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Study on the Loss of Strength of Denim-like Knitted Fabrics after Different Washing Treatments

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Abstract
Garments produced from denim-like knitted fabrics have been popular for few years because of the many advantages of knitted fabrics. To increase the worn-look denim appearance of these fabrics, washing treatments should be carried out. In this experimental study eight different washing treatments were applied to denim-like knitted fabrics produced from 18 different fleecy yarns. The bursting strength test was applied to the samples obtained and their strength losses calculated. At the end of the study, the most suitable washing treatment for denim-like knitted fabrics was selected, and according to the treatments applied, the best fabric type was chosen.

Key words: *denim-like knitted fabric, bursting strength, denim washing.*

Introduction

Among all the textile products, no other fabric has received such a wide acceptance as denim, and it is the only fabric which has been produced in such large quantities. Conventionally denim is a heavy 3/1 twill fabric made from 100% cotton with indigo-dyed warp yarn [1, 2]. In denim fabric of indigo color, only the warp threads are dyed, whereas the weft threads remain plan white; therefore one side of the fabric shows blue colour, while the other shows white colour [3]. Unlike other materials, denim can express various styles and colors, depending on variations in texture and after treatment processes [4]. Actually denim is very strong, stiff and hard wearing fabric. Denim garment washing is known as one of the finishing treatments widely used. Thanks to washing, a special appearance can be created, and fashionable and comfortable garments be made. Without finishing treatments, denim garments are uncomfortable to wear. Garment washing is a novel process to impart a worn-out look, to modify the appearance and to improve the comfort ability of the garments. The most common denim washing methods are enzyme washing, bleach washing, acid washing, normal wash and stone washing [5]. Denim washing is known as one of the finishs ing treatments that have vast usage because it creates a special appearance and modernises clothes. The washing treatment consists of making denim turn for one or two hours in a barrel machine or washing machine with a perforated drum containing stones or chemical detergents and water [6]. Enzymes are applied to denim fabrics to improve their aesthetic performance. Enzyme treatment has led to a drop in friction, which implies that the handle has improved [7]. Stone washing can be carried out on denim garments using cellulase alone or along with pumice stone. The enzyme enters into the amorphous areas on cotton, hydrolyses cellulose, removes surface naps of the fabric and imparts brightness and softness to it [8]. Bleach washing is used to fade the colour of denim to a higher degree [9]. The most common industrial bleaching agent for cotton is hydrogen peroxide, which removes the natural colour of cotton and increases whiteness. It is also fairly effective in denim washing, where it is applied under boiling conditions, but it increases fiber damage [10].

There are many studies about the washing treatments of denim fabrics applied, and some of them which are directly related to our study are summarised here. Khan and Mondal; manufactured 3/1 twill indigo dyed woven denim fabrics and exposed them to standard enzyme washing treatment by changing only the processing time. Then they measured the performance properties of the samples. Results showed that the tensile strength, stiffness and colour shade decrease after cellulase enzyme washing treatment [11]. Khalil et al tested the effect of potassium permanganate on denim jeans performance. They used 3/1 warp faced twill woven indigo dyed denim fabrics. They applied a standard enzyme recipe but they changed the potassium permanganate concentration (1.5-2.5 g/l) and processing time (1.5-2.5 min) during acid washing. As a result of their study, increasing the amount of potassium permanganate along with respective increasing of the processing time during washing treatment; the tensile strength, stiffness and fabric weight decreased [12]. Sarkar and Khalil produced cotton 3/1 twill warp faced indigo dyed denim fabrics and applied a standard desizing recipe, bleaching and neutralizing processes. The process was then completed by softening, and the effects of washing on performance were examined. Bleaching and softening treatment have a great influence on the mechanical and colour properties of denim fabrics. Especially bleaching reduces the fabric weight, tensile strength and seam strength [9]. Miah et al studied 3/1 twill warp faced indigo dyed denim fabrics and tried to explore the difference between two types of cellulose enzyme and their effects. They reported that neutral enzyme is more preferable than acid enzyme according to the results of weight loss and fastness tests [10].

Figure 1. *Jeans sewn by denim-like knitted fabrics [19].*

Denim-like knitted fabrics are produced on a knitting machine with the use of indigo and white color yarns separately in the same fleecy fabric. The diagonal fleecy pattern and indigo color of the face yarn give a denim appearance to the knitted fabric. Therefore these fabrics are called as denim-like knitted fabrics. Nowadays denim-like knitted garments (***Figure 1***) are extremely popular [13]; however, there are limited studies about denim-like knitted fabrics.

