COMMERCIALIZED DENIM FABRIC PRODUCTION WITH POST-INDUSTRIAL AND POST-CONSUMER WASTES

ENDÜSTRİYEL VE TÜKETİCİ SONRASI ATIKLAR İLE TİCARİLEŞEBİLİR DENİM KUMAŞ ÜRETİMİ

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ABSTRACT

The purpose of this study was to produce 100% recycled denim without a tradeoff in quality according to zero waste concepts. Initially, the waste points from raw materials to final product in denim fabric production process were determined. Then, denim fabrics were produced from post-industrial (recycled cotton fibers obtained from denim wastes) and post-consumer wastes (produced from recycled PET bottles). Classic cotton fibers and alternative regenerated cellulose fibers (Tencel®) were used as carrier fiber in addition to mentioned fibers for eliminating recycled fibers disadvantages. The effect of fiber types on yarn or fabric characteristics were investigated in accordance with planning design and construction. Furthermore, the relationships between fibers and yarns/fabric results were statistically evaluated using correlation analysis. The results of this investigation show that the amount of fibers have a significant effect on yarn unevenness, thick places, neps, hairiness, air permeability and abrasion resistance of the samples.

Keywords: Cotton, Tencel®, recycling, r-PET fibers, OE Rotor yarn, denim fabric

ÖZET

Bu çalışmanın amacı, sıfır atık konseptine uygun olarak kaliteden ödün vermeden %100 geri dönüşüm denim üretimidir. Öncelikli olarak denim kumaş üretim sürecinde hammaddeden mamule atık noktaların tespiti yapılmıştır. Sonraki süreçte endüstriyel atıklar (denim sektöründe geri kazanılan pamuk lifleri) ve tüketici sonrası atıklardan (PET şişe atıklarından geri kazanılan lifler) denim kumaşlar üretilmiştir. Bahsedilen liflere ek olarak olumsuz yönleri elimine edebilmek için klasik pamuk lifleri ve rejenere selülozik Tencel® lifleri de taşıyıcı lifler olarak çalışmada kullanılmıştır. Yapılan tasarıma ve konstrüksiyona bağlı olarak, lif tiplerinin iplik veya kumaş karakteristikleri üzerine etkisi araştırılmıştır. Ayrıca, lifler ve iplik/kumaş sonuçları arasındaki ilişki korelasyon analizi ile istatistiksel olarak değerlendirilmiştir. Araştırmanın sonuçları lif miktarının iplik düzgünsüzlüğü, kalın yer, neps, tüylülük, kumaş hava geçirgenliği ve aşınma direnci üzerinde önemli etkiye sahip olduğunu göstermektedir.

Anahtar Kelimeler: Pamuk, Tencel®, geri dönüşüm, r-PET lifleri, OE Rotor iplik, denim kumaş

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INTRODUCTION

Nowadays, sustainable and eco-friendly product concepts have been begun to discover and use frequently. However, both producer and consumer did not perceive these concepts literally. People were only interested in final products ecological character. As long as the final product didn't cause any harm to the consumer, that product could be defined as ecological character. For example, the chemical effects of a textile product (garment) on human body were taken into consideration. The determination of pH, formaldehyde, heavy metal ions, color fastness or smell tests known as ecological tests were applying for final products. But, the deterioration of the global ecological balance is a direct factor on human's life and these mentioned efforts are not enough to protect from global

environmental risks. Therefore, production process and recycling technology are no longer given on a new significance in addition to human ecology [1]. Furthermore, sustainability or eco-friendly applications in previous years came to mean extra expenditure but today, we read them as extra added value. The slightest improvements for sustainability are being used by most of companies so as to change consumer perception. It also provides important opportunities to trademarks in order to canalize consumer perception. Therefore, outstanding companies carry out responsibilities in terms of sustainability and point out clearly in their mission or vision [2].

