Investigation of Low Formaldehyde Easy-Care Textile Finishes on Dyed Cotton Fabric

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Summary: Crosslinking of cellulose is considered a necessary process in creating anti-wrinkling cotton fabrics. In the recent years, the concern of buyers regarding the wrinkle-resistant fabric has increased the demand of easy-care finishes. Formaldehyde based easy care finishes are carcinogenic but still used in the textile industry. Low formaldehyde reagents are being developed and tested to replace formaldehyde based easy care finishes. In this research the low formaldehyde easy care finishes; Fixapret ECO and Alkaknit WFR were investigated for their effect on color fastness to crocking, tear strength, tensile strength and durable press rating. Findings of the research showed that the there was a subsequent decrease in tensile and tear strength as compared to original fabric with the increase in resin concentration on both type of dyes. From the results we can say that higher the resin concentration, better the washing durability. This is due to the fact that resin decreases the chance of fiber chain displacement. The fabric with navy blue dye displayed much better performance and compatibility with non-formaldehyde resins as compared to turquoise blue dye.

Keywords: Easy-care finishes; Low formaldehyde; DMDHEU; Cotton fabric; Crosslinking.

Introduction

Industrial growth plays a very important role in the economic growth of any country [1]. Fabrics made of cellulose fibers for example viscose, cotton and flax, have necessary properties such as softness, comfort and absorbency [2, 3]. In textile industry, natural fibers (cotton fibers) play a vital role in preparation of garments. Because of high moisture absorbency, the garments made of cotton fabric are the most comfortable [4, 5]. The common disadvantages of using cotton fabric are easy soiling, microbial degradation, easy wrinkling, low protection to ultra violet radiation and little thermal stability [6-10]. The recent studies have revealed that the mechanical properties of cellulose and cellulosic blend fabric with easy- care finishes is highly subjected [11, 12]. The demand of easy-care finishes has focused the momentum of research in the field of textile finishing. Textiles with value added aspects that provide the customers with excellent fabric characteristics are antimicrobial properties, ultra violet blocking, self-cleaning, softness, comfort and safety [2, 3, 13-18]. Goal of the finishing is to convert dyed or printed and bleached fabric by chemical or mechanical treatments into a useful product for sale. Cotton can be colored by using several classes of dyes. 85% of the dyes used for cotton dyeing are sulphur (29%), vat (19.4%), reactive (9.7%) and direct (27.4%). Reactive dyes have extensive range of color with excellent washing fastness and brightness [19]. Reactive dyes need alkaline medium to react with cotton fiber and washing of the sample is needed [19]. Dye ability and easiness of handling are exclusive properties of the cotton fabric [20-22]. But due to weak bonding especially in the amorphous region it displays high wrinkling after washing [23].

Crosslinking agents are the product, which carry out resin finishing as an important textile process. It can be defined as a method in which cellulose fiber are reacted with specific compound, in a way that cellulose chains are connected together [24-30]. First efforts to overcome wrinkling was the use of formaldehyde base compounds specially dimethyloldihydroxyethylene urea (DMDHEU) [31-33]. For cotton cross-linkers, acidic pH, extended curing time and temperature with strong catalyst are needed [34]. To improve the crease resistant properties, appropriate portion of resilient resin or polymeric substances were introduced into polymeric fibers [35]. Different factors affect the proper formulation of the chemical finishes such as cost to benefit ratio, fiber type, compatibility or interaction of different formula components and purpose of finishing [5, 16]. Mechanical strength and whiteness index is reduced, when cross-linking is applied on cellulose fibers [11, 36-41]. Every cross-linker and resin has its own specific purpose in wrinkle resistant finishing. These are useful in producing shape retention, better dimension stability, crease resistant, increase smoothness and softness, more durable and better

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appearance and also improve wet fastness of prints and dyeing. These are not only environmentally friendly in applying and finished product, also show compatibility with other finishing agents, little loss in mechanical strength, minimum effect on handling and no effect on whiteness of fabric. The best durable finishing of cotton is done by a formulation which gives a balance between wrinkle resistant performance and ideal physical properties [42]. Add-on technique is used to accomplish easy-care finishing of cellulose fibers [4, 43].

