



Investigation of Dyeing Performances of Woven Fabrics Having Recycled Cotton Fibers by Reactive with Different Functional Groups

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Abstract

Sustainability is becoming increasingly important in the textile industry. Recycled cotton fiber contributes to the conservation of natural resources and reduces the carbon footprint. However, the physical and chemical structure of recycled cotton fibers can directly affect the dyeing performance. In this study, the dyeing behavior of fabrics containing 55% Polyester 45% Cotton, 55% Polyester 45% Recycled Cotton and 38% Polyester 62% Recycled Cotton with reactive dyes of different functional groups was compared. The results showed that dyeing performance of recycled cotton fibers is quite similar to fabrics containing virgin cotton fibers and fabrics containing recycled cotton showed the best color strength performance when dyed with bifunctional dyes. As the recycle rate increased, a decrease in the mechanical strength of the fabrics was observed, but significant gains were achieved in terms of environmental sustainability. These findings provide valuable data for increasing the use of recycled cotton.

Article Info

*Research Article
Received: 13/05/2025
Accepted: 15/10/2025*

Keywords

Cotton, recycled cotton, reactive dyeing, sustainability

Highlights

Cotton, recycled cotton, reactive dyeing, sustainability

Geri Dönüştürülmüş Pamuk İçerikli Dokuma Kumaşların Farklı Fonksiyonel Gruba Sahip Reaktif Boyarmaddelerle Boyanma Performanslarının İncelenmesi

Özet

Tekstil endüstrisinde sürdürülebilirlik giderek daha fazla önem kazanmaktadır. Geri dönüştürülmüş pamuk elyafı, doğal kaynakların korunmasına katkı sağlayarak karbon ayak izini azaltmaktadır. Ancak, geri dönüştürülmüş pamuk liflerinin fiziksel ve kimyasal yapısı boyama performansını doğrudan etkileyebilmektedir. Bu çalışmada, %55 Polyester %45 Pamuk, %55 Polyester %45 Geri Dönüşüm Pamuk ve %38 Polyester %62 Geri Dönüşüm Pamuk içeren kumaşların farklı fonksiyonel gruplara sahip reaktif boyarmaddeler ile boyanma davranışı karşılaştırılmıştır. Sonuçlar, geri dönüştürülmüş pamuk lifi içeren kumaşların boyama performansının konvansiyonel pamuk lifi içeren kumaşlara oldukça benzer olduğunu ve geri dönüştürülmüş pamuk içeren kumaşların bifonksiyonel boyarmaddelerle boyandığında en iyi renk şiddeti performansını gösterdiğini ortaya koymuştur. Geri dönüşüm pamuk oranı arttıkça kumaşların mekanik dayanıklılığında azalma gözlemlenmiş, ancak çevresel sürdürülebilirlik açısından önemli kazanımlar elde edilmiştir. Bu bulgular, geri dönüştürülmüş pamuk kullanımının artırılmasına dair değerli veriler sunmaktadır.

Anahtar Kelimeler

Pamuk, geri dönüştürülmüş pamuk, reaktif boyama, sürdürülebilirlik

Öne Çıkanlar

Sürdürülebilirlik, geri dönüştürülmüş pamuk, reaktif boyama

1. Introduction

The textile sector is an industry that has negative effects on the environment due to its high natural resource and chemical substance use, uses the most resources in terms of water, air and energy consumption and produces a large amount of waste [1]. The ready-made clothing sector, while growing with the effect of increasing consumer demands and fast fashion worldwide, causes problems such as waste of resources and environmental pollution. Textile waste is generated due to increasing fiber consumption and most of the waste is disposed of with unsustainable methods. In Europe, 10% of clothing waste is recycled, 8% is reused, approximately 57% of the remaining waste is sent to landfills and 25% is incinerated. In the USA, the textile recovery rate varies between 15-16% [2]. The textile industry is responsible for 10% of global CO₂ emissions and 20% of waste production, therefore sustainability studies have become increasingly important in recent years [3]. Extending the life of clothing by 3 months can reduce carbon and water footprints by 5-10%, while recycling 2 million tons of clothing per year is equivalent to removing 1 million vehicles from traffic in terms of environmental impact [4,5]. Recycling is defined as the reprocessing of used and discarded materials and their inclusion in the production process. In this way, waste can be evaluated as raw materials and different materials can be recycled [1].

The increasing consumption with the industrial revolution has caused ecological and economic problems by negatively affecting the environment and human health. While fast fashion increases textile waste, sustainable production aims at waste reduction, recycling and energy saving [6]. Textile waste is classified as pre-consumer and post-consumer. Pre-consumer waste includes excess fabric, sewing errors and production surpluses resulting from production. Post-consumer waste consists of old or damaged clothing that is thrown away after use [7].