As a matter of course, sustainability for the textile industry is firstly associated with raw material's environmental awareness. This view includes a series process containing the choice of materials, production specifications and re-using [2, 3]. In this context, there are limited studies in the literature. Most of reseachers were giving particular importance to economic advantage. In 2007, Halimi *et al.* published a paper in which they studied the effect of cotton wastes and different spinning parameters on the rotor yarn quality. It has been demonstrated that the secondary raw material can be blended in a proportion between 15% and 25% without hardly noticeable changes in quality [4]. Another example, Kurtoglu Necef *et al.* (2013) investigated the usability of recycled garments which were manufactured by evaluating fabric scraps. In their study, single jersey fabrics were knitted with reycled yarns in the same conditions. It has been asserted that there is not a distinctive difference between recycled and virgin garments qualities and recycled garments obtained from fabric scraps can be used in apparel manufacturing industry [5]. Moreover, there has been an increasing studies on sustainability in addition to economic advantage in the literature. For example; Muthu et al. (2011) investigated the Recyclability Potential Index (RPI) of commonly used textile fibers. Researchers used "Environmental Gain Index" and "Economic Gain Index" conjunctively obtained from previous studies for the relationship between fibers and RPI. According to developed system, polyester fibers have the highest recyclability potential together with polypropylene fibers than other fibres [6].

In this study, denim fabrics were produced from post-industrial (recycled cotton fibers obtained from denim wastes) and post-consumer wastes (produced from recycled PET bottles). Contrary to belief, our purpose is to produce 100% recycled denim without a tradeoff in quality. Zero waste concepts [7] are supported by this way. Furthermore, this paper presents a multi-perspective approach for denim fabric production. Global denim market will grow in the coming years and is foreseen to reach $ 56 billion according

to various reports of international organizations [8]. Taking into risks of that growth with regard to total environmental load, the importance of sustainability efforts related to denim industry will be better understood. However, most of the studies about denim wastes are related with insulation [9, 10]. Additionally, there are not many studies about yarns and fabrics from recycled PET bottles [11, 12]. These studies are also not related to denim. Moreover, there is no study about denim fabric properties which have been produced from ternary blended yarns with mentioned fibers. It is thought that this study can contribute to sustainable denim production.

MATERIAL AND METHODS

In this study, the waste points from raw materials to final product were determined primarily (Figure 1). As a result of determination, recyclable materials to be re-used in yarn production and waste materials to be used in different areas (backfill, composite, isolation, flock, secondary products and etc.) were separated. Recyclable materials to be used in the production of new yarns were also evaluated into two categories. Undyed ecru fibers (Ecru-r-Co) on left section and dyed indigo fibers (Indigo r-Co) on right section are shown in Figure 1.

Mentioned recyclable materials were reclaimed by Garnett machines in a recovery factory in Turkey according to desired color. However, recovery fibers aren't a repeatability and controllability of these fibers properties due to problems during the fiber measurements. They have non-uniform character and the different lot every time. Therefore, we have to use carrier fibers for the purpose of eliminate recycled fibers disadvantages and compensate the average fiber length. Firstly, r-PET fibers which are produced from PET bottle wastes with recycling were preferred. PET bottle voluminous structure is cause of decreased waste storage area. These wastes are a big problem for ecology. r-PET fibers are also produced by melt-spinning process of the post-consumer PET bottle flakes, which requires less energy to produce than virgin polyester [2, 11]. Classic cotton fibers and alternative regenerated cellulose fibers (Tencel®) were used as carrier fiber in addition to r-PET fibers. Table 1 provides the properties of three types fibers. Fibers properties are based on producer companies' data. The denim yarns were produced through Open-end Rotor spinning system by using four different fibers with same production parameters (Table 2).

Commercialized yarns were achieved by using five different blending ratios with regards to labor and efficiency costs as a result of yarn production trials. Table 3 presents blending ratios of yarn designs by using four different fibers.

