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Evaluation of mechanical properties of woven blankets with recycled yarns

Geri dönüşüm iplik içeren dokuma battaniyelerin mekanik özelliklerinin değerlendirilmesi

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Abstract

In recent years, considering production technologies and consumption habits in textiles, the issue of recycling textile waste has attracted great attention from the researchers. Textile waste have been re-used as raw materials during the production processes to maintain the benign effects for economical and ecological sides. In this study, determined performance features of woven blankets including recycled yarns are investigated in terms of different production parameters. In the production of blankets, the yarns used in the weft direction consist of 35%/35%/30% acrylic/cotton/polyester recycling fibers. The warp yarn consists of 70%/30% acrylic/cotton and contains a total of 85% recycled fiber. In the study, the blankets were produced in 3 different weft density: plain and twill weave. In order to investigate the effect of the raising process, samples were prepared as raised and non-raised. The air permeability, tensile strength and elongation and bending rigidity performances of the blankets are determined by standard test methods and the results are statistically evaluated. As a result of the evaluations, it was observed that these examined properties were affected by the fabric parameters in different ways. Considering the results, recycled fibers have become prominent in textile production processes where they provide the target durability by determining the appropriate usage areas.

Keywords: Waste, Recycling, Blanket, Mechanical properties.

Öz

Son yıllarda tekstilde üretim teknolojileri ve tüketim alışkanlıkları göz önüne alındığında tekstil atıklarının geri dönüştürülmesi konusu araştırmacıların büyük oranda ilgisini çekmektedir. Ekonomik ve ekolojik açıdan olumlu etkilerin korunması amacıyla tekstil atıkları üretim süreçlerinde hammadde olarak yeniden kullanılmaktadır. Bu çalışmada geri dönüştürülmüş iplik içeren dokuma battaniyelerin belirlenen performans özellikleri farklı üretim parametreleri açısından araştırılmıştır. Battaniyelerin üretiminde, atkı yönünde kullanılan iplikler %35/%35/%30 akrilik/pamuk/poliester geri dönüşüm liflerinden oluşmaktadır. Çözgü ipliği ise; %70/%30 akrilik/pamuktan oluşmaktadır ve toplamda %85 oranında geri dönüşüm lif içermektedir. Çalışmada battaniyeler bez ayağı ve dimi örgüsünde olmak üzere 3 farklı atkı sıklığında üretilmiştir. Şardonlama işleminin etkisinin araştırılması amacıyla numuneler şardonlu ve şardonsuz olarak hazırlanmıştır. Battaniyelerin hava geçirgenliği, kopma mukavemeti ve uzaması ve eğilme rijitliği performansları standart test yöntemleri ile belirlenmiş ve sonuçlar istatistiksel olarak değerlendirilmiştir. Değerlendirmeler sonucunda incelenen bu özelliklerin kumaş parametrelerinden farklı şekillerde etkilendiği gözlemlenmiştir. Sonuçlara bakıldığında geri dönüştürülmüş elyafların, uygun kullanım alanlarının belirlenerek hedeflenen dayanıklılığı sağlamasıyla tekstil üretim süreçlerinde öne çıktığı görülmektedir.

Anahtar kelimeler: Atık, Geri dönüşüm, Battaniye, Mekanik özellikler.

