



Kahramanmaraş Sutcu Imam University

Journal of Engineering Sciences



Geliş Tarihi : 17.06.2025
Kabul Tarihi : 09.02.2026

Received Date : 17.06.2025
Accepted Date : 09.02.2026

SINGLE BATH- SINGLE STAGE DYEING OF COTTON BAMBOO WOOL BLEND WITH TURMERIC: EXPERIMENTAL STUDY

PAMUK BAMBU YÜN KARIŞIMININ ZERDEÇAL İLE TEK BANYODA-TEK AŞAMALI BOYANMASI: DENEYSEL ÇALIŞMA

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ABSTRACT

The dyeing process in textiles is a process that uses a lot of chemicals and is very harmful to the environment. For this reason, people apply alternatives such as dyeing with natural dyes to minimise these damages. Especially in the dyeing of yarns consisting of blended fibres, dyeing in a single bath and in a single step reduces both water consumption and the use of chemicals. In this study, a Ne 20/1 ring yarn consisting of 50% cotton, 30% bamboo and 20% wool blend, all natural fibers, was dyed with turmeric in single bath. The effect of the treatments on the performance characteristics of the yarn was determined. Cotton, bamboo and wool fibers with different chemical structures were dyed in a single bath and uniform dyes were obtained. Dozens of trials were conducted to determine the optimum dyeing conditions. As a result of these trials, pH, time and temperature values, which are the most important parameters of a dyeing, were adjusted. The ideal conditions were found for the dyeing of a blended yarn consisting of cellulosic cotton and bamboo fibers and protein wool fibers in a single bath and the dyeing process was carried out. Washing, perspiration, saliva and rubbing fastnesses of the dyed yarn were examined and the results were evaluated. In addition, the color yield was evaluated by reflectance spectrophotometry and the interactions between natural dyes and fiber were interpreted by FTIR analysis and SEM images.

Keywords: Cotton-bamboo-wool blended, natural dyeing, turmeric, eco-friendly, dye yield.

ÖZET

Tekstilde boyama işlemi çok fazla kimyasal maddenin kullanıldığı ve çevreye oldukça zarar veren bir süreçtir. Bu nedenle insanlar bu zararları en aza indirmek için doğal boyalarla boyamak gibi alternatifleri uygulamaktadır. Özellikle karışım liflerinden oluşan ipliklerin boyanmasında tek banyoda ve tek adımda boyama yapmak hem su tüketimini hem de kimyasal madde kullanımını oldukça azaltmaktadır. Bu çalışmada, tamamı doğal elyaf olan %50 pamuk, %30 bambu ve %20 yün karışımından oluşan Ne 20/1 ring ipliği tek banyoda zerdeçal ile boyanmıştır. Yapılan terbiye işlemlerinin ipliğin performans özellikleri üzerindeki etkisi belirlenmiştir. Farklı kimyasal yapılaraya sahip pamuk, bambu ve yün lifleri tek banyoda boyanmış ve abrazyöz boyamalar elde edilmiştir. Optimum boyama koşullarını belirlemek için onlarca deneme yapılmış ve bu denemeler sonucunda bir boyamanın en önemli parametreleri olan pH, zaman ve sıcaklık değerleri ayarlanmıştır. Selülozik pamuk ve bambu lifleri ile protein yün liflerinden oluşan karışım bir ipliğin tek banyoda boyanması için ideal koşullar bulunmuş ve boyama işlemi gerçekleştirilmiştir. Boyanan ipliğin yıkama, ter, tükürük ve sürtme haslıkları incelenerek sonuçlar değerlendirilmiştir. Ayrıca renk verimi reflektans spektrofotometresi ile değerlendirilmiş ve doğal boyalar ile elyaf arasındaki etkileşimler FTIR analizi ve SEM görüntüleri ile yorumlanmıştır.

Anahtar Kelimeler: Pamuk-bambu-yün karışımı, doğal boyama, zerdeçal, çevre dostu, boya verimi.