Cotton, a natural fiber based on cellulose, is rapidly degraded in nature, but has environmental impacts due to high water consumption, land use, emissions and pesticide use during its production [8]. Traditional cotton cultivation poses sustainability challenges due to intensive water and chemical use. It is estimated that 11% of global pesticide use belongs to cotton. Recycling of cotton fibers is important to reduce these impacts. However, recycled cotton is often converted into low-quality products, and difficulties are experienced in clothing production due to the decrease in fiber quality. During mechanical recycling, the fiber length is shortened, resulting in the production of coarser yarns [2].

Textile waste processing strategies are classified as reduction, reuse, recycling and energy recovery. Reduction aims at resource consumption, reuse aims at reuse of products and recycling aims at evaluating waste as raw materials [1]. While conventional cotton causes environmental problems, recycled cotton contributes to the circular economy. Sustainable waste management is important in textile plants, but separation challenges continue [2]. Therefore, higher quality fiber production should be achieved by minimizing the negative effects on fiber quality [2]. During recycling, fibers are shortened and strength is lost, which leads to different coloring results in the dyeing process. Recycled cotton is usually reinforced by blending with fibers such as polyester and various products are produced [9].

Reactive dyes are synthetic dyes that stand out with their wide range of colors and bright colors in the coloring of cotton [10]. These dyes are classified as monofunctional and bifunctional (homo- and hetero-bifunctional) [11]. The first commercial reactive dyes were developed as monofunctional structures containing the reactive groups of dichlorotriazine (DCT) with high reactivity and monochlorotriazine (MCT) with lower reactivity [12]. The number and reactivity of reactive groups increase dye efficiency while supporting environmental sustainability by reducing waste dye [11]. Reactive dyes bind to the fibers by forming covalent bonds with the hydroxyl groups of cellulose, this binding mechanism occurs through nucleophilic substitution and nucleophilic addition reactions. The chemical structures of the dyes directly affect the fixation rate and dyeing efficiency [13]. Washing processes may be required due to hydrolysis after dyeing [14].

Many studies in the literature have focused on only mechanical properties or a single functional group when using dyed samples containing recycled cotton fiber; however in this study, the dyeing performance of fabrics with virgin and recycled cotton fibers different type of reactive dyes differing in color; along with tear strength and pilling performances in accordance with common quality control tests of a clothing fabric production mile. The paper focused on the usability of recycled cotton fibers in clothing fabrics.

2. Material and Method

2.1. Material

In this study, 3 fabrics were woven with Ne 20 yarns containing recycled cotton/polyester fibers with a blend ratio of 50/50 and 70/30 as weft and 20 Denier Polyester yarn as warp, in twill 2/1 weave and 51x32 (warp x weft) density. The warp yarns were commercially available and it was declared that recycled cotton fibers were obtained physically recycling process from post-consumer wastes through Garnett machine by the supplier. Fabric structural details are shown in Table 1. After alkaline bleaching was applied to the fabrics as pretreatment process, the polyester yarns in the fabrics were dyed using disperse dyes kindly provided by CHT Türkiye according to the disperse dyeing process to achieve a uniform color appearance on the fabric surface before reactive dyeing. For reactive dyeing process, Vinylsulfone (VS), monochlorotriazine (MCT) and bifunctional (BF) reactive dyes were used for the three primary colors (red, yellow, and blue) kindly supplied by CHT Türkiye. After the dyeing process, an anionic washing agent (a water-based anionic structure consisting of special polymers and dispersion agents) kindly supplied by Tanatex was used for the washing process.

Table 1. Woven fabric information

Fabric Properties	Sample Name		
	45% Cotton	45% Recycled Cotton	62% Recycled Cotton
Construction (%)*	55% Polyester 45% Cotton	55% Polyester 45% Recycled Cotton	38% Polyester 62% Recycled Cotton
Warp Yarn	20 Denier Polyester Monofilament		
Weft Yarn	Ne 20 Cotton – Polyester (50%-50%)	Ne 20 Recycled Cotton – Polyester (50%-50%)	Ne 20 Recycled Cotton – Polyester (70%-30%)
Density	Warp: 51 ends/cm, Weft: 32 picks/cm		
Weave Pattern	Twill 2/1		
Weight (g/m ²)	135		

* Fiber ratio was also confirmed through test using TS 4739 standard

2.2. Method

The fabrics were dyed in a laboratory type dyeing machine (ATC-Lab Dye HT 24) with a dye concentration of 1% and a 1:10 liquor ratio. The reactive dyeing steps of the fabrics were completed according to the dyeing diagram shown in Figure 1. After dyeing, the washing process was carried out using anionic washing agent. Finally, the dyeing process was completed with cold washing.

