

Research Article

Evaluation of the Performance of Fabrics Produced with Oncedye Acrylic™, Ecocell™, and Cotton Fiber Blends Contributing to Sustainability Goals

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Abstract

In this study, the reactive dyeability of 100% cotton, acrylic-cotton (Co)/acrylic, and Ecocell/acrylic blend woven fabrics in a single bath was examined. The results were assessed in terms of washing fastness, hydrophilicity values, and color fastness. Additionally, the effect of using cotton and Ecocell fibers together with acrylic fibers on the physical properties of the fabrics was investigated, and the test results were analyzed. Experiments were conducted on satin weave and plain weave fabrics with two different yarn counts. As a result, no negative effect was observed on the fastness values when reactive dyeing was

performed in a single bath on 100% cotton, Ecocell/acrylic, and cotton/acrylic blend woven fabrics, although differences were observed in K/S values.

Keywords: Cotton, Acrylic, Ecocell, Acrylic Blend Yarn, K/S Value, Single Bath Dyeing

1. Introduction

Cotton yarns are one of the basic materials of the textile industry, known for their high particle count, soft texture, and breathability. Cotton, which has a wide range of applications, especially in fabric production, offers many advantages in terms of user comfort. It reduces sweating by allowing air circulation to the skin and is used in a wide range of products, from summer clothing to underwear.

As a natural fiber, cotton also stands out as an environmentally friendly option. With its sustainability and recyclability properties, it has a lower negative impact on global warming. Cotton can be used in various blends, providing different textures and properties through different weaving techniques and yarn types.

Acrylic yarns are synthetic fibers, and they are known for their softness, durability, and color characteristics in the textile sector. Acrylic fiber, first registered in the 1940s, is widely used in winter clothing and home textiles due to its wool-like structure [1]. Literature indicates that acrylic yarns have high thermal insulation properties, keeping warmth effectively.

Another important feature of acrylic yarns is their color retention capacity. Acrylic fibers absorb dye well, allowing for the creation of permanent colors and ensuring long-lasting color vibrancy in products [2]. This increases the appeal of acrylic yarns, especially in fashion and decoration. Moreover, acrylic yarns are lighter than natural fibers, providing comfort in use and reducing the weight of garments [3].

The durability and elasticity of acrylic yarns also offer significant advantages. Acrylic yarns are known for their high breakage resistance and flexibility, making them suitable for long-lasting textile products. Additionally, their high resistance to breakage and ease of care make them preferred [4]. These features make acrylic yarns resistant to washing and drying processes, thereby extending their lifespan. Due to these characteristics, high-quality acrylic yarns offer many advantages in both performance and aesthetics.

Lyocell fibers are products that stand out for their eco-friendly production components and sustainable features. These fibers are produced by processing

biopolymers derived from natural sources into fibers through a special process, and they are particularly preferred by consumers looking for ecological alternatives in the industry [5]. One of the most important features of lyocell fibers is their biodegradability [6].

As a naturally derived material, lyocell has a skin-friendly structure and is therefore a suitable option for individuals with allergic sensitivities [7]. Ecocell brand lyocell fiber, with its natural cellulose-based structure and superior moisture management capability, stands out. Thanks to its high moisture absorption capacity, it contributes to regulating body temperature, enhancing comfort, and providing structural comfort. These features make the fiber an ideal option for applications that require high performance and comfort, such as sportswear. Lyocell fibers extend the lifespan of products and keep them from wear and tear for longer. This durability is important for a sustainable economy, as long-lasting textile products reduce the need for constant replacements and minimize growth impacts [8]. Ecocell offers an environmentally friendly alternative by consuming low energy and water during production, making it an important solution for sustainable textile manufacturing. These features support growth aimed at reducing environmental impacts and strengthen the production approach focused on sustainability in the textile economy.

1.1 Cotton-Acrylic Blend Yarns

Cotton-acrylic blend yarns offer a combination of durability and comfort by strongly merging cotton and acrylic fibers. Cotton, as a natural fiber, provides softness, breathability, and moisture absorption properties; while acrylic contributes to the yarn with its lightness, durability, and vibrant color features.

