Conference Article

Analysing the Effect of Flax Fiber Content on Knitted Garments

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Abstract

This study focused on the performance properties of flax blended knitted fabrics. Firstly, fabrics were knitted using flax/recycled polyester/polyester yarns developed in different blend ratios. Physical tests such as dimensional properties, fastness tests and bursting strength of the obtained fabrics were carried out. Then, comfort properties were examined in terms of drying rate and air permeability. In conclusion, while the best fabric performance was obtained in single jersey and pique quality, it was determined that flax-containing yarns were not suitable for rib quality. Increasing the flax ratio has a negative impact on fabric performance, and the optimum flax ratio to be used has been determined as 20%.

Keywords: Flax, sustainable, knitted fabric, recycle pes

1. Introduction

Knitted fabrics prepared from blended yarns attract great attention from modern customers (Islam et al., 2023). The addition of linen to clothing fabrics keeps the skin cool by helping to remove moisture from the skin surface and has an air permeability feature that allows the fabrics to dry quickly (Senthil & Dhurai, 2021). The main disadvantage of linen fabric is that it has a hard hand feeling and wrinkles easily. For this reason, it is mostly used in blends with natural or synthetic fibers to provide the desired performance properties in certain end uses (Senthil & Dhurai, 2021; Dalbaşi & Özçelik Kayseri, 2019). Also, flax fiber-based knitted fabric is becoming more and more popular due to its characteristics such as strong tensile strength, higher stiffness, higher moisture absorption, greater cooling effect, better comfort, elegant appearance and absorbent power (Islam et al., 2023). Seven main goals have been set by the European Textile Technology Platform (TETP). Among these, the first place is the orientation towards sustainable textile raw materials (recycling, natural fibers, biopolymers) (Göktaş & Ertekin, 2022). Flax fiber has unique properties and therefore blending it with different natural fibers or blending it with a minimum amount of synthetic fibers will also provide diversified end uses when sustainable goals are concerned (Gardetti & Larios-Francia, 2021). Blending natural fibers with synthetic fibers has received great attention as it successfully combines the best properties of both fibers and increases the aesthetic properties and performance of the fabric produced. Flax fibers are characterized by high strength, natural shine and comfort. Polyester fibers are characterized by their high strength, brightness, aesthetics and low cost (Saad & Abd-Elkawe, 2022). However, the use of polyester is decreasing day by day due to static electricity generation, decreased breathability and non-biodegradability. Combining the properties of polyester with natural fiber is a clever concept to enhance them (Islam et al., 2023).

There are limited studies on knitted flax blended fabrics in the literature. Sanad (2011), studied cotton and cotton/linen blended fabrics and compared them in terms of their properties. It has been stated that linen blended fabrics increase cotton UV protection factor and color efficiency, reduce burst strength and allow more moisture absorption (Sanad, 2011). In another study, Bukhonka (2023), conducted a study on the dimensional changes and air permeability of Swiss double pique knitted fabrics produced using PAN/linen, cotton/linen and pure linen. It was determined that there was more dimensional change in knitted fabrics made from cotton/linen and pure linen yarns and that the knitted fabric made from pure linen yarn had the highest air permeability (Bukhonka, 2023).

In this work, flax/recycled PES/PES blended fabrics with different structures (single jersey, rib, pique) were developed. Dimensional stability, pilling, bursting strength, air permeability and drying behavior of the produced fabrics were examined and comparative analyzes were made.

2. Materials and Methods

2.1. Materials

In this study, flax/recycle polyester/polyester blend yarns used as a raw material. All types of yarns are provided by MEM Textile. Using these yarns, flax/recycle polyester/polyester fabrics are knitted in three different structures: single jersey, rib and pique. 17 types of fabrics containing different amounts of flax have been developed. In the scope of the project, knitted fabric samples in different mixtures were developed and fabric compositions are given in table 1.