Shin [14] designed knitted denim-like trousers suitable to wear in each season and compared their properties to trousers manufactured from woven denim fabrics. He reported that this type of trouser had more advantages than the woven type, except dimensional stability and strength properties. Gokernasan et al. [15] tried to find a knitted fabric type resembling woven denim fabric in terms of appearance and performance properties. Therefore they manufactured knitted fabrics with different patterns and properties. They showed that diagonal two fleece patterned fabric was the most convenient one. Degirmenci and Celik investigated the dimensional stability of denim-like knitted fabrics and reported that fleecy yarn raw material affected the dimensional change behavior of sample knitted fabrics. Therefore to produce denim-like knitted fabrics; selecting gray polyester as fleecy yarn and indigo dyed cotton as face yarn gives the most convenient result [16, 23]. Degirmenci and Çelik studied the thermal comfort properties of denim-like knitted fabrics. According to the study, the thermal absorptivity of denim-like knitted fabrics is influenced by the raw material, thickness and unit weight of the products. The unit weight and thickness of denim-like knitted fabrics are low, and thus they can be used as summer cloth when fleecy yarn from cellulosic raw materials like bamboo, modal and cotton is selected [17, 23]. The strength and elasticity of denim-like knitted fabrics were researched by Degirmenci and Çelik. They explained that using elastomeric yarn with the face yarn make the fabric elastic and strong. Denim-like knitted fabrics are convenient to produce jeggings as their resistance to bursting increases with the use of synthetic yarns such as fleecy yarn [18, 23]. Degirmenci applied some washing treatments on denim-like cotton knitted fabrics and tested their abrasion resistance variation. The result of the study showed that the fabrics' resistance to abrasion after 20000 cycles is adequate to use after normal washing, super washing and super stone washing treatments [19].

In the available literature there is no adequate systematic study of the effects of washing treatments on the performance

Table 1. *Strength and elongation values of yarns [18, 23].*

Yarns	Elongation at break, %	Strength, g/tex	Breaking force, cN	Yarns	Elongation at break, %	Strength, g/tex	Breaking force, cN
Face yarn	5.51	22.63	436.59				
Bamboo20	10.35	14.37	416.01	Bamboo30	10.46	14.60	281.75
Tencel20	5.36	16.28	471.18	Tencel30	5.62	18.53	357.50
Modal20	8.02	21.52	622.88	Modal30	6.82	17.75	342.41
Viscose20	9.64	15.36	444.62	Viscose30	8.47	13.54	261.26
Cotton20	6.14	14.35	415.22	Cotton30	5.12	13.45	259.40
Cotton/Modal20	7.19	16.61	480.88	Cotton/Modal30	6.62	16.02	309.09
Cotton/Polyester20	9.78	23.07	667.57	Cotton/Polyester30	8.41	20.37	402.78
Viscose/Polyester20	3.83	10.35	480.88	Viscose/Polyester30	9.58	22.47	433.55
Polyester20	9.42	28.45	823.49	Polyester30	10.01	28.82	556.05

Table 2. Structural properties of unwashed fabrics [17, 18].

Samples		Loop density, cpc X wpc	Thickness, mm	Weight, g/m²
30-30 Fabrics	DB20	263	0.69	201
	DT20	252	0.72	200
	DM20	250	0.67	194
	DV20	250	0.69	197
	DC20	244	0.74	196
	DP20	252	0.69	210
	DP-C20	244	0.70	200
	DM-C20	252	0.71	199
	DP-V20	267	0.71	204
30-20 Fabrics	DB30	242	0.66	169
	DT30	267	0.70	179
	DM30	258	0.64	170
	DV30	250	0.66	165
	DC30	240	0.69	167
	DP30	252	0.66	171
	DP-C30	244	0.65	171
	DM-C30	247	0.67	167
	DP-V30	247	0.67	184

loss of denim-like knitted fabrics, and a suitable recipe for washing them has not been investigated in detail yet. For this reason; in this study different recipes were applied to sample knitted fabrics and their strength loss of examined, where strength is one of the most important parameters in denim-like knitted fabrics.

Experimental

Materials

In this study, 18 denim-like knitted fabrics were produced with a circular knitting machine of 22 gauge 30″ diameter using constant setting values. After the knitting process, pre-fixation, cold washing, and fixation processes were applied to the grey sample knitted fabrics. The fabrics were knitted in a fleecy pattern. The face yarn of the samples was Ne 30/1, ring spun, 100% cotton and indigo colored. (Yarns were dyed by the rope dyeing method in a conventional mill). The fleecy yarns were air-jet spun and grey. A list of the yarns and their strength and elongation tests are illustrated in ***Table 1***.

