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Wash fastness properties of pre-mordanting cotton fabrics dyed with natural dyes

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ABSTRACT

With the awareness of the negative effects of synthetic products on the environment and human health, there is a global search for environmentally, friendly and sustainable consumer products with natural dyes. The concept of naturalness gains importance for textile products that are in direct contact with human body. Therefore, dyeing process of cellulosic based fabrics in different colours with natural dyes has been developed. In this study, cotton fabrics were dyed in different colours at 1% and 3% concentrations by pre-mordanting with a cationic mordanting agent, and the washing fastness of the fabrics was tested. Before dyeing the fabrics were pre-treated and made sustainable for dyeing. Tube dyeing was performed with five different commercial natural dyes at different concentrations using the HT dyeing technique. Cotton fabrics structures in different colours were obtained by using a thickening agent in dyeing and a colour chart that could be presented to the market was created. In the studies carried out, it was observed that the fastness results were quite good in the acceptable value range (3-5), although there were dyeing defect, especially in dark dyed fabrics. It was determined that the prepared dyes should be filtered in order to minimize the dyeing defect.

I. INTRODUCTION

With the industrialization in the world, textile and ready-made clothing sectors have started to develop. In the 22nd century, it has come to the fore to take measures that affect the ecological balance and prevent its deterioration in all kinds of industrial applications. The issue of environmentally friendly textile production plays a major role in guiding the future of the textile industry. It is necessary to pay attention to the damage caused to the environment as a result of the raw materials used the recycling of the product and the production of the product [1].

The rapid population growth has led to a decrease in natural resources and the concept of sustainability has begun to be talked about as a result of the fact that human needs have become unmet. On the one hand, the increase in people's demand for water, energy, food and space, on the other hand, global population growth, climate change, the spread of urbanization and excessive industrialization as a result of water, energy, etc. resulted in resource scarcity and increased concerns about the sustainability of natural resources [2]. Accordingly, as in many sectors, the search for increasing sustainability in the textile field has emerged and increased.

Textile wet processes generally include pre-treatment (cleaning, bleaching), dyeing, printing and finishing. Many chemicals are used in these process steps and a large amount of wastewater is discharged. Therefore, some

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environmentally friendly methods (foam and supercritical carbon dioxide dyeing, natural dyeing, etc.) have been developed to improve dyeing processes and reduce the damage to the environment [3].

With the discovery of synthetic dyes by WH Perkin in 1856, various advantages such as brightness, durability and cost-effectiveness of colours came to the fore and attracted attention [4-6]. However, scientists have reported that the production and synthesis of synthetic dyes cause serious human health and environmental problems [7-9]. Therefore, in recent years, the re-introduction of environmentally friendly and more reliable colourants from natural sources has become an increasingly green trend around the world. [10-12]. In addition, some natural dyes have been found to have effective UV protection, fluorescence, antibacterial, antioxidant and antifungal properties in the development of functional textiles [5, 13-15, 16-17]. Renewable resources such as natural dyes are predicted to reduce the environmental impact in textile dyeing applications [3]. Today, many natural dye studies have been started to support the use of natural dyes and their numbers continue to increase day by day. [18, 19]. In addition, there is increasing research on the extraction of natural dyes from waste materials to reduce waste and reduce natural dye production costs [10].

Apart from the textile sector, natural dyes, which can be used in many sectors, may have various advantages and disadvantages. Disadvantages include the difficulties in obtaining large quantities of natural dyes on a continuous basis, the limited colour palette that can be obtained, the difficulties of standardizing the colour palette and dye properties, and the acquisition and dyeing costs, which can be high depending on the dye source. In spite of these disadvantages, the use of such paints that provide benefits to the user as well as important features such as being obtained from renewable resources to meet increasing sustainability expectations, causing less damage to nature that will not cause pollution and waste water problems, being able to degrade more easily at the end of use, and not being toxic and carcinogenic [20-23].

Considering the way they are applied, natural dyes can be divided into two classes as fixed dyes and dyes that require the use of fixatives. Fixed dyes are dyes that do not require any tool and can be applied directly to the fabric and offer good fastness. Dyes that require the use of fixatives, on the other hand, need an intermediary called mordant to establish a bond between the fibre and the dye [24]. Mordants are substances that provide the fixation of the dyes to the material, improve the fastness properties and create differences in colours. The mordants used have the effect of deepening or changing the original colour of natural dyes. For example, the dye obtained from the leaves of *Anogeissus leiocarpus* changes from dull yellow to bright yellow with mordant, while the pale yellowish green dye obtained from the leaves of *Mangifera indica* changes from purple to ochre. [25].