Table 1: Developed flax based fabrics

Sample code	Fabric composition			Knitted type	Number of dyeing	Basis weight (g/m^2)	Color
	Flax	Recycle polyester	Polyester				
F0S-1	-	30	70	Single-jersey	1	179	Black
F20S-1	20	30	50	Single-jersey	1	173	Black
F30S-1	30	30	40	Single-jersey	1	158	Black
F40S-1	40	30	30	Single-jersey	1	153	Black
F0R-1	-	30	70	Rib	1	181	Black
F20R-1	20	30	50	Rib	1	147	Black
F30R-1	30	30	40	Rib	1	203	Black
F40R-1	40	30	30	Rib	1	173	Black
F20S-2	20	30	50	Single-jersey	2	180	Black
F30S-2	30	30	40	Single-jersey	2	170	Black
F40S-2	40	30	30	Single-jersey	2	161	Black
F20R-2	20	30	50	Rib	2	221	Black
F30R-2	30	30	40	Rib	2	194	Black
F40R-2	40	30	30	Rib	2	186	Black
F20P-1	20	30	50	Pique	1	158	Beige
F30P-1	30	30	40	Pique	1	142	Beige
F40P-1	40	30	30	Pique	1	140	Beige

2.2. Method

In the scope of the work, 20/30/50, 30/30/40 and 40/30/30 (flax/recycle PES/PES) yarns developed with different blend ratios were prepared. In addition, 30/70 (recycle pes/pes) yarn was developed as a reference. Then, single jersey, rib and single pique fabrics were developed using these yarns. Single jersey fabrics were produced on a 32 pus 28 fine, rib fabrics were developed on a 34 pus 18 fine, pique fabrics were produced on a 30 pus 22 fine circular knitting machine. Two different dyeing processes were performed on the blended single jersey and rib fabrics: single and double dyeing. For blended pique fabrics, a single dyeing process was carried out in a light colour. The process is schematized and presented in figure 1.

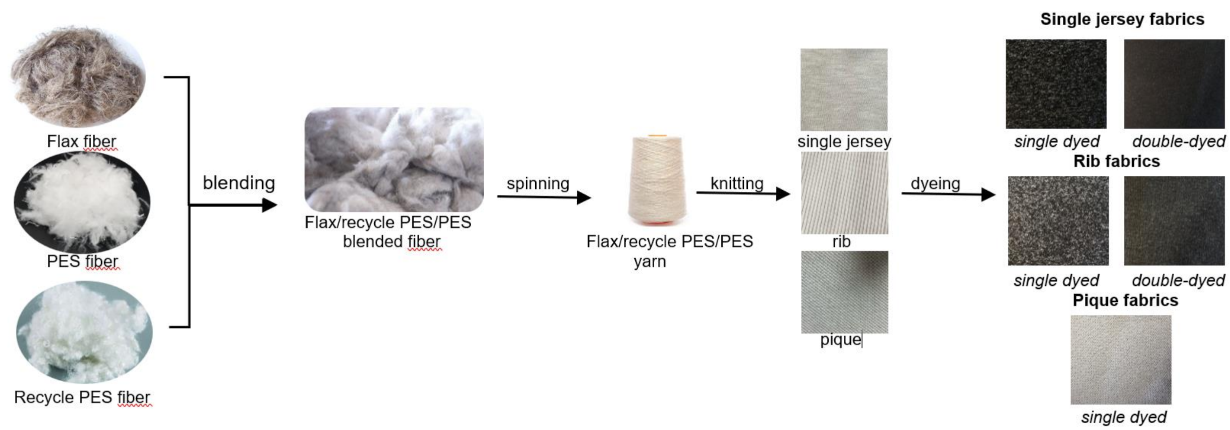

Figure 1: Process flow in the work

Fabric tests were carried out after the fabrics were conditioned under standard laboratory conditions (65 ± 4% RH and 20 ± 2°C). The dimensional change of fabrics was measured according to TS EN ISO 5077 test standard. Perspiration fastness, water fastness, fastness to rubbing and washing fastness were tested according to ISO 105 E04, ISO 105 E01, ISO105X12 and ISO 105 C06 standards respectively. Fabric bursting strength was measured using Digital Bursting Strength Tester according to TS EN ISO 13938-2 test standard and test results were represented in units of kPa. Pilling tests was performed according to ISO 12945-2 test standard using the SDL ATLAS Martindale M235 pilling tester. According to ASTM D737 standard, the knit fabric air permeability was examined using the Prowhite air permeability tester, and the test results were given in terms of cm3/cm2/s. Drying rates were measured using Fourt et. al. and Coplan methods [9,10]. 10 cm2 samples were cut from each fabric and their dry weights were taken. Then, the fabrics were soaked in distilled water for 30 minutes and after being removed, their wet weights were recorded. The samples were then laid on a porous wire rack raised from the bench surface so that the bottom can be in contact with the air and left to dry. Drying test process was carried on until the weight of samples reaches the 105% percentage of their initial dry weight. The test was repeated 3 times and the average result was

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calculated. In addition, water absorption calculations of fabrics were made to interpret the rapid drying tests.