INTRODUCTION

Textile is a sector that people cannot give up. This sector has many different working areas such as spinning, weaving, knitting, garment and dyeing. The part that produces the most pollution among these areas is dyeing. Dyehouses cause a lot of damage to both human health and the environment. This situation is not sustainable for the future of the world. Especially the damage caused to nature by the use of synthetic dyes poses a serious threat to living things (Özdemir, 2023a). People are looking for both scientific and legal measures to prevent this threat. Some of these measures include using natural dyes instead of synthetic dyes in dyeing processes (Kovacevic et al., 2021; Özdemir, 2023b), using cationic cotton instead of normal cotton to reduce dye waste load (Özdemir, 2014), and installing treatment systems for the waste load of dyehouses (Chen et al., 2017; Santra et al., 2019). Among these measures, the use of natural dyes is increasing rapidly. The use of natural dyes in the textile industry has a long history (Silva, 2007). However, as a result of the discovery of synthetic dyes in 1856 and their use in textile dyeing, the importance of natural dyes has decreased day by day. The low production cost and good reproducibility of synthetic dyes have a great effect on the decline of natural dyes (Saravanan et al., 2011). Nowadays, with the emergence of environmental awareness worldwide, interest in the use of natural dyes in natural fibers has increased (Samanta et al., 2009). In addition, the advantages of natural dyes compared to synthetic dyes, such as non-toxicity, high environmental compatibility, ultraviolet protection, non-allergenicity and biodegradability (Ibrahim et al., 2010; Adeel et al., 2012), have a great effect on this increase (Mirjalili et al., 2011; Prusty et al., 2010). Vegetable and to a lesser extent animal dyes are used as natural dyes. One of these vegetable dyes is turmeric. Turmeric plant is a plant that grows widely in tropical regions, especially in Southeast Asia. This plant is used as a colorant in textiles and food (Mirjalili et al., 2013). It is also known that turmeric is used in the treatment of some diseases in India and China. This feature of turmeric, which has a very wide range of uses, is due to the many different active ingredients in its structure. Among these active ingredients are curcuminoids as colorants and curcumin predominantly and demethoxycurcumin and bis-demethoxycurcumin in small amounts (Bechtold et al., 2009). It is also known that other active ingredients have antioxidant, anti-inflammatory, wound-healing, anticancer, anti-proliferative, antifungal, and antibacterial properties (Barik et al., 2007). In addition, the composition, morphological and tensile properties of turmeric fibers are similar to various lignocellulosic fibers, which allows its use as a natural cellulose source. Materials derived from the plant's fibers may be ideal for medical applications (Ilango et al., 2018). Due to all these positive properties of turmeric, its production and importance have been increasing in recent years. Especially there are many studies on turmeric as a natural colorant. It is used not only in dyeing but also in printing (Karpagam et al., 2017). In a dyeing process, many features such as reproducibility of dyeing, fastness properties, mechanical performance properties, contribution to clothing comfort, color properties, antibacterial properties and ecological effects are sought. In this sense, these properties have also been examined in dyeing with turmeric. For example, Sundrarajan et al. dyed cotton modified with enzymes and chitosan with turmeric and examined the fastness (Sundrarajan et al., 2012). In another study, dyeing with the most commonly used reactive dyes in cotton dyeing was compared with dyeing with turmeric (Umbreen et al., 2008). In another study, in addition to the fastness properties of turmeric used in the dyeing of a cotton fabric, mechanical performance properties were also examined and positive improvements were found in both fastness and mechanical performance properties. It was also observed that turmeric provides very good UV protection functionality to cotton fabrics in dyeing with turmeric. Another important feature of turmeric is its antibacterial effect. Turmeric used in the dyeing of silk fibers was found to provide antibacterial properties (Naveeda et al., 2022; Karabulut et al., 2020; Ghoreishian et al., 2013). The most important process parameters affecting dyeing in a dyeing process are pH, time and temperature. The situation is similar in natural dyeing. However, the mordanting process and the substances used in mordanting are also important in natural dyeing. Because the mordants used also affect the color obtained and its properties (Cheunsoon et al., 2006; Sarker et al., 2020; Rahman et al., 2020; Hosen et al., 2021). Natural dyes are used for dyeing fibers with very different properties and structures. They can be used for dyeing cellulosic, protein or synthetic fibers. Protein fibers such as wool, silk, cellulosic fibers such as cotton, jute and synthetic fibers such as polyamide have been dyed with natural dyes (Mulec et al., 2015; Balbas et al., 2022; Mathur et al., 2003; Srivastava et al., 2019; Hedge et al., 2018; Uddin et al., 2022).

In this study, a blended yarn consisting of cotton bamboo and wool was dyed using turmeric plant. In the study, environmentally friendly production was realized by dyeing natural fibers with natural dyes. Thus, a more livable world is aimed for future generations with natural dyes instead of chemical dyes that produce a lot of pollution.