Table 1. Fiber properties

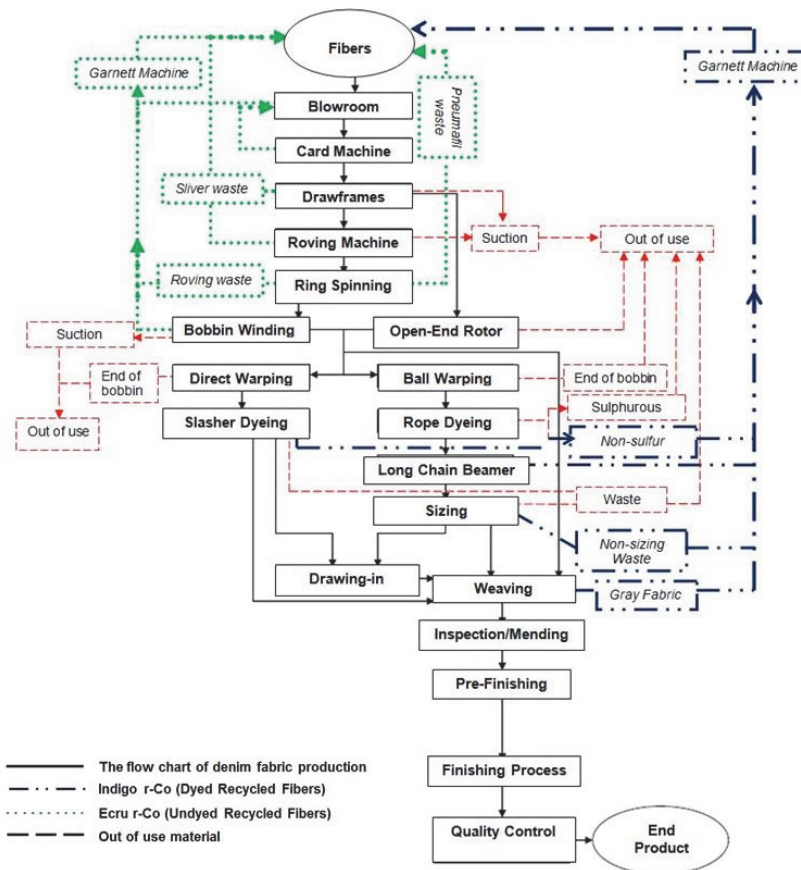| Fiber properties	r-PET	Cotton	Tencel®	r-Co
Fineness (dtex)	1,55	1,79	1,44	1,81
Mean Length (mm)	38	29,5	38	24,5
Tenacity (cN/tex)	41,5	31,1	37	30,25
Elongation at Break (%)	32,5	5,1	13	3,85

Figure 1. The flow chart of denim fabric production and waste formation points

Table 2. Yarn production parameters

Yarn Count (tex / Ne)	74 / 8
Twist Coefficient (α_e / α_m)	5 / 151
Machine Type	Rieter R20
Rotor Type	U40
Rotor Speed (r/min)	50.000
Opening roller speed (r/min)	8.000

Table 3. Blending compositions and ratios

Design Code	Blending Composition
C1	85% r-Co 15% r-PET
C2	70% r-Co 30% r-PET
C3	40% r-Co 30% r-PET 30% Co
C4	30% r-Co 40% r-PET 30% Tencel
C5	30% Co 50% r-PET 20% Tencel

Then, tensile strength, elongation at break, unevenness, hairiness properties and IPI fault values of yarns were measured. Unevenness measurements of the yarns were carried out by using"Uster Tester 4- FX" instrument, in conformity with ISO 16549 standards in measurement speed of 400 meters per minute for 1000 meters of yarn. Ten tests were done each type of yarn and the average value was taken. Unevenness (CVm), imperfections (IPI values) values [thin places (-50%), thick places (+50%) and neps (+280%)] and hairiness values were determined.