The water retention calculation was calculated using the following equation 1:

$$Q = [(W2 - W1) / W1] * 100 \quad (1)$$

where Q is absorption, W1 – initial weight and W2 – wet weight.

After the tests were carried out, the qualities with the best test results were determined according to the fiber content, and design and product development studies were initiated to show the flax's own characteristics. In the continuation of the work, application for design registration from the developed designs is being considered.

3. Result

Dimensional Tests

Firstly, dimensional tests of the developed fabrics were carried out. Dimensional change in width (DC_W) and dimensional change in length (DC_L) of single jersey, rib and pique fabrics after washing are presented in figure 2 and figure 3, respectively. When the shrinkage values of single dyed black single jersey fabrics are examined; as the flax ratio decreased and the polyester content increased, the shrinkage in length values decreased. The minimum shrinkage value in width was observed in the F20S-1 fabric and the maximum shrinkage value was observed in the F40S-1 fabric.

When single dyed rib fabrics are examined; The lowest shrinkage value in width was found at F20R-1. F0R-1 fabric gave minimum results in terms of length shrinkage. Increases and decreases were observed depending on the flax content.

In single jersey and rib fabrics, the minimum shrinkage value in length was obtained in 100% polyester fabrics, while the lowest shrinkage value in width was obtained in fabrics containing 20% flax in both knitted types. For this reason, it is thought that by using polyester raw material in mixture with other fibers, the width shrinkage value is improved to a certain point.

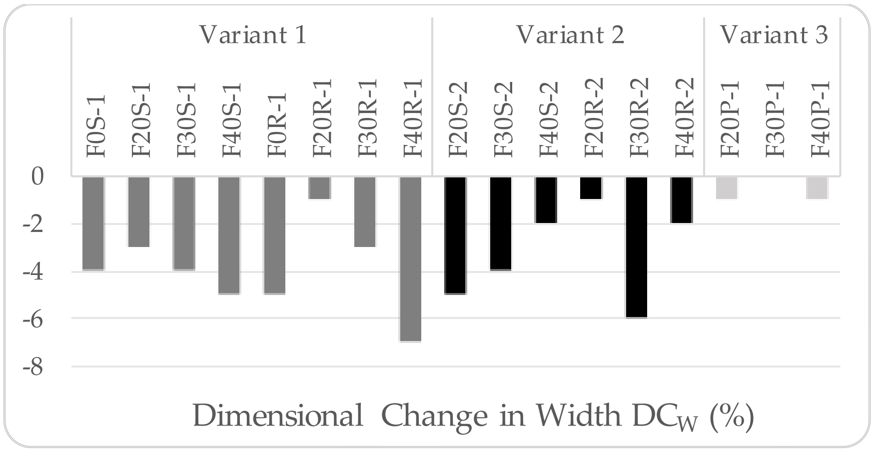

Figure 2: Dimensional changes of developed fabrics in width (DCw)

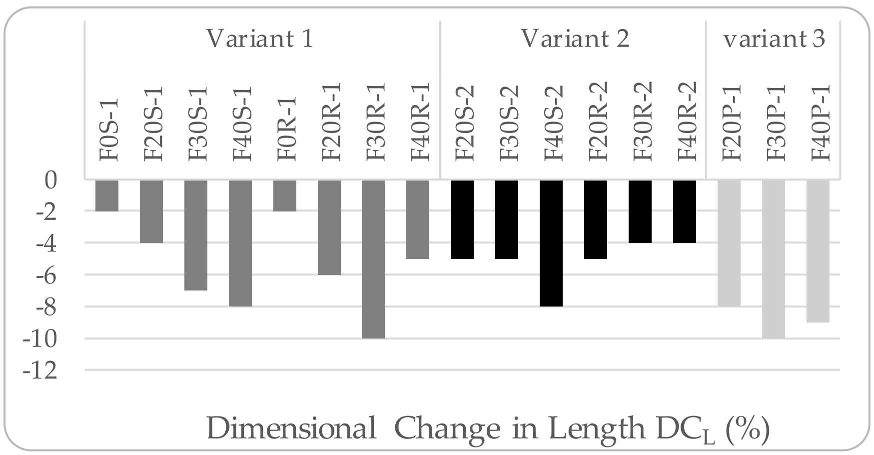

Figure 3: Dimensional changes of developed fabrics in length (DC_L)

In double dyed single jersey fabrics; as the flax ratio increased, the shrinkage value in width decreased. The shrinkage value in length decreased up to a point with the decrease in flax content, and then no positive or negative effect was observed. While the torque value after washing was always 0 in single dyed fabrics, in double dyed single jersey fabrics, torque was observed in the F30S-2 and F40S-2 samples, while the spirality value was found to be 0 in the F20S-2 sample.