Formaldehyde-free or low formaldehyde crosslinking agents were introduced because of the possible danger and environmental pollution of formaldehyde [44-47]. For the application of finishing followed by the dyeing of the fabric, is introduced to the cross-linker treatment [48]. Cross-linking is a good way to control wrinkling but the use on the dyed fabric can change the color [19]. Although there is extensive research on the comparison of low formaldehyde and formaldehyde resins on cotton [49] and knitted fabric [50]. There is no genuine specific work to evaluate the performance and quality of low formaldehyde resins on dyed cotton as this type of fabric has different characteristics then knitted and cotton fabric. Hence, the present study emphasizes on the assessment of the influence of low formaldehyde resins on different properties of dyed cotton which include tensile, tear, colorfastness to crocking and SA rating. Furthermore, it discusses the comparative study of non-treated samples (controlled) and treated samples so that the readers can better understand the working and application of different low formaldehyde based resins.

Experimental

The finishing effects of low formaldehyde easy care finishes on dyed cotton fabric was investigated by measuring the tear strength, tensile strength, colorfastness and washing test. The present research work was carried out in the research Lab of Alka PVT Ltd, Faisalabad.

Chemicals and reagents

All the chemicals to be used in this research work were of analytical grade, otherwise specified and were used without any further purification mainly including Reactive Turquoise Blue dye, Reactive Navy Blue dye, Soda ash (ICI), globular salt (ICI), Alkabid LDR (Alka PVT Ltd), Alkapan DPA (Alka PVT Ltd), Fixapret ECO (BASF), Alkaknit WFR (Alka PVT Ltd), $MgCl_2$ (Merck), Alkasoft PEN (polyethylene), Alkasil SIM and acetic acid.

Collection of materials

The fabric used for the project was 100% cotton (32×32/ 76×66) donated by Dawood Export for research. The dyes Reactive Turquoise Blue (C.I. Turquoise blue 03) and Reactive Navy Blue (C.I. Reactive blue 21) and resins i.e. Fixapret ECO and Alkaknit WFR (modified dimethyloldihydroxyethylene urea) having low formaldehyde values were donated by Alka PVT Ltd, Faisalabad for research work.

Application of easy- care finish

The grey cotton fabric (32×32/ 76×66) was desized, bleached and dyed [51, 44]. In the dyeing process, samples were cut in appropriate sizes (16inch × 16 inch). Cotton fabric was dyed in light shade (2%) of the Reactive Navy blue (C.I. Reactive blue 21) and Reactive Turquoise blue (C.I. Turquoise blue 03) dyes on the basis of weight of the fabric, separately [19]. The finishing of cotton samples was done by pad-dry-cure process [4]. Dyed cotton fabrics were treated with different concentrations of Fixapret ECO and Alkaknit WFR resins (50g/L, 100g/L) to impart easy-care properties. During testing, pick up of 70% was used in padding technique [44]. The padded fabric was then dried at 120 °C for 3 minutes. Curing was done in a ROACHES curing machine at 160 °C for 4 min. The samples were kept free from any tension or crease carefully. All samples were conditioned in the standard atmosphere for at least 48 h prior to testing. To compare the variation in physical properties of the samples, untreated control sample were also prepared under the same set of condition. The contents of each pad bath included: Fixapret ECO and Alkaknit WFR resins 50,100 g/L; Catalyst $MgCl_2$ 8-18 g/L; Alkasoft PEN and Alkasil SIM softener were used. To produce a desirable medium, the addition of acetic acid was added to maintain the recommended level of pH 4.5-5.

