EVALUATION OF WEAVING AND DYEING PROPERTIES OF LOCAL REGENERATED YARNS

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Abstract: *As the demand for energy and raw material is increasing everyday, so the challenge of finding sustainable and environment friendly alternatives are becoming very crucial and challenging for the textile industry. Sustainability is one of the most required characteristics in textile production and consumption. As a result, regenerated cellulose fibers have become very popular for their identical properties to cotton, conforming to the sustainability goals of this sector. Production of regenerated cellulose fiber known as Ecocell the trend of sustainability is getting promoted. The aim of this study is to evaluate the performance and dyeing properties of Ecocell in woven fabrics. In order to evaluate the viability, six different fabrics with different construction was weaved and dyed and subjected to several testing. The results indicate that the successful development of Ecocell can be a sustainable and eco-friendly replacement to the imported fibers. By enhancing our country's self-sufficiency in regenerated cellulose fiber production, the textile industry is taking a crucial step towards greater eco-consciousness and sustainability. This study not only contributes to the academic understanding of regenerated cellulose fibers but also holds practical implications for the industry's green transformation.*

Keywords: Sustainability, Regenerated Cellulose Fiber, Woven Fabrics, Lyocell, Ecocell, Reactive Dyeing.

OCENA SVOJSTVA TKANJA I BOJENJA LOKALNIH REGENERISANIH PREĐA

Apstrakt: *Kako se potražnja za energijom i sirovinama svakodnevno povećava, tako i izazov pronalaženja održivih i ekološki prihvatljivih alternativa postaje veoma ključan i izazovan za tekstilnu industriju. Održivost je jedna od najpotrebnijih karakteristika u proizvodnji i potrošnji tekstila. Kao rezultat toga, regenerisana celulozna vlakna su postala veoma popularna zbog svojih identičnih svojstava kao i pamuk, u skladu sa ciljevima održivosti ovog sektora. Proizvodnja regenerisanog celuloznog vlakna poznatog kao Ecocell, trend održivosti se promoviše. Cilj ove studije je da se proceni performanse i svojstva bojenja Ecocell-a u tkanim tkaninama. Da bi se procenila održivost, šest različitih tkanina različite konstrukcije je tkano i obojeno i podvrgnuto nekoliko testiranja. Rezultati pokazuju da uspešan razvoj Ecocell-a može biti održiva i ekološki prihvatljiva zamena za uvozna vlakna. Povećanjem samostalnosti naše zemlje u proizvodnji regenerisanih celuloznih vlakana, tekstilna industrija čini ključni korak ka većoj ekološkoj svesti i održivosti. Ova studija ne samo da doprinosi akademskom razumevanju regenerisanih celuloznih vlakana, već ima i praktične implikacije za zelenu transformaciju industrije.*

Ključne reči: Održivost, regenerisana celulozna vlakna, tkane tkanine, liocel, ekoćel, reaktivno bojenje.

1. INTRODUCTION

The expanding growth of industrialization is accelerating the decline of the important resources of this world. Sustainable raw materials are highly demandable in today's textile industry as it helps to minimize the adverse effect of environmental impact caused by various processes and operations conducted in the textile production process [1]. When all factors are considered, regenerated cellulose fibers are more preferred due to their similar properties like cotton fibers [2]. Regenerated cellulose fiber is counted as a revolutionary and eco-friendly materials which in a sense has transformed the landscape of this industry. It is evident that the production of popular synthetic fibers possesses potential threat to the environment [3]. On the other hand, regenerated cellulose fibers are sourced from renewable plant-based materials such as wood pulp, bamboo or other cellulose based rich plants and the production process of regenerated cellulose fiber is done through a sophisticated approach. It has become a trend not only worldwide but also left a huge impact in the textile sector of Türkiye.

The prompting investment and local production of regenerated cellulose fiber helped to gain a huge momentum [1]. Moreover, the production process of regenerated cellulose fibers don't require much energy and that's one of the important remarks for being an eco-friendly material. The biodegradable nature of this fiber make it a more sustainable alternative for the fashion industry. Likewise, the utilization of fast-growing plants like bamboo fiber reduces the environment impact and assist in conservation efforts. Versatility is one of the impressive factors about regenerated cellulose fiber as it can be easily blended with other natural and synthetic fibers [4]. These properties can create a wide range of products for diverse applications. This eco-friendly fiber can produce fabric which have the unique properties of lightweight and breathability and can be used easily for summer clothing or a strong material which is ideal for active wear and technical textiles. The moisture absorption properties of regenerated cellulose fibers have created a better impression to use in the fabric in different climates to reduce sweat buildup. It has a soft and smooth texture which follow through a gentle behavior on the skin and turn this into an excellent choice for individuals with sensitive skin or better comfort in their garments. These unique characteristics has enable regenerated cellulose fiber to be one of the most popular fibers among the consumers, brands and designers who are environmentally concerned [4].