In double dyed rib fabrics, the minimum shrinkage value in width was observed in the fabric F20R-2. The shrinkage value in length increased by 1% at the minimum flax amount. In rib fabrics, the amount of torque after washing was found to be 0.

When single dyed and double-dyed fabrics are compared in terms of shrinkage values; while the lowest shrinkage value in width was obtained with the minimum amount of flax in single dyed fabrics, the lowest shrinkage value was obtained with the highest amount of flax in double dyed fabrics. In both groups, the shrinkage value in length decreased with the decrease in the amount of flax. It has been clearly observed that polyester has a positive effect on shrinkage values in length. Spirality after washing was observed in single jersey fabrics that were double dyed and whose flax content exceeded 20%.

In single pique fabrics the minimum shrinkage value in width was obtained in the fabric F30P-1 and the minimum shrinkage value in length was obtained in the fabric F20P-1. Meaningful interpretation could not be made with the results obtained in this knitting type.

Pilling tests

According to the pilling test results taken on single dyed single jersey fabrics, it has been observed that F0S-1 fabric has a higher tendency to pilling. It was observed that the pilling resistance improved slightly by increasing the flax fiber. In rib fabrics, the highest pilling resistance was found in fabric F20R-1. In general, not all developed rib fabrics meet the acceptance criteria in terms of pilling resistance. The results are meaningful considering that pilling values increase or decrease depending on the fiber type.

The highest pilling tendency in double-dyed single jersey fabrics was found at the maximum amount of flax. It is among the acceptance criteria for fabrics F20S-2 and F30S-2. In rib fabrics, the highest pilling resistance was found in F40R-2 fabric.

In pique fabrics, the pilling value was obtained as 3, and it was determined that the flax and polyester content had no effect on pilling. As a result, the pilling resistance of single-dyed pique fabrics is equivalent to single-dyed single jersey fabrics with flax additives, and the pilling tendency did not change significantly with double dyeing. The pilling test results all type of fabrics are given in table 2.

Table 2: Pilling test results of developed fabrics

Sample code	Fabric composition (%)			Pilling resistance (200 rpm)
	Flax	Recycle polyester	Polyester	
F0S-1	-	30	70	2
F20S-1	20	30	50	3
F30S-1	30	30	40	3
F40S-1	40	30	30	3
F0R-1	-	30	70	2
F20R-1	20	30	50	2/3
F30R-1	30	30	40	2
F40R-1	40	30	30	2

F20S-2	20	30	50	3
F30S-2	30	30	40	3
F40S-2	40	30	30	2/3
F20R-2	20	30	50	2
F30R-2	30	30	40	2
F40R-2	40	30	30	2/3
F20P-1	20	30	50	3
F30P-1	30	30	40	3
F40P-1	40	30	30	3

Fastness tests

The fastness values (fastness of perspiration, washing fastness, water fastness) of the developed fabrics were examined (Table 3).

Table 3: Fastness test results of developed single dyed fabrics

Sample code	Fabric composition (%)			Perspiration fastness		Water fastness	Washing fastness
	Flax	Recycle polyester	Polyester	Acid	Alkaline		
F0S-1	-	30	70	3	3/4	3/4	3/4
F20S-1	20	30	50	4/5	4/5	4/5	4/5
F30S-1	30	30	40	4/5	4/5	4/5	4/5
F40S-1	40	30	30	4/5	4/5	4/5	4/5
F0R-1	-	30	70	4	3/4	3/4	3/4
F20R-1	20	30	50	4/5	4/5	4/5	4/5
F30R-1	30	30	40	4	4	4	4
F40R-1	40	30	30	4	4/5	4	4/5

In single dyed products, the lowest fastness values were obtained in F0S-1 single jersey fabric (from 3 to 3/4). In blended fabrics, the fastness value was obtained as 4/5. As a result, although the fastness values of polyester fiber are lower, it has been determined that the fastness values are improved when blended with flax fibers.