Many of the traditional mordant materials are heavy metal salts such as aluminium, iron, copper, tin, chromium [23]. Mordant type and mordanting method significantly affect colour yield and coordinates. Different colours and fastness properties can be obtained as a result of the formation of different dyes complexes [21, 23, 25]. In natural dyeing, mordant and dye type, mordant and dye concentrations are important in terms of fastness and colour darkness. Therefore, it is ecologically and economically important to use the lowest amounts that give the darkest colour, as there is no change after increasing the darkness up to a certain concentration level [26].

Most natural dyes cannot be permanently attached to the fibre and mordants (fixers) must be used for this [27]. There are basically three different mordanting methods. These; pre-mordanting, co-mordanting and postmordanting. Dyeing can be performed in a single step as the mordants are added to the dyebath in co-mordanting, which requires an additional step in a separate bath for pre-mordanting and final mordanting [28].

With the effects of synthetic products on both the environment and human health, natural origin products are now given importance. With the increase of conscious consumers in recent years, natural dyeing is seen as an alternative. In this study, it was aimed to develop sustainable natural dyeing processes with commercial natural dyes on cotton fabric qualities with pre-mordanting technique and to create a market share. Meanwhile, cotton fabric was dyed with natural dyes using the pre-mordanting method. In these dyeing, different parameters (temperature, dyeing time, thickening agent, dye concentration, etc.) were applied and optimization studies were carried out. Dyeing was done with 5 different natural dyes at 1% and 3% concentrations and colour charts containing different colours were created with thickening agents. Wet and dry rubbing fastness, washing fastness, acid sweat fastness, alkali sweat fastness and water fastness tests were used to evaluate the fastness properties of dyed cotton fabrics.

II. EXPERIMENTAL METHOD

2.1 Materials and Methods

2.1.1. Materials

100% Cotton fabrics were used and the fabrics properties are given Table 1. Natural dyes and commercial auxiliary chemicals used in the study were supplied from the market.

Table 1. 100% Cotton fabric properties

	%100 Cotton	
Grammage	115 g/m^2	
Weft	Ne 30/1 Cotton	22 (weft/cm)
Warp	Ne 30/1 Cotton	32 (warp/cm)
Weave	Plain	

In dyeing process, 5 different commercial natural dyes obtained from *Quercus infectoria*, *Acacia catechu*, *Terminalia chebula*, *Kerria lacca* and *Morus alba* and coded as DB1, DB2, DB3, DB4 and DB5 respectively were used. Through chemicals, VP1 was used as a pre-mordant material, which increases the affinity of the dye to the fabric. At the same time, VD1 was used as the dispersing agent. Soda was used to provide an alkaline environment, VD and VDB were used as thickeners. VS were used as a washing agent and VUP was used as a light fastness enhancer. Colour measurements were made on a Minolta CM-3006d spectrophotometer device. The chemicals used during the studies are used as commercial products. The full names of the chemicals cannot be given in order to avoid a legal sanction by the supplier company.

2.2 Methods

2.2.1 Preliminary trials in glass beaker

First, 5g cotton fabric was put into the VP1 solution prepared in a glass beaker and pre-mordanting was done by mixing it with the help of a glass baguette.

Cotton fabric samples, which were pre-mordanted in glass beakers, were dyed with commercial dye obtained from *Quercus infectoria* at different concentrations of 1%, 3% and 5%, and the dyeing stages and results were evaluated. The dyeing process was carried out in a 1/10 liquor at 25 °C room temperature, in a glass beaker, by mixing with the help of a glass baguette in 10 minutes. Rinsing was done after each dyeing step. The applications were continued by dosing VD1 and soda separately in the same beaker with an interval of 10 minutes. Process steps and chemicals used are shown in Table 2.

In the next step, washing with VS chemical and light fastness increasing treatment with VUP chemical were applied to the fabrics, respectively, and then rinsing was performed. The drying process was carried out in a laboratory scale Ataç brand stenter machine for 3 minutes.

Table 2. DB1 dyeing process steps and applied recipes

Process Steps	**1% DB1 Dyeing**	**3% DB1 Dyeing**	**5% DB1 Dyeing**
Pre-Mordanting	2% VP1	5% VP1	8% VP1
Rinsing	Rinsing	Rinsing	Rinsing
Dyeing	1% DB1 1 %VD1 1% Soda	3% DB1 3% VD1 1% Soda	5% DB1 5% VD1 1% Soda
Rinsing	Rinsing	Rinsing	Rinsing
Washing	1% VS	2% VS	3% VS
Rinsing	Rinsing	Rinsing	Rinsing
Light Fastness	2% VUP	2% VUP	2% VUP
Rinsing	Rinsing	Rinsing	Rinsing

2.2.2 Optimization studies on the HT dyeing machine

In HT tube dyeing process steps, 1/10 liquor was applied to all tubes each step. 5g cotton fabric samples were cut as standard and placed in tubes and the studies were carried out by adding solutions.

