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An Observation on Dyeing Techniques of Polyester/Cotton Blended Fabrics Using Various Dyes

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Abstract

IN recent years, a lot of emphasis has been focused on the widespread use of polyester and cotton textiles in the textile business, whether through their mixing with one another or with other fabric materials. Cotton may be combined with organic materials like hemp, jute, wool, banana cloth, and chitosan, and it can be colored naturally using dyes made from plant roots, some types of flowers, or even the peels of some vegetables like onions. As with viscose, wool, flax, and cotton, polyester may be combined with other natural and synthetic fabric materials. It could also be used with synthetic materials like spandex and polyamide. Polyester and cotton may be blended as well, which opens up the possibility of using a variety of dyes, including reactive dyes, direct dyes, azo dyes, and even combinations of these dyes with other substances like carbon black (CB) as well as being able to be dyed with natural dyes like allum cepa and indigo in addition to synthetic dyes. These various dyes were applied with effective dyeing techniques to provide uniform dyeing results and high dye intake in the blends. Additionally, various pretreatments for the textiles were utilized to increase the fabric's inherent performance, which in turn improved the performance of the dyes.

Keywords: Polyester – cotton – blended fabrics-natural dyes – synthetic dyes.

Introduction

Around the world, the practice of combining natural and synthetic fiber to create fabrics with superior properties has long been well-established and refined. The fabric can offer integrated characteristics of all the mixed fibers with a synergistic impact if it is merged with one kind of fiber or more fibers [**1**]. Because they include a range of fibers, blended textiles have good wearing properties. Blended fabric is an essential future path for textile manufacturing due to the desire for appropriate clothes [**2**]. There can be blended fabrics consisting of synthesized fibers only, several types of natural fibers only, or mixing the two types of fibers, synthesized fiber, and natural fiber. Generally, the operation of blending is used to enhance a variety of yarn characteristics, including durability, while incorporating more durable fibers may lengthen the useful life of a less durable one [**3**].

One of the most common raw fiber combinations in the textile industry is the mixing of polyester and cotton [**4**]. Fabrics made of polyester and cotton are frequently utilized in the apparel business because of their complementing qualities. Over 50 percent of textiles are made of polyester/cotton blends, which are frequently discovered in clothing, household textiles, and various other products [**5**]. Polyester fibers offer crease restoration, impact resistance, damage tolerance, tensile strength, and convenient qualities, [6-8] whereas cotton fabrics offer breathability, biodegradability, softness, and comfortability [9]. Yet, the existence of both cotton, as well as polyester substrates in textiles, creates challenges for the dye bath [10-12].

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To obtain the greatest coloring effects from dyeing blends, we utilize dyes that work well on both sorts of blended substrates, along with auxiliaries and perhaps some pre-treatments to create union dyeing. For instance, a polyester/cotton blend can be treated with alkali and chitosan solutions of various concentrations to improve dyeing with reactive dye by a one-bath two-stage dyeing method [13]. Or it could be dyed using a single-bath, one-step method that uses disperse dye once the cotton is esterified, which demonstrated good wash resistance and color strength [14]. Also, a great deal of additional dyes was employed to successfully dye this fabric mixture.

When it comes to the cotton itself, it was shown that it can be combined with several synthetic and natural fibers. synthetic materials like spandex, nylon, and polyester. In addition, it has the potential to be combined with organic materials like hemp, jute, and banana cloth. These blends are colored using a variety of dyes. For example, to attain the optimum washing fastness and color intensity, a jute-cotton mix can be dyed using a natural dye prepared from onion skin and mordants created from banana peel and guava leaf extract. [15]. And other natural dyes like Calendula officials and Rubia tinctorum L. were included as colorants for cotton blended fabrics [16].

Moreover, a variety of additional synthetic dyes can be applied to color the cotton blend, including The modified nylon/cotton blend that was dyed using direct and acid dyes. A cationizing agent called 3-Chloro-2-hydroxypropyl trimethyl ammonium chloride (CHPTAC) was employed to chemically alter the cellulose in the blended fabric and give it a positive charge. The dyes were applied to the blended fabrics in a single bath at various concentrations, changing the fabric's K/S and color fastness to rubbing, washing, and light [17]. Besides this, reactive dyes were thought to be able to be used to color the cotton blend textiles as well.

Polyester can also indeed be combined with other natural and synthetic materials, similar to cotton when it comes to blended fabrics. In addition to cotton, polyester can be used with other natural fibers like wool and viscose. Furthermore, polyester can be blended with synthetic materials like spandex, polyamide, and polylactide. The polyester fabric blends can be dyed using a range of synthetic dyes, among them the carbocyclic vat dye, which may be utilized to color the polyester/polyamide blend using the one-bath, one-stage process to produce quite good fastness qualities [18]. Also, azo dyes and other species of dispersed dyes might well be effective to color polyester blended fabric. The polyester blends can likewise be colored naturally using extracts from plants like Allium cepa by a one-bath dyeing procedure to dye polyester/wool blend [**1**]. A polyester/viscose fabric blend can as well be colored using Alkanna orientalis as an extract for a natural dye [19].

The possibility to incorporate an additional fiber, whether it's a natural fiber like flax or a synthetic fiber like spandex, is another advantage of polyester/cotton (PC) blends. The fabric blend also commonly uses a variety of dyes, including reactive, disperse, and cationic dyes, with the potential of additionally using natural dyes like indigo.

Here in this review, we will analyze thoroughly the procedures of dyeing these types of blends and the effect of the fabric's pre-treatment on the dyes' intake.

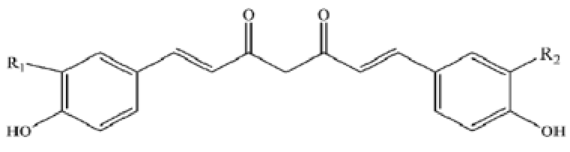
Dyeing Polyester and cotton blended fabrics

Dyeing the blended fabric with natural dyes

People have recently been pushed to limit hazardous toxins and discontinue the use of hazardous dyes as a result of an increase in environmental, ecological, and health consciousness on a global scale. As a result, while being aware of their acknowledged drawbacks, natural products are currently preferred globally over their synthetic competitors. And Because of their vibrant hues plus non-toxic qualities, plant-derived natural dyes are typically employed, notably in the textile industry [19].

Dyeing of Cotton/Banana blended fabric

The many remarkable physical and chemical qualities of banana fibers make them a great raw material for textile manufacturing especially when they get blended with another natural fiber like cotton. Turmeric is one of the natural colors, which has become a very popular subject for study due to environmental concerns. The pigments in the colorant extracts made from Curcuma are widely referred to as curcuminoids, with curcumin serving as the primary component and demethoxycurcumin and bisdemethoxycurcumin serving as minor components. (**Scheme 1**) [20].



R1 = OCH_3, R2 = OCH_3 - curcumin
R1 = R2 = H - bisdemethoxycurcumin
R1 = OCH_3, R2 = H - demethoxycurcumin

Scheme 1: Curcumin and its analogs' chemical composition *[20]*

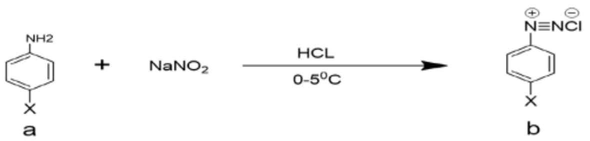
M.Mosaad et al. pretreated the banana sample first by scouring procedure in a 3% sodium hydroxide solution (depending on the weight of the fabric w.o.f.) at the boiling temperature for an hour before being neutralized with acetic acid and then the sample was left to dry. The dye was then extracted in the manner described below 1000 ml of filtered water was combined with 100 g of dried curcuma "turmeric" powder and boiled for 30 minutes while on reflux. The substance was cooled to room temperature before being filtered. Using a lab rotavapor, the diluted solution was concentrated. The following simultaneous and pre-mordanting techniques were used on the cloth samples[20]:

pre-mordanting: before the dyeing procedure, the banana specimens were pre-mordanted using an alum mordant. The samples were subjected to a 60-minute mordant procedure at simmering temperature and pH 4 in mordent liquors made in a mordent liquors proportion of 1:20 with a variety of mordents according to the material weight. After cooling, the specimens were pressed and left to dry [20].

Simultaneous mordanting (one-pot method): the banana specimens got mordanted with Alum [hydrated aluminum potassium sulfate ($KAl(SO_4)2.12H_2O$], or, Copper Sulphate $CuSO_4(H2O)$, or Ferrous Sulphate $FeSO_4$ [20].

Different ratios of blended fabric such as (50%banana: 50%cotton, 25% banana: 75%cotton and 34.4% banana: 66.6%cotton) were then colored by M. Mosaad et al. using the obtained curcuma natural color in the presence of sodium sulfate (20g/L). Using acetic acid at L: R 1:50, the PH was corrected to 6.5. The specimens were introduced to the dyeing bath at 30°C, and after 10 minutes, the temperature was increased to 75°C. For one hour, the specimens were kept at 75°C. The samples were left to settle in the liquor once the dyeing procedure was finished. The specimens were then washed under running water. The samples were first cleaned in 60°C heated water, then rinsed with cold water, and then allowed to air dry. The dying process might either include stirring with or without a mordant [20].