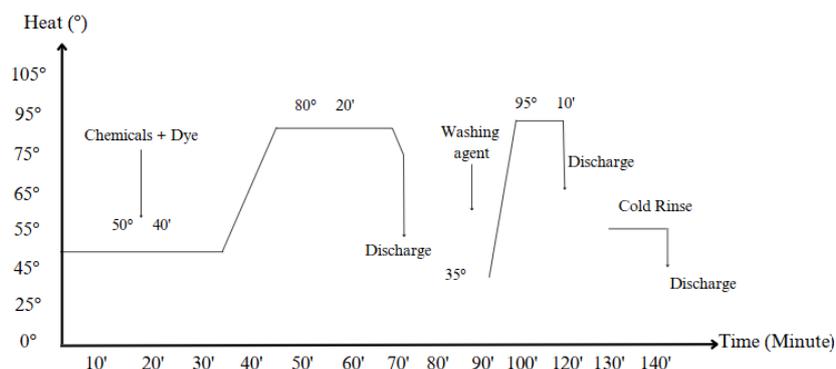


Figure 1. Dyeing and Washing Diagram

The color coordinates of the samples were measured with a spectrophotometer (Datacolor SF600 / USA). The measurements were carried out according to the CIELab color space in D65 daylight using a 10° standard observer with a 6.6 mm aperture.

Color fastness to washing tests of the samples were performed using a Gyrowash (James H. Heal / UK) device. Color fastness to washing according to TS EN ISO 105-C06 A1S, to water according to TS EN ISO 105-E01, to acid and alkali perspiration according to TS EN ISO 105 E04, to dry and wet rubbing according to TS EN ISO 105 X12 was completed.

Tearing strength tests were completed by universal strength tester (James H.Heal Titan 3 / UK) according to TS EN ISO 13937-2.

Pilling tests after 2000 cycles were carried out on a Martindale (James H. Heal Midi-Martindale / England) according to TS EN ISO 12945-2.

3. Results and Discussion

The images of the fabrics obtained after the dyeing process are presented in Figures 2–4. Subsequently, the CIELab color measurement results of the samples are provided in Figures 5–7, while the fastness properties are summarized in Table 2–16.



Figure 2. a) 45% Cotton fabric dyed with VS blue dye b) 45% Cotton fabric dyed with MCT blue dye c) 45% Cotton fabric dyed with BF blue dye d) 45% r-Cotton fabric dyed with VS blue dye e) 45% r Cotton fabric dyed with MCT blue dye f) 45% r Cotton fabric dyed with BF blue dye g) 62% r-Cotton fabric dyed with VS blue dye h) 62% r Cotton fabric dyed with MCT blue dye i) 62% r Cotton fabric dyed with BF blue dye



Figure 3. a) 45% Cotton fabric dyed with VS red dye b) 45% Cotton fabric dyed with MCT red dye c) 45% Cotton fabric dyed with BF red dye d) 45% r-Cotton fabric dyed with VS red dye e) 45% r Cotton fabric dyed with MCT red dye f) 45% r Cotton fabric dyed with BF red dye g) 62% r-Cotton fabric dyed with VS red dye h) 62% r Cotton fabric dyed with MCT red dye i) 62% r Cotton fabric dyed with BF red dye



Figure 4. a) 45% Cotton fabric dyed with VS yellow dye b) 45% Cotton fabric dyed with MCT yellow dye c) 45% Cotton fabric dyed with BF yellow dye d) 45% r-Cotton fabric dyed with VS yellow dye e) 45% r Cotton fabric dyed with MCT yellow dye f) 45% r Cotton fabric dyed with BF yellow dye g) 62% r-Cotton fabric dyed with VS yellow dye h) 62% r Cotton fabric dyed with MCT yellow dye i) 62% r Cotton fabric dyed with BF yellow dye