In rib fabrics, the lowest fastness results were obtained from F0R-1 and the highest results were obtained from F20R-1. The addition of flax to fabric contents increases the fastness values and increasing the flax ratio above 20% causes a small decrease in the rib fastness values.

Acid, base, water fastness and washing fastness values of double-dyed single jersey fabrics gave the same results (4/5). No change was observed depending on fabric content.

In double dyed rib fabrics; the highest results were obtained with F30R-2 fabric. For this reason, it is thought that this ratio is the optimum flax amount in terms of fastness for rib fabrics (Table 4).

Table 4: Fastness test results of developed double dyed fabrics

Sample code	Fabric composition (%)			Perspiration fastness		Water fastness	Washing fastness
	Flax	Recycle polyester	Polyester	Acid	Alkaline		
F20S-2	20	30	50	4/5	4/5	4/5	4/5
F30S-2	30	30	40	4/5	4/5	4/5	4/5
F40S-2	40	30	30	4/5	4/5	4/5	4/5
F20R-2	20	30	50	4	4	4	4
F30R-2	30	30	40	4/5	4/5	4/5	4/5
F40R-2	40	30	30	4	4/5	4/5	4

When the fastness results of single dyed pique fabrics were examined, no positive or negative effects of the fabric content on the fastness values were observed. In general, the highest fastnesses were obtained in pique knitted fabrics (Table 5).

Table 5: Fastness test results of developed pique fabrics

Sample code	Fabric composition			Perspiration fastness		Water fastness	Washing fastness
	Flax	Recycle polyester	Polyester	Acid	Alkaline		
F20P-1	20	30	50	5	5	5	5
F30P-1	30	30	40	5	5	5	5
F40P-1	40	30	30	5	5	5	5

Dry rubbing fastness was found to be 4/5 in all single jersey fabrics, regardless of fiber content (Table 6). The wet rubbing fastness was 4/5 in F0S-1 fabric, but it decreased slightly by increasing the flax content, but after a certain point it increased again.

In rubbing fastness of rib; changing the amount of flax and polyester did not have any effect on dry fastness. While wet rubbing fastness gave the same value in F0R-1 and F20R-1 fabrics, wet rubbing fastness increased by half a point in F30R-1 and F40R-1 fabrics.

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Table 6: Rubbing fastness test results of developed single dyed fabrics

Sample code	Fabric composition			Rubbing fastness	
	Flax	Recycle polyester	Polyester	Dry	Wet
F0S-1	-	30	70	4/5	4/5
F20S-1	20	30	50	4/5	4
F30S-1	30	30	40	4/5	4
F40S-1	40	30	30	4/5	4/5
F0R-1	-	30	70	4/5	4
F20R-1	20	30	50	4/5	4
F30R-1	30	30	40	4/5	4/5
F40R-1	40	30	30	4/5	4/5

When double-dyed single jerseys were evaluated, highest dry rubbing fastness was obtained in the fabric F20S-2, while dry rubbing fastness decreased by half a point when the flax ratio was increased. The highest wet rubbing fastness value was obtained in the fabric F20S-2. In double-dyed rib fabrics, the highest dry and wet rubbing fastness was achieved with F40R-2 (Table 7).

Table 7: Rubbing fastness test results of developed double dyed fabrics

Sample code	Fabric composition			Rubbing fastness	
	Flax	Recycle polyester	Polyester	Dry	Wet
F20S-2	20	30	50	4/5	3/4
F30S-2	30	30	40	4	2/3
F40S-2	40	30	30	4	3
F20R-2	20	30	50	4	3
F30R-2	30	30	40	4	2/3
F40R-2	40	30	30	4/5	3/4

While the dry rubbing fastness was 5 for all pique fabrics, the wet rubbing fastness decreased by half a point (Table 8).