As, fashion industry are going towards to the plan of becoming the sustainable one, so it got a great popularity among them for its eco-friendly and natural availability characteristics [5,14,15].

1.1. The Significance of Regenerated Cellulose Fiber

Regenerated cellulose fibers are prominent because they are sustainable and their performance characteristics are similar to cotton. Regenerated cellulose fibers resemblance to cotton turn them as an ideal alternative which can make the industry's less dependent on traditional raw materials [4]. As a result, it helps to maintain the environmental balance by reducing the harmful impact. In Türkiye, this fiber already has gained a lot of demands because in textile sectors the necessity of producing local regenerated cellulose fibers are sky high because of the challenges associated with imports and promoting domestic production [1].

1.2. Lyocell

Lyocell is mostly known as a semi-synthetic fiber which is used to manufacture textiles for clothing and other similar products. As the production of cotton requires more land and water consumption is also higher, so it became necessary to find out a suitable and sustainable replacement of cotton with same properties. After years of research, scientists were able to develop lyocell fibers [6]. Lyocell fiber has a good comfort property like a natural fiber with excellent delicacy. Lyocell fibers are derived from wood pulp which is considered as natural cellulose. Lyocell have other trademark names such as Tencel, Newcell, Seacell etc. It is high-performance material obtained through an environmentally friendly production process. Lyocell fibers are a type of fiber widely used in the textile industry [7].

The production process of Lyocell fibers is conducted using N-methylmorpholine oxide (NMMO), an environmentally friendly solvent [8]. This process starts with the preparation of a soluble cellulose pulp which is later dissolved in the solvent to produce a viscous solution. This solution is passed through a plate of pinholes to form yarns using dry jet-wet spinning method. The resulting yarns solidified in a water bath to finally form lyocell fibers [6].

Lyocell fibers are obtained through an environmentally friendly production process. NMMO solvent is recyclable, and it doesn't use carbon disulfide. The solvent and water used in Lyocell production are recovered through closed circuit systems, thus minimizing water consumption and waste. Furthermore, the wood pulp comes from a source that is usually obtained through sustainable forest management, making lyocell fibers an environmentally sustainable option [8].

In terms of technical parameters, Lyocell fiber has excellent tensile strength with the range from 35-75 cN/tex. It also ensures durability and resistance in terms of wearing or tearing properties. The range falls in between 10%-50% for elongation at break and this behavior provides flexibility. The fibers have a fineness or denier with range from 1.0-2.5 dtex which gives it a soft and smooth texture [9]. Lyocell fiber has a structure that absorbs dyes better during dyeing [10]. This ensures that fabrics remain in more vibrant colors. Additionally, lyocell fibers are resistant to sunlight and washing, thus preventing color fading and deterioration.

In textile industry, lyocell fabrics are used in many different products such as clothing, underwear, bedding, towels, nappies and sportswear. In addition, the use of lyocell fibers is also common in areas such as home textile products, furniture coverings, automotive interiors and hygienic products. There are some special modifications of Lyocell which has improved the properties of this fiber and named as different brand. Tencel is one of them [10]. It was created, used for apparel applications and called 'Lyocell' when it is used for technical or industrial application [6].

1.3. The Ecocell Initiative

To meet the demand for sustainable fibers in Türkiye, the textile industry has invested in the production of regenerated fibers, which are sold under the trade name of "Ecocell". This local initiative aims to provide a reliable and environmentally friendly alternative to imported materials, ensuring the industry's sustainability and reducing the carbon footprint associated with transportation and production. These Ecocell fibers are in the group of "Lyocell" which is a generic name of regenerated cellulose fiber.