Shimadzu UV/Visible spectrophotometer was used to analyze the brightness (K/S) of the specimens, and it was found that regardless of the mordanting process utilized, the K/S values of the dyed samples increased as the banana fiber ratio increased. By utilizing alum in the simultaneous mordanting procedure, the banana 50:50 cotton blended fabric displayed the greatest K/S of all of them (**Scheme 2**). Also, it was found that the simultaneous mordant samples had extremely good to exceptional washing and rubbing sweating qualities [20].



Scheme 2: 2 Potential diazotization reactions include (a) primary amine and (b) diazonium salt, where X is either NO_2 or $-OCH_3$ [**1**].

Dyeing of Hemp/Cotton blended fabrics

Due to the downsides of using cotton, such as the fact that there is now not enough land available for its production to satisfy the need on the global market. Moreover, cotton's high water use during growing is a disadvantage. As a result, it is possible to acquire comparable or superior characteristics by blending cotton with other natural fibers, such as hemp. Also, because natural dyes don't naturally have an affinity for cellulose, a mordanting process is required to securely bond them to the threads of textiles [16].

Before dying the fibers using common madder powder (Rubia Tinctorum) and dried calendula (Calendula Officinalis) flowers, Gabriela M. et al. first prepared the fibers. The hemp fibers were opened, cleaned with a non-ionic surfactant, dried, and then subjected to an alkaline bath, mostly containing NaOH (10 g/L), followed by an oxidizing treatment, primarily containing H_2O_2 (50% w/v) 1 g/L. Hemp was cooled after the treatments, washed, neutralized with acetic acid at a concentration of 0.6 g/L, rinsed with distilled water, and dried at room temperature [16].

Before actually spinning yarn, the fibers underwent a sizing process that uses hemp seed oil to lower the friction coefficient of the open-treated hemp fibers. A circular knitting machine was then used to produce knitted garments from the spun yarns. A hemp/cotton 25/75 blend was determined. After obtaining the knitted materials, various procedures were conducted to determine the most appropriate dying circumstances for the chosen cloth [16]. The following are these procedures:

Washing of fabrics: To get rid of any oiling or pollution that might have accumulated during the knitting process, the materials were cleaned before being dyed. Using a liquor ratio (LR) of 1:30, a total of 1 g/L of washing detergent was administered at 37 to 40 °C for 30 minutes. Four washes with pure water were then completed. The first wash was carried out at 37–40 °C, while the next three were done at room temperature [16].

Mordanting: All of the specimens underwent two alum mordants to assure the dye's attachment to the fiber. Before applying the alum, tannin was used to mordant the fabric. Water from the faucet or distilled water was used to apply the mordanting [16]. And it proceeded like this:

Mordanting with tannin: The Linitest containers were filled with a sum of 300 mL of an 8% tannin overweight fiber combination with 5 g of fabric and heated to between 50 and 60 °C for one hour. When the textiles were separated, two alum mordantings were placed right away [16].

Mordanting with alum: 5 g of the fabric and 300 mL of alum 15% o.w.f. and sodium carbonate 2% o.w.f. the solution was used for such initial mordanting for 1 hour at 50–60°C. In identical circumstances, a 10% o.w.f. alum and 2% o.w.f. sodium carbonate solution was utilized for the next mordanting. Along with its ability to act as a detergent, this reagent was used with alum to control the pH and enhance the dye's reception into the fiber. The procedure was completed by allowing the materials to air dry at room temperature [16].

Based on the knowledge of natural colorants, Gabriela M. et al. colored the blended cloth while taking into account the temperature required to dye it. The first solution the researchers tested was an 8% o.w.f. the powder produced from common madder. Then, 5 g of fabric was utilized at an L: R ratio of 1:60. This procedure was run at 60 °C for one hour. Depending on the circumstances, the colored textiles were taken out of the vessels and allowed to air out with or without rinsing. The other dye was then taken from the calendula flower that had been dried. In other words, a solution comprising 40 g/L of calendula flower was made and simmered for 30 minutes in a flask with a reflux condenser and magnetic stirring. The fabric was then added, together with 300 mL of the purified dye solution, to the vessels at a ratio of 1:60 for 1 hour at 100 °C. Eventually, depending on the situation, the textiles were also taken out once more and allowed to dry [16].

The outcomes demonstrated that several factors can influence how well the dye is absorbed. Analysis showed that the tannin-alum mixed mordanting was efficient, particularly when it was done concurrently with dyeing, whether the dye was made from calendula flower or common madder because there were more interactions with the various ingredients in the bath. As shown in (**Table 1**) for the dye derived from common madder and (**Table 2**) for the dye derived from calendula flowers, the procedure of mordanting also influences the rubbing and washing resistance of the colored materials. When the effects of the two dyes were compared to the untreated cloth, it was discovered that common madder had a slightly different hue. And yet, because of its excellent fastness against wet and dry rubbing, the dye produced from calendula flowers is a preferable choice [16].

Table 1: Outcomes of samples with pre-mordanting, post-mordanting, and mordanting throughout common madder dyeing were tested for washing and rubbing durability and resistance *[16]*.

Sample	Washing			Rubbing	
	Color Change	Staining		Dry	Wet
		Cotton	Wool		
1RTD	1	4–5	4–5	3	1
2RTD	2	5	4–5	3–4	3
3RTD	2–3	5	4–5	4	2–3

Table 2: Outcome of the pre-mordanting, post-mordanting, and mordanting throughout calendula dyeing samples' washing and rubbing fastness analyses *[16]*.

Sample	Washing			Rubbing	
	Color Change	Staining		Dry	Wet
		Cotton	Wool		
1CTD	3–4	5	5	4–5	3
2CTD	4	5	5	4–5	3–4
3CTD	4–5	5	5	4	2–3

Dyeing of Jute/Cotton blended fabrics

The essential efficient and environmentally friendly and biodegradable fiber jute can open the door to a greener manner. In addition to being inexpensive, jute offers several technical benefits, including greater dye acceptance, dimensional stability, high tensile strength, initial modulus, moisture recovery, and good sound and heat insulation. Jute's reactive carboxylic acid groups give it a little stronger affinity for natural colors than cotton. Hence, it qualifies as a fiber for natural dyeing. Also, Cotton yarns are interwoven with jute to improve fabric flexibility and increase the overall hand feel [15].

This type of sustainable blended cloth was dyed using a natural dye made from onion peel (allium CEPA), along with a few bio-mordants like guava leaves and banana peel. These bio-mordants are beneficial tannin suppliers. Chrysin, quercetin, caffeic acid, cinnamic acid, and catechin are the main phenolic chemicals present in banana peels. Moreover, the substances found in banana peels are categorized into four subgroups: catecholamines, flavonols, flavan-3-ols, and hydroxycinnamic acids. Together with tannin, green guava leaves also contain coloring substances akin to those found in onion skin. Moreover, it has the coloring agent myricetin-3-O-b-D-glucoside [15].

Initially, Md. Raijul Islam et al. dried the external membrane of onion skins, smashed them, and then immersed them in pure water to obtain the color. The proportion of the substance to the water was 1:5. It was then boiled in a water bath for three hours at 90°C. The extract was processed once it had been cooled. Afterward, the extract was concentrated by taking a third less of the original volume. The dye was kept cooled until usage. The researchers then prepared the extracts of both mordants driven from guava leaves and banana peel [15].

The ripe banana peels and green guava leaves were obtained by the researchers, cleaned, and dried. Each of the components was pulverized into a fine powder. As an extracting solvent, 80% ethanol was mixed in a 1:3 ratio with finely powdered green guava leaves. With a proportion of 1:3, the fine powder of ripe banana skins was also mixed in 80% methanol as an extraction fluid. The two bio-mordants were prepared and stored for three days at room temperature with little shaking. three days later. To get a concentrated extract, the preparations were filtered, evaporating the extract. To prepare the extraction for future usage, it was cooled [15].

Md. Raijul Islam et al. then pretreated the bleached fabric blend (65% jute and 35% cotton) with mordants. Banana peel and guava leaf extract were used to mordant the textiles at the following concentrations: 10%, 20%, 30%, and 40% according to the weight of the cloth. Pre-mordanting, simultaneous-mordanting, and post-mordanting were the three techniques used to mordant the cloth. The cloth was mordanted for pre-mordanting without first being dyed. The cloth was mordanted at 80°C for one hour. A wetting and trapping agent at 1 g/L was utilized. The cloth was then kept, dried, and prepared for dyeing. It was washed with hot water after being dyed. The textiles were first colored, dried, and then post-mordanted using mordants. The textiles underwent post-mordanting for one hour at 80 degrees Celsius with 1 g/L wetting and sequestering agents as auxiliary chemicals. In the dyeing process, the materials were sequentially colored and mordanted [15].

