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Investigation of the Usability of Cationization Process in Towel Fabric Pretreatment and its Effect on Product Properties

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ABSTRACT

In the scope of the study, it was aimed to examine the usability of cationization process instead of bleaching process in the pretreatment process of terry fabrics and the effect of these process parameters on fabric performance properties on tensile strength, softness and hydrophility values. For this purpose, 4 different towel fabrics with two different weights and two different pile raw materials (100% cotton and 100% modal) and all other characteristics are same, were produced. Then, sample fabrics were subjected to the cationization process at different concentrations after the bleaching process, while some of them were unbleached. After all the processes applied, the processed samples were tested in accordance with the standards. As a result, it was determined that applying cationization process instead of bleaching process contributed positively to terry fabrics in terms of tensile strength and softness, and acceptable results were obtained in terms of hydrophility.

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KEYWORDS

Cationization, Bleaching process, Towel fabrics, Performance properties

1.INTRODUCTION

Turkey's textile sector is growing day by day thanks to intensive and skilled labor, designers which captures standards of quality production processes and closely followed developments, equipped and modern enterprises, the understanding of environment-friendly production. Turkey is constantly increased in the world most preferred textile-producing country list with Integrated production, fast delivery and geopolitical advantages. While the importance of the home textile group, which has an important place in terms of textile import and export, is increasing day by day, the most important product of this group is the towels and terry fabrics. When Turkey textile industry exports values of January-November 2020 were examined, it was shown that the values of home textile fabrics was decreased at 11.6% ratio compared to the 2019 data and it was realized as 334 million dollars [1].

When the export values of home textiles are analyzed on the basis of product groups in the January-November period of 2020, it is seen that the exports of towels and cleaning cloths, the most important product group, decreased by 8.5% compared to the previous period and realized at a value of 510 million dollars. The share of this product group in total home textile exports is 31.2% [1].

The most requirement properties of terry fabrics according to their usage areas; high hydrophility, softness, short drying time, suitablity for easy and frequent cleaning, antibacteriality and high color fastness.

Cationization process is a pretreatment process applied to cellulosic textile fibers and especially cotton products to change the surface load and facilitate the dyeing process. With the application of the cationization process, the dyeing efficiency of cotton products increases and the waste water in the dyestuff bath contains less chemical and dye

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molecules. In today's competitive conditions, where environmentally friendly products and production processes draw attention, the fact that the cationization process is shorten the processes and reduce costs, as well as reduce the waste water problem, shows the importance of this process in terms of the production process [2]. Chattopadhyay stated in his study in 2001 that it is possible to improve the dyestuff substantivity of cotton without using or using a small amount of salt by cationization process [3]. Srikulkit and Larpsuriyakul, in 2002, dyed cationized bleached cotton fabrics with reactive dyestuffs without salt [4]. In addition, with the cationization process, a lower dye concentration is used compared to conventional dyeings and a better color yield is obtained. Also, when the cationization process is applied together with the bleaching process, it saves water and energy, and there is no need to remove salt since salt is not used in the process. Onar (2006) emphasized the importance of cationization pre-treatment as an environmentally friendly application by saving energy and chemicals and examined the studies in the literatüre [5]. He investigated the chemicals used in the cationization of cotton fabrics, application methods of the cationization process and optimum conditions for the cationization process. Kannan et al. applied their chosen cationization component to cotton and compared it with cotton dyed by conventional methods in 2006 [6]. It was determined that the color strength and color force of the cationized groups were better than the normal dyed cotton in all dyeing. In addition, the environmental effects of cationized cottons were also investigated. It was determined that the cationized cottons gave almost the same quality values as the normal dyed cotton, but did not leave environmental pollution. Uğur et al., in their studies in 2011, tried to determine the effect of the cationization process on the whiteness and yellowness levels and yarn strength properties of cotton fabrics [7]. As a result of the analysis, no yellowing effect and a significant decrease in strength in the weft-warp direction were found in the cationized fabric. Farrell and Hauser, in their study conducted in 2012, compared cotton products that were cationized with cold pad-batch and exhaustion methods and then dyed with conventional reactive dyeing [8]. The results of the analysis showed that the fastness properties were improved and significant cost savings were achieved when compared with conventional reactive dyeing.