1 Introduction

Textile manufacturing is one of the most wide-spread industrial applications worldwide. It has major effects from the economic aspect in terms of trade, investment, and employment. On the other hand, rapidly changing consumption habits, reducing in the raw material sources and increasing consciousness about environmental issues highlighted recycling approaches in textiles. During the manufacturing processes such as spinning, weaving, knitting, non-woven production and apparel, undesirable outcomes of the procecesses occur in unignorable amounts which are considered as waste. Since one of the most important features in textiles is the raw material type, the physical and chemical characteristics of the raw material used in production are closely related to some product performances. In this respect, recycled fibers can be considered as ready to use raw materials. These wastes can be used in the form of fibers in blends, spun into yarns, transformed to nonwoven surfaces, hence, they are added up to a certain extent in the reproduction of various new products. From this standpoint, many researchers carried out studies on the recycling of textiles. It is possible to divide the research into two groups: research focusing on the situation of recycling studies from various perspectives such as economic, social and environmental benefits and presenting numerical data on these issues. Investigations about the usage of recycled fibers in terms of sustainability, waste fiber recovery as raw materials or useful products, and disposal of them in a way that does not cause environmental pollution can be considered in this category [1]-[7]. The second category includes studies on the usage and durability performances of recycled products in different forms obtained in textile production technologies. Although recycled fibers can be used in the form of fibers in stuffed materials and nonwovens as long as their sizes are suitable, in the majority of the studies obtaining yarn from recycled fibers and evaluating the quality parameters of the recycled yarn including textile surfaces take attention from the researchers. In these studies, it is mainly reported that waste

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type, bled ratio, yarn count and coefficient of twist have a considerably important role in yarn features. It is also emphasized that finding an optimum blend ratio can provide both cost effectiveness and promising yarn quality parameters [8]-[11]. In this type of investigation, textile surfaces in the knitted or woven form were examined with respect to the effect of recycled fiber ratio on the physical durability of the fabrics. The resulting recycled products were compared to the virgin ones in terms of acoustic, abrasion resistance, bursting strength, tensile strength, and air permeability performances to determine the substitution opportunities in appropriate usage areas [12]-[21].

Although recycling has been an attractive issue for researchers from many aspects, through the literature survey, the lack of studies about the effect of production variances on the performances of woven blankets inspired to carry out the present investigation. For this purpose, the effects of some production parameters on the usage performance, especially in terms of strength, were investigated in blankets composed of recycled yarns. Weaving construction, on-loom densities and raising processes were selected as the parameters to be changed. Weight per square meter, off-loom density and thickness values of the blankets were determined via standard test methods. Then, tensile strength and elongation, air permeability and bending rigidity properties were examined through standard test methods. Test results were statistically evaluated at 95% confidence level by using one-way analysis of variance (ANOVA) and/or independent sample t-test in SPSS 23 package program.

2 Material and method

2.1 Material

Both weft yarn and warp yarns containing recycled fibers were used in the weaving of the blankets. Acrylic, cotton, and polyester fibers used in weft yarn are recycled fibers obtained through mechanical opening and the weft yarn consists of 35%/35%/30% acrylic/cotton/polyester fibers, respectively. The warp yarn consists of 70%/30% acrylic/cotton. All of the acrylic fibers used in the warp yarn are recycled fibers obtained by mechanical opening, 50% of the cotton fiber is original cotton and the remaining 50% is recycled fiber obtained by mechanical opening method. When evaluated in general; the raw materials used in the weaving of blankets contain a very high percentage of recycled fibers. In the study conducted to examine the effect of recycled fibers on some mechanical properties, it is thought that the rate of use of 100% recycled fiber in weft yarn and 85% in warp yarn is quite high. The weft yarn count is Ne 1.3/1 and the warp yarn count is Ne 8/1.

2.2 Method

In the study, blankets with various properties were obtained depending on the weaving construction, weaving weft density and raising status. The experimental plan, which was designed to examine the effects of weaving type, density and raising process on blanket properties, is presented in Table 1. In the study, Dornier 24 frame dobby weaving machine with 180 cm loom width, Somet AGS jacquard weaving machine with 230 cm loom width and Lamberti raising machine were used. The raising process was carried out at low speed with 3 passages. As a result of the raising process, which is a mechanical finishing process, a pile layer is formed on the fabric surface and the fabric has a soft touch and bulky structure. Table 2 includes the properties of the blankets produced in the study. The blankets produced were exposed to thickness, air permeability, tensile strength and elongation at break and bending rigidity tests. Test procedures conducted on blankets are presented in Table 3.

Table 1. The experimental plan of the study.