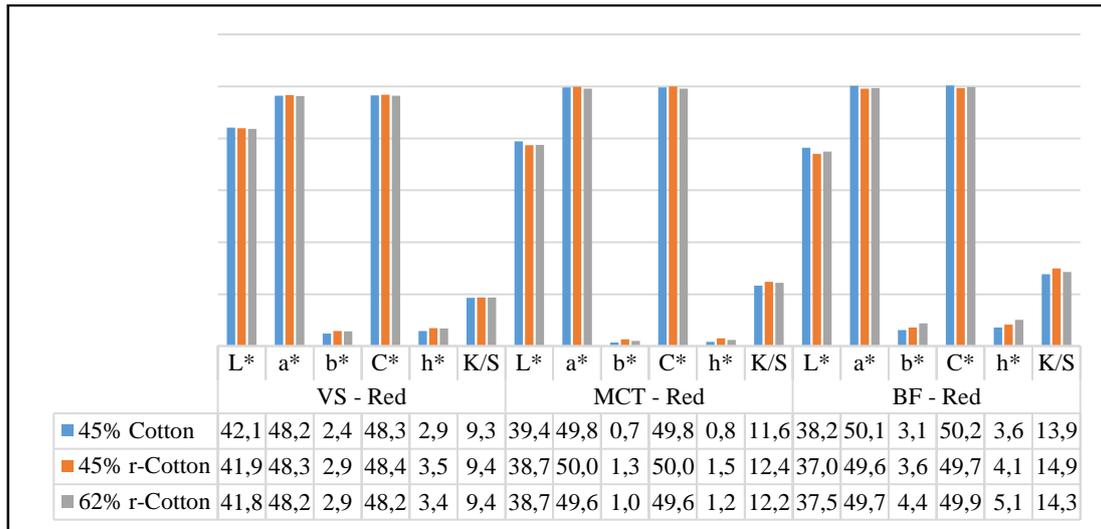


Figure 5. CIELab color measurements of fabrics dyed with vinylsulfone (VS), monochlorotriazine (MCT), bifunctional (BF) red dye

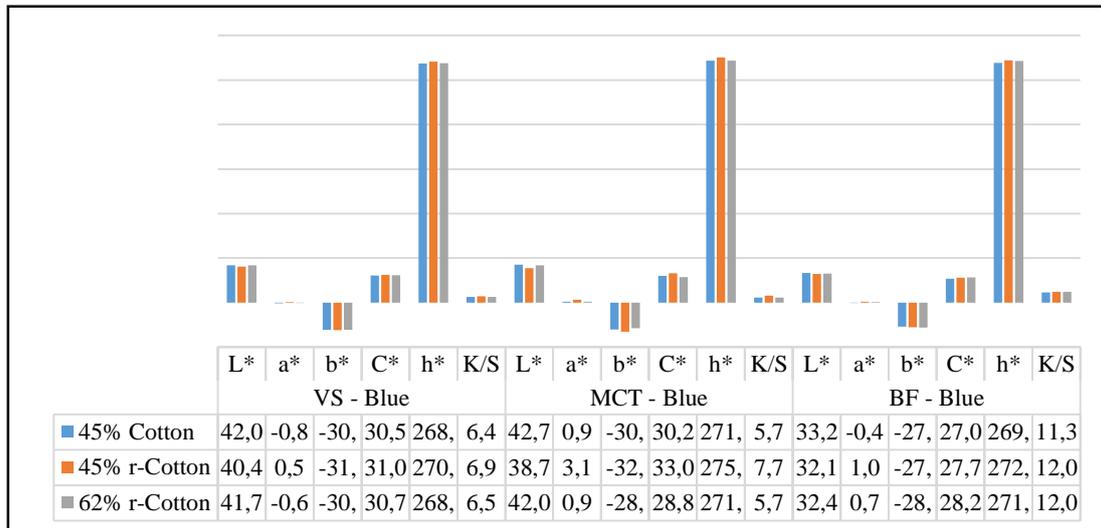


Figure 6. CIELab color measurements of fabrics dyed with vinylsulfone (VS), monochlorotriazine (MCT), bifunctional (BF) blue dye