Then 8 different washing methods which include different treatments were applied to the denim-like knitted samples (as a leg panel). In the experimental part of this study, there were actually four different types of washing: normal washing, enzyme washing, super stone washing and enzyme perlit washing. By adding the bleaching process, the number of washings was eight (Hypochlorite is the best for special finishing but not ecologically favorable; ((unfortunately still popular in many countries)), in which case the effect of bleaching by hypochlorite was studied for the samples tested in this paper). ***Table 2*** shows the structural properties of unwashed samples and ***Table 3*** the recipe of the treatments.

Table 3 shows the chemicals during washing treatments. According to all the recipes, the samples underwent the pretreatment process with 100 g of dispersants and 300 g of softeners at 50 °C with 100 l of water for 10 minutes. The aim of this process was to purify the fabrics from chemicals such as dye residue before washing treatments. A dispersant or dispersing agent was used to improve the separation of particles and to prevent settling or clumping. Softeners were used to improve the fabric's resistance to friction as well as its sewability, elasticity and hydrophilic properties [20]. By forming a water bag over the structure, fiber breakage was prevented. After all washing types, 100 g of bisulfite was sprayed at 50 °C with 100 l of water for 10 minutes. This chemical was used to decrease the PH value of the solvent and to clean the surface of the fabric. The last process was softening for all fabrics, carried out with 500 g of softener at 40 °C with 80 l of water for 5 minutes to purify the fabric from all chemical residues.

As seen from ***Table 3***, the bleaching process is applied in some types of washing. For bleaching, 2 g of hypochlorite is used at 50 °C with 100 l of water for 10 minutes for discoloration. This process is color reduction and performed to give a worn look to denim fabrics. Also neutralization is carried out by bisulfite to have a whiter and greyer appearance. Enzymes are the key process of the wash-

Table 3. Recipe applied according to washing type.

Process	Chemical amount, g	WASHING TYPES							
		Normal washing (NW)	Normal bleach washing (NBW)	Enzyme washing (EW)	Enzyme bleach washing (EBW)	Super stone washing (SSW)	Super stone bleach washing (SSBW)	Enzyme perlit washing (EPW)	Enzyme perlit bleach washing (EPBW)
Pretreatment	Dispersing	100	100	100	100	100	100	100	100
	Softener	300	300	300	300	300	300	300	300
Enzyme	Stone enzyme	–	–	160	160	100	100	100	100
	Dispersing	–	–	100	100	100	100	100	100
	Ponza stone	–	–	–	–	20	20	–	–
	Perlit	–	–	–	–	–	–	3	3
Bleaching	Hypochlorite	–	2	–	2	–	2	–	2
Neutralization	Bisulfite	–	100	–	100	–	100	–	100
Chemical spray	Bisulfite	100	100	100	100	100	100	100	100
Softening	Softener (silicone)	500	500	500	500	500	500	500	500

ings, applied at 50 °C with 80 l of water for 30 minutes. Among these enzymes, perlit does not react to any other chemicals and is not soluble in water. Moreover it is not dangerous for people and not abrasive for fabrics. The indigo colour of the fabric can be removed by a ponza stone. Stone enzyme is applied to achieve the desired worn look, not only useful for cotton but also for regenerated cellulose fabrics, especially for tencel. By incorporating enzymes into detergents to remove protruding surface fibers, improved color retention is achieved after multiple launderings.

After washing treatments, 144 denim-like knitted samples (as a leg panel) were obtained. With the 18 un-washed denim-like knitted fabrics as a control group; a total of 162 denim-like knitted samples were tested to study loss of strength. To detect the bursting resistances of the samples, a Truburst test device was used according to the BS EN ISO 13938-2 Standard.

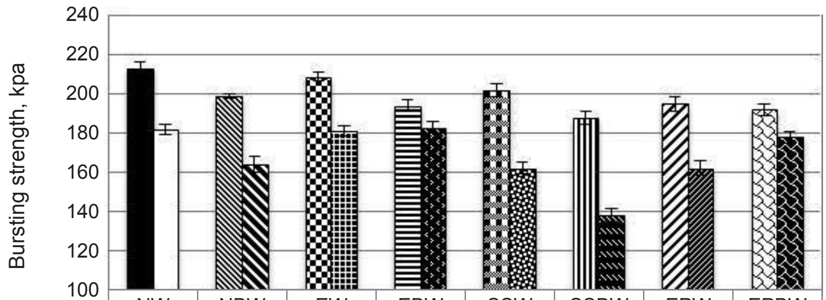
Bursting strength test results were evaluated on behalf of both fleecy yarn raw material and applied washing treatments with graphics. To control the significance of the dependent variables for the bursting strength of the samples, ANOVA analyses were performed using the Design Expert 6.0 statistical programme.

Results and discussion

Statistical analysis of the study is presented in ***Table 4***.