Table 4. Fabric production details

Yarn (Warp)	74 tex, OE-Rotor
Yarn (Weft)	74 tex, OE-Rotor
Reed Number	60
Reed Width (cm)	180
Fabric Width (cm)	160
Warp Ends / cm	28
Picks / cm	18
Number of ends	4480+40 (selvedge)
Fabric Structure	Twill 3/1 Z
Mass per unit area (g/m^2)	350

Tensile strength and elongation at break of the yarns were carried out by using TITAN tensile testing device in conformity with TS 245 EN ISO 2062 standard. Fifty results per yarn type were determined as tenacity (cN/tex) and elongation at break (%). After that, sustainable denim fabrics were produced from these yarns used in weft and warp direction pursuant to planning design and construction on Picanol Rapier Weaving Machine according to fabric details from Table 4. Singeing, washing, drying and sanforizing were performed respectively on all produced gray fabrics. After these operations, mass per unit area of fabrics were controlled in order to make reliable comparisons on finished denim fabrics. Breaking strength (warp/weft), elongation at break (warp/weft), tear strength (warp/weft) and abrasion resistance were measured so as to see the fabric mechanical behavior against encountered external factors and effects. Moreover, air permeability and circular bending rigidity tests were measured to obtain information about the physical comfort of finished fabrics. All of performance the tests were carried out after conditioning in standard atmospheric conditions according to TS EN ISO 139. Tests were done 5 times and the average values were taken. Mass per unit area determination of fabrics was done according to TS 251. Breaking strength and elongation at break tests were carried out in weft and warp direction according to TS EN ISO 13934-1:2002 with strip method by using TITAN tensile testing device. Tear strength tests were also fulfilled according to TS EN ISO 13937-4 on the same device. Abrasion resistance of the fabrics were obtained using "Martindale Abrasion Tester" with 9kPa weights according to ISO 12947-3 standard. For observing the first break on the fabric, machine was used up to 40.000 rubs. For this reason, results were based on the weight loss at 10.000, 15.000, 25.000, 40.000, 50.000, 60.000 and 75.000 rubs. Additionally, before and after abrasion images of fabrics were taken for 75.000 rubs. Circular bending rigiditiy tests were performed using ASTM D 4032 standards with A&T 200-A Digital Pneumatic Stifness Tester. Air permeability tests of the fabrics were carried out with "Prowhite Air Permeability Tester" according to TS 391 EN ISO 9237. 20 cm^2 measurement area and 100Pa air pressure were used.

RESULTS AND DISCUSSION

Table 5 shows the yarn results and Table 6 provides the results of fabrics produced from these yarns. Furthermore, the relationships between preferred fibers types and the measurement results obtained from yarn/fabric values were statistically evaluated using correlation analysis (Table 7). According to the data set, Sperman's rho correlation analysis and coefficient of correlation (r) was used to examination of the correlation. The value of "r" is such that -1<r<+1. A correlation greater than 0,75 is generally described as strong, whereas a correlation less than 0,5 is generally described as weak [13]. The test results and statistical evaulations revealed that the amount of mentioned fibers have an important effect on yarn unevenness, thick places, neps, hairiness, fabric breaking force (weft), tear strength (warp) and air permeability after planning design and preferred production parameters (Table 7).

From the Table 7, we can see that there is a weak relationship between fiber content and the results of yarn tensile strength, elongation at break, thin places, elongation at maximum force and stiffness. A possible explanation for this might be that the preferred production parameters have higher effect than fiber content for these specifications. The results of this study indicate that the strong positive effect of r-Co (r=0,906) and the strong negative effect of r-PET (r=-0,869) was found on yarn unevenness. Moreover, the good negative effect of Co (r=-0,646) and Tencel (r=-0,605) was found yarn unevenness. As the increase of r-PET, Co and Tencel content cause decrease in yarn unevenness, the increase of r-Co content cause increase. The reason for this can be explained with short fiber content and length uniformity. r-Co is composed of roving waste, sliver waste, pneumafil waste, gray fabric waste, non-sulfur and non-sizing yarn wastes (Figure 1).