Özdemir compared normal cotton and cationic cotton in terms of fastness properties, dye consumption, behavior during the finishing process and costs in his study in 2014 [9]. When washing fastnesses of normal and cationic cotton dyed with direct and reactive dyestuffs were compared, it was seen that cationic cottons gave better results. Roy Choudhury stated, in his study in 2014, that the affinity of cellulosic fibers should be increased in order to dye cellulosic fibers with pigment dyestuffs in a less harmful way to the environment, and it was cationized the cellulose fibers to increase affinity [10]. The researcher also stated that although there are many theoretical studies on the cationization process, it could not find the right commercial place. Nakpathom et al, in their experimental study they conducted in 2017, firstly cationized cotton fabric and then dyed it with natural dyestuffs [11]. They compared the color and washing fastness values of cotton fabrics processed by various chemicals with unprocessed cotton fabrics. Hamdaoui et al, in their study in 2018, stated that cotton fiber can be dyed with organic dyes without using any electrolyte [12]. For this purpose, they were able to dye cationized cotton fabrics with metal complex dyestuffs.

In the scope of the study, the effect of the cationization process applied in different concentrations with or without bleaching process on tensile strength, softness and hydrophility values, which are important properties of terry fabrics, was investigated. Thus, the usability of the cationization process in terry fabric production instead of bleaching was tried to be revealed.

2. MATERIAL AND METHOD

2.1 Material

Within the scope of the study, terry fabric samples with different pile warp raw materials and different weights were grouped according to whether the bleaching process was applied or not, and then they were subjected to cationization process in different concentrations. While trying to determine the tensile strength, softness and hydrophility values of the treated fabrics, the applicability of the environmentally friendly cationization process instead of the bleaching process was also investigated. For this purpose, 4 different towel samples having two different weights and having two different pile raw materials (100% cotton and 100% modal) were produced and all other characteristics were kept constant. Then, some of the these fabrics were subjected to the cationization process at different concentrations, after the bleaching process, some of them without bleaching. The physical properties of all terry fabrics used in the study are the same, and the weight difference was obtained by changing only the weft density. The physical properties of the towel samples are shown in Table 1.

Table 1. Physical properties of towel samples

Sample code	Raw material of weft and ground warp	Raw material of pile	Weight (g/m^2)	Pile warp yarn number (Ne)	Weft yarn number (Ne)	Ground warp yarn number (Ne)	Warp density (yarn/cm)	Weft density (yarn/cm)
M1	%100 Cotton	%100 Modal	340	16/1	12/1	20/2	14	14
M2	%100 Cotton	%100 Modal	430	16/1	12/1	20/2	14	19
C1	%100 Cotton	%100 Cotton	340	16/1	12/1	20/2	14	14
C2	%100 Cotton	%100 Cotton	430	16/1	12/1	20/2	14	19

2.2 Method

2.2.1 Cationization and Bleaching Procedures

Within the scope of the study, bleaching process was applied to one part of each of the desized samples. Cationization process was applied to bleached and unbleached fabrics to determine the effect of cationization process and different cationization rates on towel properties. Table 4 shows the distribution of the bleaching and / or cationized samples. The mentioned process was not applied to samples with a cationization rate of 0%. Thus, 20 different samples were obtained from 4 different raw towel samples with different structure by finishing processes.

Non-bleached fabrics were subjected to cationization at the rate of 3% and 9%. There is no sample fabric group that has not been bleached and cationized in the experimental plan. However, fabrics that were bleached but not cationized were included in the study.

In the cationize process, Affinitas ALK was used as cationization agent. AFFINITAS ALK can be applied by exhaustion in an alkaline media. This chemical that polyfunctional ammonium derivative is a reactive cationic agent for cellulose fibers. This cationize process was carried out in the same liquor ratio with the bleaching process, with the same method and in the same machine. The bath temperature of the fabrics treated at 25 ^{0}C for 10 minutes was raised to 60 ^{0}C and waited for 30 minutes. While amount of the cationization agent determined according to the cationization ratio was given to the bath at at 25 ^{0}C, caustic was added when the bath temperature reached 60 ^{0}C. When the process was completed, cold rinsing was applied at 25 ^{0}C for 10 minutes and the bath was emptied.