Evaluation of the fabric

Textile tensile strength tester (1992) was used to determine the tensile strength of the treated and untreated samples by following method ASTM D5034-95 [51-55]. Elmendorf Tear Tester (1992) apparatus was used to determine the tearing strength of treated and untreated samples by method ASTM D1424-96 [52-54, 56, 57]. Crock meter (auto crock) was used to determine colorfastness to crocking of the treated and untreated samples by standard method AATCC 08-2001 [52, 56, 58, 59]. The samples were exposed to standard home laundering in front loading LG (F10B9) washing machine to determine the smoothness of the treated and untreated samples by AATCC 124-2001 method [44, 51, 55, 57, 60, 61].

Results and Discussion

The current research is carried out to check the effects of resins, Fixapret ECO and Alkaknit WFR on dyed cotton fabric. The study was carried out by altering the concentration and quantifying its results to be applicable in textile sector as end user industry.

Evaluation of tensile and tear strength of treated fabric

The use of low formaldehyde resins resulted in considerable decrease in the tear and tensile strength of the fabric as compared to untreated one [54]. Dual concentrations of the resins on navy blue and turquoise blue dyes showed different rates in decrease of tensile-tear strength in warp and weft wise directions.

In Navy blue dye, resins Fixapret ECO and Alkaknit WFR were used in concentrations of 50g/L and 100g/L. As compared to untreated sample, Fixapret ECO exhibited the percentage loss of tensile strength in warp-wise direction between the range of 4.8 to 12.01 % and Alkaknit WFR showed decrease of 6.99 to 12.73 %. Similarly, the tensile strength loss in weft direction was reported to be in the range of 6 to 20% for Fixapret ECO and 5 to 21% for Alkaknit WFR. Turquoise blue dye displayed even more loss in tensile strength, warp wise a decrease of 12 to 23% for Fixapret ECO and 9 to 20% for Alkaknit WFR was noted. Weft-wise the percentage reduction of tensile strength was in range of 22 to 41% and 22 to 39 % for Fixapret ECO and Alkaknit WFR respectively (Table-1). The tear strength of navy blue dyed fabric decreased warp-wise in the percentage range of 3 to 12 % with Fixapret ECO and 3 to 13 % with Alkaknit WFR. The loss in tear strength weft-wise was reported to be 1 to 17 % for Fixapret ECO and 1 to 18% for Alkaknit WFR. However, in case of turquoise blue dye, the warp-wise loss of tear strength was even greater with the range between 2 to 19% and 2 to 18% and weft-wise decrease was in between 1 to 49 % and 1 to 48 % for Fixapret ECO and Alkaknit WFR respectively (Table-2).

The results indicated that with the increase of resin concentrations from 50g/L to 100g/L, there was a subsequent decrease in tensile and tear strength as compared to original fabric. The loss of strength in treated fabric is because of crosslinking caused by the catalyst. Presence of organic acid also triggers the de-polymerization of cellulose. Therefore, there is a direct relation between the strength loss and concentration of cross-linker. Our findings of present research are in line with previously conducted studies [19, 44, 51, 54, 55, 62, 63].

Evaluation of Colorfastness to crocking of treated fabric

The results from (Table-3) indicate that there was a definite decrease in colorfastness of the treated sample as compared to the controlled fabric. However, with the increase in resin concentrations from 50g/L to 100g/L there was a respectable increase in the colorfastness of the treated fabric. The color grading of Navy blue and turquoise blue dyed fabric samples, using 50g/L of both Fixapret ECO and Alkaknit was 4/5(dry state) and 3 (wet sate). Likewise, with the increase in the concentration of resins to 100g/L the color fastness property of both dyed fabrics also improved at 4/5(dry state) and 3/4 (wet state) (Fig. 1). This was due to the bonding of resin and dyed fabric surface. This bonding does not allow the dye to come out of the fabric. Therefore, the resin treatment not only improves the easy care performance but it also improves the fastness [19, 64]. Our findings of present research are in line with previously conducted studies [56, 64].

Table-1: Effect of resin finish on performance properties of treated cotton fabrics.