The combination of acrylic fiber and cotton yarn's high moisture absorption capacity provides extra comfort for users while offering ease of use due to its light structure [9]. Another advantage of these blends is the increased yarn strength, which enhances the lifespan of frequently used products like home textiles and everyday wear [4]. Acrylic's strong color retention capability ensures the fabric maintains durable and vibrant colors over time, preserving its aesthetic properties [3].

Especially in cold weather conditions, cotton-acrylic blend yarns are preferred because acrylic offers high thermal insulation, keeping warmth, while cotton ensures the garment remains breathable by absorbing moisture, preventing sweating.

1.2 Lyocell-Acrylic Blend Yarns

Lyocell-acrylic blend yarns are advanced yarns combining eco-friendly features with performance. Lyocell is a biodegradable fiber and is known as an environmentally friendly option with a low impact when sourced sustainably. Acrylic fiber contributes to textile products with its lightness and color retention properties [5, 10].

This blend combines the eco-friendly and soft texture of lyocell fiber with the flexibility and color-changing capabilities of acrylic. Lyocell fibers offer a skin-friendly structure, making them suitable for sensitive skin, and their moisture-absorbing properties enhance comfort. Acrylic, on the other hand, contributes to the flexibility of the blend and maintains the fabric's long-lasting and vibrant appearance [7, 11, 12].

1.3 Dyeing Acrylic Blended Products in a Single Bath

Ecocell fibers and cotton, being cellulose-based, are typically dyed using reactive group dyes in industrial applications. Acrylic fibers, however, are dyed with acid group dyes. In standard procedures, blends of Ecocell and cotton with acrylic are dyed using dual-dyeing systems. In this study, the newly developed Oncedye acrylic fiber, which can be dyed in a reactive bath, was used for reactive dyeing, and the yarn properties were analyzed. This study also includes some performance and comfort tests of the final woven fabric.

Dyeing acrylic blended products in the same bath is a method developed to improve textile production efficiency and minimize production costs. Typically, different bath options are developed for dyeing various fiber types such as cotton, wool, and acrylic, due to their differing dyeing temperatures and chemical processing requirements. However, with the single-bath dyeing method, it is possible to dye various fiber blends together in the same bath.

The single-bath dyeing process offers the advantage of dyeing acrylic-cotton or acrylic-wool blends in a single operation. This method speeds up the production process while saving on chemicals, water, energy, and costs, offering an environmentally friendly approach [11].

To dye acrylic-blended yarns in a single bath, special dyes and dyeing conditions are required. The selection of dye sections must be compatible with all fiber types, ensuring the completion of color fastness. For example, acid and cationic dyes may be suitable for acrylic, while reactive dyes are available for cotton [10, 13].

In this study, the reactive-dyeable acrylic fiber developed by Aksa Acrylic, the Ecocell lyocell fiber developed by Karafiber Textile, and cotton fiber were used in the yarn production blend. The yarns were produced by Karafiber Textile, and fabric production and dyeing processes were carried out by Ozanteks. In this context, yarns with Ne 30/1 and Ne 40/1 counts were produced in 50:50 blend ratios of acrylic/cotton and acrylic/Ecocell using the ring spinning system. These yarns were then used to produce 40/1 satin and 30/1 plain weave fabrics at Ozanteks Textile's weaving unit. The produced fabrics were dyed in a single reactive black bath in the HT dyeing machine. After dyeing, the fabrics underwent fastness tests, hydrophilicity tests, and color value tests, including K/S comparison, and the results of these tests were evaluated.

2. Materials and Methods

In the study, 100% cotton yarn was used as the warp yarn. The blend yarns, including Ecocell-reactive dyeable acrylic and cotton-reactive dyeable acrylic yarns, were provided in a 50%-50% blend by the Karafiber Textile R&D Center. During the weaving process, two different weft densities were used: Ne 30/1 weft fabric quality (blend yarn) with 25 picks Ne 30/1 cotton 30 warp density, and Ne 40/1 weft fabric (blend yarn) with 28 picks Ne 40/1 cotton 49 warp density. Plain weave and satin weave were selected as the weaving types. The fabric properties used in the study are given in Table 1.