2.2.2 Tests Applied to Sample Fabrics

The properties determined experimentally of towel fabrics and the standards used for this purpose are given in Table 3.

Table 2. Pretreatment processes experimental plan applied to samples

Sample code	Status of bleaching	Rate of cationization	Sample code	Status of bleaching	Rate of cationization
M1	Unbleached	%3	C1	Unbleached	%3
		%9			%9
	Bleached	%0		Bleached	%0
		%3			%3
		%9			%9
M2	Unbleached	%3	C2	Unbleached	%3
		%9			%9
	Bleached	%0		Bleached	%0
		%3			%3
		%9			%9

Table 3. Test standards applied in the experimental study

Test	Standard no
Determination of tensile strength	TS EN ISO 13934-1
Determination of softness degree	ASTM D4032 – 08 (2016)
Determination of hydrophility degree	TS EN 14697

3. RESULT AND DISCUSSION

3.1 Experimental Analysis Results

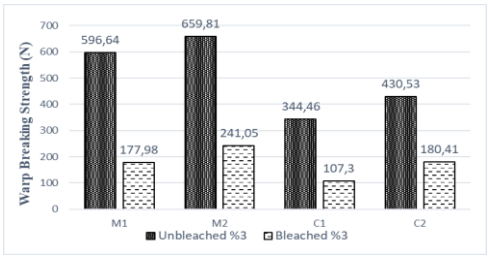
The average values obtained by the experimental study are given in Table 4.

3.1.1 Tensile Strength Test Results

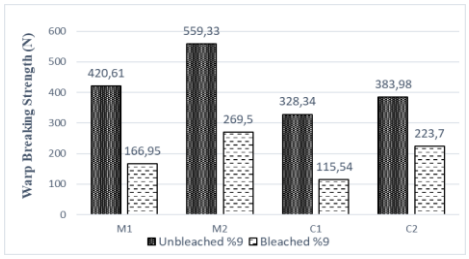
The weft and warp tensile strength test results made with the Titan Strength Tester are shown in Table 4 [13]. It can be seen from the graphs that the warp and weft tensile strength values of terry fabrics applied only bleaching process or cationized after the bleaching are much lower than the fabrics cationized without bleaching generally. The graphics obtained to examine the tensile strength values determined experimentally according to the selected parameters are shown in Figure 1.

Table 4. Experimental test results

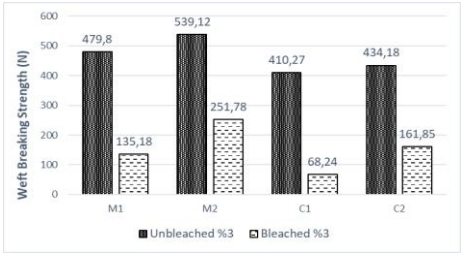
Sample code	Status of bleaching	Rate of cationization	Warp tensile strength (N)	Weft tensile strength (N)	Softness (kg)	Hdyrophility (sec)
M1	Unbleached	%3	596,64	479,80	0,219	17,73
		%9	420,61	459,80	0,174	25,13
	Bleached	%0	207,16	111,52	0,327	1,00
		%3	177,98	135,18	0,355	1,37
		%9	166,95	109,71	0,333	3,78
M2	Unbleached	%3	659,81	539,12	0,405	89,25
		%9	559,33	675,25	0,429	244,00
	Bleached	%0	257,02	231,26	0,559	1,17
		%3	241,05	251,78	0,622	1,73
		%9	269,50	228,57	0,670	3,27
C1	Unbleached	%3	344,46	410,27	0,233	12,05
		%9	328,34	401,24	0,200	26,13
	Bleached	%0	118,41	92,79	0,377	1,37
		%3	107,30	68,24	0,356	1,10
		%9	115,54	83,84	0,361	1,17
C2	Unbleached	%3	430,53	434,18	0,398	65,48
		%9	383,98	490,88	0,433	42,72
	Bleached	%0	136,41	188,56	0,801	1,17
		%3	180,41	161,85	0,806	1,13
		%9	223,7	181,79	0,856	1,77