Table 5. Yarn test results [3]

Material	Tensile Strength (cN/tex)	Elongation at Break (%)	Unevenness (%CVm)	Thin Places (-%50)	Thick Places (+%50)	Neps (+%280)	Hairiness (H)
C1	11,51	8,52	14,96	6,4	41,6	41,6	7,37
C2	11,99	9,50	12,84	0	38,4	22,4	7,16
C3	12,09	9,62	12,13	0	12,8	32	6,83
C4	12,09	7,73	11,91	0	25,6	6,4	8,16
C5	12,04	9,24	11,28	3,2	6,4	0	8,98

Table 6. Means of fabric test results [14]

Material	Breaking Force (Max Load- N)		Elongation at Break (%)		Tear Strength (Mean Peak Force- N)		Air Permeability (mm/s)	Circular Bending Rigidity (N)
	Warp	Weft	Warp	Weft	Warp	Weft		
C1	1263,6	912,9	26,27	22,95	65,26	57,07	105,41	12,37
C2	1206,3	851,1	29,85	19,61	61,56	48,46	127,82	38,82
C3	1237,8	960,3	29,69	18,49	64,84	50,94	129,79	40,19
C4	1137,7	904,8	26,96	19,88	56,96	50,60	187,19	41,80
C5	1237,6	934,7	27,98	19,72	65,61	56,33	161,42	31,28

Table 7. The obtained correlation coefficient between blending compositions and yarn/fabric performance according to fiber types

Test Types	Coefficient of correlation (r) values according to fiber types			
	r-Co	r-PET	Co	Tencel
Tensile Strength	-0,140	0,140	0,070	0,099
Elongation at Break	-0,008	-0,001	0,426	-0,419
Unevenness	0,906**	-0,869**	-0,646*	-0,605*
Thin Places (-50%)	0,174	-0,179	-0,050	-0,097
Thick Places (+50%)	0,471	-0,398	-0,525*	-0,237
Neps (+280%)	0,699*	-0,630*	-0,550*	-0,485
Hairiness	-0,604*	0,672*	0,011	0,768**
Breaking Force (Weft)	-0,357	0,217	0,600*	0,118
Breaking Force (Warp)	0,263	-0,328	0,328	-0,478
Elongation at Max. Force (Weft)	0,367	-0,321	-0,481	0,011
Elongation at Max. Force (Warp)	-0,067	0,083	0,362	-0,386
Tear Strength (Weft)	-0,059	-0,018	0,260	0,079
Tear Strength (Warp)	-0,020	-0,082	0,657*	-0,377
Stiffness	-0,259	0,243	0,023	0,202
Air Permeability	-0,853**	0,864**	0,198	0,869**