MATERIAL AND METHOD

Material

In the study, various pre-treatments were applied to triple blend ring yarn consisting of 50% cotton, 30% bamboo and 20% wool before dyeing. Genkol from Genkim company was used to remove sulfur from bamboo, tubotex OW from CHT company was used for pretreatment, cottocs DPA from ACN company and ion trap from Akkim company were used as wetting agents. $KAl(SO_4)_2 \cdot 12 H_2O$ (alum) used for mordanting the finished product and turmeric used for dyeing were obtained from Arslanyürek (Gaziantep). In the study, the yarns were dyed in 20 gram skeins. The blend yarn to be dyed with turmeric is Ne 20/1 ring yarn consisting of 50% cotton, 30% bamboo and 20% wool. This yarn was produced in Zafer Tekstil for this study. Codes are given according to the processes applied to the yarn used in the study. Untreated yarn CBWE, pretreated yarn CBWPT, mordanted yarn CBWM, turmeric dyed yarn without mordant CBWT-NM and mordanted turmeric dyed yarn CBWTM. These codes were used in the analysis and evaluation of the results of the study.

Method

The blended yarn consisting of cotton, bamboo and wool was dyed with dyes obtained from turmeric according to the exhaustion method. In this study, cotton bamboo and wool blend ring yarn was dyed with turmeric extraction solution in one bath. The yarn was subjected to desulfurization and pre-treatment before dyeing. The dyeing process was carried out separately for both mordanted and unmordanted yarn. pH control was carried out throughout all stages of the study. This is because pH is important, along with temperature and duration, for achieving the optimum dyeing conditions, which was one of the objectives of the study. The pH of the pre-dyeing bath was measured at 7.55-7.89, the pH of the pre-treatment bath at 10.61-11.71, the pH of the mordanting bath at 4.14-4.21, the pH of the turmeric dyeing bath at 5.92-5.97, and the pH of the post-dyeing waste bath at 6.81. The exhaustion method, a finishing method, was used in this study. A pretreatment was performed to remove the sulfur on the bamboo in the blend. In the pretreatment, 1 g/L Genkol (Genkim) was used at 70 °C for 20 minutes with a flotte ratio of 1:10. The pretreatment recipe for turmeric dyeing of 50% cotton, 30% bamboo, 20% wool blend Ne 20/1 ring yarn with turmeric was 2.5 g/L tubotex OW (CHT), 1 g/L ion trap, 2 g/L wetting cottoclarn DPA, 95 °C temperature and 40 minutes. The pH of the tubotex OW flotte used during the process was 11.5. Wetting agent and ion trap had no effect on the pH of the flotte. Citric acid (lemon salt) was used for neutralization as post-treatment. 0.5 g/L citric acid was treated in soft water. Mordanting was done with alum and the mordanted yarn was conditioned for 1 day.

For 20 grams of hank yarn to be dyed, 10 grams of turmeric powder was used. Turmeric was extracted at 100 °C for 60 minutes. The dyeing process took approximately 120 minutes at 100 °C. After the dyeing process, overflow washing, soaping and final rinsing were performed. After dyeing, the yarn was kept for 24 hours for conditioning. It was then wound on bobbins and prepared for the tests (Figure 1 and 2).

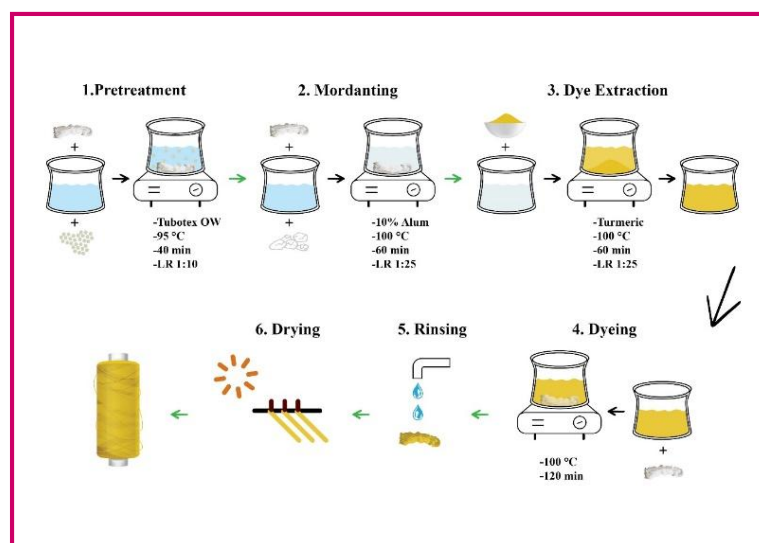


Figure 1. Schematic Diagram of Dyeing Procedure.