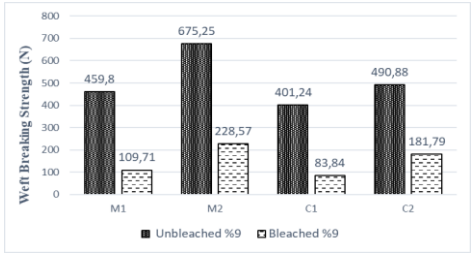
Warp tensile strength (rate of cationization: %3)



Warp tensile strength (rate of cationization: %9)



(c)Weft tensile strength (rate of cationization: %3)



(d)Weft tensile strength (rate of cationization:%9)

Figure 1. The effect of bleaching on tensile strength of towel fabrics applied different cationization concentrations

As can be seen from Figure 1, the weft and warp tensile strength values of the unbleached-cationized samples in both modal and cotton pile samples at both 3% and 9% cationization rates were higher than the bleached samples. A decrease in strength was detected in all terry fabrics applied bleaching and cationization. For this reason, the chemical stages formed by the bleaching and cationization processes with cotton fibers were examined and the results were found in the literature that the bleaching process increases energy costs, causes damage to the fibers and loss of time [14]. In this case, applying the cationization process instead of the bleaching process is low-cost and environmentally friendly, as well as minimizing the application risks by causing less damage to cotton fibers.

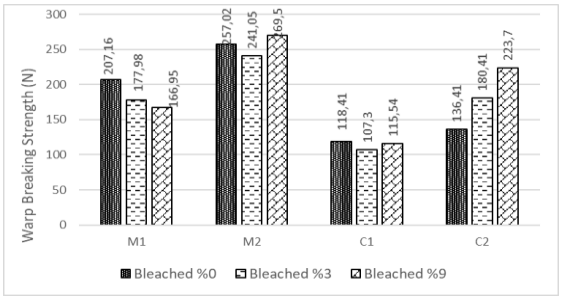
In order to evaluation the usability of cationization instead of bleaching (to compare the only cationized fabrics (non-bleached) and only bleached fabrics (not cationized)) , the values of the samples in the bleached-not cationized (0% category) were also added to the graphs (b) and (d). The same arrangement was made also in the graphs where the softness and hydrophility results were examined.

When Figure 2. (b) and (d) are examined, it was seen that the strength values of fabrics that have only been bleached and have not been cationized are much worse than those with only cationized fabrics.

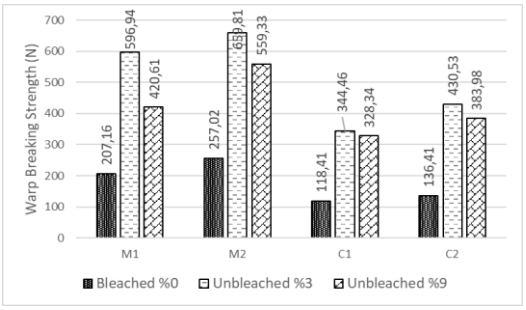
3.1.2 Softness Test Results

The measurement results of the softness test performed with the pnomatic stiffness tester are given in Table 4[15]. The graphics created in order to examine the experimentally determined softness values according to the selected parameters are shown in Figure 3. As the softness value obtained with test decreases, terry fabrics become softer.

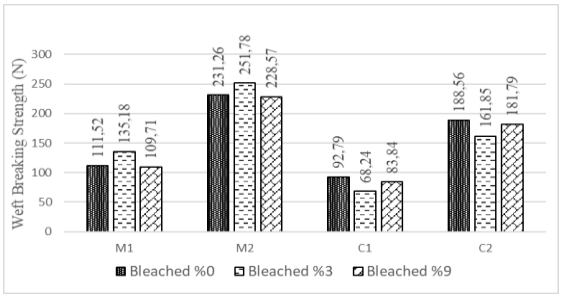
As can be seen in Figure 3 (a), application of the cationization process on bleached fabrics did not have a significant effect on softness. However, when Figure 3 (b) is examined, it is seen that the softness values of only bleached fabrics are higher than the softness values of only cationized fabrics (non-bleached). In other words, bleached fabrics is more softer than that of other. As can be seen from Figures 3 (c) and (d), it was determined that the softness values of the fabrics that were applied both bleaching and cationization (at both cationization ratios) were higher (harder) than the fabrics applied only with cationization. Therefore, when evaluated in terms of softness as well as tensile strength, the application of cationization process in terry fabric production instead of bleaching seems more advantageous in terms of fabric performance. However, it cannot be said that the cationization rate has a significant effect on the towel softness[16]. In addition, it was observed that the samples with higher weight (M2 and C2) in towels containing both cotton and modal had higher softness values, in other words, they were harder. This is due to the principle of the test method applied for the determination of the degree of softness. The relevant test method is based on the determination of the load that must be applied to pass the sample fabric with the help of the presser foot through a hole. It is expected that the value in question will increase as the fabric gets heavier.