2. MATERIALS AND METHOD

Ecocell yarns produced from domestic regenerated cellulose belonging to Karafiber, Türkiye, were used in fabric production. Two different quality of Ecocell fibers, Ne 20/1 and Ne 30/1, were used in the study. The test results obtained from both yarns used are as follows:

Table 1: Yarn Test Results

	20/1 R	30/1 R
Twist	19.7/R	30.0/1R
STD Twist	18.3 Z	23.0 Z
Actual Twist	19.6 Z	20.3 Z
CV%	3.5	2.3
USTER	8.73	8.74
Thin -50%	0	0
Bold +50%	12	6
Neps +200%	9	17
Neps +140%	49	69
H% Max.	6.61	4.66
Strength min.	655	655
Strength CV%	7.3	10.4
Rm Min.	22.2	33.3
Elong% min	9.31	9.10
Lycra%	LYC 7.2%	-

The yarn information and composition values used for the fabrics produced are as follows.

Table 2: Yarn composition of Fabric A and B

Warp Yarn	30/1 R Ecocell T23Z-ELY12
Weft Yarn	20/1 R 50% Ecocell 50% Combed Cotton T19,3Z 78DTEX-ELPEL0
Composition	77% Ecocell 20% Cotton 3% Lycra

Table 3: Yarn composition of Fabric C and D

Warp Yarn	30/1 R Ecocell T23Z-ELY12
Weft Yarn	20/1 R 50% Ecocell 50% Combed Cotton T19,3Z 78DTEX-ELPEL0
Composition	77% Ecocell 20% Cotton 3% Lycra

Table 4: Yarn composition of Fabric E and F

Warp Yarn	30/1 R Ecocell T23Z-ELY12
Weft Yarn	30/1 R Ecocell T23Z-ELY12
Composition	100% Ecocell

The developed fabric production took place with industrial scale production facilities. The production phase was carried out in accordance with the classical woven fabric production parameters. Picanol Optimax-i Connect brand weaving machine was used for weaving the fabric. The parameters used during the production of the fabric were applied as follows for each fabric.

For Fabric A, B, C and D, a total of 9450 warps and 224 wefts were used. Warp density (cm) is 45 and weft density (cm) is 25. Fabric GSM is 380. Weaving was conducted using 6 frames flat drawing. The comb number is 15x3 and the comb width is 210 (cm).

A total of 5678 warps and 114 wefts were used for Fabric E and F. Warp density (cm) is 34 and weft density (cm) is 23. Fabric GSM is 270. Weaving was conducted using 6 frames flat drawing. Comb number is 17x2 and comb width is 167(cm). Three different knitted patterns were used to evaluate the weaving performance of the fabrics with accuracy.

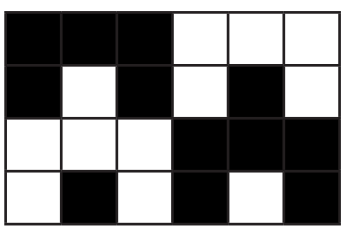

Figure 1: Weaving plan of Fabric A and B

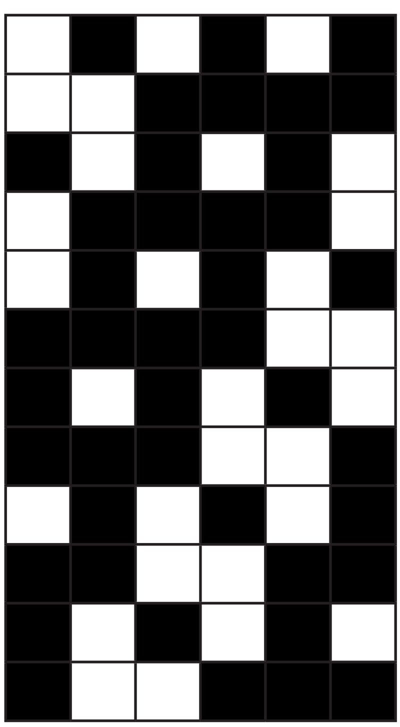

Figure 2: Weaving plan of Fabric C and D

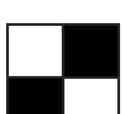

Figure 3: Weaving plan of Fabric E and F

Each fabric was subjected to dyeing in two different colors, light and dark, to measure the dyeing parameters and properties.