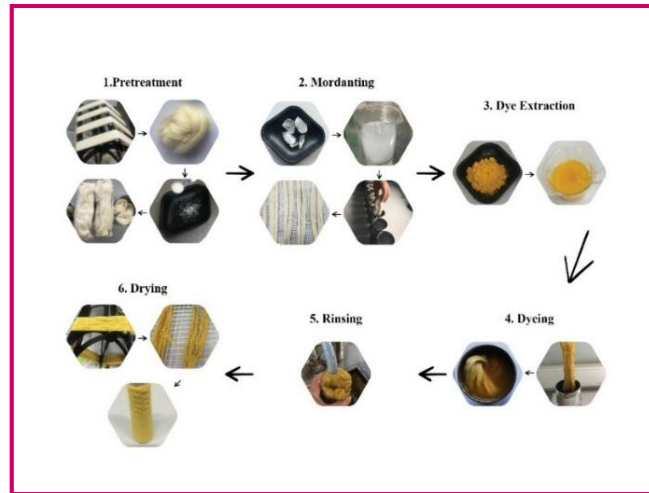


Figure 2. Stages of Dyeing Blended Yarn with Turmeric

The blended yarn used in the study was subjected to desulphurisation, pretreatment, mordanting, turmeric extraction and dyeing with turmeric. Graphs of extraction and dyeing processes are shown in Figure 3.

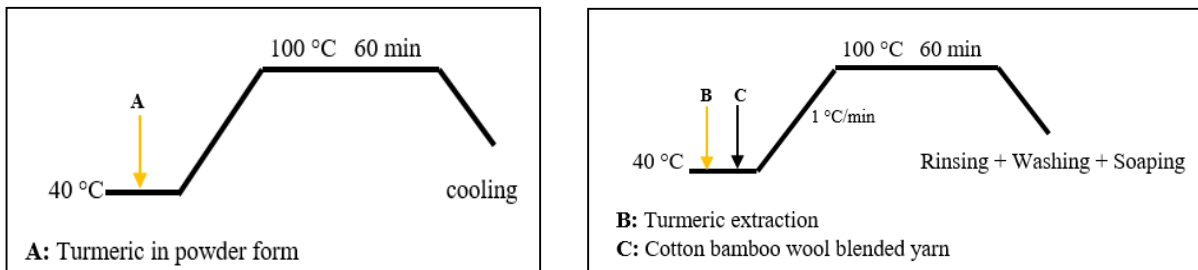


Figure 3. Graphs of the Treatment of Cotton Bamboo and Wool Blend Yarn; Extraction Process, Dyeing of Cotton, Bamboo and Wool Blend with Turmeric Extract

Fastness Testing

Fastness tests were performed on the blended yarn in accordance with the standards and the results were evaluated on a gray scale according to the standard light sources in the light box (Figure 4).



Figure 4. a) Rubbing Fastness (ISO 105-X12, 2021), b) Washing Fastness (ISO 105-C06, 2020), c) Saliva Fastness (DIN 53160-1, 2010), d) Perspiration Fastness (ISO 105-E04, 2018)

Yarn Strength Measurements

The changes in the strength and elongation of the blended yarn in all process steps before and after dyeing were examined. USTER® UTR 5 20.8.4.6f19301 device was used for this purpose. The tests with 10 repetitions were performed at 23 °C and 62.1% relative humidity.

RESULTS AND DISCUSSION

Fastness Testing Results

Perspiration, washing, dry-wet rubbing and saliva fastness test results are given in table 1.

Table 1. Fastness Results of Cotton Bamboo and Wool Blend Dyed with Turmeric with and without Mordant

Fastness Type	Multifiber Fabric	Test Conditions (Acidic–Alkaline)	CBWT-NM Greyscale Value	CBWTM Greyscale Value
Perspiration fastness (staining)	Acetate	Acidic	3	3
		Alkaline	3	3
	Cotton	Acidic	3	2
		Alkaline	3	2
	Nylon 6.6	Acidic	3	2
		Alkaline	3	2
	Polyester	Acidic	3-4	3
		Alkaline	3-4	3
	Acrylic	Acidic	3-4	3
		Alkaline	3-4	3
Wool	Acidic	3-4	3	
	Alkaline	3-4	3	
Fastness type	Multifiber Fabric		CBWT-NM Greyscale value	CBWTM Greyscale value
Washing fastness (contamination)	Acetate		3-4	3
	Cotton		2-3	2-3
	Nylon 6.6		2	1-2
	Polyester		4-5	4
	Acrylic		4-5	4
	Wool		4	4
Fastness type	Test conditions		CBWT-NM Greyscale value	CBWTM Greyscale value
Rubbing fastness	Dry		4-5	4-5
	Wet		4	4
Fastness type			CBWT-NM Greyscale value	CBWTM Greyscale value
Saliva fastness			4-5	4-5