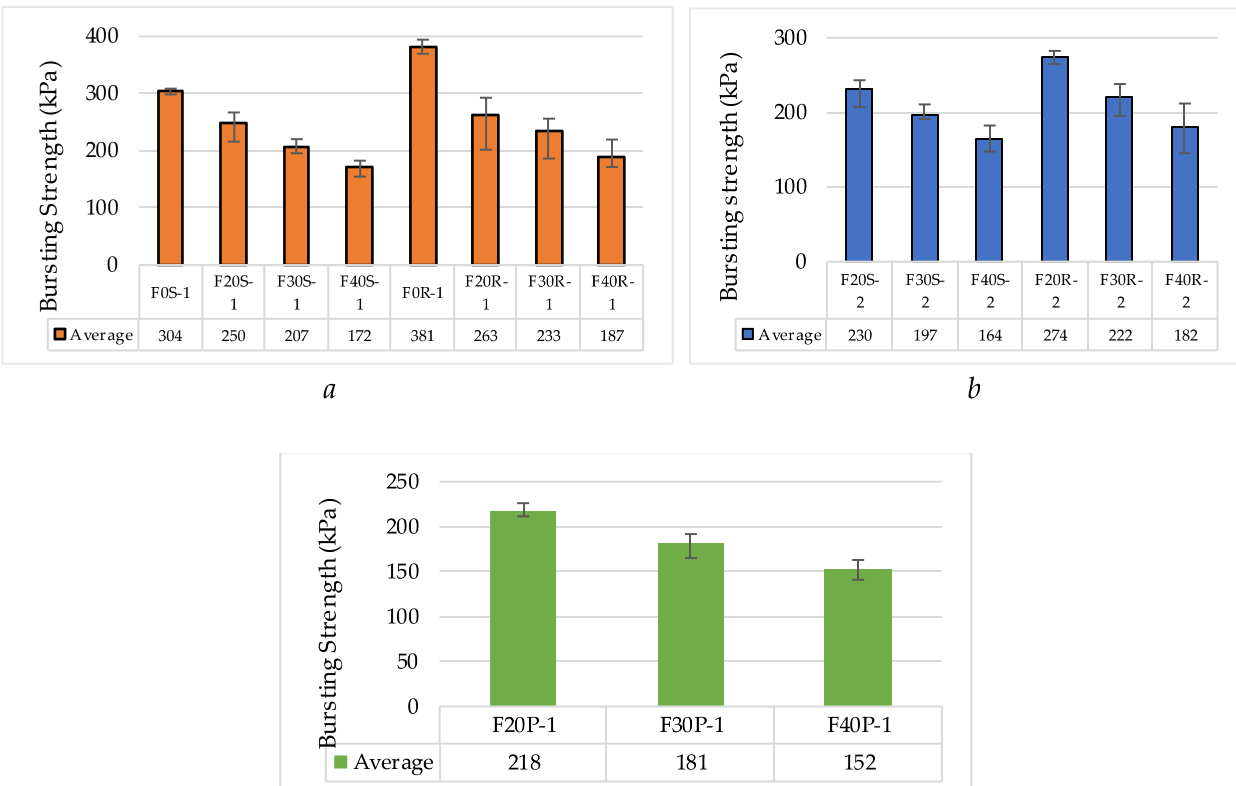
Table 8: Rubbing fastness test results of developed pique fabrics

Sample code	Fabric composition			Rubbing fastness	
	Flax	Recycle polyester	Polyester	Dry	Wet
F20P-1	20	30	50	5	4/5
F30P-1	30	30	40	5	4/5

F40P-1	40	30	30	5	4/5

Bursting Strength

In single dyed fabrics, the bursting strength decreased with the increase in the flax ratio and the decrease in the polyester ratio. It was determined that the highest bursting strength was in the fabric with 100% PES content. The same results were obtained for rib and pique fabrics. The decrease in the flax content in double-dyed fabrics also resulted in increased bursting strength (Figure 4).



c

Figure 4. Bursting strength of developed fabrics (a – single dyed fabrics; b – double dyed fabrics; c- pique fabrics)

Compared to knitted structures, the highest bursting strength was determined in rib, single jersey and pique fabrics, respectively. Double dyeing has also been found to have a slightly negative effect on the bursting strength of fabrics.

In conclusion, as expected, the bursting strength decreased with the decrease in synthetic fibers and the increase in flax which is a natural fiber, in all fabric types. Knitting type and raw material content play a significant role in bursting strength. The minimum effect was observed with double dyeing.

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Drying Rate

The tested fabrics were soaked in water for 30 minutes and after being removed, their wet weights were recorded. It was then left to dry and measurements were repeated at 30-minute intervals. The test was completed when the fabrics reached 105% of their initial weight. Drying rates and absorption rates are given in figure 5 and figure 6, respectively.