Dye	Sample treatment	Concentration (g/L)	Curing Temperature (°C)	Tensile strength	
				Warp (kg)	Weft (kg)
Navy blue	Untreated fabric	-	-	34.665	16
	Fixapret ECO	50 g/L Low strength	160 for 4 min	32.995	14.965
		100 g/L High strength	160 for 4 min	30.5	12.883
	Alkaknit WFR	50 g/L Low strength	160 for 4 min	32.24	15.15
		100 g/L High strength	160 for 4 min	30.25	12.66
Turquoise blue	Untreated fabric	-	-	38.83	24.66
	Fixapret ECO	50 g/L Low strength	160 for 4 min	34	19
		100 g/L High strength	160 for 4 min	30.165	14.74
	Alkaknit WFR	50 g/L Low strength	160 for 4 min	35.33	19.165
		100 g/L High strength	160 for 4 min	31.25	15.21

Contents of pad bath include: Fixapret ECO and Alkaknit WFR resins 50,100 g/L; catalyst $MgCl_2$ 8-18 g/L; Alkasoft PEN and Alkasil SIM softener 15-20 g/L; pH 4.5-5; dried at 120°C for 3 mins; light shade 2%; pick up of 70%.

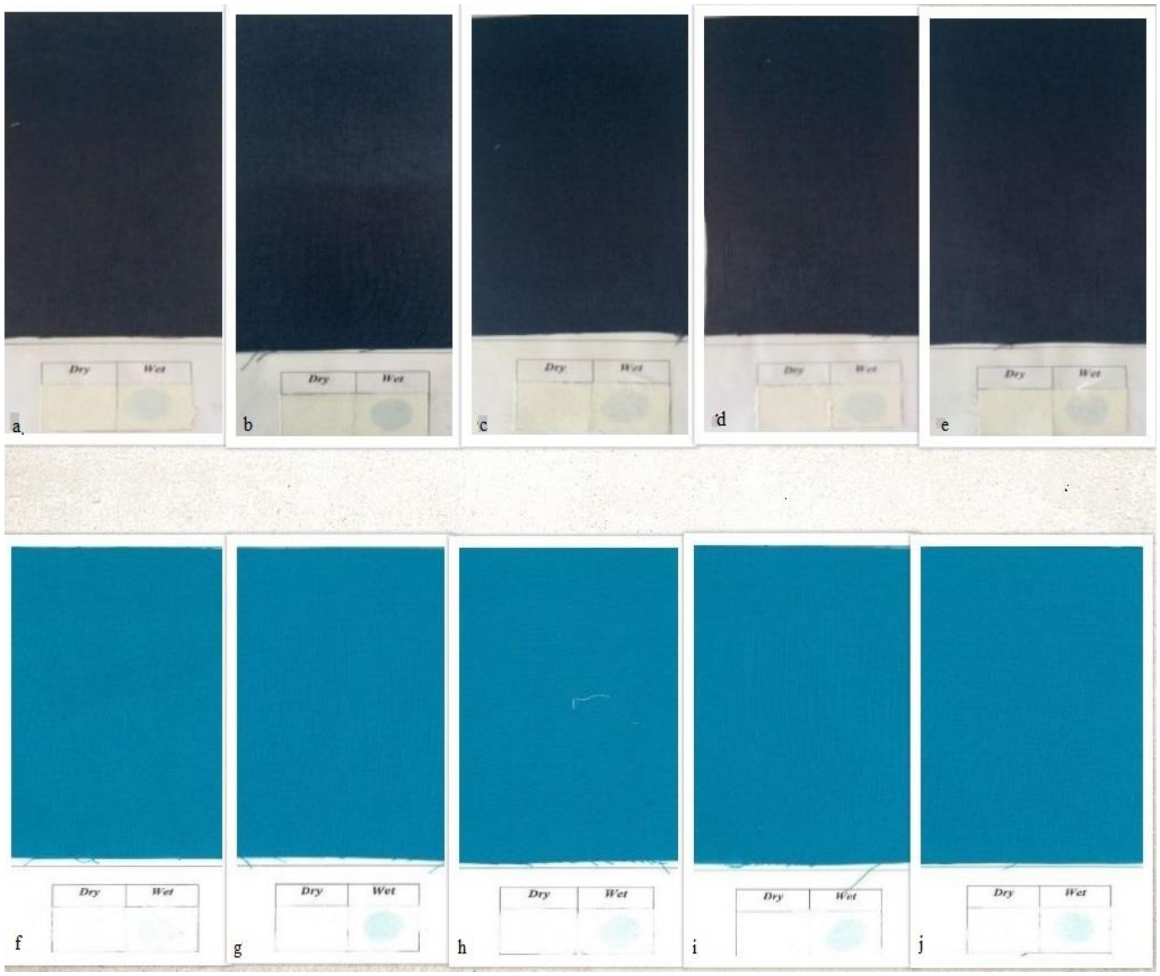

Fig. 1: Resin treatment on colorfastness to crocking of dyed cotton fabric (a) untreated sample (b) sample treated with Fixapret ECO 50g/L (c) sample treated with Fixapret ECO 100g/L (d) sample treated with Alkaknit WFR 50g/L (e) sample treated with Alkaknit WFR 100g/L (f) untreated sample (g) sample treated with Fixapret ECO 50g/L (h) sample treated with Fixapret ECO 100g/L (i) sample treated with Alkaknit WFR 50g/L (j) sample treated with Alkaknit WFR 100g/L.

Table-2: Effect of resin finish on tear strength of treated cotton fabrics.

Dye	Sample treatment	Concentration (g/L)	Curing Temperature (°C)	Tear strength	
				Warp (gm)	Weft (gm)
Navy blue	Untreated fabric	-	-	1266.66	943
	Fixapret ECO	50 g/L Low strength	160 for 4 min	1226.64	927