The researchers utilized the Dysin sample dyeing machine to dye the cloth samples. The textiles were dyed with 6 g/L of aqueous dyes (based on the weight of the fabrics), 1 g/L of wetting agent, 1 g/L of isolating agent, 20 g/L of sodium chloride, and 3 g/L of acetic acid. The dyeing took place for one hour at 100° C in an acidic medium with a pH of 4. The ratio of substance to alcohol was 1:20. The research determined that mordanting cloth concurrently with 40% guava leaf extract produced the deepest tone. Also, it was found that the guava leaves extract had the greatest outcomes, especially for cloth post-mordanted with 30% guava leaf extract and then 40% guava leaves extract (owf). Indicating that the greatest K/S was achieved by using guava leaves as a mordant. However, when it came to the colored fabric's fastness, post-mordanted materials with banana peel extract produced the greatest performance by offering an acceptable fastness characteristic. Whereas the fastness qualities (**Table 3**) of the textiles mordanted with 20% and 30% banana peel extract were reasonable and color fading was applicable, these materials produced the best results. In conclusion, enhancements were seen in the wash fastness results of the cloth mordanted with banana peel extract. Moreover, guava leaf extracts produced outcomes with greater color intensity [15].

Table 3: Washability of post-mordanted materials' colors *[15]*

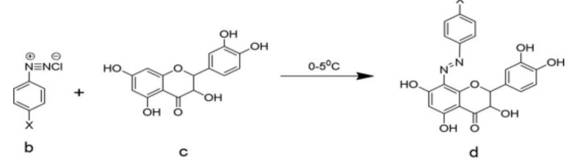
0%	Amount of mordant (owf)	Color change	Color staining
Control		1	2–3
Post mordant			
For banana peel	10%	2	4
	20%	2–3	4–5
	30%	2–3	4–5
	40%	2	3–4
For guava leaves	10%	1	3
	20%	2	3–4
	30%	2	3–4
	40%	1–2	3–4

Dyeing of Polyester/wool blended fabric

A. B. Pawar et al. managed to alter a natural dye and dyed polyester with higher performance characteristics [21]. Then, in a different piece of work, they aimed to enhance a dye to be utilized to create a bath dyeing technique for dying blended polyester and wool fabrics at a reduced temperature. Allium cepa, the plant that provides the natural color, has bioactive phytomolecules like phenolic compounds, notably flavonoids, and several organosulfur compounds. The goal is to chemically alter the natural dye to create a single-bath dyeing method employing two separate semi-synthetic dyes made through a diazo coupling reaction [**1**].

A. B. Pawar et al. dyed a polyester/wool blend cloth (55/45) using waste skin from the Alluim cepa as a source of organic colorant. The material was exposed to sunshine to dry before being processed into something like a cloud of fine dust. Using Soxhlet equipment and solvent extraction procedures, ethanol was used to extract the powdered form of Allium cepa. A Hoover rotary evaporator was used to further evaporate the solvent from the mixture, and then the mixture was vacuum-dried at 30°C. The coupler for the diazotization and coupling reaction was this granular extract [**1**]. Then, using conventional techniques, the diazotization reaction was performed to produce the diazonium salts of two primary amines, namely p-nitro aniline and p-anisidine (**Scheme** 2) [**1**].

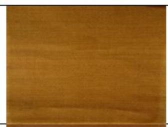
In a 2 N sodium hydroxide solution, the granular extract of Allium cepa residual skin (coupler) was hydrolyzed. The cold diazonium salt was then gradually added while being stirred continuously. A Buchner funnel was used to filter the liquid after it had been agitated for a further two to three hours in an ice-bath. After several rounds of washing with cold water to remove any impurities and drying in an oven set at 40°C, the dye was finally produced. The main amine utilized to create the diazonium salt also affects the sort of changed dye. And the resulting modified dyes have the names OPNA and OANI, accordingly, since OPNA is a dye modified by the primary amine p-nitro aniline and OANI is a dye modified by the primary amine p-anisidine. The potential reaction plan for the fusion of diazotized salt with the coupling agent (quercetin) is displayed in (**Scheme 3**) [**1**].



Scheme 3: Proposed coupling reactions using (b) diazonium salt; (c) a coupling ingredient (quercetin); and (d) a potential modification to the original dye's structure [**1**].

The polyester/wool 50/50 blend material was colored using partially synthetic dyes in an individual bath. To make an initial solution, the dyes were dissolved in N, N-dimethyl formamide (DMF) solution. To guarantee that the material-to-liquid proportion (MLR) was 1:30 and the pH varied from 4.5 to 5.5, coloring with glacial acetic acid was carried out at a simmer for 60 minutes. To eliminate any leftover color, this substance was washed and dried after being soaped in a nonionic surfactant solution at 80°C for 20 minutes [**1**].

Chemically altered dyes were relatively pure chemicals for the dyeing of textiles and were employed on PES/Wo mix fabric in a single bath at boiling temperature regardless of the need for any extra auxiliary. The dyeing process created a solid hue with acceptable dyeing uniformity and outstanding all-around durability qualities. As a result of their examination, the researchers found that the altered dyes had excellent shade development properties, with OPNA dye having a higher K/S value than OANI dye, which results in a somewhat deeper shade on PES/Wo blend fabric as demonstrated in (**Scheme 4**). Concerning the wash durability of the colored materials, neither of the altered dyes left any stains on the wool, but they did leave some stains on the polyester fabric next to it. And when it comes to dry rub fastness, the altered dyes work well in terms of fastness, however wet rub fastness resulted in a very small discoloration of the nearby wool fabric. Since there may be not a noticeable shift in the color of the colored cloth when subjected to light, both improved dyes have satisfactory light fastness, as shown in (**Table 4**). So, both altered dyes' durability findings were good and in line with what was needed for business purposes.[**1**].

Dye	Dye appearance and Solid shades obtained		Shade obtained on the fabric
OPNA			Greenish yellow
OANI			Reddish brown

Scheme 4: colored specimens with altered dyes [**1**].

Based on the AATCC 147 testing technique, the altered dyes also demonstrated an efficient zone of inhibition for both gram-positive (S. aureus) and gram-negative (K. pneumoniae) bacteria. Following the AATCC 100 testing technique, colored polyester/wool blend textiles also had good antimicrobial efficacy, proving that the altered dyes possess great antimicrobial properties that can slow the development of bacteria. Therefore, it may be inferred that synthetic alteration is the promising method for endowing organic materials with enhanced qualities that do away with the need for a mordant for natural dyeing and assists in resolving additional obstacles. Due to its ability to reduce energy, and expenses, as well as time-consuming, a single bath dyeing process with semi-synthetic azo dyes is appropriate to be employed as industrial colorants in massive quantities [**1**].

Dyeing of Polyester/viscose blended fabric

Natural dyes made from plants are typically employed, notably in textiles because of their vivid color and environmentally friendly qualities. Their modest substantivity, however, represents one of their drawbacks, and to address this issue, a metallic mordant was employed to create a kind of affinity among the dye molecules and the material by creating a coordination complex through a process known as covalent bonding. An example of these organic dyes, Alkanna orientalis, is derived from a herb root and is utilized together with the metallic mordant alum ($Al_2(SO_4)_3$), to color polyester/viscose combined fabrics. The latter mordant is regarded as the least dangerous mordant for coloring owing to its accessibility, affordability, safety, and lack of influence on color [19].

Eser et al. first dried and ground the herbal matter into a fine grinding before cutting the plant matter into portions to remove the colorant from the roots of (Alkanna Orientalis). Using a Soxhlet system, 200 mL of water and ethanol (EtOH) were used to obtain 10 g of the root matter. Under decreased pressure, the solvents were evaporated to produce water extract (12.30%) and EtOH extract (4.54%), accordingly. The phenolic compounds had been determined using the extracts. The roots (42 g) were separated utilizing purified water (1500 mL) using a Soxhlet device reaching its highest temperature right until the mixture was colorless [19].

The 60/40 combination of polyester and viscose was then colored by the researchers utilizing an efficient and money-saving continues-mordanting procedure. The solution containing the dye was mixed with 0.1 M of dry alum mordant, so it's the same as 0.1 Mordant liquid. They carried out the dying process on a Termal HT 610 NHT coloring device, maintaining a 1:30 material-to-liquor (M: L) ratio. Using pH 4, polyester-viscose combined fabrics were dyed. The temperatures used to dye garments made of a polyester-viscose combination were 75°C for 60 minutes and 130°C for 30 minutes, correspondingly (75°C for viscose, 130°C for polyester). The substance was finished by being washed with purified water and dried out [19].

Table 4: Evaluation of lightfastness, washability, and rubbing [**1**]

	Wash fastness			Rub fastness				Light fastness
				Dry rubbing		Wet rubbing		
Dye	Colour change	Stain on polyester	Stain on wool	Stain on polyester	Stain on wool	Stain on polyester	Stain on wool	Colour change
OPNA	4	4	3-4	5	4	4	3-4	6
OANI	4	4-5	3	5	4	4	3-4	6

Once the colored fabrics underwent analysis, it was discovered that using the natural dye to dye polyester-viscose mixed substances resulted in a relatively low K/S (1.66) value, which could be due to the dye decomposing at 130°C. An un-mordanted colored cloth was checked to establish this conclusion, however, once the dyed material was studied after being mordanted with alum, it was found that the K/S had risen until it had reached (3.55).