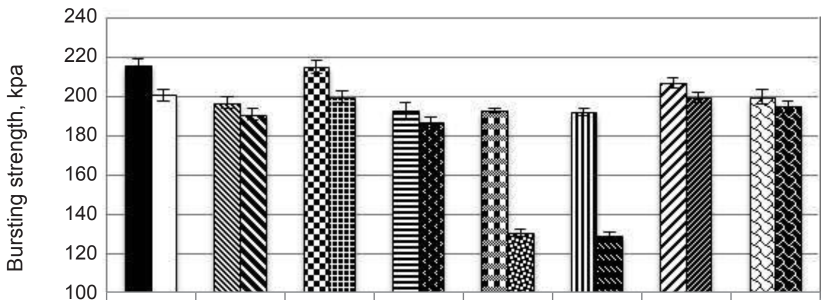
According to ***Table 4***, the Model F-value of 12.37 implies that the model is significant. There is only a 0.01% chance that a "Model F-Value" this large could occur due to noise. Values of "Prob > F" less than 0.0500 indicate that the model terms are significant. Values greater than 0.1000 indicate that the model terms are not significant.

In this case, the fleecy yarn number, fleecy yarn raw material and washing recipe are significant model terms for bursting strength values of the sample knitted fabrics. The R^2 value of the model calculated is 0.7850, the adjusted R^2 value – 0.7215, and the predicted R^2 value – 0.6360. It is concluded that the predicted R^2 value is in reasonable agreement with the adjusted R^2 value according to statistical analysis results attained by Design Expert. According to ***Table 4***, all the variables have significant and similar influences on bursting strength values of the sample knitted fabrics.



	NW	NBW	EW	EBW	SSW	SSBW	EPW	EPBW
■ 20Fleecy	213	199	209	194	202	188	195	192
□ 30Fleecy	182	164	181	183	162	138	162	178

Figure 2. *Bursting strength of sample knitted fabrics with cotton fleecy yarns according to washing type.*



	NW	NBW	EW	EBW	SSW	SSBW	EPW	EPBW
■ 20Fleecy	216	197	215	193	193	192	207	200
□ 30Fleecy	201	191	200	187	131	129	200	195

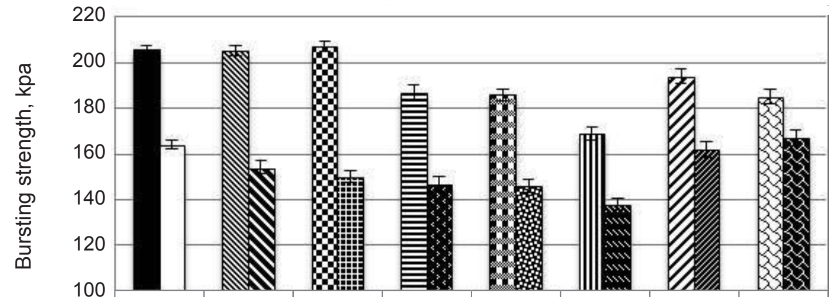
Figure 3. *Bursting strength of sample knitted fabrics with tencel fleecy yarns according to washing type.*

Effect of treatments on the strength of the samples

The strength of knitted fabrics is related to that of yarns inside (fiber type, count, twist ratio), the pattern type, and the finishing treatments applied. In this paper the face yarn of all the samples is the same. The fleecy yarns are different in raw material and count. The intermediate process between knitting and washing is same, while the washing treatments are different. The difference in fleecy yarn makes the knitted sample fabric different

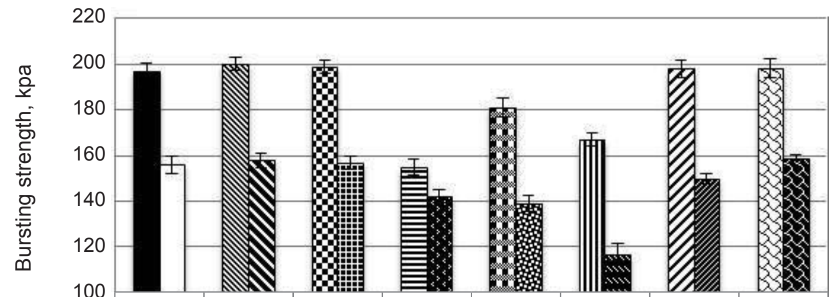
Table 4. *Statistical analysis of dependent factors for bursting strength values by ANOVA.*

Dependent factors	F-value	P-value	Contribution, %	Significance
Model	12.37	< 0.0001		significant.
Fleecy yarn count	113.12	< 0.0001	24.77	significant.
Fleecy yarn raw material	16.08	< 0.0001	25.90	significant.
Washing recipe	16.05	< 0.0001	23.07	significant.
R^2 Values				
R^2	Adjusted R^2	Predicted R^2		
0.7850	0.7215	0.6360		