2.2.2.1 Pre-Mordanting

5% VP1 solution was prepared to pre-mordanting 6 cotton fabric samples. The application was made with the mordant chemical VP1 for 10 minutes in an HT tube dyeing machine at a room temperature of 25 °C. Then, the fabric samples were rinsed with distilled water for 10 minutes.

2.2.2.2 Dyeing

The sample fabrics that were rinsed after pre-mordant were dyed with DB1 natural dyes. The dyeing process step was carried out in 3 stages. For the first step, 3% DB1 dye solution was prepared and mixed in a magnetic stirrer at 80 °C for 30 minutes, filtered to prevent dyeing defect and made ready for dyeing. For the second and third stages, 40% VD1 and 35% soda solutions were prepared. First, the prepared dye solution and 5g cotton fabric were added to the tubes and the tubes were rotated in the HT dyeing machine for 10 and 20 minutes. Then the machine was stopped and the soda solution was dosed into the tubes and the tubes rotated again for 10 minutes and 20 minutes. After dyeing, the fabrics were rinsed for 10 minutes until the rinsing water remained clear. Prescription applications of the dyeing process are given Table 3.

Table 3. Prescription applications of the dyeing process

Sample	Chemicals	Temperature *(ºC)*	Time *(min.)*
Sample 1	3% DB1 3% VD1 1% Soda	25	30
Sample 2		25	60
Sample 3		60	30
Sample 4		60	60
Sample 5		25	30
Sample 6		25	60

2.2.2.3 Color darkening

After the dyeing process step, 1% VD + VDB solution was prepared for the colour darkening process. In order to see the effect of the thickening agent in the HT tube dyeing machine at 25 °C room temperature, the application was made for 30 minutes and 60 minutes. Then, the fabric samples were rinsed with distilled water for 10 minutes. Prescription applications of the thickening process are given in Table 4.

Table 4. Prescription applications of the thickening process

Sample	Chemicals	Temperature *(ºC)*	Time *(min.)*
Sample 5	1% VD + VDB	25	30
Sample 6		25	60

2.2.2.4 Washing

After the colour darkening process step, 2% VS solution was prepared for the washing process. The soaping agent VS was applied to 6 samples of fabric in an HT tube dyeing machine at 25 °C room temperature for 10 minutes. Then, the fabric samples were rinsed with distilled water for 10 minutes.

2.2.2.5 Increasing light fastness

After the washing process step, 2% VUP solution was prepared to increase the light fastness. The light fastness increasing agent VUP was applied to 6 sample fabrics in an HT tube dyeing machine at 25 °C room temperature for 10 minutes. Afterwards, the cotton fabric samples were rinsed with distilled water for 10 minutes and the lab temperature was at 120 °C. The drying process was carried out in a scale stenter machine increasing light fastness.

A dyeing diagram was created based on the optimum values obtained after the optimization studies. The process steps and applied recipes of HT tube dyeing are given in Table 5. And the diagram is given in Figure 1. Based on this diagram, dyeing was done at 1% and 3% concentration using 5 different natural dyes, DB1, DB2, DB3, DB4 and DB5. In the HT tube dyeing machine where dyeing was performed, the process application temperature (T2) was achieved with an increase of 2 °C per minute, based on the initial temperature (T1) for each step, and the application continued.

Table 5. Process steps and applied prescription of HT tube dyeing for 1% dyeing

Process Steps	1% Dyeing	1% Dyeing + Thickening
Pre-Mordant	2% VP1	2% VP1
Rinsing	Rinsing	Rinsing
Dyeing	1% Dye 1% VD1 1% Soda	1% Dye 1% VD1 1% Soda
Rinsing	Rinsing	Rinsing
Thickening	-	1% VD + VDB
Rinsing	Rinsing	Rinsing
Washing	1% VS	1% VS
Rinsing	Rinsing	Rinsing
Light Fasting	2%VUP	2%VUP
Rinsing	Rinsing	Rinsing

Table 6. Process steps and applied prescription of HT tube dyeing for 3% dyeing

Process Steps	3% Dyeing	3% Dyeing + Thickening
Pre-Mordanting	5% VP1	5% VP1
Rinsing	Rinsing	Rinsing
Dyeing	3% Dye 3% VD1 1% Soda	3% Dye 3% VD1 1% Soda
Rinsing	Rinsing	Rinsing
Thickening	-	1% VD + VDB
Rinsing	Rinsing	Rinsing
Washing	2% VS	2% VS
Rinsing	Rinsing	Rinsing
Light Fasting	2% VUP	2% VUP
Rinsing	Rinsing	Rinsing