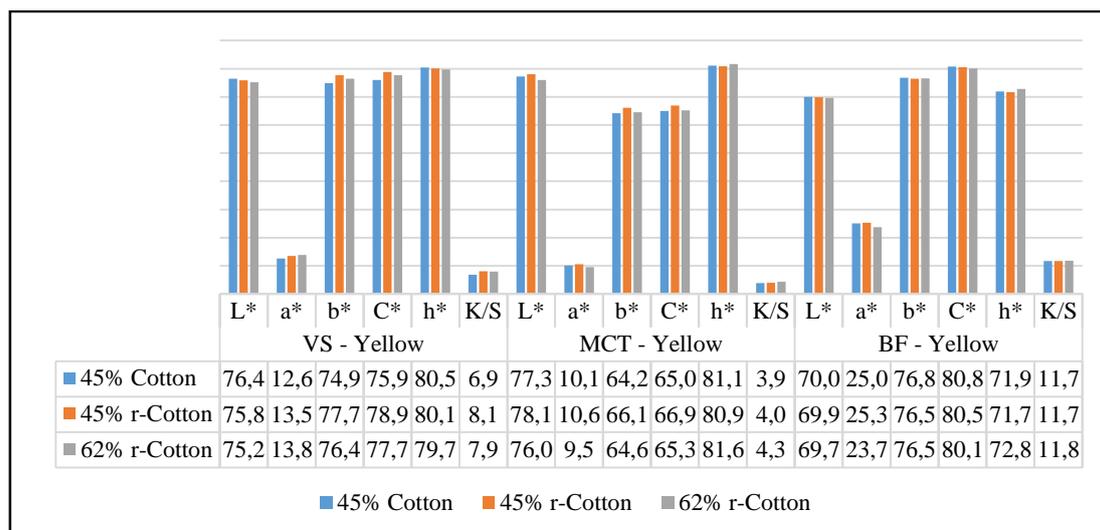


Figure 7. CIELab color measurements of fabrics dyed with vinylsulfone (VS), monochlorotriazine (MCT), bifunctional (BF) yellow dye

Table 2. 45% Cotton Color fastness to washing

Color Name	Color Group	Washing Fastness						
		Staining						Color Change
		Acetate	Cotton	Polyamid	Polyester	Acrylic	Wool	
Red	VS	4-5	4-5	4	4-5	4-5	4-5	4-5
	MCT	4-5	4-5	4	4-5	4-5	4-5	4-5
	BF	4-5	4-5	4	4-5	4-5	4-5	4-5
Blue	VS	4-5	4-5	4-5	4-5	4-5	4-5	4-5
	MCT	4-5	4-5	4-5	4-5	4-5	4-5	4-5
	BF	4-5	4-5	4-5	4-5	4-5	4-5	4-5
Yellow	VS	4-5	4-5	4-5	4-5	4-5	4-5	4-5
	MCT	4-5	4-5	4-5	4-5	4-5	4-5	4-5
	BF	4-5	4-5	4-5	4-5	4-5	4-5	4-5

Table 3. 45% r-Cotton Color fastness to washing

Color Name	Color Group	Washing Fastness						
		Staining						Color Change
		Acetate	Cotton	Polyamid	Polyester	Acrylic	Wool	
Red	VS	4-5	4-5	4	4-5	4-5	4-5	4-5
	MCT	4-5	4-5	4	4-5	4-5	4-5	4-5
	BF	4-5	4-5	4	4-5	4-5	4-5	4-5
Blue	VS	4-5	4-5	4-5	4-5	4-5	4-5	4-5
	MCT	4-5	4-5	4-5	4-5	4-5	4-5	4-5
	BF	4-5	4-5	4-5	4-5	4-5	4-5	4-5
Yellow	VS	4-5	4-5	4-5	4-5	4-5	4-5	4-5
	MCT	4-5	4-5	4-5	4-5	4-5	4-5	4-5
	BF	4-5	4-5	4-5	4-5	4-5	4-5	4-5

Table 4. 62% r-Cotton Color fastness to washing

Color Name	Color Group	Washing Fastness						
		Staining						Color Change
		Acetate	Cotton	Polyamid	Polyester	Acrylic	Wool	
Red	VS	4-5	4-5	4	4-5	4-5	4-5	4-5
	MCT	4-5	4-5	4	4-5	4-5	4-5	4-5
	BF	4-5	4-5	4	4-5	4-5	4-5	4-5
Blue	VS	4-5	4-5	4-5	4-5	4-5	4-5	4-5
	MCT	4-5	4-5	4-5	4-5	4-5	4-5	4-5
	BF	4-5	4-5	4-5	4-5	4-5	4-5	4-5
Yellow	VS	4-5	4-5	4-5	4-5	4-5	4-5	4-5
	MCT	4-5	4-5	4-5	4-5	4-5	4-5	4-5
	BF	4-5	4-5	4-5	4-5	4-5	4-5	4-5

Table 5. 45% Cotton Color fastness to water

Color Name	Color Group	Water Fastness						
		Staining						Color Change
		Acetate	Cotton	Polyamid	Polyester	Acrylic	Wool	
Red	VS	4	4	3-4	4	4-5	4	4-5
	MCT	4	4	4	4	4-5	4	4-5
	BF	4-5	4-5	4-5	4-5	4-5	4-5	4-5
Blue	VS	4-5	4-5	4-5	4-5	4-5	4-5	4-5
	MCT	4-5	4-5	4-5	4-5	4-5	4-5	4-5
	BF	4-5	4-5	4-5	4-5	4-5	4-5	4-5
Yellow	VS	4-5	4-5	4-5	4-5	4-5	4-5	4-5
	MCT	4-5	4-5	4-5	4-5	4-5	4-5	4-5
	BF	4-5	4-5	4-5	4-5	4-5	4-5	4-5