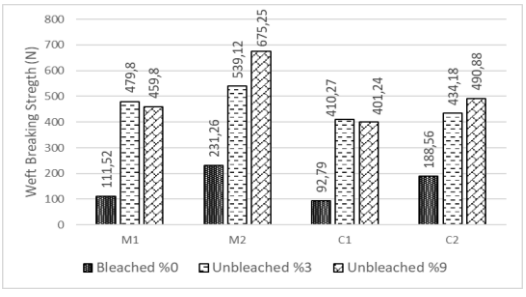
a. Warp tensile strength (bleached samples)



b. Warp tensile strength (unbleached samples)



c. Weft tensile strength (bleached samples)



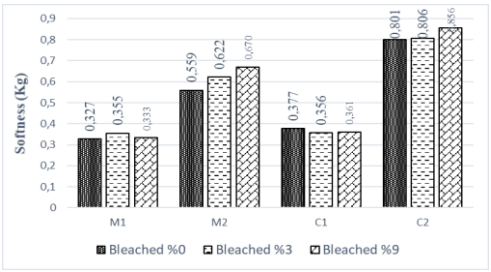
d. Weft tensile strength (unbleached samples)

Figure 2. The effect of cationization process and ratio on tensile strength of bleached and unbleached towel fabrics

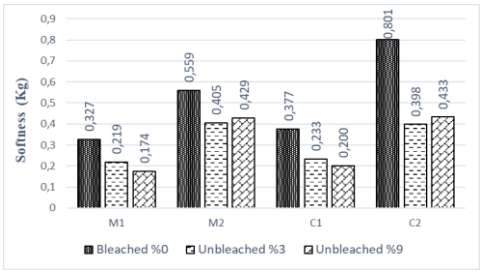
3.1.3 Hydrophility Test Results

The results of the hydrophility test applied to sample fabrics within the scope of the study are given in Table 4. Graphics created using these results are given in Figure 4. It is understood that as the value obtained with test increases, the hydrophility of the fabric decreases.

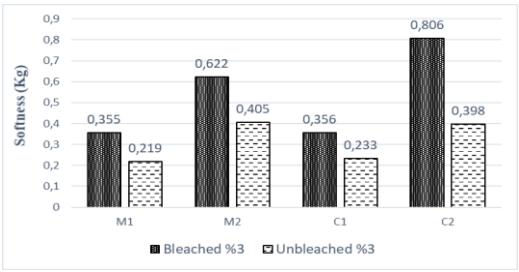
As can be seen from the table and graphs, the results of the hydrophility test of the bleached samples were very low compared to the unbleached fabrics whether the cationization process was applied or not. In other words, it can be said that these fabrics (bleached samples) have better hydrophility. In this case, it is seen that the bleaching process is more advantageous than the cationization process in terms of hydrophility. However, when cationization is applied to non-bleaching samples, it is seen that the hydrophility values obtained are within acceptable limits except for the M2 coded sample. According to the values specified in the standard for towel fabrics, the hydrophility value of the sinking test result in terry fabrics is required to be 100 seconds at most[17]. For this reason, it can be said that the use of the cationization process instead of bleaching in the towel production process negatively affects the hydrophility somewhat unlike the tensile strength and softness, but the values obtained are within acceptable limits according to the place of use.