These values mean medium and good. Again, the perspiration fastness values measured in turmeric dyeing with mordant in acidic and basic environment showed a bad value of 2 in cotton and nylon 6.6. The value of 3 was found in others. The lowest washing fastness was 2 in polyamide 6.6 and the highest was obtained in polyester and acrylic fibers. Dry rubbing fastness was as high as 4-5 in both mordanted and unmordanted dyeing with turmeric. Wet rubbing fastness was also found to be 4. The saliva fastness of the blended yarn dyed with turmeric was 4-5 in both mordanted and unmordanted dyeings. These values are quite good. These values are very important especially for infants, elderly and intensive care patients.

Colorimetric Analysis

CIELAB values, K/S graph, reflectance graph and space image of the blended yarn dyed with and without turmeric mordant were taken with datacolor500 spectrophotometer and the measurement results were evaluated. (Figure 5).

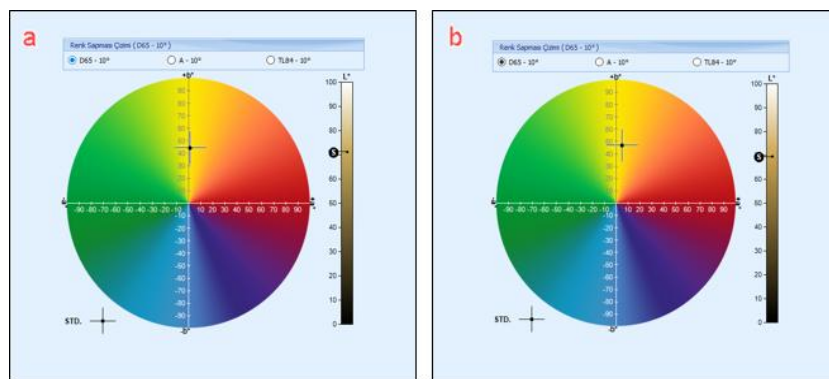


Figure 5. The CIELAB Color Space of Turmeric-Dyed Cotton Bamboo and Wool Blend; a) Non-Mordant b) Mordant.

The L value of dyeing without mordant was slightly higher. This result shows the effect of mordant. The mordant used increased the fiber affinity of turmeric, which resulted in more dye affinity. As a result of the measurement, the space appearance of the colors is similar and is located in the +a and +b region. This is evidence that the colored pigments in the structure of turmeric are predominantly +a (red) and +b (yellow). According to the measurement result at D65 - 10° standard light source, the a* value was 4.80 in mordant staining and 1.26 in non- mordant staining. Again, the b* value was 44.27 in dyeing without mordant and 46.96 in dyeing with mordant. This means that both red and yellow color weight were higher in mordant dyeing. This difference was also observed in other light sources (Table 2).

Table 2. CIELAB Values of Turmeric Dyeing of Cotton Bamboo and Wool Blend with and Non- Mordant

Standard	Sample code	L*	a*	b*	C*	h°	X	Y	Z	x	y
D65 - 10°	CBWT-NM	71.22	1.26	44.27	44.28	88.37	40.71	42.51	16.03	0.41	0.43
	CBWTM	69.58	4.80	46.96	47.20	84.16	39.58	40.16	13.66	0.42	0.43
A - 10°	CBWT-NM	73.63	7.97	45.50	46.20	80.07	54.50	46.12	5.70	0.51	0.43
	CBWTM	72.46	11.14	49.25	50.50	77.25	53.73	44.34	4.84	0.52	0.43
TL84 - 10°	CBWT-NM	73.07	1.82	48.84	48.88	87.86	47.30	45.27	9.01	0.47	0.45
	CBWTM	71.72	4.63	51.75	51.96	84.88	46.19	43.24	7.72	0.18	0.45

The absorption and scattering values of the dyestuff used in a dyeing process in the range of 400-700 nm are explained by the Kubelka-Munk theory. The K/S values at different wavelengths in the visible region showed which colors the colorant was composed of. The peak of the %R value of turmeric in the yellow and red region was close to each other in mordanted and unmordanted staining. It was seen to be equalized especially in the 570-585 nm region where the yellow color was present. Only in the mordant staining of turmeric, more red reflection was observed after 600 nm (Figure 6).