		100 g/L High strength	160 for 4 min	1114	780
	Alkaknit WFR	50 g/L Low strength	160 for 4 min	1225.3	926
		100 g/L High strength	160 for 4 min	1112.6	778.7
Turquoise blue	Untreated fabric	-	-	1244.66	863
	Fixapret ECO	50 g/L Low strength	160 for 4 min	1211.25	847.58
		100 g/L High strength	160 for 4 min	1010.72	446.66
	Alkaknit WFR	50 g/L Low strength	160 for 4 min	1212.33	849
		100 g/L High strength	160 for 4 min	1012.83	448

Contents of pad bath include: Fixapret ECO and Alkaknit WFR resins 50,100 g/L; catalyst $MgCl_2$ 8-18 g/L; Alkasoft PEN and Alkasil SIM softener 15-20 g/L; pH 4.5-5; dried at 120°C for 3 mins; light shade 2%; pick up of 70%.

Table-3: Effect of resins treatment on colorfastness to crocking of dyed cotton fabric.

Dye	Sample treatment	Concentration (g/L)	Curing Temperature (°C)	Rubbing test Dry	Rubbing test Wet	References of figure
Navy blue	Untreated fabric	-	-	4/5	4	1(a)
	Fixapret ECO	50 g/L Low strength	160 for 4 min	4/5	3	1(b)
		100 g/L High strength	160 for 4 min	4/5	3/4	1(c)
	Alkaknit WFR	50 g/L Low strength	160 for 4 min	4/5	3	1(d)
		100 g/L High strength	160 for 4 min	4/5	3/4	1(e)
Turquoise blue	Untreated fabric	-	-	4/5	4	1(f)
	Fixapret ECO	50 g/L Low strength	160 for 4 min	4/5	3	1(g)
		100 g/L High strength	160 for 4 min	4/5	3/4	1(h)
	Alkaknit WFR	50 g/L Low strength	160 for 4 min	4/5	3	1(i)
		100 g/L High strength	160 for 4 min	4/5	3/4	1(j)

Contents of pad bath include: Fixapret ECO and Alkaknit WFR resins 50,100 g/L; catalyst $MgCl_2$ 8-18 g/L; Alkasoft PEN and Alkasil SIM softener 15-20 g/L; pH 4.5-5; dried at 120°C for 3 mins; light shade 2%; pick up of 70%.