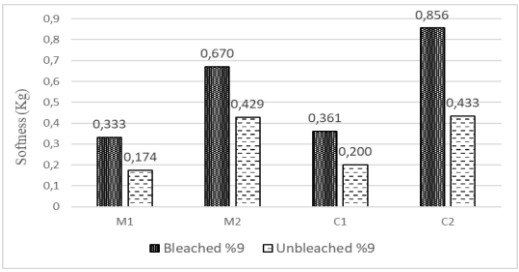
(a) Softness values (bleached samples)



(b) Softness values (unbleached samples)

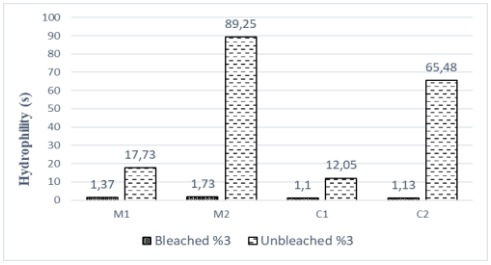


(c) Softness values (rate of cationization: %3)

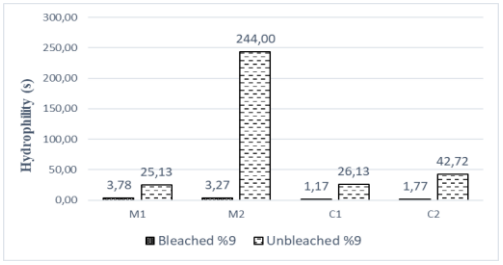


(d) Softness values (rate of cationization: %9)

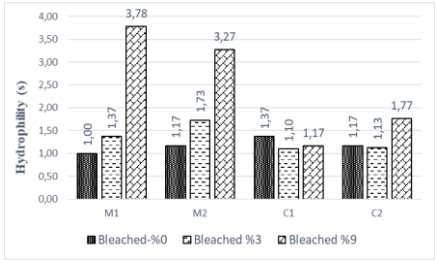
Figure 3. The effect of bleaching proses and cationization rate on softness values



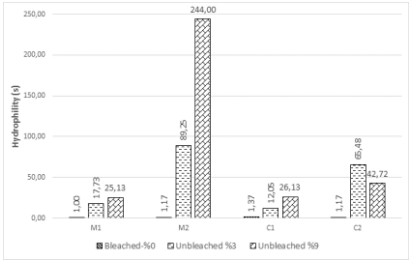
(a) Hydrophility values (rate of cationization: %3)



(b) Hydrophility values (rate of cationization: %9)



(c) Hydrophility values (bleached samples)



(d) Hydrophility values (unbleached samples)

Figure 4. The effect of bleaching process and cationization rate on hydrophility values

3.2 Statistical Analysis Results

The tensile strength, hydrophility and softness values of bleached and unbleached terry fabrics cationized at different concentrations were tested with the SPSS statistical package program. Normal distribution suitability and randomness of the data were tested in order to decide which variables would be applied to parametric or non-parametric analyzes. For this purpose, One-Sample Kolmogorov-Smirnov test was applied, and it was determined that warp tensile strength and weft tensile strength were suitable to normal distribution. Histogram graph was drawn for softness and hydrophility variables that do not conform to normal distribution, and it was determined that these variables show distribution close to normal according to the "Central Limit Theorem", since the data of the softness variable is bell-shaped and has a single peak point [18]. For this reason, while parametric tests were applied for warp tensile strength, weft tensile strength and softness variables, nonparametric test was applied for hydrophility. Collective results of the statistical tests applied are given in Table 5.

Within the scope of the study, the statistical evaluation of the effect of the cationization rate on the performance properties was applied separately for the bleached and unbleached samples. Since there were 3 groups, 0%, 3% and 9% in the bleached samples, One Way Anova analysis was applied and no statistically significant relationship was found between the cationization rate and all performance characteristics. These results also fits with the graphical results. Since there are two groups (3% and 9% cationized samples) in unbleached samples, the Independent Sample-t test was applied to the warp tensile strength, weft tensile strength and softness variables, and the non-parametric Mann-Whitney U test was applied to the data of the hydrophility variable. In this group, it was determined no significant relationship between the variables (except softness) and the cationization rate.

In the analyzes where the independent variable was the bleaching state, the bleached and unbleached samples were compared. According to the results obtained, it was determined that the bleaching state had a significant effect on each parameter tested. In the analyses where the samples were examined according to the cationization status, the samples that were bleached and not subjected to the cationization process were compared with the samples that were applied cationization process without bleaching. According to the data obtained, applying the more economical and environmentally friendly cationization process instead of bleaching has created a statistically significant difference on all performance properties.