Table 1. Experimental Fabric Properties

Yarns Used		Weaving Density (picks/cm)	Weaving Type	Weight (g/m ²)
Yarn Type	Twist (T/m)			
Ne 30/1 Cotton	950	25 Weft/30Warp	Plain Weave	124,2
Ne 30/1 Cotton-Acrylic	780			137,7
Ne 30/1 Ecocell-Acrylic	900			137,7
Ne 40/1 Cotton	1100	28 Weft/49Warp	Satin Weave (S ¼)	113,4
Ne 40/1 Cotton-Acrylic	780			143,1
Ne 40/1 Ecocell-Acrylic	900			145,8

The produced fabrics underwent several tests according to the specified standards, including color fastness to domestic and commercial washing (ISO 105-C06), color fastness to rubbing (TS EN ISO 105-E04), hydrophilicity test (EN ISO 14697), colorimetric evaluation with a spectrophotometer, and fabric pilling resistance using the Martindale method (TS EN ISO 12945-2). Washing fastness was tested in a Gyrowash machine, and dry-wet rubbing fastness was tested using a crockmeter device. The results of the study

were evaluated graphically and discussed with R&D Centers during focus group meetings.

3. Results

The tests and analyses conducted during the step of examining the dyeability of fabrics made from 100% cotton, acrylic/cotton, and ecocell/acrylic yarn blends in a single bath are reviewed under subheadings.

Color Fastness to Domestic and Commercial Laundering – (ISO 105-C06) and Color Fastness to Rubbing – (TS EN ISO 105-E04)

The test results for the color fastness of the samples to washing are presented in Table 2. Fastness evaluations were performed using a 150 mL water solution containing 4 g/L of ECE-formulated phosphate-free reference detergent, added to stainless steel containers without optical brighteners. The dyed sample was placed in the container along with 25 steel balls. Washing was carried out at 40°C for 30 minutes. After rinsing and drying, the change in the color of the sample and the multi-fiber control fabric were evaluated using the gray scale. Dry and wet rubbing fastness tests were conducted using a crockmeter device. The rubbing fastness measurements are provided in Table 3.

Table 2. Washing Fastness of Samples to Domestic and Commercial Laundering

	Washing Fastness (ISO 105-C06)						
	Color Change	Staining					
		Wool	Acrylic	PES	Nylon	Cotton	Acetate
Ne 30/1 Cotton	5	5	5	5	5	5	5
Ne 30/1 Cotton-Acrylic	5	5	5	5	5	4/5	5
Ne 30/1 Ecocell-Acrylic	5	5	5	5	4-5	4-5	5
Ne 40/1 Cotton	5	5	5	5	5	5	5
Ne 40/1 Cotton-Acrylic	5	5	5	5	5	5	5
Ne 40/1 Ecocell-Acrylic	5	5	5	5	5	4-5	5

Table 3. Rubbing Fastness Results of Samples

	Rubbing Fastness (TS EN ISO 105-E04)	
	Dry Rubbing	Wet Rubbing
	Ne 30/1 Cotton	4-5
Ne 30/1 Cotton-Acrylic	5	4
Ne 30/1 Ecocell-Acrylic	5	4
Ne 40/1 Cotton	5	4-5
Ne 40/1 Cotton-Acrylic	5	4
Ne 40/1 Ecocell-Acrylic	5	4

Hydrophilicity Test (EN ISO 14697)

The fabrics were cut into 10x10 cm pieces and laid flat on the surface of a beaker filled with distilled water, with their front sides facing the water. A stopwatch was started, and the time required for the sample to become completely wet was recorded. Before the tests, the fabrics were conditioned at $65\% \pm 4$ relative humidity and a temperature of $20 \pm 2^\circ\text{C}$. The experiment was repeated 5 more times, and the arithmetic mean of the results was calculated to determine the wetting times of the fabrics. The shorter the average time, the more absorbent the fabric was evaluated to be. The results of the hydrophilicity test are presented in Table 4.

Table 4. Hydrophilicity Test Results

	Hydrophilicity ISO EN 14697
Ne 30/1 Cotton	30,00
Ne 30/1 Cotton-Acrylic	4,66
Ne 30/1 Ecocell-Acrylic	5,92
Ne 40/1 Cotton	30,00
Ne 40/1 Cotton-Acrylic	2,24
Ne 40/1 Ecocell-Acrylic	2,35

Colorimetric Evaluation Test with Spectrophotometer

CIE Lab L* (lightness-darkness), a* (red/green), b* (yellow/blue), C* (chroma), and ho (hue angle) values were measured using a spectrophotometer (Minolta Spectrometer CM-3600D) (Yurt, 2006). The measurements of the fabric color values were taken under D65 daylight, with a 10° observation angle. The K/S and CIE Lab* values were calculated by averaging the five measurements produced by the spectrophotometer.