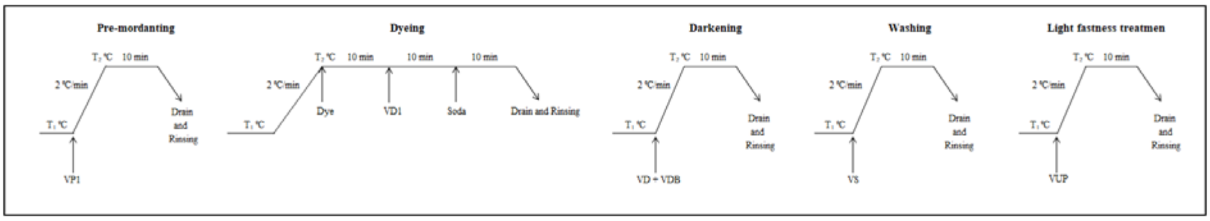


Figure 1. Diagram of HT tube dyeing process steps

III. RESULTS AND DISCUSSIONS

3.1 Pre-Trial Results in Glass Beaker

In the image given in Figure 2, it was seen that the dyes mixture prepared was not completely dissolved. It was aimed to dissolve and homogeneously disperse the prepared DB1 dyes by mixing the for 30 minutes in a magnetic stirrer at 25 °C and 80 °C, but it was determined that the dyes were not completely homogeneously dispersed in the water dye residues at the bottom of the beakers. Therefore, the prepared dye mixture was filtered, and the residues were removed.

a) 25 ºC **b)** 80 ºC

Figure 2. Residues of dye mix

The natural dye used is not water-soluble. Depending on the production method, it can be said that there are impurities and precipitations in it, since it is both a natural dye and not a fabricated production. By increasing the temperature from 25 °C to 80 °C, the dyestuff can be dissolved at high temperature. Besides dissolving at high temperature, it was also freed from impurities by filtration of the solution.

The prepared dye solution and pre-mordanting cotton fabric samples were treated in a glass beaker with the help of a glass baguette for 10 minutes. Then, soda was added to the dye solution and mixed for 10 minutes. It was observed that the colour of the dye solution darkened after the addition of soda. The colour change of the dye solution after the addition of soda is given Figure 3.

It provides different additives such as soda used as alkali, colour brightener, pH adjustment of baths. The acidity or alkalinity of the water causes the colour to change. The soda used also makes the baths more alkaline and provides a colour change feature. Soda, which is used as alkali, increases the effectiveness of the mordant material used as a fixator and can cause the colours to change significantly [30-32]. Opoku-Asare et al. they stated that there were serious differences in the colors obtained in dyeing with soda ash [26].

Figure 3. Colour change of dye solution after soda addition

In order to see the effect of soda on colour change, a dark colour green dyeing study was carried out. The visuals of the work done are given in Figure 4. In this study, rinsing and dyeing processes were carried out after the mordanting process. Sample 1 was dyed using only green dyes.

Sample 2 was dyed with a solution containing green dyes and dispersant. Sample 3 was dyed with a solution containing dyes, dispersant and soda.

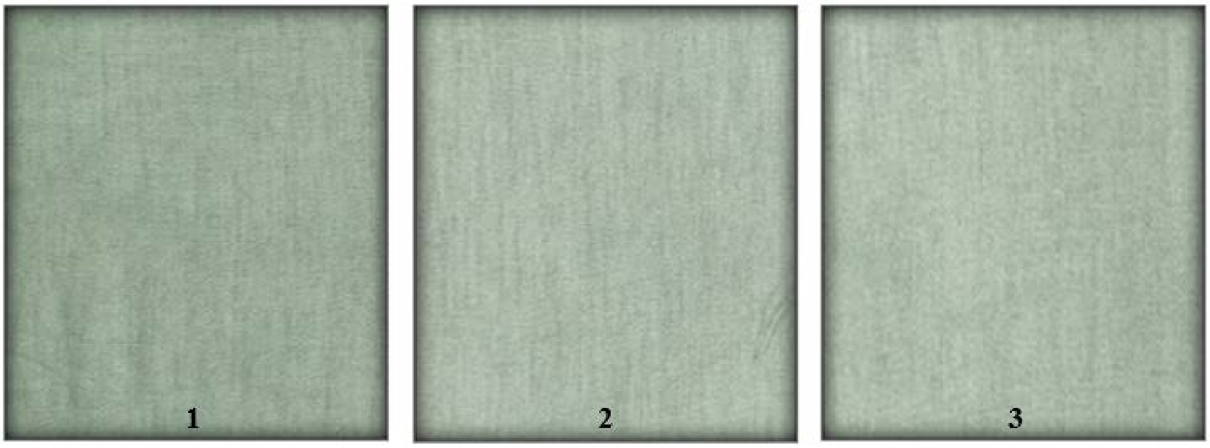


Figure 4. Colour comparison of fabric samples

Colour comparison measurements of fabric samples were performed in spectrophotometer. As a standard, fabric no. 1 containing only dye was taken as a reference. When examined under daylight, the effect of soda and dispersant chemicals on the colour change can be clearly seen. The total standard deviation values between fabric samples are given in Table 7.