Table 5. Statistical test results

Independent variable	Subgroup	Dependent variable	Applied test	Sig. value	Evaluation
Cationization rate	Bleached samples	Warp tensile stregth	One way anova	0,993	Insignificant
		Weft tensile stregth	One way anova	0,995	Insignificant
		Softness	One way anova	0,990	Insignificant
		Hydrophilicity	Kruskal wallis	0,757	Insignificant
	Unbleached samples	Warp tensile stregth	Independent Samples t-test	0,325	Insignificant
		Weft tensile stregth	Independent samples t-test	0,303	Insignificant
		Softness	Independent samples t-test	0,002	Significant
		Hydrophilicity	Mann whitney u	0,686	Insignificant
Bleaching condition		Warp tensile stregth	Independent samples t-test	0,000	Significant
		Weft tensile stregth	Independent samples t-test	0,000	Significant
		Softness	Independent samples t-test	0,011	Significant
		Hydrophilicity	Mann whitney u	0,000	Significant
Cationization condition	Bleached (uncationizated) and unbleached (cationizated) sample	Warp tensile stregth	Independent samples t-test	0,001	Significant
		Weft tensile stregth	Independent samples t-test	0,000	Significant
		Softness	Independent samples t-test	0,040	Significant
		Hydrophilicity	Mann whitney u	0,000	Significant

4. CONCLUSION

Within the scope of the study, it was aimed to examine the applicability of the cationization process and the effect of the cationization rate on the towel performance in the pretreatment of towels having cotton and modal pile raw materials, and the selected results are summarized below.

- It has been observed that cationization process can be applied instead of bleaching process in towel fabrics and

dyeing process can be performed without using salt and soda in fabrics that have undergone cationization.

- When the cationization process was applied instead of the bleaching process, it has been determined that the tensile strength values improved of all towel fabrics.
- It has been determined that the tensile strength values of towel fabrics applied bleaching and/or then cationized are considerably lower than the fabrics cationized without bleaching. In the other word, it has been observed that the warp and weft tensile strength values of terry fabrics applied only bleaching process or cationized after the bleaching are much lower than the fabrics cationized without bleaching generally. It is thought that this is due to the bleaching process (the chemicals of this process and high temperature) that damage the structure of modal and cotton fibers and the bonds in the structure [14].
- The change of cationization concentration applied did not significantly affect weft and warp tensile strength.
- It has been determined that applying the cationization process to the terry fabric instead of the bleaching process improves the softness property. In addition, it has been also observed that the softness values of fabrics that were applied both bleaching and cationization (at both cationization ratios) were higher (harder) than the fabrics applied only with cationization. Bleaching process removes substances such as oil, and wax in the structure of cotton more effectively than cationization process. These substances are substances that give softness to the fiber and therefore to the fabric. In addition, it provides a hydrophobic structure. Therefore, when this substances are removed from fibres, while the hydrophilicity of the fabric improves, its softness decreases slightly [19]. It is thought that this is the reason why only the fabrics that are treated with cationization process are softer. In addion, it has been observed that no matter what rate of cationization process is applied to bleached fabrics, it reduces the softness value.
- The cationization concentration did not have a significant effect on the softness value.
- It has been found that applying bleaching, independent of the cationization process, shortens the sinking time. It has been observed that the results of the hydrophility test of the bleached samples were low (more hydrophil) compared to the unbleached fabrics whether the cationization process was applied or not. Bleaching is very important process in terms of removing the oil, waste and natural dyes that are inherent in cotton and obtaining a ground with all the same properties all over before painting. Therefore, bleached fabrics have higher water absorbency than cationized fabrics. However, in general, the hydrophility values of cationized fabrics were within acceptable limits according to the place of use.
- It has been determined that the change in the cationization rate does not have a significant effect on hydrophility.

As a result, it has been observed that if 100% cotton is used as the pile raw material, weft and ground warp of towel, more environmentally friendly and lower cost cationization process can be used instead of bleaching in the pretreatment process. Similar situation is valid for terry fabrics produced with 100% modal pile yarn and having low weight. However, this case was not valided for the heavy sample group whose pile raw material was 100% modal due to the deterioration in hydrophility.

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