Table 6. 45% r-Cotton Color fastness to water

Color Name	Color Group	Water Fastness						
		Staining						Color Change
		Acetate	Cotton	Polyamid	Polyester	Acrylic	Wool	
Red	VS	4	4	3-4	4	4-5	4	4-5
	MCT	4	4	3-4	4	4-5	4	4-5
	BF	4-5	4-5	4-5	4-5	4-5	4-5	4-5
Blue	VS	4-5	4-5	4-5	4-5	4-5	4-5	4-5
	MCT	4-5	4-5	4-5	4-5	4-5	4-5	4-5
	BF	4-5	4-5	4-5	4-5	4-5	4-5	4-5
Yellow	VS	4-5	4-5	4-5	4-5	4-5	4-5	4-5
	MCT	4-5	4-5	4-5	4-5	4-5	4-5	4-5
	BF	4-5	4-5	4-5	4-5	4-5	4-5	4-5

Table 7. 62% r-Cotton Color fastness to water

Color Name	Color Group	Water Fastness						Color Change
		Staining						
		Acetate	Cotton	Polyamid	Polyester	Acrylic	Wool	
Red	VS	4	4	3-4	4	4-5	4	4-5
	MCT	4	4	3-4	4	4-5	4	4-5
	BF	4-5	4-5	4	4-5	4-5	4-5	4-5
Blue	VS	4-5	4-5	4-5	4-5	4-5	4-5	4-5
	MCT	4-5	4-5	4-5	4-5	4-5	4-5	4-5
	BF	4-5	4-5	4-5	4-5	4-5	4-5	4-5
Yellow	VS	4-5	4-5	4-5	4-5	4-5	4-5	4-5
	MCT	4-5	4-5	4-5	4-5	4-5	4-5	4-5
	BF	4-5	4-5	4-5	4-5	4-5	4-5	4-5

Table 8. 45% Cotton Color fastness to acidic perspiration

Color Name	Color Group	Acidic Perspiration						Color Change
		Staining						
		Acetate	Cotton	Polyamid	Polyester	Acrylic	Wool	
Red	VS	4	4	4	4	4-5	4	4-5
	MCT	4	4	4	4	4-5	4	4-5
	BF	4-5	4-5	4-5	4-5	4-5	4-5	4-5
Blue	VS	4-5	4-5	4-5	4-5	4-5	4-5	4-5
	MCT	4-5	4-5	4-5	4-5	4-5	4-5	4-5
	BF	4-5	4-5	4-5	4-5	4-5	4-5	4-5
Yellow	VS	4-5	4-5	4-5	4-5	4-5	4-5	4-5
	MCT	4-5	4-5	4-5	4-5	4-5	4-5	4-5
	BF	4-5	4-5	4-5	4-5	4-5	4-5	4-5

Table 9. 45% r-Cotton Color fastness to acidic perspiration

Color Name	Color Group	Acidic Perspiration						Color Change
		Staining						
		Acetate	Cotton	Polyamid	Polyester	Acrylic	Wool	
Red	VS	4	4	4	4	4-5	4	4-5
	MCT	4	4	3-4	4	4-5	4	4-5
	BF	4-5	4-5	4-5	4-5	4-5	4-5	4-5
Blue	VS	4-5	4-5	4-5	4-5	4-5	4-5	4-5
	MCT	4-5	4-5	4-5	4-5	4-5	4-5	4-5
	BF	4-5	4-5	4-5	4-5	4-5	4-5	4-5
Yellow	VS	4-5	4-5	4-5	4-5	4-5	4-5	4-5
	MCT	4-5	4-5	4-5	4-5	4-5	4-5	4-5
	BF	4-5	4-5	4-5	4-5	4-5	4-5	4-5

Table 10. 62% r-Cotton Color fastness to acidic perspiration

Color Name	Color Group	Acidic Perspiration						Color Change
		Staining						
		Acetate	Cotton	Polyamid	Polyester	Acrylic	Wool	
Red	VS	4	4	3-4	4	4-5	4-5	4-5
	MCT	4	4	3-4	4	4-5	4	4-5
	BF	4-5	4-5	4	4-5	4-5	4-5	4-5
Blue	VS	4-5	4-5	4-5	4-5	4-5	4-5	4-5
	MCT	4-5	4-5	4-5	4-5	4-5	4-5	4-5
	BF	4-5	4-5	4-5	4-5	4-5	4-5	4-5
Yellow	VS	4-5	4-5	4-5	4-5	4-5	4-5	4-5
	MCT	4-5	4-5	4-5	4-5	4-5	4-5	4-5
	BF	4-5	4-5	4-5	4-5	4-5	4-5	4-5