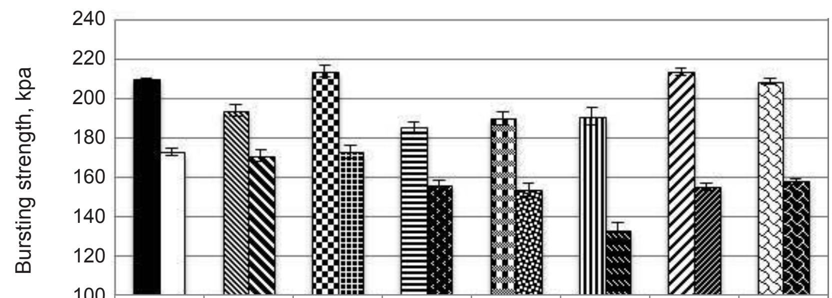
	NW	NBW	EW	EBW	SSW	SSBW	EPW	EPBW
■ 20Fleecy	206	205	207	187	186	169	194	185
□ 30Fleecy	164	154	150	147	146	138	162	167

Figure 4. *Bursting strength of sample knitted fabrics with viscose fleecy yarns according to washing type.*



	NW	NBW	EW	EBW	SSW	SSBW	EPW	EPBW
■ 20Fleecy	197	200	199	155	181	167	198	198
□ 30Fleecy	156	158	157	142	139	117	150	159

Figure 5. *Bursting strength of sample knitted fabrics with bamboo fleecy yarns according to washing type.*



	NW	NBW	EW	EBW	SSW	SSBW	EPW	EPBW
■ 20Fleecy	210	194	214	186	190	191	214	209
□ 30Fleecy	173	171	173	156	154	133	155	158

Figure 6. *Bursting strength of sample knitted fabrics with modal fleecy yarns according to washing type.*

in appearance and structural characteristics. Moreover the washing treatments applied affect the samples differently, and hence evaluations were made according to the washing treatment sample by sample with the following graphics. ***Figure 2*** shows the strength of the samples with cotton fleecy yarn.

According to the values given in ***Figure 2***, unwashed denim-like knitted fabrics with Ne 20/1 are more resistant than those of Ne 30/1. Owing to the fact that fabrics knitted by coarser yarns tend to show more resistance than others, the test results are logical. According to the results for 20 Fleecy fabrics, the most convenient washing type is "NW" and the worst "SSBW". When the recipes are examined in detail, it is seen that for each washing method the strength of the fabric decreases after adding the bleaching process to the washing. The fabrics lose strength most after EPW treatment, therefore they are thought that to have a worn look. Furthermore applying perlit to washing treatment is not a preferable way according to the strength loss results. If enzyme washing is done with only stone enzyme and with or without the bleaching process the desired worn look is obtained and the fabric can withstand forces more. Finally for cotton fleecy denim-like knitted fabrics, normal washing and super stone washing can be used. Using hypochlorite is not convenient because it damages the fabric and the strength of the fabrics decreases.

Figure 3 shows the strength loss behaviour of knitted fabrics with tencel fleecy yarns. In general, tencel fibers share many properties with other cellulosic fibers such as cotton or viscose. Their main characteristics are softness, absorbance and strength when wet and dry [22]. When the strength test results of the samples after washing are observed, it is seen that after NW the strength is quite high. However, bleaching affects these fabrics very much because hypochlorite impacts the hairy structure of tencel yarns more. When the other treatments are evaluated, it is concluded that there is no significant difference between the washing methods, except SSW, as fabrics made of finer yarns are affected by this type of washing very much, caused by the ponza stone. Ponza stone was applied after the stone enzyme, consequently the cellulosic part of the fabric became loose and then the strength decreased. According to the test results, Ne 30/1 tencel yarn in fabrics are affected by stone enzyme more. In general, all other washing types may be used to obtain a worn-look with respect to the strength test results.

According to ***Figure 4*** fabrics with viscose fleecy yarn can withstand EW. 30 Fleecy viscose fabrics did not lose significantly strength after bleaching, related to the strength behaviour of viscose, which is higher when wet than dry. Other results are similar to the results of samples with cotton and viscose fleecy yarns.

Analysing the strength results of sample knitted fabrics with bamboo fleecy yarns from ***Figure 5***, it is seen that generally 20 Fleecy fabrics are quite strong after any type of wash. In general bamboo fibers have high breaking strength values and low elongation. Their water affinity is high because of the small lumen structure in the cross section of the fiber. Both the cotton face yarn and bamboo fleecy yarn make the fabric sensitive to the treatments. Among the washing types the most dangerous for this type of fabric is SSW, where ponza stone is used, which deteriorates the strength of bamboo yarn. Using perlit as an enzyme is seen as more convenient, and moreover using a bleaching agent with this recipe did not change the strength of the samples significantly.