Table 5: Dyeing recipe for Fabric A and B

Chemicals	Fabric A (gr)	Fabric B (gr)
Yellow	3.90	31.58
Red	0.385	15.50
Blue	0.70	17.00
Wetting agent	2.00	2.00
Caustic soda	6.00	16.50
Sodium silicate	120.00	120.00

Table 6: Dyeing recipe for Fabric C and D

Chemicals	Fabric C (gr)	Fabric D (gr)
Yellow	1.58	27.70
Red	0.21	7.25
Blue	0.385	19.00
Wetting agent	2.00	2.00
Caustic soda	6.00	16.50
Sodium silicate	120.00	120.00

Table 7: Dyeing recipe for Fabric E and F

Chemicals	Fabric E (gr)	Fabric F (gr)
Yellow	7.10	0.770
Red	8.00	0.260
Blue	65.00	0.480
Wetting agent	2.00	2.00
Caustic soda	21.00	6.00
Sodium silicate	120.00	120.00

The finishing agents applied for all fabrics is shown in Table 8.

Table 8: Finishing recipe used of fabrics

Chemicals	(gr)	Chemicals
Plasticizer	5.00	Plasticizer
Fixator	10.00	Fixator
Seam anti-slip finish	2.00	Seam anti-slip finish
Acetic acid	0.80	Acetic acid

Figure 4: Fabric A

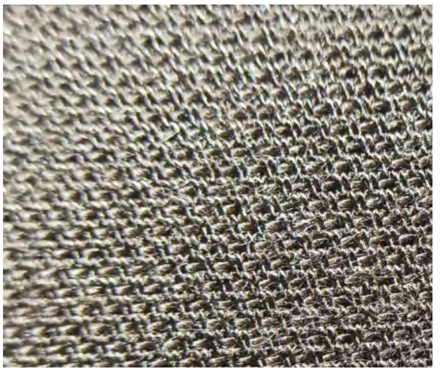

Figure 5: Fabric B

Figure 6: Fabric C

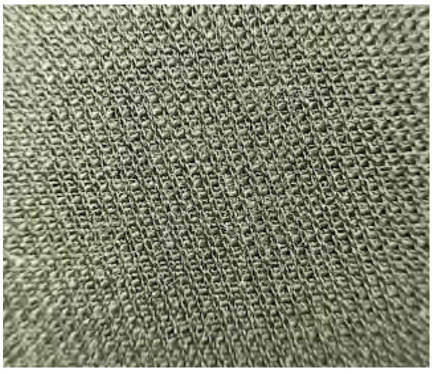

Figure 7: Fabric D

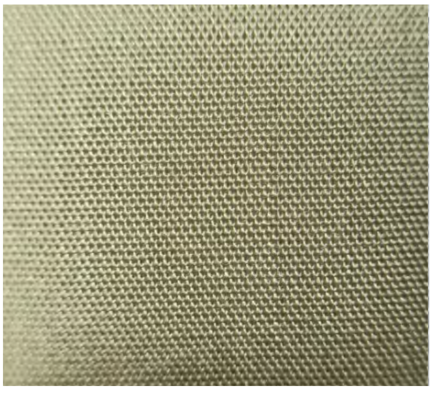

Figure 8: Fabric E

Figure 9: Fabric F

The flowchart for dyeing is shown in Figure 8

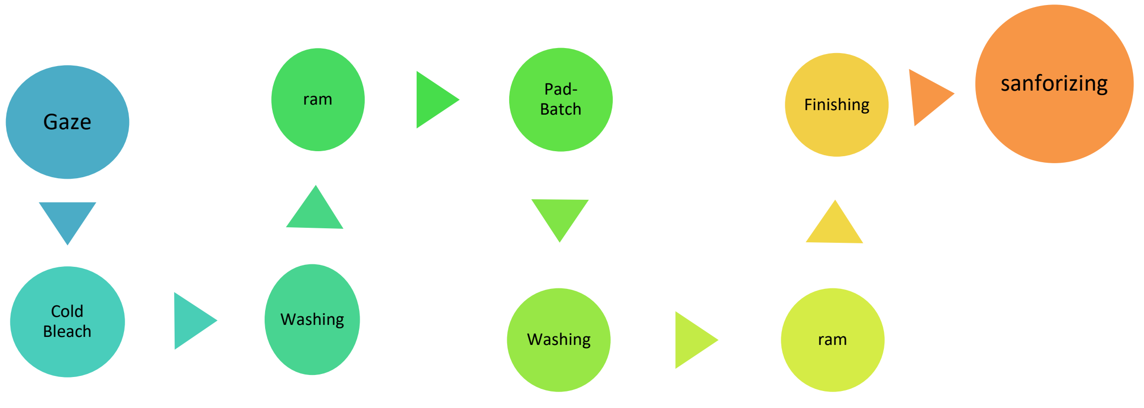

Figure 10: Dyeing flowchart

3. TEST RESULTS

3.1. Tensile Strength Test

Fabric breaking strength is also known as tensile strength, which implies the maximum amount of tensile force when the sample is stretched to break. This test helps to determine the resistance of fabric against breaking and tearing when force is applied in warp or weft direction.