The laundering, rubbing, and light durability of the colored textiles are also improved by the use of alum mordant, which varies from 2 to 4 (i.e., acceptable to great) for un-mordanted dyed fabrics and from 4 to 5 (i.e., superb to exceptional) for the colored fabrics that have been mordanted. (**Table 5**) compares the fastness ratings of several colored specimens, such as a polyester/viscose material combination. [19]. The efficacy of coloring a fabric mix like polyester/viscose with an organic dye like the dye generated from Alkanna orientalis in a single dyeing process has been established, in resolution. This eco-friendly, reasonably priced method of dying fabrics yields excellent outcomes in terms of color saturation and fabric stability.

Table 5: Fastness values of the dyed samples *[19]*.

			Rubbing		
Mordant	Fabric type	Washing	Wet	Dry	Light
$AlK(SO_4)_2$	Cotton	4/5	5	5	5
	Viscose	4/5	5	5	4
	Wool	5	5	5	5
	Polyester–viscose blend	5	5	5	4
Unmord.	Cotton	3	5	5	2
	Viscose	2/3	5	5	3
	Wool	4	5	5	5
	Polyester–viscose blend	2	5	5	4

Dyeing polyester/cotton blended fabric

Because of their substantial endurance, minimal shrinkage, and suitable-care qualities, polyester/cotton (P/C) blended textiles are frequently utilized as fabrics.[22]. Additionally, one of the greatest significant organic dyes, vat blue dye, is obtained by extracting the indigo-rich plant Strobilanthes cusia (Nees) Kuntze. It can be applied to dye The P/C blended fabric [23]. Organic indigo-dyed textiles, nevertheless, have low color durability and are vulnerable to the growth of bacteria. In an attempt to solve both of these problems, self-organized iron (III)-tannic nanoparticles (Fe-TA NPs) were created. Tannic acid (TA) is a substantial polyphenolic compound having antimicrobial characteristics. The use of TA as a bio-mordant during the dyeing procedure is now recognized. Additionally, iron chloride is one of the metal-based mordants that's able to react with organic colorants and ultimately generate compounds of metals that improve durability characteristics. It is believed that a polydentate TA ligand can interact alongside ferric ions to create very stable self-assembling Fe-TA compounds [22].

The P/C mixed fabric was colored using a standard indigo dyeing procedure by Keereeta, Y., et al., who maintained a consistent fabric mass to liquor proportion of 1:100 while using a dying solution which includes 100 g/l natural indigo paste, 50 g/l Ca (OH)2, and 50 g/l tamarind. The specimen was submerged carefully in the dye mixture for two minutes at a temperature of 45 °C. The cloth was subsequently taken out of the dye water and allowed to oxidize for two minutes before going through the immersing and airing procedure an additional five times. The cloth was colored and subsequently air-dried and rinsed in purified water to the point there was no shift in color to produce the (I1) cloth.[22].

The researchers essentially combined water-based solutions of 1 mM ferric chloride and 1 mM TA at ambient temperature to create Fe-TA NPs. The impact of various molar combinations of ferric chloride and tannic acid on the indigo-dyed textiles was then investigated more thoroughly the indigo-dyed textiles (I1) were subsequently exposed to a Fe-TA compound mixture for 30 minutes at 50 C with varying mole ratios of Fe^{3+}: TA of 1:1 (I2), 1:3 (I3), and 1:9 (I4), respectively. On a scale used in laboratories, the liquid proportion between the fabric and the Fe-TA solution was fixed at 1:100. The treated textiles were cleaned with a 2 g/l soap and air-dried [22].

Following examination of the dyed materials that were not subjected to treatment and those that had, it was discovered that the treated samples had taken on a more intense color as a result of the blackish-green hue the Fe-TA complex solution had developed. The deeper shade of the colored materials barely changed as a result of treatments. As the molecular weight of TA rose, the K/S measurements for indigo-dyed fabrics subjected to Fe-TA NPs progressively elevated. Research demonstrated that complexes of coordination between ferric ions and indigo dye exist. As the mole of TA rose, the K/S measurements for indigo-dyed materials enriched in Fe-TA NPs systematically grew. (**Table 6**) displays K/S values and material color coordinates. Additionally, the colored specimens' lightfastness, washability, and color permanence were assessed and given grades ranging from ideal (4) to outstanding (5) [22]. The P/C fabric was diagnosed using an assessment of the antibacterial activity of the treated samples using the AATCC 100 standard. having a population of microbes reduced by 92%, all textiles treated with Fe-TA NPs exhibit substantial antimicrobial activity towards both gram-positive and gram-negative bacteria. As the TA mole increased, the attraction to S. aureus bacteria decreased [22].

It has been determined that the Fe-TA NPs have been employed to create a natural indigo-dyed polyester cotton mixed fabric with good antimicrobial and color durability qualities. The surface modification of the cloth was significantly impacted by the nanosized particles Fe-TA. A complicated bonding process and a massive surface area improved the absorption of additional moles of the dye [22]. Consequently, both the dyeing of the blended fabric and the modification of the dyed fabric were very successful.

Table 6: K/S readings and the material's color coordinates[22].

Samples	K/S	Color coordinates	
		L*	a*
P/C	–	81.14	0.12
I1	0.00806	31.34	−1.79
I2	0.00832	27.57	−1.34
I3	0.00841	26.55	−1.06
I4	0.00844	28.63	−1.20

Dyeing the blended fabrics with synthetic dyes

A higher degree of quality and more repeatable application procedures were made possible with the invention of synthetic dyes around the turn of the 20th century [24]. Synthetic dyes are diverse in their characteristics and their ability to dye different types of fabrics and their blends.

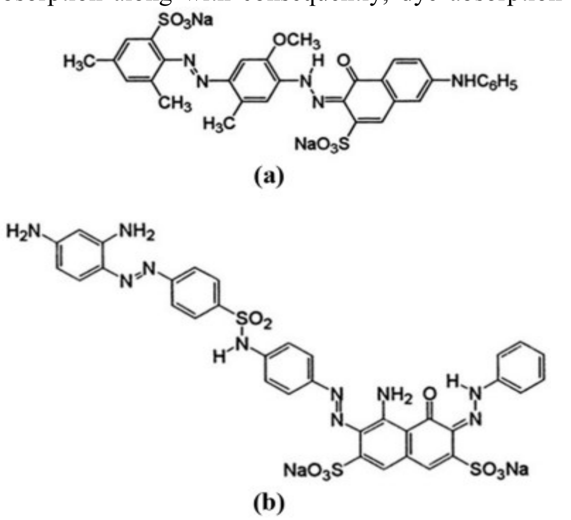
Dyeing cotton/nylon fabric blend

Cotton and its mixes are becoming more important because of the possibility of creating affordable, long-lasting goods with improved functional and aesthetic qualities arising from the combining of cellulosic fibers with artificial fibers [25]. A cotton/nylon hybrid fabric made with at least 17% nylon produces an incredibly strong fabric. Nonetheless, the chemical composition of the two fibers differentiates, and dying blended fabrics can be challenging, especially cotton/nylon combinations. Traditionally, acid dyes are used to color nylon, however reactive and dispersion dyes may additionally be used. And a cationic agent, such as the cationic agent t 3-chloro-2-hydroxypropyl tri-methyl ammonium chloride (CHPTAC), was utilized to change the cotton fabric to improve the absorption of those colors for the cellulosic fibers [17].

The cotton/nylon (75/25) material mix was initially prepped by Kashif Iqbal et al. by having it desized as it underwent washing with non-ionic detergent at 90 °C for 30 min, then alkaline scouring at 90 °C for 45 min. H_2O_2 was utilized for bleaching the cotton/nylon blend cloth at 80°C for 30 minutes. The cotton-based component of the mixed material was subsequently taken out by the researchers and cationized using the cold pad-batch process with the cationizing agent (CHPTAC). Before stirring for 15 minutes, 20 g of CHPTAC had previously been dissolved in 100 g of water. The CHPTAC liquid was then given a steady addition of 20 g of 50% w/v NaOH and was continually agitated for an additional 30 minutes at the ambient temperature. Exactly as the chemical mixture was prepared for the pad application of the fabric made from cotton to the blend with the CHPTAC treatment, the non-ionic wetting compound in the quantity of 2 g/l had been applied. Additionally, additional water was included in the mixture to generate up to 200 g of pad liquor. The cloth was coated with the CHPTAC pad solution using a wet picker of one hundred percent, wrapped for 18 hours (overnight), and subsequently unwrapped. The cloth was rinsed off in batches after being wrapped nightly. To ensure that the material is clear of any unfixed or hydrolyzed CHPTAC, several items of washing took place because some CHPTAC might undergo hydrolysis [17].

subsequently, using CI Direct Violet 51 and CI Acid Black 234, as well, the researchers individually dyed the unaltered and altered cotton specimens in the combined fabrics. The two aforementioned dyes' chemical compositions are shown in (**Scheme 5**). Both the altered and unaltered textiles were dyed using an elevated temp dying machinery using a 10:1 liquor-to-fabric ratio. With every single one of the dyes, five different shades (0.5, 1, 2, 4, and 6%) were achieved, and acetic acid was used to keep the pH between 5.5 and 6.5. The device's heat was set to 100°C, and specimens were treated for 60 minutes. The specimens were dyed, then washed with 2 g/l detergents (Lutensol AO) at 70 °C for 15 min, then cold rinsed [17].