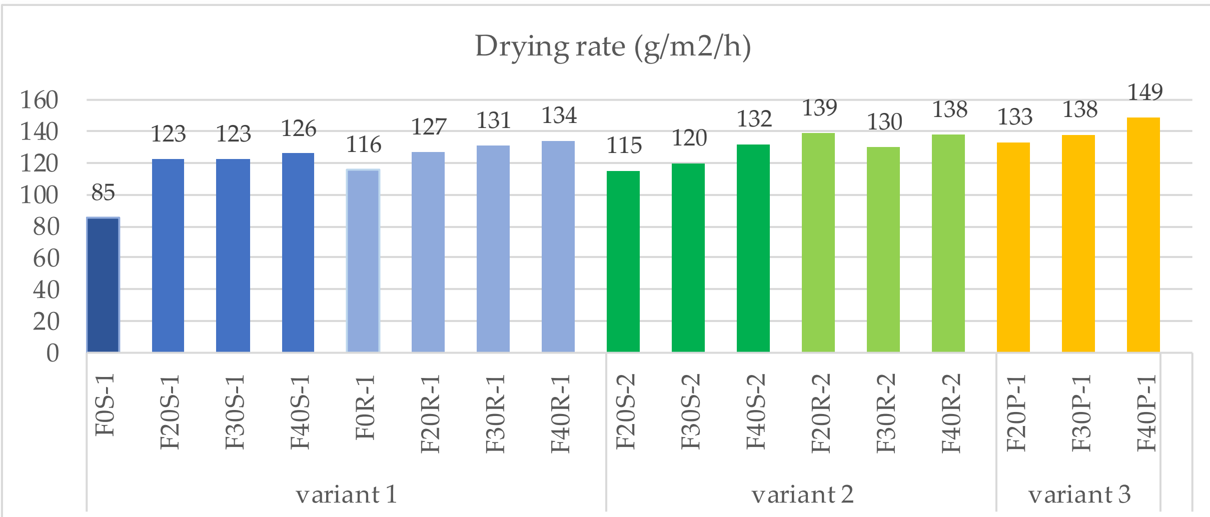

Figure 5. Drying rate of developed fabrics

The drying rate of the fabrics developed increased with the increase in the content of flax in single jersey and rib fabrics. When single jersey and rib fabric structures are compared to each other, the drying rate of rib fabrics is higher with higher water retention. When evaluated according to the number of dyeings, single jersey fabrics with double dyeing showed faster drying. As for rib fabrics, F40R-2 fabric dried almost at the same rate as the F40R-1 with higher water retention.

It is stated in the literature that drying rates are proportional to the amount of water they initially absorb [9, 10]. The results of the study are not compatible with the literature.

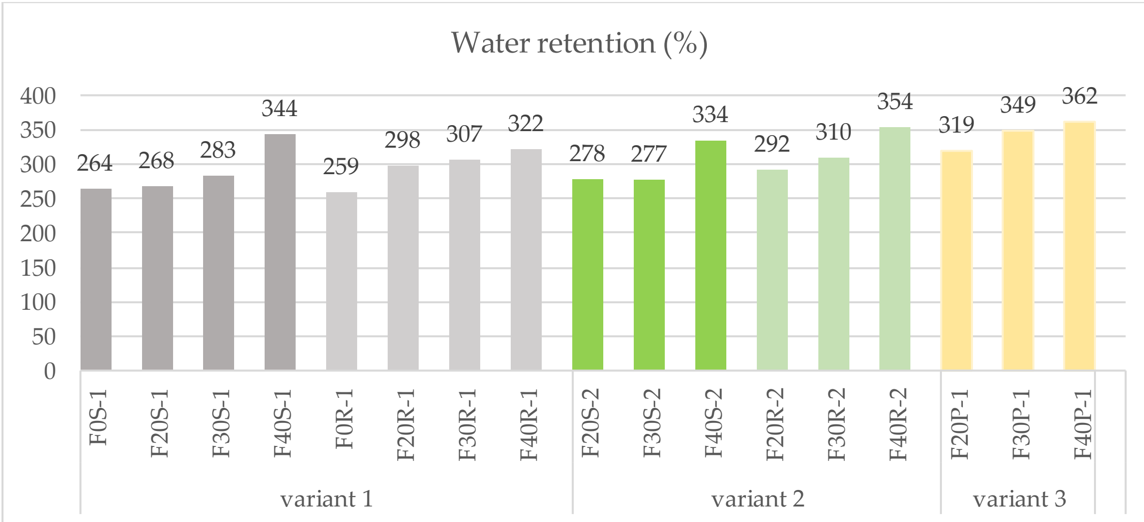

Figure 6. Water retention of developed fabrics

When the water retention properties of the developed fabrics are examined, it has been determined that the water retention rates increase as the flax content increases. Maximum water retention has been observed in pique fabrics. The water retention rate in rib fabrics increased prominently in fabric containing 40% flax.