(*) good correlation (**) strong correlation (-) negative correlation

C1 yarns have recycled cotton fiber proportion up to 85% and they have highest unevenness among the all yarns. As shown in Table 7, a good negative correlation was determined between thick places and cotton fiber (r=-0,525). The decreases of thick places were obtained with the increase in cotton fiber content. C3 and C5 types including cotton fiber have lower thick places comparing to the other. In terms of yarn neps, C1 have highest neps values among the all yarns. There is a significant positive correlation between neps values and r-Co content (r=0,699). Moreover, a good negative correlation of r-PET (r=-0,630) and cotton (r=0,550) fibers was found on yarn neps. As the increase of r-PET, Co and Tencel content cause decrease in yarn neps, the increase of r-Co content cause increase. There were not r-Co fibers in composition of C5 yarns and these yarns have lowest neps values. No significant differences were detected with the amount of fiber types in yarn tensile strength, elongation at break and thin places. In terms of yarn hairiness, we can surmise that if the chemical fibers (r-PET and Tencel®) ratio in the yarn increases, yarn hairiness increases (C4 and C5). Because of taper, only one end, the weightier part of the cotton fiber, leads to appear as a protruding end in a cotton yarn. But, both ends have an equal probability of showing up as protruding ends in chemical fibers. As can be seen from Table 7, there was a strong positive correlation between hairiness and Tencel (r=0,768). The findings of the current study are consistent with those of Kilic and Okur (2011) who found an increase on hairiness values with the increasing ratio of regenerated cellulosic fibre content [15]. Moreover, a positive correlation was found between hairiness and r-PET fibers (r=0,672). From the data in Table 7, a negative correlation was observed between hairiness and r-Co fibers (r=-0,604). Cotton yarns are already known to be less hairy than yarns spun from chemical fibers. However, all yarn types have higher hairiness values according to a standard yarn. It is generally agreed today that if the short fiber content in the yarn increases, the number of protruding fibers increases. This study produced results which corroborate the findings of a great deal of the previous work in this field. In reviewing the literature, the empirical findings shows that recycled cotton fibers can be blended in a proportion between 15% and 25% without hardly noticeable changes in quality by using optimum spinning conditions; however, there has been a geometrical increase in the values of unevenness, thick places and neps for more than 25% recycled cotton proportion [4, 16]. The first serious discussions and analyses of r-PET fibers and their blends were emerged by Telli and Ozdil (2013). Properties of the yarns produced by r-PET fibers and their availability for textile industry were comparatively investigated. The yarn unevenness values and IPI faults of 100% r-PET yarns are worse than 100%PET yarns. But, there was no significant difference between r-PET fiber's blends with cotton and PET for these properties [11]. Telli and Özdil (2015) investigated comparatively fabric characteristics features which were produced by using 100% r-PET fiber with cotton and polyester fibers. It emphasized that the taken results will be able to positive effect if r-PET fibers are blended with cotton [12]. In this study, the content of recycled fiber was preferred at least 30% r-Co. Up to 85% recycled cotton fiber proportion (C1) was used. Furthermore, the amounts of recycled material have reached 100% with r-PET fibers (C1 and C2). The results of this study indicate that yarns from recycled fibers have higher unevenness, IPI faults and hairiness comparing to the standard yarns. These yarn imperfections contributed to negative effects on fabric surface. Denim fabrics obtained from these yarns have noticeable nubs in fabric surface. However, there was not an important problem with regard to fabric physical and mechanical properties. Furthermore, positive results were also obtained for fabric properties.

The breaking strength, elongation at break, tear strength, air permeability and circular bending rigidity results of denim fabrics are presented in Table 6. Data from this table like yarn test results were closer values in fabric with regard to mechanical behaviours such as breaking strength, elongation at break and tear strength. However, there were significant differences in air permeability and circular bending rigidity amongst fabrics. The abrasion/friction

performance of fabrics generated from produced yarns with blending proper combination of recycled fibers is a piquant question in terms of place of use. Thereby, abrasion resistance values of fabrics were investigated in this study. Figure 2 compares the results of obtained from mass loss of denim fabric according to selected number of rubs. The situations of equal variances of the parameters were checked and statistically evaluated with "Tukey" Post-Hoc techniques. The results (p values) of multiple comparisons of the fabric properties for the mass loss in each number of rubs were also given in Figure 3. The first changes were started in 25.000 rubs (p=0,006). After this, the first break on the fabric was observed in 40.000 rubs and the differences of fabric types in respect of abrasion resistance were started to show similar results. Most of fabrics also have been structural imperfections completely up to 75.000 rubs. Actually, abrasion resistance values were found very well and these rubs were higher than the expected value of a textile product. Figure 3 shows before and after images of fabrics subject to 75.000 rubs. Contrary to expectations from recycled products, fabrics have better abrasion resistance values.

To evaluate fiber effect on abrasion resistance, we begin by taking a closer look at the Spearman's rho correlations for selected rubs according to mass loss from Table 8. It can be deduced from mass loss data in Table 8 that the fiber effect on abrasion resistance is usually associated with rubs. A negative correlation was found between mass loss and cotton fiber up to 25.000 rubs (r=-0,717). What is interesting in data that the first changes were began in this rubs. One anticipated finding was that the fiber effect on mass loss changed after the observed the first break on the fabric in 40.000 rubs. After this rubs, there was a significant positive correlation between Tencel (r=0,794) and r-PET (r=0,708) with mass loss. And, there was a negative correlation between mass loss and r-Co fibers (r=-0,574). Previous studies have reported that Co/r-PET blended fabrics have the lower mass loss values for each number of rubs than