To examine the coloring processes using multiple hues as 0.5, 1, 2, 4, and 6% owf derived from altered and unaltered specimens colored with CI Direct Violet 51 and CI Acid Black 234, it was determined that the coloring of the altered cotton/nylon (75:25%) mixed fabric demonstrated greater color strength as contrasted with unaltered dyed specimens. It happens because altered cotton/nylon material has the highest color absorption along with consequently, dye absorption



Scheme 5: Chemical compositions of (a) CI Direct Violet 51 and (b) CI Acid Black 234 *[17]*.

Additionally, in comparison with other dyes, specimens colored with CI Direct Violet 51 showed the greatest color shift. In contrast with comparable dyes, that possess nonlinear structures, this dye's linear composition makes rinsing it easier to remove. Additionally, the improved blended fabric outperformed the untreated fabric in terms of lightfastness for the two CI Direct Violet 51 and CI Acid Black 234. The cationized cotton/nylon fabric mix demonstrated generating the smallest amount of dye waste when dyed and its wastewater included just a tiny amount of the remaining dye, indicating that the alteration of the cotton fibers in the cotton/nylon fabrics mix may outcome in an effective single-dye bath dyeing procedure along to preserve money and decrease the volume of wastewater released into the environment [17].

characteristics. Because of the magnetic relationship between the positive electrical charges onto the material with the negative ones on the acidic colorant, the insertion of quaternary ammonium groups onto the cellulose offers fibers made of cotton substantivity acid colors as CI Acid Black 234 [17].

Additionally, both changed as well as unaltered specimens had strong dry crocking durability as well as medium moist crocking resistance. Altered specimens of fabric nevertheless perform marginally worse than unaltered ones for several hues. The difference in the number of dye molecules between the changed and untreated fabrics could have been the cause, and additional dye particles may have been removed through rubbing. Furthermore (**Table 7**) provides the aforementioned color durability ratings.

Table 7: Color durability under friction after using CI Direct Violet 1 and CI Acid Black 234 for dyeing *[17]*.

	CI Direct Violet 51				CI Acid Black 234			
	Unmodified		Modified		Unmodified		Modified	
Shade depth (%)	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet
0.5	4-5	4	4-5	4	4-5	4	4	4
1	4-5	3-4	4-5	3-4	4-5	4	4-5	3-4
2	4-5	3-4	4-5	3-4	4	3-4	4	3-4
4	4-5	3-4	4-5	3	4-5	3-4	4	3-4
6	4-5	3-4	4-5	3-4	4-5	4	4	3-4

Dyeing of recycled cotton/chitosan fabric blend

Cotton farming and wet manufacturing both hurt the ecosystem. Cotton recovery is a significant method for lowering cotton's ecological impact. In the context of environmentally friendly production, recycled cotton was used in combination with chitosan yarns for this reason, and the dyeing behavior of textiles made from this blend was investigated [26]. The water-friendly polymer chitosan has generated quite a bit of attention in the realm of textiles [27].

T. Toprak-Cavdur et al. performed an enzymatic scouring technique for woven untreated cotton textiles using pectinase at pH 8 for 30 minutes at 55 to 60 degrees Celsius using a 5% (owf) dosage of the enzyme. After that, this enzymatic inactivation procedure took place within the tub for 10 to 15 minutes at a temperature of 90 °C. The ratio of the used liquor was 25:1. The researchers subsequently experimented with two different coloring techniques. The reactive coloring of the mixed textiles was carried out by varying the amounts of salt (NaCl) (40 g L1 and salt-free) and alkalinity (pH 11.5 and ph 7) in the dyeing tubs while maintaining a temperature of 80 degrees Celsius and a liquor proportion of 40:1. Five phases made up the reactive rinsing process: cold (20°C–30°C, 10'), heated (70–80°C, 10'), boiling with soap (90–95°C, 20'), as well as cold (20–30°C, 10') washings, in that order [26].

Parallel to reactive dyeing, researchers additionally carried out direct coloring; the sole distinctions between the two were the coloring temperature (100 C) plus the rinsing phases (cold, warm, as well as treatment using a cationic fixator). Ever direct Blue 4BL and C.I. Direct Blue 200, direct dyes, were employed. Because of the inclusion of chitosan within the fabric mix, they also performed a dyeing treatment using an acid dye (C.I. Acid Blue 221). At a liquor proportion of 40:1 with a colorant concentration of 2%, the acid coloring procedure was conducted. A further variable in the dyeing process that took place under neutral and acidic circumstances (pH 7 and 4.5) at 100 degrees Celsius for 60 minutes was the salt (Na_2SO_4) concentration of the aforementioned baths (10 g L1 and salt-free). Warm (70-80°C, 10') as well as cold (20-30°C, 10') washing took place after acid coloring [26].

The specimens were studied, and it turned out that adding salt to the bath and raising the pH level caused the color hues of the R-CO/chitosan blended cloth to deepen when dyed directly and reactively. It was additionally found that among the three dyeing processes, direct dyeing at pH 11.5 within a medium containing salt had the maximum depth of color and intensity. This might occur as a result of the direct dye's potent tinctorial properties plus the higher dying temperatures. The colors of the acid dyeing were less vivid than those of the other direct and reactive dyes, it was nevertheless successful on the fabric mix. Reactive coloring also displayed the best values in terms of dry, wet, and washing durability qualities in the findings for fastness [26]. Regardless of the outcomes, the dyeing of the R-CO/chitosan seemed to be a success with the employment of several sorts of dyes.

Dyeing of cotton/flax/polyester fabric blend

The procedure of blending aims to enhance a variety of fabric characteristics, including endurance, while integrating stronger fibers may prolong the lifespan of an already less sturdy one. For example, a material made by combining cotton, flax, and polyester might be used for its physical benefits and colored using reactive dyes with the use of alkaline processes like sodium hydroxide and sodium hydroxide/methanol. to increase its additional characteristics [**3**].

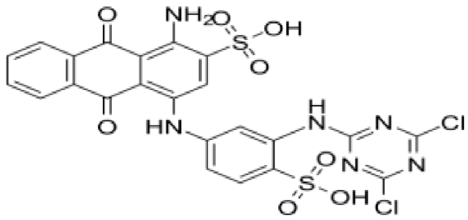
H.A. Saad et al. used 2g/l Na_2CO_3 and 0.5g/l non-ionic wetting compound at 80˚ C for 3h to lightly scour the cotton/flax/polyester (CFP) (40:30:30) fabric combination. After an extensive water rinse, the specimens that underwent treatment were allowed to air dry. Afterward, they had three separate pretreatment procedures. The traditional method is one such method. 6% sodium hydroxide solution was used for this procedure, which involved submerging the samples at L: R 1:30. 40° C was the initial temperature, and it took 30 minutes to elevate it to simmering. The samples were given the proper amount of time to simmer (1 hour), then they were neutralized with 6% acetic acid, washed with filtered water, and then allowed to air dry. (HC) is the name of this method. The second method involved soaking CFP at L: R 1:30 in an alkaline solution containing 6% NaOH. The material was then pressed with a lab padder to obtain a 100% moisture pick-up. The specimen was placed in a plastic sheet and heated in the microwave for three minutes at 300 watts. The specimens were washed with purified water, neutralized with 6% acetic acid, and then allowed to air dry. This method is known as (HM) [**3**].

Similar to the second pre-treatment technique, the third and last pre-treatment technique was carried out, but methanol was employed as an acceleration agent with a concentration of 50%. The specimens were washed with purified water, neutralized with 6% acetic acid, and subsequently allowed to air dry. This method was referred to as (H-MM). The researchers next used a traditional approach of one dye bath method to color the specimens that were treated using ProcionBlue MX-R reactive dye whose chemical structure is shown in (**Scheme 6**). Following the dying process, the specimens were soaped with 2 g/L detergent at 90 C for ten minutes before being dried up [**3**].