Number	Raising process	Weaving Type	Weft Density/5 cm	Warp Density/5 cm
1	Raised	Plain	31	55
2	Raised	2/2 Twill	31	55
3	Raised	Plain	26	55
4	Raised	2/2 Twill	26	55
5	Raised	Plain	22	55
6	Raised	2/2 Twill	22	55
7	Non-raised	Plain	31	55
8	Non-raised	2/2 Twill	31	55
9	Non-raised	Plain	26	55
10	Non-raised	2/2 Twill	26	55
11	Non-raised	Plain	22	55
12	Non-raised	2/2 Twill	22	55

Table 2. Properties of the blankets produced in the study.

Number	Raising Process	Weaving Type	Weft Density/ 5 cm	Warp Density/ 5 cm	Measured Weft Density/ 5 cm	% CV	Measured Warp Density/ 5 cm	% CV	Mass per unit area (g/m²)	% CV
1	Raised	Plain	31	55	33.20	3.51	55.60	8.01	465.24	1.16
2	Raised	2/2 Twill	31	55	31.00	0	59.80	1.95	467.97	1.57
3	Raised	Plain	26	55	29.40	1.67	56.80	3.03	431.02	1.46
4	Raised	2/2 Twill	26	55	25.80	1.55	60.80	2.83	415.90	1.12
5	Raised	Plain	22	55	24.20	1.65	55.40	2.45	378.99	0.76
6	Raised	2/2 Twill	22	55	22.40	2.19	59.40	1.35	361.28	1.53
7	Non-raised	Plain	31	55	34.60	1.42	58.20	3.15	483.99	1.92
8	Non-raised	2/2 Twill	31	55	33.40	2.40	56.80	1.32	488.41	1.99
9	Non-raised	Plain	26	55	29.80	1.34	53.60	0.91	423.74	1.69
10	Non-raised	2/2 Twill	26	55	29.00	0	56.40	1.42	423.22	1.66
11	Non-raised	Plain	22	55	25.80	1.55	58.60	2.55	379.78	1.88
12	Non-raised	2/2 Twill	22	55	25.40	1.93	57.20	2.80	377.45	3.13

Table 3. Test procedures applied to blankets.

Test	Standard	Equipment	Repetition
Mass Per Unit Area	TS 251 [22]	Radwag AS 220.R2	10
Density	TS 250 EN 1049-2 [23]	Counted manually	5
Thickness	TS 7128 EN ISO 5084 [24]	Unitronics	10
Air Permeability	TS 391 EN ISO 9237 [25]	Prowhite Airtest II	10
Tensile Strength and Elongation at Break	TS EN ISO 13934-1 [26]	Utest Profi X6	5
Bending Rigidity	TS 1409 [27]	Test device designed in accordance with the standard	5

Values in bending rigidity test were calculated from the formula below.

$$G = 0.1\, WC^3\ mg.cm \qquad (1)$$

Where,

X	=	Falling length (cm),
$C=X/2$	=	Bending length (cm),
W	=	Fabric mass per unit area (g/m^2),
G	=	Bending rigidity (mg.cm).

The findings obtained after the test procedures were statistically evaluated at 95% confidence level by using one-way analysis of variance (One Way Anova) and independent sample t-test via SPSS 23 package program (α=0.05).

3 Results and discussions

3.1 Thickness results

The thickness test results of the raised and non-raised blankets produced in the current investigation are indicated in Figure 1.

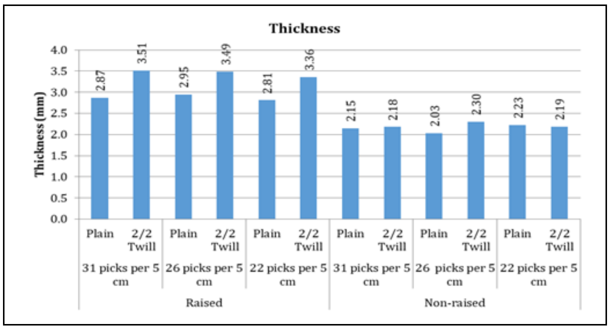

Figure 1. The thickness test results of the raised and non-raised blankets.