pure cotton fabrics. But for the higher than 10.000 rubs, 100% r-PET fabrics displayed higher tendency to be abraded as compared with Co/r-PET blended fabrics in knitted structure [12].
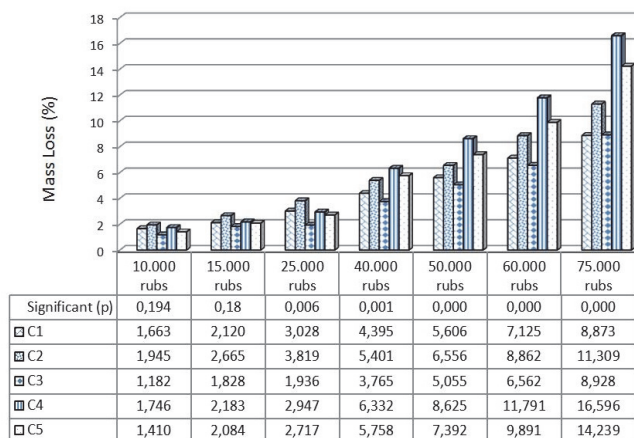
	10.000 rubs	15.000 rubs	25.000 rubs	40.000 rubs	50.000 rubs	60.000 rubs	75.000 rubs
Significant (p)	0,194	0,18	0,006	0,001	0,000	0,000	0,000
C1	1,663	2,120	3,028	4,395	5,606	7,125	8,873
C2	1,945	2,665	3,819	5,401	6,556	8,862	11,309
C3	1,182	1,828	1,936	3,765	5,055	6,562	8,928
C4	1,746	2,183	2,947	6,332	8,625	11,791	16,596
C5	1,410	2,084	2,717	5,758	7,392	9,891	14,239

Figure 2. Mass Loss according to selected number of rubs

Table 8. Spearman's rho correlations for selected rubs according to mass loss

Test Types	Correlation coefficient			
	r-Co	r-PET	Co	Tencel
10.000	0,348	-0,211	-0,667*	-0,063
15.000	0,195	-0,035	-0,513*	-0,096
25.000	0,374	-0,176	-0,717*	-0,167
40.000	-0,574*	0,708*	-0,205	0,794**
50.000	-0,620*	0,748*	-0,154	0,836**
60.000	-0,660*	0,777**	-0,102	0,836**
75.000	-0,699*	0,807**	-0,051	0,836**

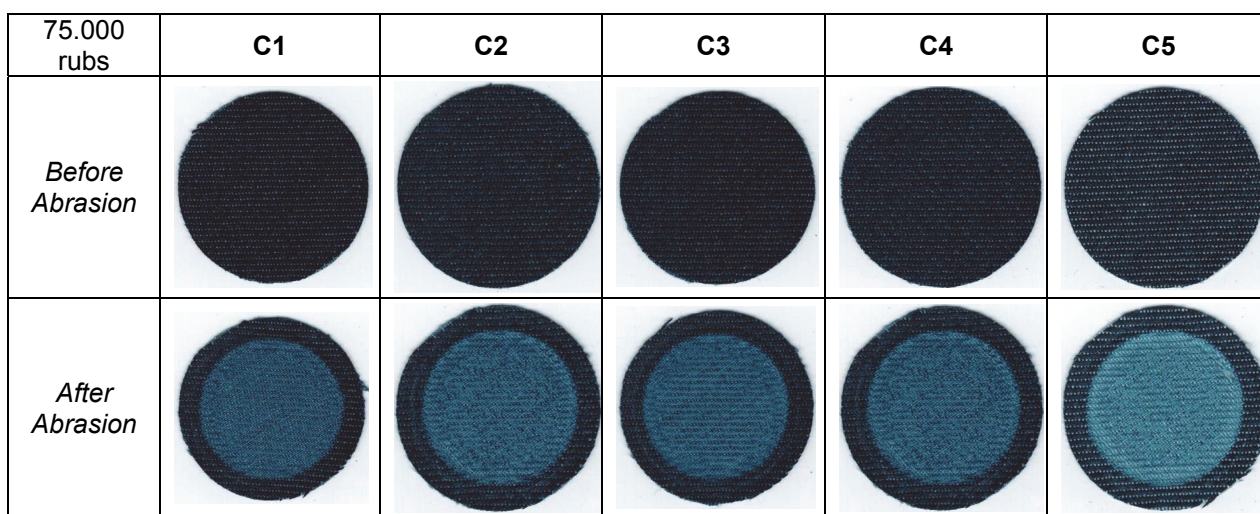(*) good correlation (**) strong correlation (-) negative correlation