The tensile strength test results shown in table 5 exhibits that the values are almost similar for fabric Fabric A - B, C, D in both warp and weft direction. E and F sample has lower strength values because they are rigid. The elastane plays a significant role in increasing fabric strength.

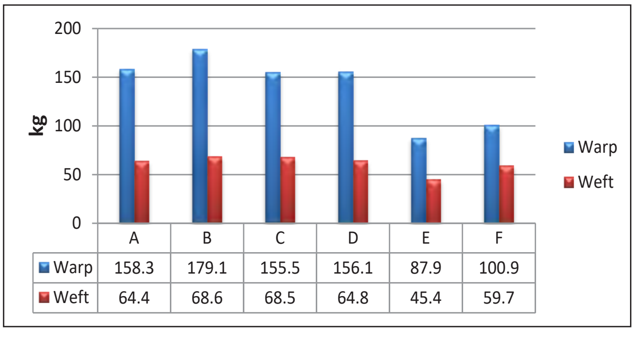

Figure 10: Tensile strength test results

3.2. Tensile Strength Test

Tearing strength is the resisting force required to initiate, maintain, or enlarge a tear under established conditions on a fabric. For this, force is applied on the fabric by the testing machine and the resistance of the fabric is measured.

When the results are examined, it is seen that the knit structure of the fabric affects the resistance to tearing. Although elastane is not supported in the values of the fabrics, it was observed that the E and F fabrics give a result close to the other fabrics. It can be said that the strength-increasing feature of the plain weave structure also has an effect.

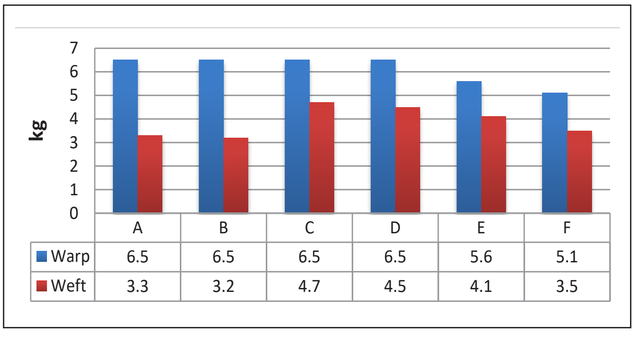

Figure 11: Tearing strength test results

3.3. Color fastness to wash test

Color fastness to wash test is conducted to determine the durability of color of the dyed textile products against different washing conditions. Test results range from 1 to 5, where fastness rating 5 means good and 1 means bad fastness properties. Table 7 depicts that the color fastness to wash of the dyed fabric is at a high level.

Table 9: Color fastness to wash test result

	Cotton	Nylon	Polyester	Acrylic	Wool
A	5	5	5	5	5
B	4/5	4/5	4/5	4/5	4/5
C	5	5	5	5	5
D	4/5	4/5	4/5	5	5
E	4/5	4/5	5	5	5
F	5	5	5	5	5

3.4. Color fastness to dry rubbing

Rubbing fastness is the resistance of a fabric to transfer its color to another fabric with which it is in contact by rubbing. It is one of the crucial tests as rubbing can cause a problem during the production of ready-garment and usage period. Generally, dark colors attain lower rub fastness in comparison to light colors. Dry rubbing fastness test is the fastness test performed to check the durability of the color when the dyed and/or printed textile products are rubbed with accompanying cloths. The product and accompanying cloth used here must be dry. According to the results in the graph, the test values are 4 and above. When the results are evaluated according to the standards, the color performance of the fabric gives good results in dry rubbing. These results show us that there will be no color transition on the rubbing fabric or it will be difficult in the fabric-fabric rubbing that will occur in the use of the finished fabric as ready-to-wear [16].