After more analysis of the specimens, it turned out that the specimens treated using the microwave technique (HM) produced superior K/S results than the ones treated using the traditional method. But when applying the methanolic NaOH microwave method (H-MM), the specimens displayed the highest K/S values since the processing time was accelerated. This caused the specimens to completely absorb the electromagnetic energy, which sped up the process of hydrolysis of the polyester outer layer and increased the number of functional groups that are polar at the surface of the CFP fabric, increasing the dye's consumption. Additionally, the fastness characteristics of the CFP specimens were examined, and it was shown that regardless of the treatment method, all pre-treatment samples had results of 3–4 for wet rubbing fastness whereas 4-5 for dry rubbing. When it comes to laundering fastness, only the prepared CFP fabric using the methanolic NaOH microwave technique had the greatest results, displaying a result of 3–4, while other treatments only showed a result of 3. These earlier analyses showed that CFP has excellent fastness as well as elevated measured color results. The aforementioned treatment processes used a lesser amount of time, water, and money [**3**].

Dyeing of Polyamide/polyester fabric blend

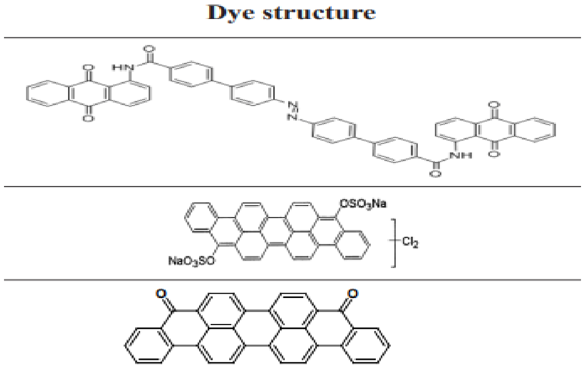
Many scientists have looked into the vat dyeing of synthetic materials. Due to their exceptional light and moisture durability qualities, vat dyes are regarded as being one of the most significant classes of cotton fabric dyes from a commercial perspective. Nevertheless, because of their often-poor substantivity toward synthetic textiles and the typically light-colored hues that result from their constrained dispersion inside the synthetic fabrics, vat dyes are rarely employed on synthetic textiles. Vat dyes of the carbocyclic and heterocyclic kinds can be used in an acid leuco exhaust coloring procedure to color a fabric mix made of polyamide and polyester (PA/PET) [18].



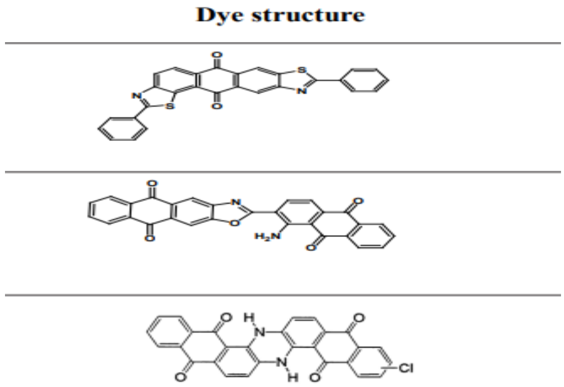
Scheme 6: Procion Blue MX-R's chemical composition [**3**]

To vat dye a PA/PET 20:80 fabric mixture, Abdalla A. Mousa et al. chose to use a variety of vat dyes, that involve carbocyclic and heterocyclic vat colorants, whose chemical structures are shown in (**Scheme 7**) and (**Scheme 8**). At a liquor proportion of 40:1, the operation was carried out in a mixture of 5–20 g/l sodium hydrosulfite, 2 g/l sodium hydroxide, and 10 g/l dispersion chemical at 1-4% depth of hue. They used acetic acid to bring the dyebath's pH to 5.5. Within these circumstances, the decreased anionic vatted dye transforms into its additional hydrophobic nonionic acid state, enabling the particles of dye to become more substantial to the hydrophobic PA/PET mixed material. The dyebath temperature was subsequently raised from 40°C to 110-120°C at a rate of 2.5 °C/min, remained at this temperature for 60 min, and subsequently lowered to 60 °C at a pace of 3 °C/min to complete the vat dyeing process. The colored specimen was subsequently washed in purified water for 5 minutes before the dye was oxidized for 15-20 minutes with 2 g/l of 35 weight percent hydrogen peroxide at pH 4.5, 70°C, and a liquor proportion of 20:1. The mixed cloth that had been colored and oxidized underwent reduction cleaning after being thoroughly cleaned using water. The fabric specimen was then completely washed with water and allowed to air dry after the reduction cleaning process was completed at 60-70 °C for 10 min in a mixture comprising 3 g/l sodium hydroxide, 3 g/l sodium hydrosulfite, and 2 g/l nonionic detergents at a liquor proportion of 40:1 [18].

After examination, it was discovered that the amount of polyamide within the cloth's mix had an impact on the K/S of the PA/PET material. Decreased K/S of the blended fabric results from decreased carbocyclic vat dye affinity to the mix as the PA fraction in the fabric mixture drops. In addition, to get an even impact on a PA/PET mix, one must raise the K/S value on the PET portion rather than lowering it on the PA portion. Additionally, the laundering and sweat durability ratings obtained for vat dyes appeared to be very good to exceptional in terms of the durability of the colored fabric mix. Additionally, the light durability of fabrics that had been vat dyed was similar [18].



Scheme 7: Carbocyclic vat dyes' chemical formula [18]



Scheme 8: Molecular structures of heterocyclic vat dyes *[18]*

Dyeing of polyester/spandex fabric blend

Disperse dyes are often used to color polyester fabric. Elastane (spandex), which is introduced to the polyester fabric in a modest amount, can be mixed with polyester fiber. This fabric combination has several potential applications in the textile sector, particularly for sportswear. The need for such mixed textiles with good wet durability capabilities has recently increased, therefore novel N-butyl substituted phthalimide dyes have been researched and applied to the fabric blend [28].

Zhao used the coupling processes of nitration, alkylation, amination, bromination, and diazotization to create the N-butyl substituted phthalimide dispersion dyes. Then, the researcher used 5.0 g of polyester/spandex mix material (97:3) to color the cloth in the dyeing equipment within the laboratory. Using a 15:1 liquor proportion, the dyeing treatment was carried out at 130 degrees Celsius for 50 minutes. The dye bath's pH had been raised to 4.5 by adding acetic acid and sodium acetate, and the dye dosage was 2% (owf). After dying, the mixed textiles were cleared at 80°C for 15 minutes (2 g/L NaOH) before being rinsed in mild temperature water at 50°C. The materials were subsequently washed in water and dried for 40 seconds at 190 degrees Celsius [28].

Following examination, it turned out that K/S grew in ratio as the dyeing procedure's pH declined. The colored specimens additionally displayed acceptable color durability to laundering, measuring 3 to 4, while they further demonstrated color durability to sweat, measuring 3 to 4. Since the phthalimide ring of the dyes may have been hydrolyzed to soluble groups, alkali-washed textiles also demonstrated good washing and sweat durability. These hydrolyzed dyes have high wet durability and can be removed easily by alkaline wash-offs. As a consequence of their high color permanence capabilities, the newly developed phthalimide dispersion dyes achieved highly effective coloring for the polyester/spandex fabric mix [28].

An additional approach to dye the polyester/spandex blend is the use of the modified carbon black with dispersed dyes. Eco-friendly carbon-based products, like carbon black (CB), have lately gained importance [29]. The conductivity of electricity, magnetic protection, anti-static properties, and anti-ultraviolet activities are the main CB uses in clothes and textiles [30]. This has to do with the weaknesses of CB's pale hue in textile materials and its inconsistent distribution on mixed materials like polyester/spandex, which make it challenging to match the specifications for useful garments. Increased contact between particles area, CB preparation, alteration techniques, exterior polar structures, and its micron-sized structure all have a greater impact on CB's conductivity to electricity. The absence of black depth along with excellent color durability, nevertheless, is CB's most significant drawback for textile uses. To address this issue, a technique was developed that involves generating liquid DB@CB through the combination of CB and disperse dye black (DB), whereas DB is a combination of C.I. Disperse Blue 79 (DB-79), C.I. Disperse Orange 288 (DO-288), and C.I. Dispersing purple 93 (DV-93) [31].

Ai, L., et al. first made a solution of DB@CB by mixing 50.0 g of deionized water with 9.5 g of a combination of anionic and non-ionic dispersant and emulsion (DE-22), plus 25.0 g of carbon black. The prior combination was repeatedly and steadily processed for 120 minutes in an upright zirconium mill at 2000 rpm. Then, DE-22 (3.0 g) and disperse blue 79 (4.7 g), orange 288 (5.4 g), and violet 93 (2.5 g) were incorporated into the resulting solution, which was then constantly grounded (at 2000 rpm) for 90 minutes. Then, filtering was performed to create an aqueous DB@CB. After incorporating liquid DB@CB, binding agent AE-20 (5% of the mass of CB), and deionized water into the color aqueous solution, the researchers colored the polyester/spandex mixed materials. Next, the polyester/spandex materials were integrated, padded (100 2% pick-up), dehydrated at 80 °C, and cured by heat at 180 degrees Celsius for 90 seconds [31].