Table 7. Colour comparison measurements

Standard Fabric Sample (Fabric Sample 1)	**Fabric Sample 2**	**Fabric Sample 3**
Total Chromatic Aberration $\Delta E^* \leq 1$ D65 – 10° Source of light	2,22	1,14

It was determined that cotton fabrics dyed with DB1 natural dyes at different concentrations were dyes homogeneously and the colour tones were different as expected. Images of cotton fabrics dyed with DB1 natural dyes are given Figure 5. In the DB1 dyeing studies, it was observed that the solution of the dyes deteriorated in a short time. The visual at the dye solution kept for 3 days in shown Figure 6.

Figure 5. Cotton fabrics dyed with DB1 natural dyes

In the studies, it was observed that the prepared dye solution could not last for a long time under ambient conditions and deteriorated. It is foreseen that the dye solution will be prepared and used on the same day when dyeing will be done under operating conditions. It occurred after the dissolution of the mold/fungus dyes in the dye solution in Figure 6.

Figure 6. Dye solution left for 3 days

Since the commercial natural dyes used are 90% biodegradable, they may have decomposed and formed a food source, but in the last drying step of the dyeing processes, in the fabrics that were dried at 120 °C for 3 minutes, the natural dyes would not decompose and form a food source, so there was no mold/formation on the dyed fabric. There is no fungal growth. After the prepared paint solution was filtered, it was left to dry on the edge, and after a long time, when the environment where the paint was observed, no mold/fungus was formed. This observation showed that there was no situation that would cause any disadvantage in the fabric after drying.

The advantages such as being obtained from edible sources, being compatible with nature and easily degradable, protection from UV rays, antibacterial properties make natural dyes attractive [23]. In the literature, the easy degradability and antibacterial properties of natural dyes were mentioned, and the natural dyes used in the study created a food source based on their degradability in aqueous environments, but no mold/fungus growth was predicted because there was no aqueous phase left on the fabric at high temperatures after the application. Optimization studies were carried out on the HT sample dyeing machine, taking into account the results obtained after the dyeing studies in the glass beaker.

3.2 Results of optimization study on HT dyeing machine

In HT tube dyeing process steps, 1/10 liquor was applied to all tubes each step. 5g cotton fabric samples were cut as standard and placed in tubes and the studies were carried out by adding solutions.

3.2.1 Dyeing

With the process steps given in Table 3, sample 1 at 25 °C for 30 minutes, sample 2 at 25 °C for 60 minutes, sample 3 at 60 °C for 30 minutes and sample 4 at 60 °C dyed for 60 minutes.

In the dyeing study, it was observed that the fabrics dyes at 60 °C for 60 minutes had a slightly darker colour. However, it was decided that the dyeing process step at 60 °C for 30 minutes was more appropriate in terms of energy and time savings. In addition, it has been determined that the VD1 and soda chemicals added in repeated dyeing should be dosed slowly based on the dyeing defect that occur. The effect of time and temperature on fabrics with 3% DB1 dyeing is given in Figure 7.