According to Figure 1; when the thickness values were evaluated in terms of weaving construction, it was observed that the thickness values of the samples in twill structure were generally higher than those of plain structure. In the 2/2 twill weave structure, the floating length is 2 times longer than the plain weave structure, and therefore, the surface of the raising yarn in the twill weave structure increases and the thickness in the twill structure is higher than the plain weave structure. Hence, it is expected that the thickness values of the plain weave structure will be lower than the twill structure. The same result can be seen in the samples without raising, which can be related to the floating length in twill weave structure is higher than in plain weave structure. The result obtained is also in agreement with the literature [28]. In statistical evaluation; the effect of weaving type on thickness was statistically significant for the raised and non-raised blankets.

It was found that the thickness values did not exhibit a consistent variation based on the density parameter, and the impact of weft density on thickness was determined to be statistically insignificant.

Considering how the thickness values change depending on the raising process, it was observed that the thickness values increased after the raising process. The increasing effect of the raising process on the thickness is an expected result and this result coheres with the literature [29]. The influence of the raising process on thickness was found to be statistically significant.

3.2 Air permeability results

The air permeability test results of the raised and non-raised blankets produced in the study are demonstrated in Figure 2.

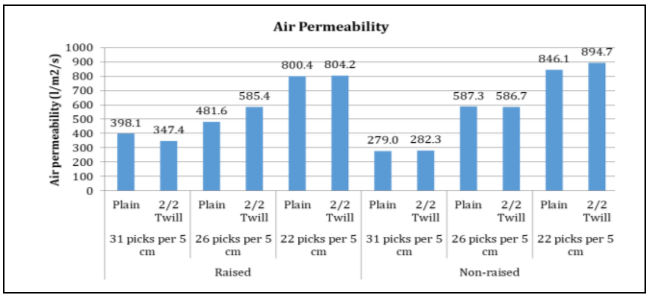

Figure 2. The air permeability test results of the raised and non-raised blankets.

According to Figure 2; in all blankets produced with and without raising, the air permeability results of the blankets woven with the highest weft density were lower than the others. It is an expected result that the air permeability decreases as the density increases and it also matches with previous studies on this subject [28]. In addition, the difference between the samples produced in 3 different weft densities was statistically significant.

Taking into account the air permeability results according to the raising process; it was seen that the air permeability results of raised blankets were lower than the results of non-raised blankets in medium and low-density blankets as an expected result. Because the raising process has a reducing effect on air permeability, and this result is in agreement with the literature [30]. The opposite was observed for the blankets with the highest density. It is thought that this evaluation is because the raising process in the highest density may not have been sufficiently effective. It was seen that there was no statistically significant difference between the samples with and without the raising process. The difference between the samples with and without raising process on behalf of air permeability was statistically insignificant.

When the air permeability results were evaluated considering weaving construction; it was observed that the results did not show a regular change according to the weave type of the blankets, and this result was found to be statistically insignificant.

3.3 Tensile strength and elongation at break test results

The results of tensile strength and elongation at break in weft and warp directions of the raised and non-raised blankets produced in the study are shown in Figure 3, Figure 4, Figure 5, and Figure 6.

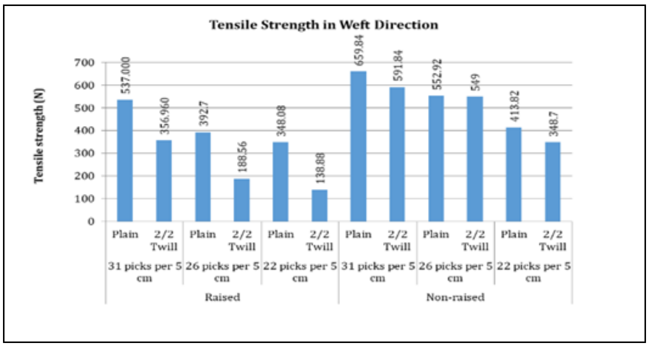

Figure 3. The results of tensile strength in weft direction.