Table 11. 45% Cotton Color fastness to alkaline perspiration

Color Name	Color Group	Alkaline Perspiration						Color Change
		Staining						
		Acetate	Cotton	Polyamid	Polyester	Acrylic	Wool	
Red	VS	4	4	4	4	4-5	4	4-5
	MCT	4	4	4	4	4-5	4	4-5
	BF	4-5	4-5	4	4-5	4-5	4-5	4-5
Blue	VS	4-5	4-5	4-5	4-5	4-5	4-5	4-5
	MCT	4-5	4-5	4-5	4-5	4-5	4-5	4-5
	BF	4-5	4-5	4-5	4-5	4-5	4-5	4-5
Yellow	VS	4-5	4-5	4-5	4-5	4-5	4-5	4-5
	MCT	4-5	4-5	4-5	4-5	4-5	4-5	4-5
	BF	4-5	4-5	4-5	4-5	4-5	4-5	4-5

Table 12. 45% r-Cotton Color fastness to alkaline perspiration

Color Name	Color Group	Alkaline Perspiration						Color Change
		Staining						
		Acetate	Cotton	Polyamid	Polyester	Acrylic	Wool	
Red	VS	4	4	4	4	4-5	4	4-5
	MCT	4	4	3-4	4	4-5	4-5	4-5
	BF	4-5	4-5	4-5	4-5	4-5	4-5	4-5
Blue	VS	4-5	4-5	4-5	4-5	4-5	4-5	4-5
	MCT	4-5	4-5	4-5	4-5	4-5	4-5	4-5
	BF	4-5	4-5	4-5	4-5	4-5	4-5	4-5
Yellow	VS	4-5	4-5	4-5	4-5	4-5	4-5	4-5
	MCT	4-5	4-5	4-5	4-5	4-5	4-5	4-5
	BF	4-5	4-5	4-5	4-5	4-5	4-5	4-5

Table 13. 62% r-Cotton Color fastness to alkaline perspiration

Color Name	Color Group	Alkaline Perspiration						Color Change
		Staining						
		Acetate	Cotton	Polyamid	Polyester	Acrylic	Wool	
Red	VS	4	4	4	4	4-5	4-5	4-5
	MCT	4	4	3-4	4	4-5	4	4-5
	BF	4-5	4-5	4	4-5	4-5	4-5	4-5
Blue	VS	4-5	4-5	4-5	4-5	4-5	4-5	4-5
	MCT	4-5	4-5	4-5	4-5	4-5	4-5	4-5
	BF	4-5	4-5	4-5	4-5	4-5	4-5	4-5
Yellow	VS	4-5	4-5	4-5	4-5	4-5	4-5	4-5
	MCT	4-5	4-5	4-5	4-5	4-5	4-5	4-5
	BF	4-5	4-5	4-5	4-5	4-5	4-5	4-5

Table 14. 45% Cotton Color fastness to wet and dry rubbing

Color Name	Color Group	Rubbing Fastness			
		Dry		Wet	
		Weft	Warp	Weft	Warp
Red	VS	4-5	4-5	3-4	3-4
	MCT	4-5	4-5	3	3
	BF	4-5	4-5	3	3
Blue	VS	4-5	4-5	4	4
	MCT	4-5	4-5	4	4
	BF	4-5	4-5	3-4	3-4
Yellow	VS	4-5	4-5	4	4
	MCT	4-5	4-5	4-5	4-5
	BF	4-5	4-5	4	4

Table 15. 45% r-Cotton Color fastness to wet and dry rubbing

Color Name	Color Group	Rubbing Fastness			
		Dry		Wet	
		Weft	Warp	Weft	Warp
Red	VS	4-5	4-5	3-4	3-4
	MCT	4-5	4-5	3	3
	BF	4-5	4-5	3	3
Blue	VS	4-5	4	4	4
	MCT	4-5	4-5	4	4
	BF	4-5	4-5	3-4	3-4
Yellow	VS	4-5	4-5	4	4
	MCT	4-5	4-5	4-5	4-5
	BF	4-5	4-5	4	4