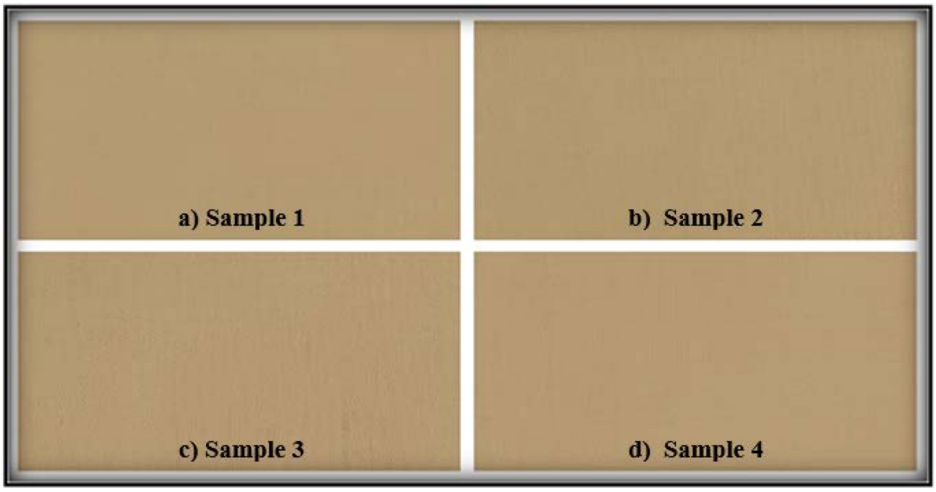


Figure 7. The effect of time and temperature on 3% DB1 dyed fabrics

3.2.2. Colour darkening

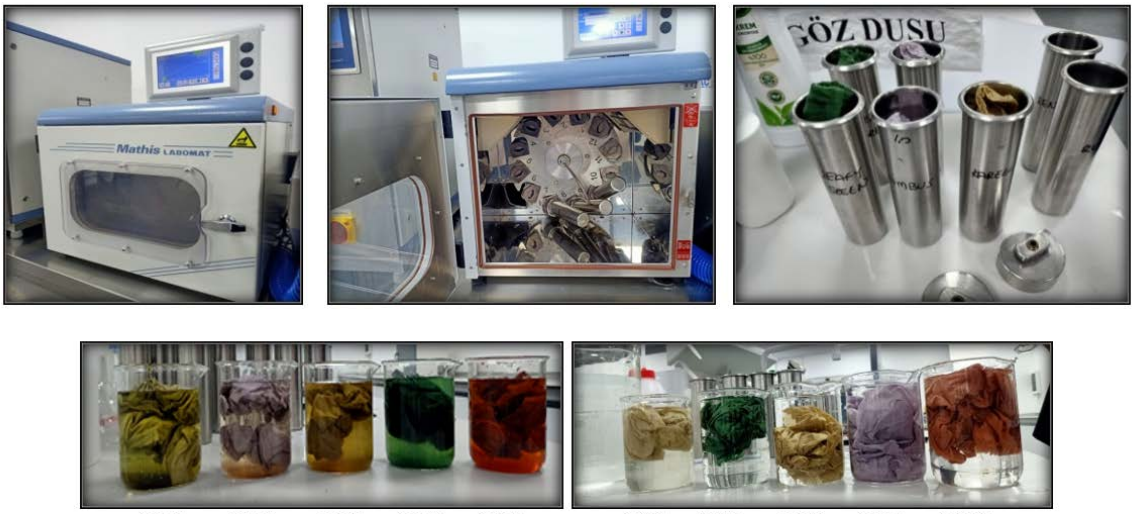
After the 3% DB1 dyeing process, the 5th sample and 6th sample fabrics were thickened. Homogeneous dyeing was achieved in the studies, but it was determined that in the studies where VD and VDB were used, barre caused by chemicals were formed, so VD and VDB additions should be given slowly and in dosage. It was observed that the fabrics applied with a thickening agent for 60 minutes had a slightly darker colour. However, it was deemed appropriate to carry out the thickening process step for 30 minutes in terms of energy and time saving. The effect of the thickening process on fabrics with 3% DB1 dyeing is given in Figure 8.

Figure 8. The effect of the thickening process on 3% DB1 dyed fabrics

The results obtained from the pre-testing and optimization studies are given below;

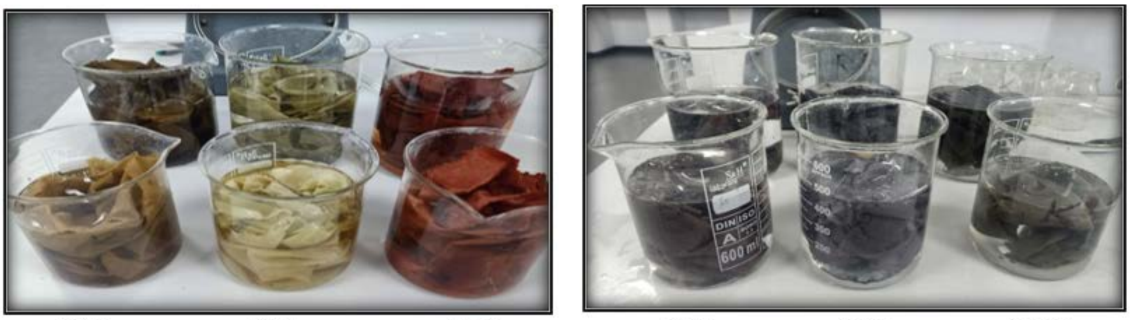
- In the studies, it was determined that the dye solutions to be prepared should be mixed for 30 minutes in a magnetic stirrer at 80 °C and filtered just in case, to be ready for use.
- It has been determined that especially chemical additions should be done by gradually dosing in order to prevent dyeing defect in the dyeing process step.
- It was observed that the solution of the prepared DB1 natural dyes deteriorated in a short time. Therefore, it has been seen that it would be healthy to prepare and use the natural dyes solutions on the same day.
- It was decided that performing the dyeing process step 60 °C for 30 minutes would be more appropriate in terms of energy and time saving.
- It has been decided that the thickening process step for 30 minutes is more appropriate in terms of energy and time saving.
- It has been determined that continuing the process until the water becomes clear, especially in the dyeing process step and then in the rinsing process, prevents dyeing defects and has a positive effect on fastness results.
- The main task of the VUP chemical is UV absorbency and it is a substance that increased the light fastness of the fabric. However, partial changes in colour were observed after the application with VUP, which has a blue colour.