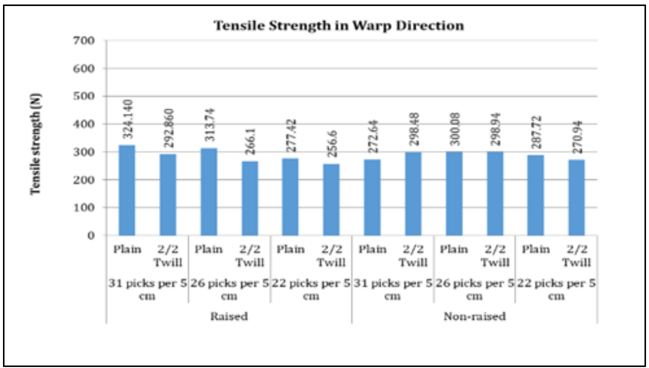

Figure 4. The results of tensile strength in warp direction.

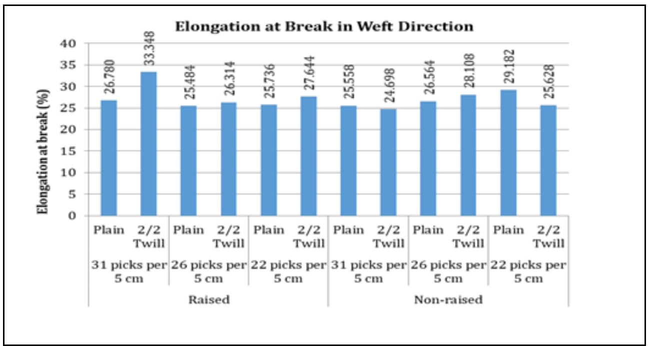

Figure 5. The results of elongation at break in weft direction.

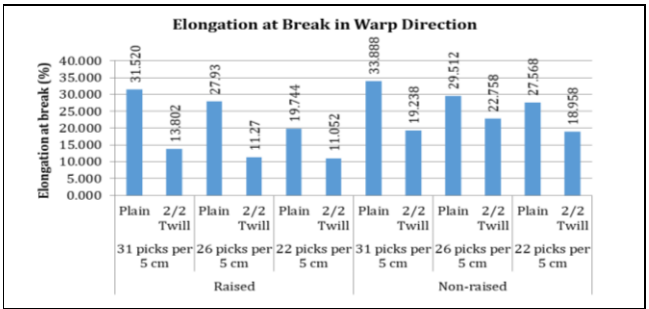

Figure 6. The results of elongation at break in warp direction.

According to Figure 3; when the tensile strength values in weft direction were evaluated in terms of the weaving construction, it was seen that the values of the blankets woven as plain were higher than those of the twill weave type.

As expected, the fact that tensile strength values in the weft direction of plain weave type, which has a higher connection point compared to the twill structure as a construction, are higher than the twill structure and this result is compatible with the results of previous studies on this subject [31].

As the weft density increases, the contact area between the weft and warp yarns and the number of yarns in the width of the fabric increases, so it is normal for the strength in this direction to increase, and this result is in agreement with the literature [31].

In the examination made according to the raising process; it was observed that the tensile strength values in the weft direction of the samples without raising were higher than the values of the samples with raising. The raising process, which weakens the weft yarns in the process, also diminishes the tensile strength in this direction. This result also agrees with the previous studies on this subject [32]. It was determined that the outcomes of weave design, density, and raising process on tensile strength in the weft direction were statistically significant.

As seen in Figure 4; when tensile strength in warp direction was considered from the perspective of weaving construction, a similar interpretation could be made to the tensile strength in weft direction result; it was detected that the tensile strength values in the warp direction of the plain woven samples were generally higher than those of twill samples and the result was statistically significant.

In evaluation made according to density; as with tensile strength in the weft direction, it was observed that the tensile strength in the warp direction was generally proportional to the weft density. The difference of the values between the woven samples at various weft densities was statistically significant.