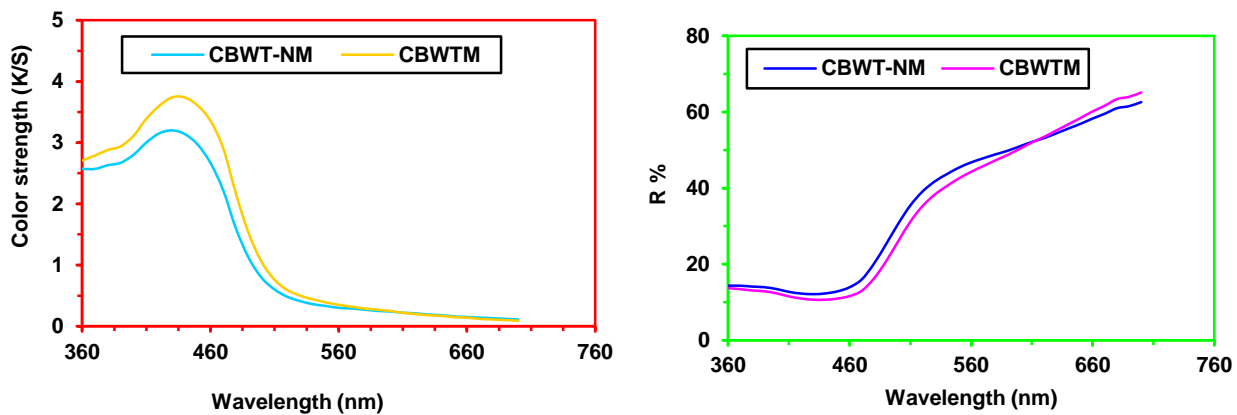


Figure 6. Color Strength (K/S) and R% Wavelength Graph of Cotton Bamboo and Wool Blend Yarn Dyed with Turmeric

Mechanical Performance of Blended Yarn Before and After Dyeing

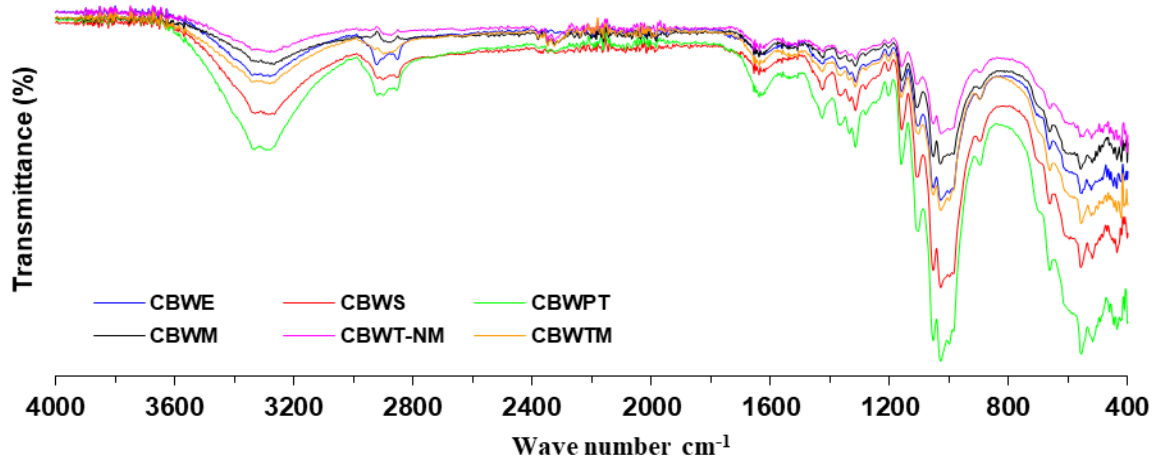
The tensile strength of cotton bamboo wool blend yarn was determined. Tensile strength decreased by 10.09% after desulfurization, 7.80% after pretreatment, 3.75% after mordanting, 7.49% after turmeric dyeing without mordant and 5.50% after turmeric dyeing with mordant. The highest decrease in tensile strength was observed after desulfurization. This means that the strength gained by sulfur to the yarn was lost after the process. As a result of the treatments, % elongation results of the yarn increased. An increase of 25.90% was observed after desulfurization, 21.66% after pretreatment, 20.88% after mordanting, 33.60% after dyeing with turmeric without mordant and 18.05% after dyeing with turmeric with mordant. According to the % elongation results, the highest increase was seen in the yarn dyed with turmeric without mordant. The measurement results are shown in table 3.