According to the results in ***Figure 6***, among the washing types with an enzyme, EPW is the most suitable. Bleaching with perlit does not change the strength of these fabrics. As predicted from the literature, perlit is not dangerous for natural fibers, and this effect did not change with the addition of hypochlorite.

Examining ***Figures 6*** and ***7*** together, it is seen that the results are similar to each other. The most suitable washing type is found to be EPW again, and hence the authors concluded that modal fibers are made strong by the effect of perlit. Using ponza stone and hypochlorite is not suitable for these types of fabrics.

According to the strength values presented in ***Figure 8***, in this type of fabric any washing type can be selected. The strengths of the fabrics are high after all treatments, with bleaching not significantly affecting the strength of the fabrics. Actually this result is related to the strength of polyester yarns inside the fabric.

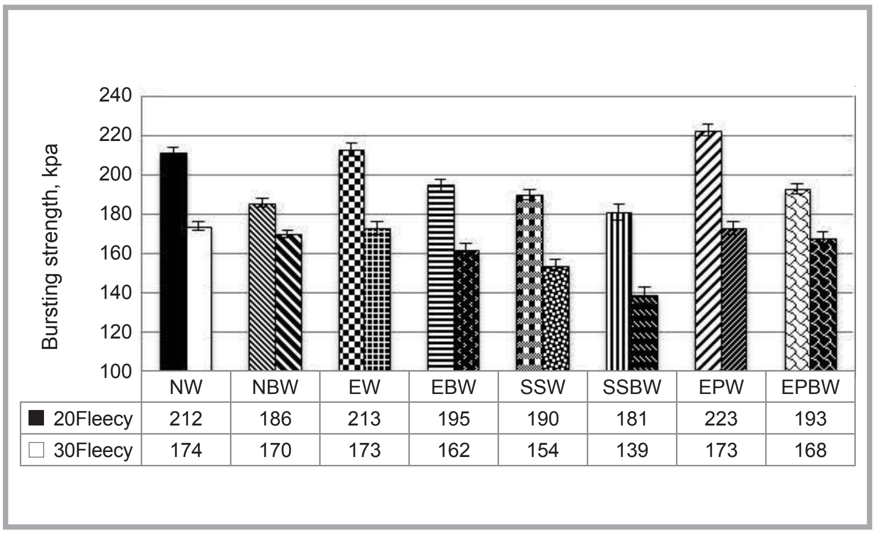


Figure 7. *Bursting strength of sample knitted fabrics with cotton-modal fleecy yarns according to washing type.*

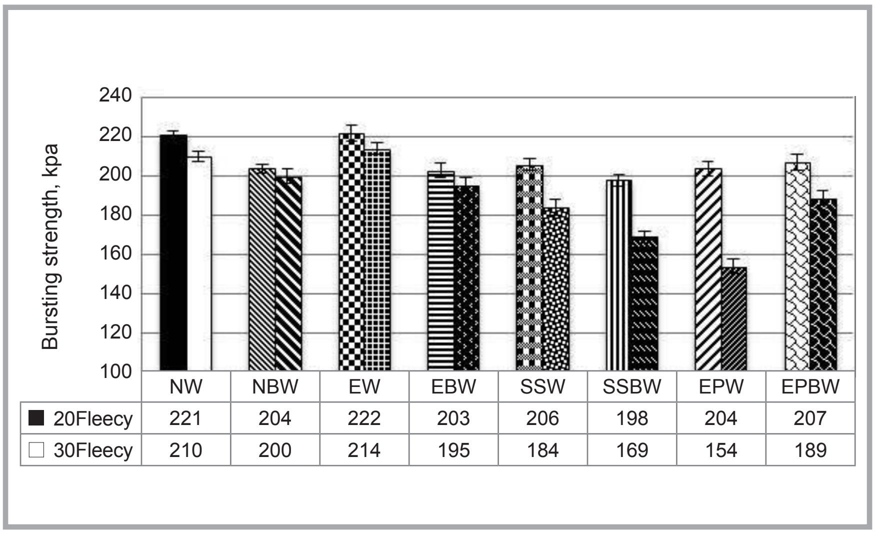


Figure 8. *Bursting strength of sample knitted fabrics with cotton-polyester fleecy yarns according to washing type.*