Table 5. CIE LAB and K/S Values of the Samples

	CIE LAB Values						<1,5	K/S
	ΔE	L*	a*	b*	C*	ho		
Ne 30/1 Cotton		18,19	0,87	-0,33	0,93	339,14	1,5	15,17
Ne 30/1 Cotton-Acrylic	4,684	21,35	-0,81	-3,35	3,45	256,34	1,5	9,69
Ne 30/1 Ecocell-Acrylic	5,008	21,53	-1,08	-3,52	3,68	252,97	1,5	9,31
Ne 40/1 Cotton		18,62	-0,86	-0,99	1,31	229,10	1,5	13,21
Ne 40/1 Cotton-Acrylic	2,852	21,13	-0,59	-2,31	2,39	255,78	1,5	10,96
Ne 40/1 Ecocell-Acrylic	3,599	21,63	-1,05	-2,95	3,13	250,42	1,5	9,72

**Values are calculated by averaging five different measurements.

The yellowish and reddish values of the CIE LAB values in the table are shown in Figure 1, the lightness and darkness values are presented in Figure 2, and the K/S graph is provided in Figure 3.

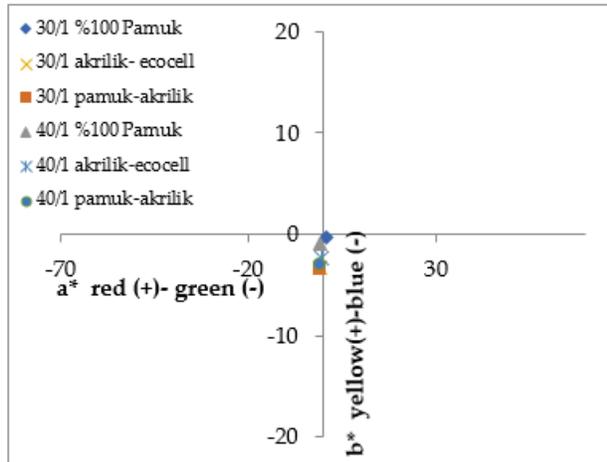


Figure 1. a (redness) - b (yellowness)

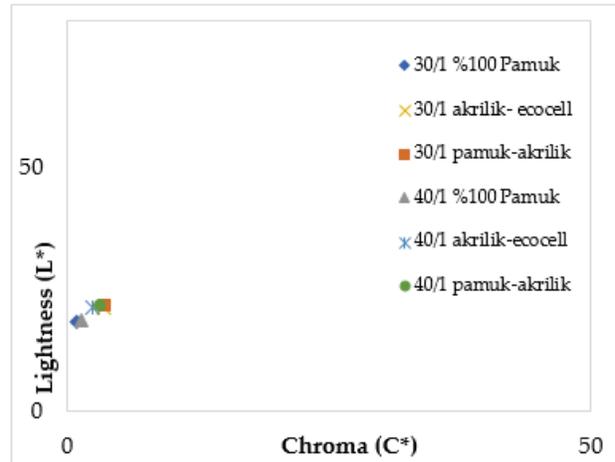


Figure 2. L (lightness) - C (chroma)**



Figure 3. K/S values of the samples

The fabrics in the study were subjected to tests after being woven. While the wash fastness showed very good results, the rubbing fastness values were found to be below expectations. Improvement alternatives should be considered for wet rubbing fastness. The color yield (K/S) and CIE Lab* values of the dyed samples were measured using a spectrophotometer. Color measurement: The CIE Lab* values of the samples were also measured with the spectrophotometer. K/S; L*: Lightness/darkness value (+ lighter, -

darker), a^* : Red/green value (+ redder, - greener), b^* : Yellow/blue value (+ yellower, - bluer), and dE^* (total color difference) values are indicated.