The images of the HT tube dyeing step are given in Figure 9. The images of the final rinse after the dyeing and thickening step are given in Figure 10.



DB1 DB4 DB3 DB5 DB2 DB1 DB5 DB3 DB4 DB2

Figure 9. HT tube dyeing machine and first and last rinses after dyeing step



DB3 DB1 DB2 DB2 DB1 DB3

Figure 10. Final rinse after dyeing and thickening step

The colours obtained after HT tube dyeing with optimum parameters and the colour chart of cotton fabrics are given in Table 8. After dyeing, colours in light, medium and dark tones were obtained.

Washing fastness, water fastness, acid sweat fastness, alkali sweat fastness and rubbing fastness tests were performed on cotton fabric samples dyed with natural dyes and applied thickening process, and their fastness properties were evaluated.

The wet and dry rubbing fastness test results on cotton fabrics dyed with natural dyes are given in Table 9. According to the washing and rubbing fastness test results on cotton fabric samples, it was determined that the wet rubbing values of the fabrics dyed with DB5 dyes were at medium levels (3) and lower than the other dyeing. When the dyeing was evaluated in terms of age and rubbing fastness, it was determined that they were generally at good levels in the 4-5 range. It has been determined that dry rubbing fastness are better than wet rubbing fastness.

Table 8. Colours chart after HT tube dyeing

	DB1	DB2	DB3	DB4	DB5
1% Dyeing					
1% Dyeing + Thickening					
3% Dyeing					
3% Dyeing + Thickening					

Table 9. Wet and dry to rubbing fastness test results

	Wet Fastness to Rubbing	Dry Fastness to Rubbing
1% DB1	4-5	4-5
1% DB1 + Thickening	4-5	4-5
3% DB1	4-5	4-5
3% DB1 + Thickening	4	4-5
1% DB2	4-5	4-5
1% DB2 + Thickening	4-5	4-5
3% DB2	3-4	4-5
3% DB2 + Thickening	3-4	4-5
1% DB3	4	4-5
1% DB3 + Thickening	4	4-5
3% DB3	3-4	4-5
3% DB3 + Thickening	4	4-5
1% DB4	4-5	4-5
3% DB4	4	4-5
1% DB5	3	3-4
3% DB5	3	4

Textiles are subjected to multiple washing processes due to their wide usage areas and frequent use. Therefore, it is important to preserve textile fastness properties. When the dyeing made with natural dyes are evaluated in terms of washing fastness, water fastness, acid and alkali sweat fastness, it has been determined that they are generally at good levels in the 4-5 range. Washing fastness test results are given in Table 10. Water fastness test results are given in Table 11. Acid sweat fastness test results are given in Table 12. Alkali sweat fastness test results are given in Table 13. When the tables given below are examined, it is seen that the thickening process partially reduces the fastness properties in general.

Table 10. Fastness to washing test results

	Fastness to Washing					
	Wool	**Acrylic**	**Polyester**	**Polyamide**	**Cotton**	**Acetate**
1% DB1	4-5	5	5	5	5	5
1% DB1 + Thickening	4-5	5	4-5	4-5	4-5	5
3% DB1	4-5	5	5	5	5	5
3% DB1 + Thickening	5	5	4-5	4-5	4-5	5
1% DB2	4-5	5	5	5	5	5
1% DB2 + Thickening	5	5	4-5	4-5	4-5	5
3% DB2	5	5	5	5	5	5
3% DB2 + Thickening	5	5	4-5	4-5	4-5	5
1% DB3	4-5	5	5	5	5	5
1% DB3 + Thickening	4-5	5	4-5	4-5	4-5	5
3% DB3	5	5	5	5	5	5
3% DB3 + Thickening	5	5	4-5	4-5	4-5	5
1% DB4	5	5	5	5	5	5
3% DB4	5	5	5	5	5	5
1% DB5	5	5	5	4-5	4-5	5
3% DB5	4-5	5	5	4-5	4	5