Tensile strength in warp direction did not show a regular change according to the raising process. Because the raising process is a weft-directional process and does not affect tensile strength in the warp direction. In addition, it was revealed that there was no statistically significant distinction between the values of the raised and non-raised samples.

In addition, if the tensile strength values of these blankets containing recycled fiber were analyzed, it was thought that sufficient strength was provided in the products obtained in the study when compared with a fabric with a similar mass per unit area and bulky structure considering usage area [33]. The fact that the blankets produced using recycled fiber have both the advantage in terms of cost and sufficient strength again revealed the importance of recycling processes.

As seen in Figure 5; when the elongation at break in weft direction was evaluated according to the woven construction, it was seen that the values of the samples produced in twill construction in the raised samples were higher than the plain ones, and this result is expected since plain fabric is a tighter structure than twill structure. It was observed that these values did not show a regular change in the samples without raising. In addition, the effect of woven type on elongation at break in weft direction was statistically insignificant.

It was obvious that the elongation at break values in the weft direction did not show a regular change according to the density and raising process parameters. The effect of raising process and weft density on elongation at break in the weft direction was statistically investigated; it is pointed out that there was no statistically significant distinction between the samples.

As seen in Figure 6; when the elongation at break in warp direction was evaluated according to the woven construction, it was observed that the values of the samples in twill structure were lower than those in plain fabric structure. This result can be explained by the fact that the fold in the warp direction is higher in plain fabrics. The effect of weave type on elongation at break in the warp direction was found to be statistically significant.

When elongation at break in the warp direction was examined according to the density, it was observed that the values rise as the density increases. It is an expected result that the elongation at break in warp direction will increase as the weft density increases, since the rise in weft density causes the warp yarn to curl more, that is, to increase the number of folds. The influence of weft density over elongation at break in warp direction was statistically investigated; it was observed that there was no statistically significant difference between the samples with varying weft density.

Upon evaluating the raising process, it was noted that it led to a decrease in elongation at break values in the warp direction. This could be attributed to the raised surface of the weft yarns increasing contact with the warp yarns, potentially resulting in lower elongation at break values in samples subjected to the raising process compared to those without it. In addition, the difference of the values between raised and non-raised samples was statistically significant.

3.4 Bending rigidity test results

Bending rigidity test results in weft and warp directions of raised and non-raised blankets produced in the study are given in Figure 7 and Figure 8.

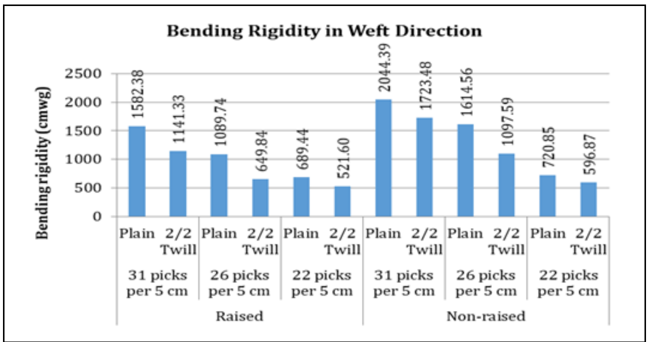

Figure 7. Bending rigidity test results in weft directions of raised and non-raised blankets.

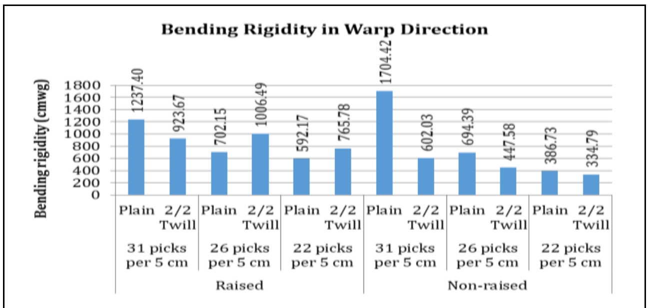

Figure 8. Bending rigidity test results in warp directions of raised and non-raised blankets.