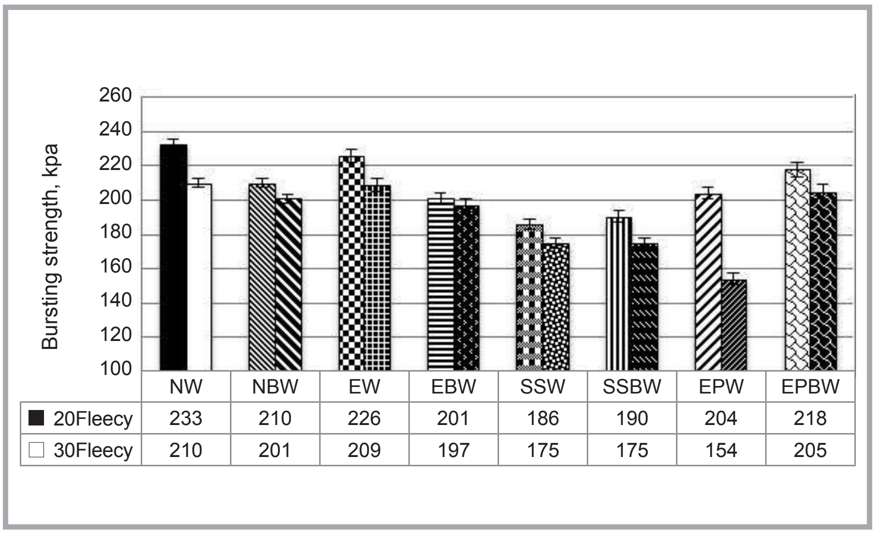


Figure 9. *Bursting strength of sample knitted fabrics with polyester-viscose fleecy yarns according to washing type.*

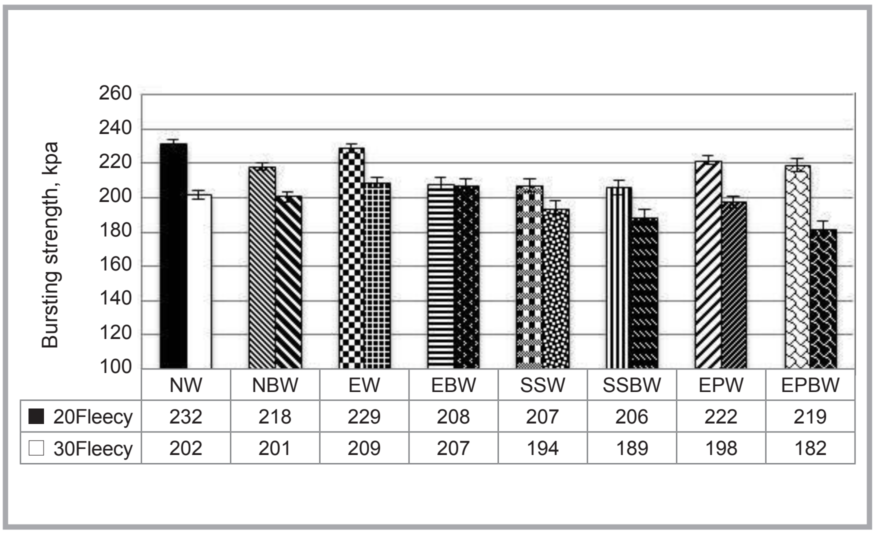


Figure 10. *Bursting strength of sample knitted fabrics with polyester fleecy yarns according to washing type.*

The results shown in ***Figure 9*** emphasize that polyester increases the strength of the fabrics, whereas that of viscose is affected by the ponza stone, with the results being similar to the fabrics with viscose fleecy yarns. Among the washing types, EPW, NW and EW are suitable for these fabrics.

Polyester is a synthetic fiber; the breaking strength of which is more than that of cellulosic ones, and hence the bursting strength of the fabric is extremely high after washing. The hydrophobic structure makes the fabric resistant to washing by blocking water inside the fabric. Like other denim-like knitted fabrics, these fabrics are affected by the bleaching process. It is obvious that the bleaching process deteriorates the resistance of cellulosic fibers, and because the face yarn of all the types of fabrics is cotton, their strength decreases as well. Among the washing types, enzyme and normal washing seem more suitable according to the strength test results; but also all the other types can be used because the strength values are clos to each other.

Strength loss of the fabrics relative to the control group

All the washing treatments performed with the various recipes have different effects on the sample knitted fabrics. In the first part of the study, the bursting strength test results are compared according to fleecy yarn type, where the best washing treatment relative to the fleecy yarn is ed attempted to be established. In this part of the study, the strength losses of the samples were analyzed, and relative to the control group (untreated fabric type) the most resistant fabric type was found according to washing treatment. For this calculation ***Equation (1)*** is performed.

$$RS = \frac{[(SU-SW)*100]}{SU} \qquad (1)$$

In this equation "RS" refers to the relative strength loss percentage of of the sample fabrics before and after washing treatment. "SU" refers to the strength of the sample fabrics before washing treatment and "SW" to their strength after the washing treatment. By using this equation, the relative strength of each sample is calculated and presented in ***Table 5***.