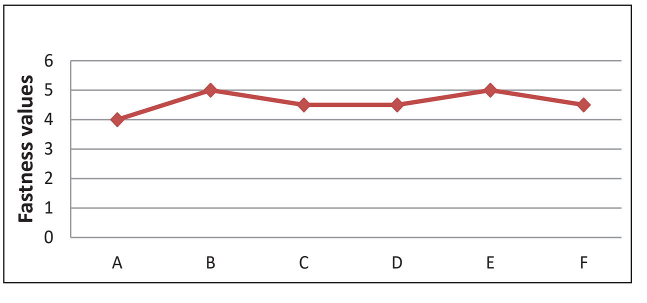

Figure 12: Color fastness to dry rubbing

3.5. Color fastness to wet rubbing

In the wet rubbing fastness test, the test sample is made dry and wetted by absorbing 100% of the weight of the rubbing cloth. The test results are evaluated after the rubbing cloth is dried at room temperature. When the results were examined, good results were observed in light-colored A, C, E fabrics, while the opposite result was observed in dark-colored fabrics.

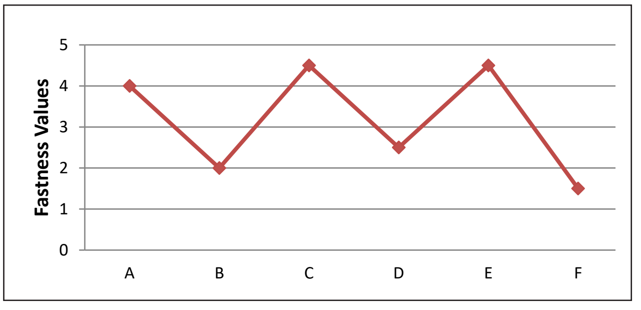

Figure 13: Color fastness to wet rubbing

3.6. Recovery test

Recovery test is performed to measure the changes of the fabric stretched by the effect of force according to its old length after the force is removed. Due to the application of this test, it also gives us the elasticity values of the fabric. The tests were only applied to fabrics containing Lycra. Lycra ratio in the compositions of the fabrics on which the test is applied is equal and is 3% for all. When the test results are examined, it is seen that the elasticity and recovery values of C and D fabrics are higher than A and B fabrics. The reason for this difference is the difference in the knitting structures of the fabrics. Fabric with more open construction have better recovery.

Table 10: Recovery test results

	E (%)	G (%)
A	24.7	5.4
B	24.1	5.2
C	31.9	7.4
D	28.7	8.0

3.7. Wash shrinkage test

During the washing, wetting and drying processes, dimensional changes in the form of shrinkage and elongation are observed in both warp and weft directions. The reason for the fabric shrinkage is the passage of the warp and weft threads under and over each other in the fabric, and when the fabric enters the aqueous environment, the amorphous regions of the fiber swell by absorbing water molecules, thus the yarns get closer to each other, causing the fabric to shorten in the warp and weft direction. According to the standards, the dimensional change in fabrics is expected to be +-3. According to the results, all fabrics except E fabric gave results in the standard range.

Table 11: Wash shrinkage test results

	Warp	Weft
A	-0.5	-1.5
B	-0.5	-1
C	+1	-2
D	+1	-3
E	-4	+1.5
F	-3	+1

3.8. Hoffman test

The Hoffman test is done to measure the dimensional change of fabrics after pressing under a steam iron. Pre-iron (PO) and post-iron (PI) values are calculated according to the formula below and the percentage value is expected to be ±2.

$$(PO - PI)/PI \times 100 = \text{Dimensional Change (\%)}$$

When the Hoffman test results of the fabrics are examined, it is observed that the values are in the desired range. According to the values, dimensional stability is maintained because of ironing and pressing in all Ecocell fiber fabrics with or without elastane.

