	1.07
B_3	2	50.75	2.69	181.8	59.76	81.77	1.24	1.18
B_4	2	52.89	2.46	179.4	63.96	75.12	1.29	0.96
C_1	3	14.65	1.084	188.5	27	77.0	*	*
C_2	2	42.67	2.152	183.4	44.04	76.85	1.23	1.02
C_3	1	48.54	2.882	181.7	46.56	75.86	1.22	1.03
C_4	<1	53.23	1.43	177.3	62.85	72.17	1.27	0.85
D_1	1.5	16.08	1.63	182.7	24	71.18	*	*
D_2	2	42.52	2.439	176.7	44.61	69.70	1.23	1.02
D_3	1	50.48	2.248	155.4	39.00	70.20	1.23	0.95
D_4	1	53.98	2.650	160.1	98.49	80.79	1.29	0.68
Conventional prepared	1	68	4	222.7	98.76	90	1.3	1.18
Gray cotton	–	–	–	239.1	–	–	–	–

E_1 = exhaustion of Bezaktive Red S-3B, E_2 = exhaustion of Novacron Yellow ST-3R, K_1 = color strength of Bezaktive Red S-3B, K_2 = color strength of Novacron Yellow ST-3R.
* Not detectable.

suitable to produce light color with sufficient brightness. The sample with WI value of around 39.43 is suitable for level dyeing. This WI value is obtained for A_2 combination. Conversely, the weight loss of the irradiated sample was lower than the conventional scoured bleached fabric. The weight loss of irradiated sample ranged from 1.084 to 2.65% for different absorbed doses and different hydrogen peroxide concentration. However, the conventionally prepared sample accounted 4% weight loss. But the strength of conventional scoured and bleached sample is higher than the irradiated samples. The bursting strength of conventional scoured and bleached fabric was recorded 222.7 kPa whereas the sample of A_1 treatment option showed strength at burst 210.4 kPa. But this sample was not suitable for light color production. The maximum and minimum bursting strength of the dye-able irradiated sample were 203.2 and 155.4 kPa for A_2 and D_3 options, respectively. The conventional prepared sample Exhibits 7% strength loss in respect to the strength of the grey fabric while the irradiated sample showed 15% strength loss for the same grey fabric. The color exhaustion of the irradiated samples was lower than the conventional prepared sample but the depth of shade was comparable with the conventional scoured and bleached fabric.

4. Conclusions

Grey cotton knitted fabric was subjected to irradiation treated with varying amounts of hydrogen peroxide. The results obtained from the experiment showed excellent water absorbency and satisfactory whiteness value for irradiated samples. The brightness and brilliance of the irradiated dyed fabric were equivalent to that of conventional scoured and bleached fabric. The most favorable results were achieved for 5 kGy total dose and treated with 10 g/L H_2O_2 (A_2 option). The irradiated samples showed 15% strength loss in respect to the strength of grey fabric whereas the conventional method indicated 7%. Nevertheless, the application of radiation for the preparation of cotton textiles is eco-friendly and less water consuming process. The conventional scouring and bleaching process is water intensive and hence produce huge amount of toxic effluent which is non biodegradable. On the other hand, radiation technology generates less effluent as the water consumption is very little as well as the effluent produced in this way may contain decomposed hydrogen peroxide and some fragments of cellulose which is also bio degradable. Consequently it is imperative that lower dose of radiation would be suitable for the preparation of the cotton fabric. However, further studies can be carried out for the optimization of total absorbed dose and the concentration of hydrogen peroxide.

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