According to Figure 7; when the bending rigidity values in the weft direction were evaluated in terms of weaving construction, it was observed that the bending rigidity values of plain fabric samples were higher than those of twill structure. It can be said that it is expected that plain weave structure, which has a tighter structure than twill structure, has higher stiffness and shows higher bending rigidity values. This result is also in agreement with the literature [34].

When the bending rigidity values in the weft direction were examined depending on density, it was observed that the bending rigidity values increased with the increase of the sample stiffness as expected as the density increases. This result is consonant with previous studies on this subject [35].

Upon investigating the impact of the raising process on bending rigidity values in the weft direction, it was discovered that these values decreased following the raising process, thereby increasing the softness of the blanket samples. This outcome was anticipated and aligned with expectations. The influence of the raising process on the handle of the blanket samples was clearly noticeable.

Based on the studies referenced in the literature, it can be concluded that this result is consistent with previous findings [30],[31]. The impacts of weaving type, density, and the raising process on bending properties in the weft direction were determined to be statistically significant.

According to Figure 8; when the bending rigidity values in the warp direction were evaluated in terms of weaving construction, similar to the bending rigidity results in the weft direction in the non-raised samples, it was observed that the bending rigidity values of plain weave samples were higher than those of twill structure, and this is an expected result. In the samples with the raising process, it was determined that the bending rigidity values in the warp direction did not follow a regular change depending on the weaving structure. It is thought that fiber drawing process in raising may have differentiated the harder structure of plain weave compared to twill. Looking at the statistical evaluation; it was observed that weaving structure did not have a significant effect on bending property in warp direction.

When the bending rigidity values in the warp direction were examined depending on density, it was observed that the bending rigidity values increased with the increase in the sample stiffness as expected as the density increases, as in the bending rigidity in the weft direction. This result is in agreement with previous studies on this subject [35]. The difference between the samples produced in 3 different weft densities was found to be statistically significant.

When the bending rigidity values in the warp direction were examined according to the raising process, it was observed that the bending rigidity values in this direction increased after the raising process. The fact that the raising process has the effect of decreasing the bending rigidity in the weft direction and increasing the bending rigidity in the warp direction can be explained by the fact that the raising process is performed in the weft direction. Statistical evaluation indicated that the difference between raised and non-raised samples was statistically significant.

4 Conclusions

This study involved producing blankets from recycled fibers using dobby and jacquard looms in two different weave structures and three weft densities, with or without the raising process. Various performance aspects of the recycled blankets, including thickness, air permeability, tensile strength, and bending rigidity, were evaluated through standardized test methods to assess their usability.

The test results were analyzed concerning weave type, density, and raising parameters. It was determined that weave type influenced sample thickness, favoring plain weave. Air permeability did not show consistent variation with weave type, but the tensile strength and bending rigidity values of blankets in plain weave were higher compared to those in twill weave. Weft density did not consistently affect thickness; however, it did lead to a systematic decrease in air permeability as density increased. Similarly, this trend was observed in both directions for the tensile strength and bending rigidity test results.

The raising process resulted in increased thickness of the samples and decreased air permeability, consistent with expectations. Regarding tensile strength, it was found that in the weft direction, samples without raising had higher tensile strength, whereas in the warp direction, no consistent change was observed. The raising process had differing effects on the bending rigidity results of the samples, resulting in a decrease in the weft direction and an increase in the warp direction.

With the evaluations made to flash on the recycled textiles; it is foreseen that by using recycled fibers in textile products that contribute both economically and environmentally benign parameters the sector will develop throughout the country as well as in the province of Uşak.

5 Acknowledgements

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6 Author contribution statement

In the present study, Ayşe Ebru Tayyar contributed to the supervision of production processes, experimental methodology, visualization, conceptualization, and writing the original draft. Hakan Macit contributed to the production processes of the blankets used in the study, Ayşe Şevkan Macit and Gonca Alan have organized and performed the testing procedure, carried out the literature review, and writing the original draft.

7 Ethics committee approval and conflict of interest statement

“Ethics committee permission is not required for the article prepared”.

“There is no conflict of interest with any person/institution in the article prepared”.

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