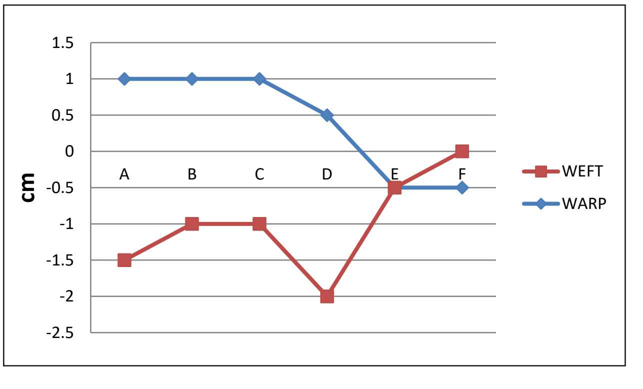

Figure 14: Hoffman test result

3.9. Martindale pilling test

Martindale test is one of the most important features when determining the performance properties of fabrics. Pilling is a very frequent problem which occurs on the surface of fabric. The chart above shows the test results tested under 2000 cycles. While evaluating the test results, 5 gives the best and 1 the worst result. When the results are examined, it is observed that the surface pilling evaluation of A, B and C fabrics gives bad results. Fabric construction or yarn structure might be the reason behind this issue.

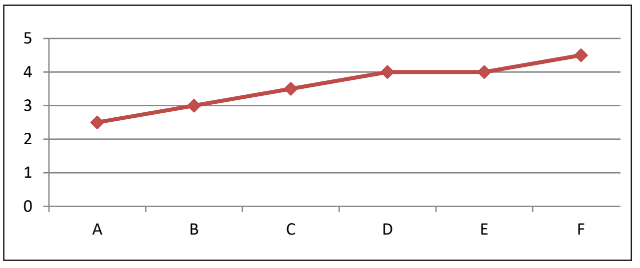

Figure 15: Martindale pilling test result

4. CONCLUSION AND DISCUSSION

In this comprehensive study, our focus was directed towards unraveling the weaving and dyeing properties of Ecocell. These yarns are derived from domestically source regenerated cellulose fibers, focusing on our commitment to sustainability in the textile industry. Our investigative efforts spanned a diverse array of parameters, encompassing six distinct fabrics, two distinct yarn varieties, three different weaving constructions, and a spectrum of light and dark color. All fabrics were meticulously produced at Akin Textile A. S., adhering rigorously to industry standards to ensure the highest quality.

The outcomes of our rigorous study are undeniably promising. In particular, our examination of woven fabrics produced from elastane yarns revealed outstanding breaking and tearing strength values. This not only indicates their sustainability for manufacturing robust and enduring textiles but also exhibits their potential to redefine the landscape of durable fabric production. Furthermore, the fabrics exhibited remarkable stretching and recovery properties, emphasizing their capacity to provide unparalleled comfort and convenience in the realm of ready-made garments.

Another noteworthy findings from this study is the fabrics resistance to shrinkage following washing and ironing procedures, as evidence by comprehensive washing and Hoffman tests. This exceptional feature imparts a crucial advantage, ensuring that finished products retain their original form and size, even when subjected to repeated laundering.

In sum, this study not only shows the capabilities of Kara fibers yarns but also underscores their potential to revolutionize the textile landscape. From durability and resilience to unmatched comfort and shape retention, these fabrics hold the promise of enhancing the overall quality of textile product.

However, this study did reveal some areas for improvement. The fastness tests indicated that light color dyeing performed well, but dark colors fell short of expectations. Addressing this issue is crucial, as consumers expect fabrics to retain their vibrant colors, regardless of shade. Similarly, the pilling test results for elastane yarns were below expectations which was a matter of great concern in terms of customers perspective as most of them seek long lasting and visually appealing ready-made products. It is essential to address these shortcomings to enhance customer satisfaction and boost marketability of these textiles.

Nonetheless, we must recognize the broader significance of regenerated cellulose fibers in prompting sustainability within the textile industry. As the fashion world increasingly prioritizes ecological sustainable practices, the use of Ecocell yarns offers a positive step towards a greener and more responsible approach to clothing production. The focus on sustainability should remain in center to future research and development efforts, ensuring the continuous improvement of these fibers and their production processes.

In conclusion, this comprehensive study has shed light on the immense potential of Ecocell yarns and regenerated cellulose fibers in spearheading a revolution within the textile industry. Nevertheless, it is imperative to acknowledge and prioritize areas in need of improvement, particularly in terms of dark color fastness and pilling resistance.

By directing everyone's collective efforts toward enhancing these critical attributes, it is possible to increase the use of sustainable fibers and contribute significantly to a more environmentally conscious and innovative fashion landscape. The road ahead may hold challenges, but it is a path that leads to progress, sustainability, and a fashion industry that harmonizes with the planet.

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