Figure 3. Before and after images of fabrics subject to 75.000 rubs

The observed differences based on for abrasion resistance could be attributed to washing processes on fabric. We did not dwell on frequently preferred different washing types in denim industry. When these fabric characteristics are exposed to enzyme washing, stone washing or bleaching, denim fabrics can also acquire amazing qualifications if the process conditions can be optimized with fiber effect on abrasion resistance from this study. Moreover, locally seen nubs on fabric surface will move off denim surface during these washing processes. Additionally, a special washing effect can be provided due to their abrasion resistance test results.

In terms of other fabric test results, we can see that the content of fiber have a significant differences on air permeability (Table 7). There is a weak relationship between stiffness, elongation at maximum force (weft/warp), tear strength (weft) and breaking force (warp) with fiber content. Indeed, a positive correlation was found between warp tear strength (r=0,657) and weft breaking force (r=0,600) with cotton fibers. In our opinion, these results are not enough to explain the effect of cotton fibers owing to fabrics were produced from same yarns used in weft and warp direction. No significant correlations were determined different direction for breaking force and tear strength. A possible explanation for this might be that the preferred machine and production parameters have higher effect than fiber for these specifications. We can see similar situation in stiffness values. Normally, Tencel fibers have lower rigidity than cotton. But, no significant correlation was found between fibers and bending rigidity due to other factors. As for air permeability, there is a strong relationship between r-Co (r=-0,853), r-PET (r=0,864) and Tencel (r=0,869) with air permeability. C4 and C5 types including Tencel fiber have higher permeability among the all fabrics (Table 6). As the increase of r-Co content cause decrease in air permeability, the increase of r-PET and Tencel content cause increase. This study confirms that the increase of air permeability can be associated with the amount of chemical fibers. Previous research findings in air permeability of Tencel fibers have identified that fabrics made of Tencel yarn have a higher value of air permeability than fabrics made of cotton yarn [17]. They have suggested that Tencel fabrics are more suitable for summer clothing from this point of view.

CONCLUSIONS

The purpose of the current study was to produce 100% recycled denim without a tradeoff in quality according to zero waste concepts. Therefore, the content of recycled fiber was preferred at least 30% r-Co. Up to 85% recycled cotton fiber proportion (C1) was used. Furthermore, the amounts of recycled material have reached 100% with r-PET fibers (C1 and C2). One of the more significant findings to emerge from this study is that yarns from recycled fibers have higher unevenness, IPI faults and hairiness comparing to the standard yarns. These yarn imperfections contributed to negative effects on fabric surface. Denim fabrics obtained from these yarns have noticeable nubs in fabric surface. However, there was not an important problem with regard to fabric physical and mechanical properties. The second major finding was that fabrics have better abrasion resistance values contrary to expectations from recycled products. But, the fiber effect on abrasion resistance is usually associated with rubs. Taken together, abrasion resistance can be able to create extra added value for subsequent process steps to be applied optionally in different washing types. Locally seen nubs on fabric surface will move off denim surface during these washing processes. Additionally, a special washing effect can be provided due to their abrasion resistance test results. Therefore, further experimental investigations are needed to examine the effects of different washing types. Moreover, a limitation of this study is that we preferred same machine and production parameters. Further research might explore the role of production parameters for this concept

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