Evaluation of washing test of treated fabric

Table-4 (Navy blue) indicated that the samples treated with 50g/L of Fixapret ECO and Alkaknit WFR after five washes showed an average SA rating of 2-3. However, with the increase in resin concentration to 100g/L, the samples displayed better average SA rating of 3.5. From the (Table-4) Turquoise blue it was also observed that at concentration 50g/L of both resins, the samples exhibited average SA rating of 2-3. While at concentration of 100g/L, the average SA rating was reported to be at 3.5. From the results we can say that higher the resin concentration, better the washing durability. This is due to the fact that resin decreases the chance of fiber chain displacement. Hence aiding the fabric to recover and maintain good appearance. Our findings of present research are found to be in agreement with the results of [44, 55, 60, 61].

Table-4: Effect of resin finish on performance properties of treated cotton fabrics.

Sample treatment	Washing cycles / SA rating (Navy blue dyed fabric) 1	2	3	4	5
Untreated fabric	1	1	1	1	1
Fixapret ECO (50g/L)	3	2-3	2	2	2
Fixapret ECO (100g/L)	4	3.5	3	3	3
Alkaknit WFR (50g/L)	3	2-3	2	2	2
Alkaknit WFR (100g/L)	4	3.5	3	3	3
Washing cycles / SA rating (Turquoise blue dyed fabric)					
Untreated fabric	1	1	1	1	1
Fixapret ECO (50g/L)	3	2-3	2-3	2	2
Fixapret ECO (100g/L)	4	3.5	3.5	3	3
Alkaknit WFR (50g/L)	3	2-3	2-3	2	2
Alkaknit WFR (100g/L)	4	3.5	3.5	3	3

Contents of pad bath include: Fixapret ECO and Alkaknit WFR resins 50,100 g/L; catalyst $MgCl_2$ 8-18 g/L; Alkasoft PEN and Alkasil SIM softener 15-20 g/L; pH 4.5-5; dried at 120°C for 3 mins; cured at 160°C for 4 min; light shade 2%; pick up of 70%; washing cycles at 30°C.

Conclusion

The chemicals used in the finishing of the fabric release formaldehyde, which is harmful for the environment and is carcinogenic. Durable press or easy-care treatment affect the fabric properties because of the crosslinking between cellulose molecules and chemicals used in the treatment process. The crosslinking reduced swelling and shrinkage thus improving the stability. The characteristics of the dye can be protected by inducing it into cross-linked cellulose, which ultimately improves fastness properties. The main objective of the research was to find relative increase in tensile strength and tear strength by applying low formaldehyde resin so that the product can meet the market value economically and ecologically. The dyed cotton fabric was finished by two low formaldehyde resins at different concentration. The effects of Fixapret ECO and Alkaknit WFR on cotton fabric were studied. With fixapret ECO in Navy blue dyed fabric, maximum loss of tensile strength in warp and weft directions was 12.01% and 19.48% respectively, similarly maximum loss of strength with Alkaknit WFR was 12.73 % and 20.87%, warp and weft wise. Whereas, in turquoise blue dyed fabric, the loss of strength in warp and weft direction with fixapret ECO was maximum 22.31% and 40.22% while Alkaknit WFR reduced the strength to a maximum of 19.52 % and 38.32 %, warp-weft wise. whereas, in case of colorfastness to crocking, the increase in resin concentrations from 50g/L to 100g/L there was a respectable increase in the colorfastness of the treated fabric although it was less than the control sample. Overall we can conclude that the fabric with navy blue dye displayed much better performance and compatibility with low formaldehyde resins as compared to turquoise blue dye. Future research could focus on the growth and improvement of low formaldehyde reagents by optimizing the synthesis process and introducing new catalyst and additives, while keeping in view the properties of different dyes as it ultimately affects the overall characteristics of the fabric.

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