Table 3. USTER Values of Cotton Bamboo and Wool Blend Yarn

Sample code	Sample name	B-Force average (N)	Elongation average (%)	Tenacity average (Rkm)	B-work average (N.cm)
CBWE	Untreated	3.47	6.37	11.97	6.34
CBWS	Desulfurisation	3.12	8.02	10.77	6.68
CBWPT	Pre-treated	3.20	7.75	11.06	6.53
CBWM	Mordant	3.34	7.70	11.54	6.54
CBWT-NM	Dyeing non-mordant	3.21	8.51	11.10	6.65
CBWTM	Mordant dyeing	3.28	7.52	11.32	6.46

FTIR Analysis

In the FTIR analysis of CBWE, it was observed that the graph obtained had 88.5% D-cellulose3 structure and resembled cotton. While the %T values in the CBWE FTIR graph were 94 in the 2850-2900 cm⁻¹ band and 93 in the 3300-3400 cm⁻¹ band, it was determined that there was a partial decrease in these values as a result of the desulfurization process. This value decreased even more after pretreatment. In the FTIR graph of CBWM, the peak in the 2850-2900 cm⁻¹ band disappeared. C-H bonds and -CH₂ branching in this band disappeared (Iman et al., 2024; Rahman et al., 2023). In the FTIR graph of the mordanted and turmeric dyed yarn, the peak in the 1700 cm⁻¹ band occurred as a result of turmeric dyeing. In turmeric dyeing with mordant, C-H bonds and -CH₂ branching, which were lost with mordanting in the 2850-2900 cm⁻¹ band, are formed again. It is thought that the effect here is due to turmeric. Again in turmeric staining with mordant, triple bonds were formed between C=C and C=N in the 2350 cm⁻¹ band (Figure 7).

**Figure 7.** FTIR Graphs of Cotton Bamboo and Wool Blend Yarn at all Stages

SEM Analysis

SEM images were taken after all treatments applied to the blended yarn and the changes caused by the treatments were determined. In Figure 8-a, it is seen that the bamboo has a cleaner surface after desulfurization of the untreated yarn. In Figure 8-c, it is seen that there is swelling in the cotton part as a result of basic pre-treatment. The pretreatment was performed in an alkaline environment. This could cause damage to the wool. However, this damage is not visible in the SEM images. SEM shows surface morphology but does not directly show molecular degradation, protein chain breaks, or bond losses. Therefore, mechanical strength may have decreased, the crystalline/amorphous ratio may have changed, and some disulfide bonds may have weakened, but if there is no flaking, erosion, or cracking in the SEM images, it may appear undamaged. In other words: The absence of visible damage in SEM does not mean that the fiber has not been chemically affected. Additionally, a 7.8% decrease in tensile strength was observed in the measurement of mechanical performance following pretreatment. Additionally, the first structure observed in SEM is usually the cuticle scales. This layer contains a high proportion of hydrophobic lipids and slows down the penetration of alkaline solutions into the cortex of the fiber. Therefore, this layer acts as a protective barrier in short-term processes. Consequently, alkaline damage begins at the molecular level, but the cuticle morphology may appear intact in SEM (Blackburn et al., 1956; Zhao, et al., 2016; Giteru, et al., 2023). This can be explained as mercerization

effect on cotton due to the alkaline condition. In Figure 8-e, it was observed that the surface of the fibers forming the blend after dyeing was smoother due to the dyeing, while this situation was more pronounced in Figure 8-f with mordant dyeing. This can be interpreted as more dye consumption in mordant dyeing (Figure 8).