When examining the color yield (K/S values) of the control fabric, which was a 100% cotton black dyed fabric, it was observed that the values were close to 15. The fabrics closest in color values to the control samples were those made from Acrylic Ecocell blends. These fabrics were woven as NE 40/1 satin, and due to the positioning of the warp threads being more prominent, the K/S value was higher.

4. Discussion and Conclusion

Increasing awareness about the environment and climate change has made sustainable production a necessity. As a result, companies in the textile industry, where water consumption is very high, are seeking alternative technologies and materials instead of harmful methods to people and the environment [14]. In dye houses, process changes are being made to reduce water consumption [15,16]. There are various studies in the literature on dyeing fabrics made from different sustainable, eco-friendly fibers in a single bath [15, 17]. This study investigates the reactive dyeing of acrylic-cotton and acrylic-ecocell blend fabrics in a single bath. A control sample was selected from 100% cotton fabric dyed under standard operating conditions without the acrylic blend.

The color fastness, wash fastness, rubbing fastness, hydrophilicity, and K/S values of the sample fabrics were compared, and their effects on the fabric were examined. When comparing the fastness values of the blend fabrics and the 100% cotton fabric, wash and rubbing fastness values were found to be commercially acceptable and showed similar results. The hydrophilicity test showed that the blend fabrics were more hydrophilic than the control fabrics. The K/S values of the blend fabrics were lighter compared to the control fabrics, showing slight mottling and a matte color finish. Overall, the feasibility of reactive dyeing in a single bath was demonstrated. By reducing the acrylic dyeing process step, savings in water, chemicals, and costs were achieved. In the continuation of the study, experiments will be conducted with different dye changes to obtain more pastel tones, and fastness and K/S values will be re-evaluated.

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References

- [1] Kirk-Othmer. (2000). Acrylic fibers. In Kirk-Othmer Encyclopedia of Chemical Technology (pp. 1- 10). John Wiley & Sons.
- [2] Karahan, M. (2013). Fiber and Textile Engineering. Ap
- [3] Wong, A. S., & Li, Y. (2005). Thermal comfort in clothing. In Improving Comfort in Clothing (p
- [4] Kadohph, S. J. (2007). Textiles (10th ed., pp. 34
- [5] Borbély, E. (2008). Lyocell, the new generated cellulose. Acta Polytechnica Hungarica, 5(3)
- [6] Zhao, C., & Koo, K. (2020). Biodegradable fibers in the textile industry. Journal of Sustainable Textiles, 15(3), 210-224.
- [7] Lee, M., Kim, H., & Park, S. (2019). Environmentally friendly fibers and their applications in clothing. International Journal of Textile Research, 12(2), 8
- [8] Taylor, R. (2018). Durability and environmental impact of sustainable fibers. Environmental Textile Journal, 22(4),
- [9] Shishoo, R. (2005). Textile developments in the automotive industry. Woodhead Publishing.
- [10] Zhao, C., & Koo, K. (2020). Advanced techniques for sustainable textile dyeing. Journal of Sustainable Textiles, 15(3), 300-315.
- [11] Smith, J., & Li, Y. (2015). Efficient dyeing techniques for fiber blends. Textile Innovations Quarterly, 8(2), 120-134.
- [12] Taylor, R. (2018). Durability and environmental impact of sustainable fibers. Environmental Textile Journal, 22(4), 122-137.
- [13] Greenberg, E., Kumar, P., & Lee, T. (2022). Innovative dyeing processes for eco-friendly textiles. Environmental and Textile Sciences Journal, 10(3), 198-215.
- [14] Greenberg, E., Kumar, P., & Lee, T. (2022). Innovative eco-friendly fibers and their roles in sustainable fashion. Environmental and Textile Sciences Journal, 10(3), 175-192.
- [15] Turan, Ö. (2002). Dyeing of cotton and cotton/acrylic blend yarns (Master's thesis, Istanbul Technical University, Institute of Science and Technology, Istanbul).
- [16] Yurt, D. (2006). The phenomenon of color in home textiles (Master's thesis, Dokuz Eylul University).
- [17] Yavascaoglu, A. (2018). Investigation of properties of woven fabrics made from acrylic-blended yarns (Doctoral dissertation, Uludag University, Institute of Science and Technology, Bursa).