Table 16. 62% r-Cotton Color fastness to wet and dry rubbing

Color Name	Color Group	Rubbing Fastness			
		Dry		Wet	
		Weft	Warp	Weft	Warp
Red	VS	4-5	4-5	3-4	3-4
	MCT	4-5	4-5	3	3
	BF	4-5	4-5	3	3
Blue	VS	4-5	4-5	4	4
	MCT	4-5	4-5	4	3-4
	BF	4	4-5	3-4	3-4
Yellow	VS	4-5	4-5	4	4
	MCT	4-5	4-5	4-5	4-5
	BF	4-5	4-5	4	4

The results indicated that all samples showed similar fastness results, there was no important contribution observed of using recycled cotton fibers in fabrics on fastness. However, presence of recycled cotton fiber resulted to lower the lightness values (L^*) of fabrics after dyeing by each reactive dye types, on the other hand k/S (color strength) and chroma (C^*) values were increased when the fabrics had recycled cotton content and that was particularly higher for all MCT reactive dyes. It is known that recycled cotton fibers have melange-like appearance, have shorter span length than that of virgin cotton [15] which leads to reduced lightness but increased intra-fibers voids and irregularity in blended yarn structure with increased dyebath absorption as a result. Also increased color strength and chroma values of MCT dyes are also precursor of increased number of ester bonds between reactive group of dye and the fiber; that should be concluded to transformation of crystalline structure in cellulose of recycled cotton when subjected to alkaline bath as did in this study and this agrees well with findings in paper of Cao et al. [16].

Tearing strength and pilling tests were only applied to raw, bleached and red dyed samples and the results are given in Table 17 and 18. Table 17 showed that fabrics with recycled cotton fibers exhibited lower tearing strength and increased amount of recycled fibers also reduced the tearing strength at most as expected. Increased tearing strength after bleaching showed that the process did not give any catalytic damage on fibers and different type of reactive dyes gave similar tearing strength values. On the other hand, reduced fiber strength of recycled cotton showed its impact on pilling performance due to increased number of removed pills from surface through lower strength of anchor fibers. Again, different types of reactive dyes usage in dyeing did not affect the pilling tendency.

Table 17. Tearing strength (single tear method) test results (N)

Fabric Name	45% Cotton		45% r-Cotton		62% r-Cotton	
	Weft	Warp	Weft	Warp	Weft	Warp
Raw	26,30	8,31	16,54	9,49	12,43	9,21
Bleached	30,40	11,94	17,90	12,89	18,18	11,31
VS – Red	27,12	9,55	16,61	10,45	17,06	9,85
MCT – Red	28,02	9,90	17,17	10,37	17,01	9,09
BF - Red	26,01	9,39	17,77	10,43	17,17	10,94

Table 18. Pilling test results

Fabric Name	45% Cotton		45% r-Cotton		62% r-Cotton	
	Face	Back	Face	Back	Face	Back
Raw	1	1	1-2	1-2	1-2	1-2
Bleached	1-2	1	2	2	1-2	1-2
VS – Red	2-3	2-3	2-3	2	3	3
MCT – Red	2	2-3	2-3	2-3	2-3	2-3
BF - Red	2	3	2	2-3	3	3

4. Conclusion

This study examines dyeing outcomes of woven fabrics in differing amount of recycled cotton fiber content when different chemical types of reactive dyes were used for dyeing. The results showed that in general, dyeing performance of recycled cotton fibers is quite similar to fabrics containing virgin cotton especially in terms of color fastness, but presence of recycled cotton fibers caused decrease in lightness of dyed fabrics but increase in color strength and chroma values. The type of reactive dye was also affective on those changes; fabrics containing recycled cotton showed the best color strength performance when dyed with bifunctional dyes. Also increased color strength and chroma values of MCT dyes were concluded as the effect of increased number of ester bonds between reactive group of dye and the fiber which pointed to the transformation of crystalline structure in cellulose of recycled cotton when subjected to alkaline bath as mentioned before in literature.

But using recycled cotton fiber or changing reactive dye type did not affect the pilling tendency but fabrics with recycled cotton fibers exhibited lower tearing strength and increased amount of recycled fibers also reduced the tearing strength at most.

It is known that recycled cotton fibres (obtained from shredded textiles wastes) have lower mechanical performances than that of virgin cotton, thus there has always hesitation in utilizing those fibers in clothing fabric production although clear benefits in terms of sustainability. This study showed that recycled cotton fibers could replace virgin cotton when dyeing behavior is concerned.

Financial Support

This study was carried out within the scope of project number AG-02-23-SYK-00 within the S.Y.K. Textile R&D Center supported by the Ministry of Industry and Technology, The Republic of Türkiye.

Conflict of Interest

There is no conflict of interest regarding this article.

Author Contribution

Authors contributed equally.

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