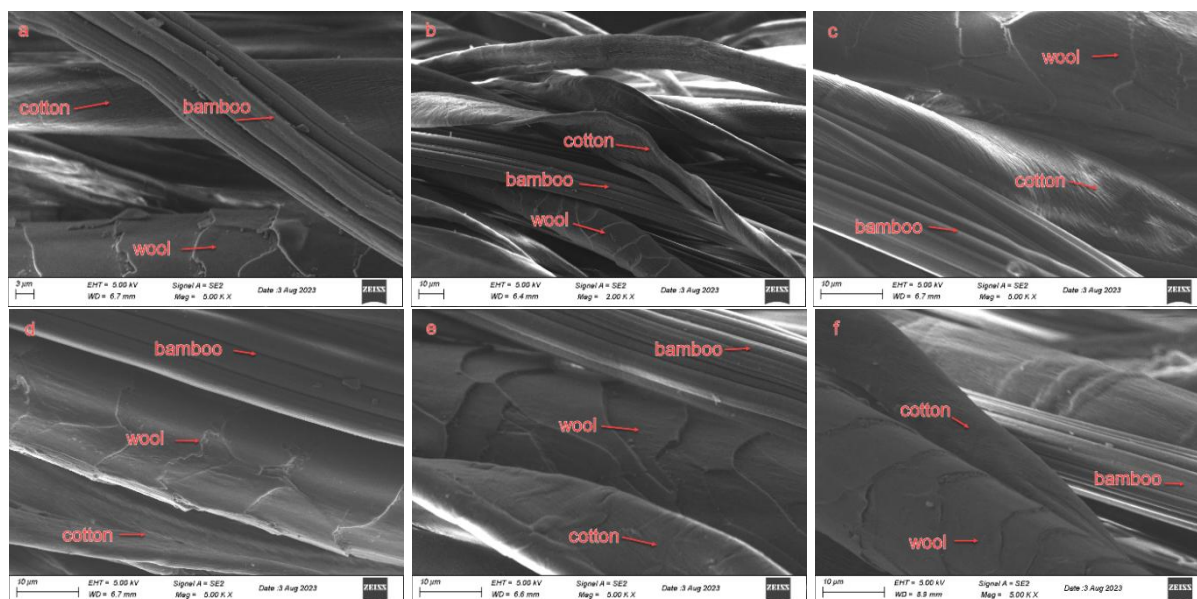


Figure 8. SEM Images of Some Cotton Bamboo and Wool Blended, a) Untreated, b) Desulfurized, c) Pre-treated, d) Mordanted, e) Turmeric Dyed without Mordant, f) Turmeric Dyed with Mordant

CONCLUSION

Blended yarn made of natural fibers was dyed with turmeric. At the end of dyeing, the mechanical performance properties of the yarn were examined and some decrease in tensile strength was observed as a result of turmeric dyeing. However, there were significant increases in % elongation values after dyeing. This means that there is an increase in the elasticity of the yarn after dyeing.

After dyeing, perspiration, washing, dry-wet rubbing and saliva fastnesses were examined. The perspiration fastness was evaluated in both acidic and alkaline media. Although the values in the mordant dyeing of turmeric were slightly lower, the results were found to be good on the gray scale. Washing fastness was very low for polyamide 6.6 in the multifiber fabric used as a companion fabric, but very good values were obtained for both acrylic and polyester. Rubbing fastness was performed both dry and wet. The results showed high values of 4-5 in both mordanted and unmordanted dyeing of the yarn with turmeric. Saliva fastness results were also very good. Gray scale values were found as 4-5.

The results of the fastness tests are acceptable values for a natural dyestuff containing a lot of color pigments such as turmeric. In dyeing, the product-dyestuff ratio, which was 1:1 in different natural vegetable dyes, was used as 1:0.5 in dyeing with turmeric due to this feature of turmeric. This reduces the amount of use considerably.

It is very difficult to dye blends in textile dyeing. It is even more difficult if the properties of the fibers used in the blend are very different from each other. In this study, a blended yarn made of cellulosic based cotton and bamboo as well as protein based wool was dyed in one bath. Numerous trials were carried out for the optimum dyeing conditions and the most ideal dyeing method without abraj and damage to the finished product was found.

In this study, the fact that natural dyes can be an important alternative in terms of sustainability and ecology in production has been demonstrated. The results also showed that turmeric can be used in the textile industry. Especially the known antibacterial properties of turmeric and high values in saliva fastness show that its use in children and elderly clothing is important.

Acknowledgement

I would like to thank Zafer Tekstil A.Ş. and its employees operating in Gaziantep/Turkey, where we used all the facilities for the study, and my teammate, Textile Engineer Ayhan Doğan, who was with me throughout the study.

Artificial Intelligence Contribution Statement

This manuscript was entirely written, edited, analyzed, and prepared without the assistance of any artificial intelligence tools. All content, including text, data analysis, and figures, was solely generated by the author.

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