Table 11. Fastness to water test results

	Fastness to Water					
	Wool	**Acrylic**	**Polyester**	**Polyamide**	**Cotton**	**Acetate**
1% DB1	5	5	5	5	5	5
1% DB1 + Thickening	4-5	5	5	4-5	4-5	5
3% DB1	5	5	5	5	4-5	5
3% DB1 + Thickening	5	5	5	4-5	4-5	5
1% DB2	4-5	5	5	5	4-5	5
1% DB2 + Thickening	4-5	5	4-5	4-5	4-5	5
3% DB2	4-5	5	4-5	5	4	5
3% DB2 + Thickening	4-5	5	5	4-5	4-5	5
1% DB3	5	5	5	5	4-5	5
1% DB3 + Thickening	4-5	5	4-5	4-5	4-5	5
3% DB3	4-5	5	5	5	4-5	5
3% DB3 + Thickening	5	5	4-5	4-5	4-5	5
1% DB4	4-5	5	4-5	5	4-5	5
3% DB4	4-5	4-5	5	5	4-5	5
1% DB5	4-5	5	5	5	5	5
3% DB5	4-5	5	5	5	5	5

Table 12. Fastness to acid sweat test results

	Fastness to Acid Sweat					
	Wool	**Acrylic**	**Polyester**	**polyamide**	**Cotton**	**Acetate**
1% DB1	5	5	5	5	5	5
1% DB1 + Thickening	4-5	5	5	4-5	4-5	5
3% DB1	5	5	5	5	4-5	5
3% DB1 + Thickening	5	5	5	4-5	4-5	5
1% DB2	4-5	5	5	5	4-5	5
1% DB2 + Thickening	4-5	5	4-5	4-5	4-5	5
3% DB2	4-5	5	4-5	5	4	5
3% DB2 + Thickening	4-5	5	5	4-5	4-5	5
1% DB3	5	5	5	5	4-5	5
1% DB3 + Thickening	4-5	5	4-5	4-5	4-5	5
3% DB3	4-5	5	5	5	4-5	5
3% DB3 + Thickening	5	5	4-5	4-5	4-5	5
1% DB4	4-5	5	4-5	5	4-5	5
3% DB4	4-5	4-5	5	5	4-5	5
1% DB5	4-5	5	5	5	5	5
3% DB5	4-5	5	5	5	5	5

Table 13. Fastness to alkaline sweat test results

	Fastness to Alkaline Sweat					
	Wool	**Acrylic**	**Polyester**	**polyamide**	**Cotton**	**Acetate**
1% DB1	5	5	5	5	5	5
1% DB1 + Thickening	4-5	5	5	4-5	4-5	5
3% DB1	5	5	5	5	4-5	5
3% DB1 + Thickening	5	5	5	4-5	4-5	5
1% DB2	4-5	5	5	5	4-5	5
1% DB2 + Thickening	4-5	5	5	4-5	4-5	5
3% DB2	4-5	5	4-5	5	4	5
3% DB2 + Thickening	4-5	5	5	4-5	4-5	5
1% DB3	5	5	5	5	4-5	5
1% DB3 + Thickening	4-5	5	4-5	4-5	4-5	5
3% DB3	4-5	5	5	5	4-5	5
3% DB3 + Thickening	5	5	4-5	4-5	4-5	5
1% DB4	4-5	5	4-5	5	4-5	5
3% DB4	4-5	4-5	5	5	4-5	5
1% DB5	4-5	5	5	5	5	5
3% DB5	4-5	5	5	5	5	5

IV. CONCLUSIONS

When the natural dyes obtained from natural sources are compared with the synthetic dyes, it is seen that their production and use are at very low levels due to the fact that the natural dye sources and dyes contents are very low and the dyeing are mostly in light colour tones [29]. Although natural dyes are much more costly than synthetic dyes and despite these disadvantages, marketing of textiles dye with value-added natural dyes in targeted markets can provide sustainability in both environmental and economic terms. As in many sectors the development of sustainable processes in the textile sector is aimed at both economical and environmentally friendly productions. It has been determined that different colours and tonnages can be obtained from the same natural dye with the natural dyeing studies and the fastness results are at acceptable values. The results obtained showed that the fastness of natural dyes were in accordance with the acceptance criteria. These;

- The prepared aqueous solution of natural dyes should be mixed at high temperatures and dispersed homogeneously by filtering.
- Since the prepared aqueous solution of natural dyes can deteriorate in a short time, it should be prepared and used within the same day.
- In order to prevent dyeing defects, chemicals such as soda, which affect the colour tone, should be dosed slowly.
- Since chemicals such as VUP, which is added as an auxiliary chemical and has a blue colour, may affect the colour tone, its use should be considered.
- It was determined that the dye solution foamed during the preparation of some natural dyes. The possibility that this foaming may cause dyeing failure should be considered.

In this study, dyeing was done at 1% and 3% concentrations. In future studies, it is aimed to prevent dyeing defect, especially in dark colours, by dyeing experiments at lower concentrations, and to reduce costs by reducing the amount of dye used. In this way, the amount of waste dyes will be reduced and the market will be addressed by obtaining softer colours preferred by customers as a result of market researches.

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