Air permeability

For air permeability, 5 measurements were taken from each sample and their average values were recorded. The results obtained are given in figure 7.

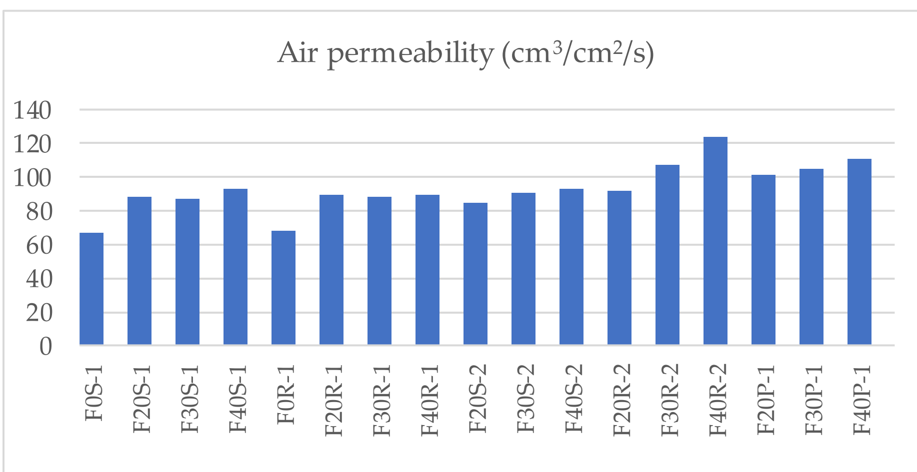

Figure 7. Air permeability of developed fabrics

When the air permeability test results are evaluated; as expected, air permeability values are lower in fabrics containing 100% polyester. In general, as the amount of flax increased, the air permeability value increased slightly. It is thought that the basis weight change in the fabrics also has an effect on the results. It was observed that the results became closer to each other by changing the basis weight as well as the flax ratio.

4. Discussion and Conclusion

When the dimensional properties of flax containing single jersey and rib quality fabrics are evaluated, it is seen that the dimensional strength of fabrics dyed with single dyeing is generally better than double dyeing.

It has been observed that the fastness values of fabrics containing 100% polyester are lower in both single jersey and ribbed quality, and that fabrics with 20% flax content have the highest fastness value in both single jersey and ribbed quality. It was observed that the wet rubbing fastness of flax containing fabrics with double dyeing decreased. As expected, it was observed that the fastness values of the pique fabrics dyed in light colors were high and that changing the fiber ratio had no effect on the fastness.

In single jersey and rib fabrics containing 100% polyester, due to the strong bond between fibers, they cannot easily move away from the fiber surface and pilling occurs by forming knots. It has been observed that the pilling resistance of flax containing fabrics is 1 point higher than that of 100% polyester. In addition, fabrics made of single jersey quality have higher pilling resistance than rib fabric. Increasing the flax ratio of the double-dyed fabrics increased the pilling resistance in rib quality. As the flax ratio increased in single jersey quality, pilling resistance decreased. It was observed that there was a small change in double and single dyeing in single jersey and rib knitted fabrics containing flax and the dyeing process did not significantly affect the pilling factor. It has been observed that different ratios of flax fiber used in single pique quality knitted fabric have no effect on pilling.

When the samples with a single dyeing process were examined, it was seen that the bursting strength decreased due to the increase in the amount of flax fiber used compared to 100% polyester and the bursting strength of the rib quality was higher than the single jersey fabric. When the samples with double dyeing process were examined, it was seen that the rib knitted fabric made with the same amount of flax content yarns had a higher bursting strength than the single jersey fabric. Additionally, it was observed that the bursting strength decreased due to the increase in the amount of flax fiber used.

Although the developed fabrics retained more water as the amount of flax increased, they dried faster or in the same time. Additionally, the fabrics that provided the highest value in terms of drying rate were found to be pique, rib and single jersey fabrics, respectively.

Air permeability values are lower in fabrics containing 100% PES. In general, as the amount of flax increased, there was a slight increase in the air permeability value.

As a result, it has been determined that the addition of flax to polyester fabric contributes positively to properties such as shrinkage, fastness and pilling. Additionally, when used as a blend, flax improves the comfort properties of the fabric. Linen's fast drying and high air permeability properties make it unique especially for the summer season.

5. Acknowledge

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