To establish which treatment is beneficial to which fabric, the values given in ***Table 5*** should be grouped in five categories according to the pick values. Therefore "Under 3%" – no significant difference, "Between 3,01 to 5,99" – acceptable difference, "Between 6,00 to 10,00 "– different; "Between 10,01 to 16" – quite different, and "Over 16,01" – significantly different. ***Table 4*** shows that the normal washing treatment is quite a useful treatment method for many fabrics. When the bleaching process is applied with normal washing, the samples with viscose, mod-

Table 5. *Relative strength loss percentage of sample fabrics.*

Samples		Relative strength loss percentage of sample fabrics after treatments applied, %							
		NW	NBW	EW	EBW	SSW	SSBW	EPW	EPBW
20-Fleecy Fabrics	Cotton	1.39	7.87	3.24	10.19	6.48	12.96	9.72	11.11
	Modal	2.33	3.77	0.00	13.49	11.63	11.16	0.47	2.79
	Bamboo	6.19	4.76	5.24	26.19	13.81	20.48	5.71	5.71
	Viscose	0.96	1.44	0.48	10.10	10.58	18.75	6.73	11.06
	Tencel	0.92	9.63	1.38	11.47	11.47	11.93	5.05	8.26
	Cotton-Modal	5.36	16.96	4.91	12.95	15.18	19.20	0.45	13.84
	Polyester-Cotton	1.78	9.33	1.33	9.78	8.44	12.00	9.33	8.00
	Polyester-Viscose	0.43	10.26	3.42	14.10	20.51	18.80	12.82	6.84
	Polyester	0.85	6.84	2.14	11.11	11.54	11.97	5.13	6.41
30 Fleecy Fabrics	Cotton	1.62	11.35	2.16	1.08	12.43	25.41	12.43	3.78
	Modal	1.70	2.84	1.70	11.36	12.50	24.43	11.93	10.23
	Bamboo	4.88	3.66	4.27	13.41	15.24	28.66	8.54	3.05
	Viscose	3.23	8.52	6.63	16.22	16.75	20.98	14.29	11.64
	Tencel	0.50	5.45	0.99	7.43	35.15	36.14	0.99	3.47
	Cotton-Modal	5.43	7.61	5.98	11.96	16.30	24.46	5.98	8.70
	Polyester-Cotton	2.33	6.98	0.47	9.30	14.42	21.40	28.37	12.09
	Polyester-Viscose	0.47	4.74	0.95	6.64	17.06	17.06	27.01	2.84
	Polyester	6.05	6.51	2.79	3.72	9.77	12.09	7.91	15.35

al and bamboo fleecy yarns can withstand it. Enzyme washing can be used for denim-like knitted fabrics, but again bleaching decreases the resistances of the samples. Super stone washing treatment with and without the bleaching process is not suitable for denim-like knitted fabrics. Enzyme perlit washing is used for the samples produced with 20 fleecy fabrics.

Conclusion

In this study, 18 denim-like knitted fabrics were measured and then 8 different washing treatments were applied to them to increase the similarity to traditional denim fabrics. Then to select the most suitable washing treatment for the samples, the bursting strength test was performed for all 162 denim-like knitted leg panels. According to the results of this study, denim-like knitted fabrics are affected by the bleaching process. Among the samples, only the fabrics which have synthetic fleecy yarns are more resistant to washing. However, natural fiber may have a hydrophilic nature, which decreases compatibility with the hydrophobic polymeric matrix, and hence they are more sensitive to the bleaching process. Despite these drawbacks, natural fibers are used for many reasons. Natural fibers can be a renewable and cheaper substitute for synthetic fibers, having numerous advantages, such as low cost, low density, high toughness, acceptable specific strength properties, ease of separation and biodegradability [21]. Among the washing types, using NW and EW are convenient for all types. SSW is more suitable for the fabrics including cotton, tencel, cotton-polyester and polyester yarns. EPW is a suitable method to wash fabrics produced with tencel, modal, polyester and polyester-viscose fleecy yarns. Generally for denim-like knitted fabrics, normal, enzyme and perlit washing are preferable treatments, but they cannot withstand super stone washing; hence it is concluded that ponza is not a usable enzyme for denim-like knitted fabrics. Finally it is decided that to produce a denim-like knitted fabric, the fleecy yarns should be synthetic or synthetic blended, and the count should be Ne 20/1. The treatment can be enzyme bleach washing because this ensures both a worn-look and the fabrics do not lose more strength after this .

Limitations of the study

In this study, the pattern type was constant, and the effect thereof could not be examined. Hence in subsequent studies the pattern type may be varied.

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