The colored polyester/spandex mixed materials had great durability, which the researchers could conclude after their examination. This is because the carbon black and dispersed dye combines strongly, forming a vortex-shaped helical molecular construction and a two-dimensional lamellar structure among the liquid DB@CB particles that exhibit pseudoplastic fluid properties. The cloth that had been colored also exhibited a deep black hue, outstanding color durability, strong conductivity of electricity, and color durability that was at least 3-4 after friction and laundering. Furthermore, the pad-dry-bake procedure used to dye the combined cloth failed to result in pollution release, making the entire procedure extremely cost-effective and unquestionably a big success in terms of the outcomes [31].

Dyeing of polyester/cotton fabric blend

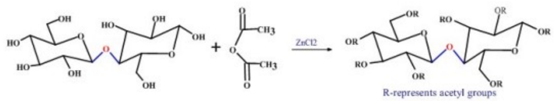
Textiles made of polyester and cotton are often employed throughout the production of clothing as well as other technological textiles due to their exceptional and complementary qualities [32]. Blending cotton and polyester results in textiles that have the best qualities of both fiber types. Polyester adds its excellent durability whereas cotton offers the cloth softness and significant water absorption [33]. To increase the dye's absorption and provide the most efficient outcomes, the aforementioned fabric mix may be colored with a variety of dyes and altered with a variety of materials.

To conserve both finances and the environment, Tegegne, W., et al. colored the polyester/cotton 65:35 mixed cloth by applying a dispersion dye blue using a single-bath dyeing technique. They changed the outermost layer of the fabric made of cotton through the esterification process to accomplish the goals mentioned above. They employed sodium hypophosphite as a form of catalyst, butane tetracarboxylic acid (BTCA), and citric acid as the solvent of choice to perform the esterification procedure. The outcomes showed that an esterification of 35% was reached after determining the ideal esterification level with an esterification concentration that was 15% and a process duration of 2.5 hours. Upon altering the cotton component in a single bath, they colored the polyester/cotton hybrid garments utilizing high temperatures and high-temperature dyeing equipment like the HTHP dyeing machinery. They calculated an L: R of 1:20 and utilized acetic acid to keep the pH around 5–6. Additionally, they carried out the dyeing process for 60 minutes at 110, 120, and 130°C. Following this, the colorant was washed and cleaned for 15 minutes at 60°C using a water-based solution of two grams of sodium per liter and two grams of sodium hydrosulfite [14].

Following an investigation, researchers discovered that a concentration of 1% was employed to dye the materials at an elevation of 120°C. The esterification adjustment additionally had a minimal effect on the tear resistance of the mixed cloth, yet it dramatically increased dye fixation, which let the dye nanoparticles penetrate through the fabric's microstructure. Furthermore, they concluded that the one-bath, one-step coloring procedure is reasonably secure and ecologically beneficial because it uses less energy, water, time, and resources because P/C mixes are only colored once. Moreover, in contrast to the conventional dyeing process, dispersion dye dyeing demonstrated good durability capabilities for wet and dry rubbing. Additionally, this technique exhibited high levels of color intensity when utilizing the dispersion dye [14].

A different strategy was under consideration to color the polyester/cotton blend fabric. The mixed cloth was dyed with a one-step bath drying technique. The alteration of the cotton part of the mix, however, is where this process differs since the cotton surface was altered by acetylation before the entire blend was colored using a form of a dispersed dye. Bana et al. could conduct the dyeing procedure as follows: they initially performed the acetylation modification by the reaction of glacial acetic acid as a solvent with acetic anhydride as the acetylating agent in the presence of zinc chloride as a catalyst. The period of the process and the concentration of acetic anhydride in the solution are two variables that rely on the reaction circumstances to establish the ideal acetylation parameters. Given the impact of temperature upon the fabric's elasticity, the acetylation process utilized 10 to 20% acetic anhydride dosage with 6 gpl of zinc chloride as a catalyst at an MLR of 1:10. The process's duration was 1-4 hours at the ambient temperature. the acetylation technique uses glacial acetic acid and the sample weight is in a proportion of 1:2. In 13 operations, the acetylation was carried out utilizing a central composite structure. And (**Scheme 9**) showed the cotton acetylation process [34].

After the researchers modified the cotton component, they carried out the dyeing procedure using dispersion. To determine the ideal dying temperature for this mix along with the least loss of elasticity of the cotton component, the dyeing operation was carried out in a single bath utilizing high temperature and high pressure (HTHP) equipment. Following the alteration of the cotton component colored in the HTHP dyeing machine at MLR 1:20, dispersion dye was used for the dying process. The use of acetic acid kept the pH between 5 and 6. For 60 minutes, the dye bath's temperature fluctuated between 100 and 140 ˚C. After rinsing, the coloring was reduced over 15 minutes at 60°C in a water-based solution of 2 gpl sodium hydroxide (NaOH) as well as 2 gpl sodium hydrosulphite ($Na_2S_2O_4$). The investigation indicated that a 16% acetylation reagent dosage and a 2.5-hour reaction duration yielded a percent acetylation of 34 as the ideal measurement of acetylation [34].



Scheme 9: Process of cellulose's acetylation reactivity [34]

The dyeing experiment's findings additionally indicated that, compared to the untreated half-bleached cloth, weft tensile strength was reduced by 9% and warp strain toughness by roughly 12% at a temperature of 120°C. Furthermore, in comparison with traditional two-bath colored fabric, one-step one-bath dyed altered PC blend with dispersion dye fabric exhibits superior durability properties, durability against abrasion, and tear toughness rating. The polyester/cotton one-bath, one-step coloring techniques using dispersion dye also demonstrated level dyeing's high color durability qualities and the technique's cost-efficiency [34]

Conclusion

In conclusion, the polyester and cotton fabric blends both by themselves and in combination with other materials demonstrated successful dyeing results in terms of the levelness of the colors, washing fastness, wet and dry rubbing fastness, as well as light fastness. With alterations that might be made to the dye itself or the blended materials typically, these natural and synthetic dyes were able to be applied to the fabric mixes within a dye bath. The treatments aided in the colors' absorption and nanoparticle dispersion. These colors range from indigo dyes to reactive dyes, direct dyes, azo dyes, dispersed dyes, or a mixture of disperse dyes and the material carbon black. Natural dyes are obtained from flowers, plant roots, onion peels, and others. In conclusion, it was found that these fabric mixes may be effectively dyed using a range of dyes, resulting in beautifully colored fabric blends with the physical benefit of both blends individually.

Conflicts of interest

There are no conflicts to declare

Funding sources

There is no fund to declare

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References

1. Pawar, A.B., Patankar, K.C., Madiwale, P. and Adivarekar, R., "Application of Chemically Modified Waste Skin for One Bath Dyeing of Polyester/Wool Blend Fabric". *Pigment & Resin Technology*, **48**(6) 493-501 (2019)
2. Pei, L., Jiang, N. and Wang, J., "Dyeing Properties of Polyester/Cotton Blended Fabric in the Silicone Non-Aqueous Dyeing System". *AATCC Journal of Research*, **8**(2_suppl) 5-8 (2021)
3. Saad, H.A. and Abd-Elkawe, E.Y., "Evaluation Properties of Cotton/Flax/Polyester Blended Fabrics after Chemical Treatments and Dyeing". *Journal of Textiles, Coloration and Polymer Science*, **19**(2) 331-338 (2022)
4. Tusief, M.Q. and Sabir, M.H., "Impact of Variant Fibre Blend Ratios, Ph Levels and Finishing Types on Comfort Properties of Polyester/Cotton Knitted Fabric". *American Journal of Modern Physics*, **12**(1) 9-13 (2023)
5. Chen, Y., Wu, X., Wei, J., Wu, H. and Fang, J., "Reuse Polyester/Cotton Blend Fabrics to Prepare Fiber Reinforced Composite: Fabrication, Characterization, and Interfacial Properties Evaluation". *Polymer Composites*, **42**(1) 141-152 (2021)
6. Zhang, W., Ji, X., Wang, C. and Yin, Y., "One-Bath One-Step Low-Temperature Dyeing of Polyester/Cotton Blended Fabric with Cationic Dyes Via B-Cyclodextrin Modification". *Textile Research Journal*, **89**(9) 1699-1711 (2019)
7. Ali, M.A., Hassabo, A.G., Seddik, K.M., yahia, s. and Mohamed, N., "Characterization of the Thermal and Physico-Mechanical Properties of Cotton and Polyester Yarns Treated with Phase Change Materials Composites". *Egyptian Journal of Chemistry*, - (2022)
8. Ali, M.A., Seddik, K.M. and Hassabo, A.G., "Polyester Fibres Enhanced with Phase Change Material (Pcm) to Maintain Thermal Stability". *Egyptian Journal of Chemistry*, **64**(11) 6599 - 6613 (2021)
9. Eid, B.M., El-Sayed, G.M., Ibrahim, H.M. and Habib, N.H., "Durable Antibacterial Functionality of Cotton/Polyester Blended Fabrics Using Antibiotic/Monps Composite". *Fibers and Polymers*, **20**(11) 2297-2309 (2019)
10. Oliveria, F.R., De Oliveira, D.A.J., Steffens, F., do Nascimento, J.H.O., e Silva, K.K.O.S. and Souto, A.P., "Dyeing of Cotton and Polyester Blended Fabric Previously Cationized with Synthetic and Natural Polyelectrolytes". *Procedia Engineering*, **200** 309-316 (2017)
11. Soliman, M.Y., Othman, H.A. and Hassabo, A.G., "A Recent Study for Printing Polyester Fabric with Different Techniques". *Journal of Textiles, Coloration and Polymer Science*, **18**(2) 247-252 (2021)
12. Saad, F., Hassabo, A.G., Hegazy, B.M., Elmorsy, H., Gamal, N., Sedik, A. and Othman, H., "Intelligent Wound Dressing Textile Fabric Using Various Smart Materials". *Materials International*, (Accept 2023)
13. Hilal, N.M., Gomaa, S. and ELsisi, A., "Improving Dyeing Parameters of Polyester/Cotton Blended Fabrics by Caustic Soda, Chitosan, and Their Hybrid". *Egyptian Journal of Chemistry*, **63**(6) 2379-2393 (2020)
14. Tegegne, W., Tesfaye, T., Zeleke, Y. and Ketema, G., "One-Bath One-Dye Class Dyeing of Polyester/Cotton Blend Fabric with Disperse Dye after Esterification of Cotton Fabric". *Discover Materials*, **2**(1) 14 (2022)
15. Islam, M.R., Khan, A.N.N., Mahmud, R.U., Haque, S.M.N. and Khan, M.M.I., "Sustainable Dyeing of Jute-Cotton Union Fabrics with Onion Skin (Allium Cepa) Dye Using Banana Peel () and Guava Leaves () Extract as Biomordants". *Pigment & Resin Technology*, **ahead-of-print**(ahead-of-print)(2022)
16. Mijas, G., Josa, M., Cayuela, D. and Riba-Moliner, M., "Study of Dyeing Process of Hemp/Cotton Fabrics by Using Natural Dyes Obtained from Rubia Tinctorum L. And Calendula Officialis". *Polymers*, **14**(21) 4508 (2022)
17. Iqbal, K., Javid, A., Rehman, A., Rehman, A., Ashraf, M. and Abid, H.A., "Single Bath Dyeing of Modified Nylon/Cotton Blended Fabrics Using Direct/Acid Dyes". *Pigment & Resin Technology*, **49**(3) 165-170 (2020)
18. Mousa, A., Youssef, Y.A., Abd El Moteleb, K.M. and Wasfy, A., "One-Bath One-Stage Dyeing Process of Polyamide/Polyester Blend Fabric Using Carbocyclic Vat Dyes". *Egyptian Journal of Chemistry*, **62**(Special Issue (Part 2) Innovation in Chemistry) 819-830 (2019)
19. Yaglıoglu, A.S., Eser, F. and Dolarslan, M., "Phenolic Compounds, Dyeing Potential, and Cytotoxic Activity of Alkanna Orientalis L. Boiss (Boraginaceae)". *AATCC Journal of Research*, **9**(2) 106-114 (2022)
20. Kamel, M.M.M., "Eco-Friendly Process for Dyeing Banana Fabrics with Curcuma Natural Dyes". (2022)
21. Pawar, A.B., More, S.P. and Adivarekar, R.V., "Dyeing of Polyester and Nylon with Semi-Synthetic Azo Dye by Chemical Modification of Natural Source Areca Nut". *Natural Products and Bioprospecting*, **8**(1) 23-29 (2018)
22. Keereeta, Y., Srithong, S., Pranamornkith, P., Tharawatchruk, W., Boonsom, K., Klinbumrung, A. and Kaowphong, S. "Effect of Self–Assembled Iron–Tannic Nanoparticles on the Fastness and Antibacterial Properties of Natural Indigo Dyed Polyester Cotton Blended Fabrics from Strobilanthes Cusia (Nees) Kuntze". in *Journal of Physics: Conference Series*. IOP Publishing (2023)
23. Rahayuningsih, E., Fatimah, W.S., Pamungkas, M.S. and Marfitania, T., "Effect of Physicochemical Process Variables on Natural Indigo Dye Production from Strobilanthes Cusia Leaves by Response Surface Methodology". *Indonesian Journal of Chemistry*, (2022)
24. Affat, S.S., "Classifications, Advantages, Disadvantages, Toxicity Effects of Natural and Synthetic Dyes: A Review". *University of Thi-Qar Journal of Science*, **8**(1) 130-135 (2021)

25. R, G., Guruswamy, K.P., Prabu, G.t.v., Raj, S. and Patil, P., "Low-Stress Mechanical Properties and Fabric Hand of Cotton and Polylactic Acid Fibre Blended Knitted Fabrics". *Indian Journal of Fibre and Textile Research*, **43** 381-384 (2018)

26. Toprak-Cavdur, T., Uysal, S. and Anis, P., "Dyeing Behavior and Characterization of Recycled Cotton and Chitosan Blended Fabrics". *Journal of Natural Fibers*, **19**(16) 2087133 (2022)

27. Massella, D., Giraud, S., Guan, J., Ferri, A. and Salaün, F., "Textiles for Health: A Review of Textile Fabrics Treated with Chitosan Microcapsules". *Environmental Chemistry Letters*, **17**(4) 1787-1800 (2019)

28. Zhao, X., "Synthesis and Application of N-Butyl Substituted Phthalimide Disperse Dyes". *Textile Research Journal*, **89**(15) 3034-3047 (2019)

29. Yadav, R., Tirumali, M., Wang, X., Naebe, M. and Kandasubramanian, B., "Polymer Composite for Antistatic Application in Aerospace". *Defence Technology*, **16**(1) 107-118 (2020)

30. Choi, H.-J., Kim, M.S., Ahn, D., Yeo, S.Y. and Lee, S., "Electrical Percolation Threshold of Carbon Black in a Polymer Matrix and Its Application to Antistatic Fibre". *Scientific Reports*, **9**(1) 6338 (2019)

31. Ai, L., Li, S., Cao, H. and Zhu, Y., "Conductive Properties of Polyester/Spandex Fabrics Using Liquid Carbon Black and Disperse Black Dye". *ACS Omega*, **8**(4) 4106-4115 (2023)

32. Fecker, T., Galaz-Davison, P., Engelberger, F., Narui, Y., Sotomayor, M., Parra, L.P. and Ramírez-Sarmiento, C.A., "Active Site Flexibility as a Hallmark for Efficient Pet Degradation by I. sakaiensis Petase". *Biophys J*, **114**(6) 1302-1312 (2018)

33. Palme, A., Peterson, A., de La Motte, H., Theliander, H. and Brelid, H., "Development of an Efficient Route for Combined Recycling of Pet and Cotton from Mixed Fabrics. Text Cloth Sustain 3 (4)", (2017)

34. Bana, G.K., Gelebo, G.G. and Janka, G.K., "One-Bath One-Step Dyeing of Polyester/Cotton (Pc) Blends Fabric with Disperse Dyes after Acetylation of Cotton". (2021)

رؤية حول تقنيات الصباغة للأقمشة المخلوطة البوليستر / القطن باستخدام أصباغ مختلفة

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الملخص

في السنوات الأخيرة ، ركز الكثير من التركيز على الاستخدام الواسع النطاق للمنسوجات المصنوعة من البوليستر والقطن في صناعة المنسوجات ، سواء من خلال خلطها مع بعضها البعض أو مع مواد النسيج الأخرى. يمكن دمج القطن مع المواد العضوية مثل القنب والجوت والصوف وقماش الموز والشيتوزان ، ويمكن تلوينه بشكل طبيعي باستخدام الأصباغ المصنوعة من جذور النباتات أو بعض أنواع الزهور أو حتى قشور بعض الخضروات مثل البصل. كما هو الحال مع الفسكوز والصوف والكتان والقطن ، يمكن دمج البوليستر مع مواد النسيج الطبيعية والاصطناعية الأخرى. يمكن استخدامه أيضا مع المواد الاصطناعية مثل الألياف اللدنة والبولي أميد. يمكن مزج البوليستر والقطن أيضا ، مما يفتح إمكانية استخدام مجموعة متنوعة من الأصباغ ، بما في ذلك الأصباغ التفاعلية والأصباغ المباشرة وأصباغ الآزو وحتى مجموعات من هذه الأصباغ مع مواد أخرى مثل أسود الكربون (CB) بالإضافة إلى القدرة على صبغها بأصباغ طبيعية مثل الشب سيبا والنيلي بالإضافة إلى الأصباغ الاصطناعية. تم تطبيق هذه الأصباغ المختلفة بتقنيات صباغة فعالة لتوفير نتائج صباغة موحدة وكمية عالية من الأصباغ في الخلطات. بالإضافة إلى ذلك ، تم استخدام معالجات مسبقة مختلفة للمنسوجات لزيادة الأداء المتأصل للنسيج ، مما أدى بدوره إلى تحسين أداء الأصباغ.

كلمات البحث: بوليستر – قطن – أقمشة مخلوطة – أصباغ طبيعية – أصباغ صناعية