



SUSTAINABLE DYEING OF WOOL FABRICS WITH A BIO-WASTE PISTACHIO TREE (*PISTACIA VERA L.*) BRANCH

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Hüseyin Benli

Mustafa Çikrikçioğlu Vocational School, Department of Chemistry and Chemical Processing Technologies, Kayseri University, 38280, Kayseri, Turkey
hbenli@kayseri.edu.tr, ORCID 0000-0002-0510-6061

ABSTRACT: *The issue of waste management is one of the most important issues both today and in the future. Therefore, lots of scholars are endeavoring to add to the economy substances such as paper, glass, and vegetable waste. In this study, the pistachio tree (*Pistacia vera L.*) branch was used for the first time as a bio waste material as a natural dye source for coloring textile material. For this purpose, waste pistachio branches were collected from Gaziantep province in the south of Türkiye. And then, the dried and grinded branches of pistachio were used for the dyeing of textiles. Dyeing was started at room temperature. The simultaneous-mordanting method was used. The method was performed at a materials-to-liquor ratio of 1:40 for one hour at 100°C. And then it was cooled, washed with soap (1 g/L non-ionic surfactant), and then dried at room temperature. Alum ($KAl(SO_4)_2 \cdot 12H_2O$) and iron sulfate ($FeSO_4 \cdot 7H_2O$), which are environmentally friendly, were used as metal salts to increase the efficiency of the dyeing process. The CIE $L^*a^*b^*$ values and K/S values of the dyed fabrics were measured using a spectrophotometer. In addition, washing, perspiration, and rubbing fastness tests were applied to colored fabrics. The results show that fabrics can be colored with sufficient fastness using pistachio tree branches.*

Keywords: *Pistachio tree branch, textile, natural dyes, bio-waste, eco-friendly, sustainability.*

ODRŽIVO BOJANJE VUNENIH TKANINA SA BIO-OTPADNOM DRVO PISTAĆA (*PISTACIA VERA L.*)

APSTRAKT: *Pitanje upravljanja otpadom jedno je od najvažnijih pitanja kako danas tako i u budućnosti. Zbog toga mnogi naučnici nastoje da u ekonomiju dodaju supstance kao što su papir, staklo i otpad od povrća. U ovoj studiji, grana stabla pistacije (*Pistacia vera L.*) je prvi put korišćena kao biootpadni materijal kao prirodni izvor boje za bojenje tekstilnog materijala. U tu svrhu prikupljene su otpadne grane pistacija iz provincije Gaziantep na jugu Turske. Zatim su osušene i samlevene grane pistacija korišćene za farbanje tekstila. Bojenje je počelo na sobnoj temperaturi. Korišćen je metod simultanog mordiranja. Metoda je izvedena u odnosu materijala prema tečnosti od 1:40 tokom jednog*

sata na 100°C. Zatim je ohlađena, isprana sapunom (1 g/L nejonskog surfaktanta), a zatim osušena na sobnoj temperaturi. Kao soli metala za povećanje efikasnosti procesa bojenja korišćeni su stipsa ($KAl(SO_4)_2 \cdot 12H_2O$) i gvožđe sulfat ($FeSO_4 \cdot 7H_2O$), koji su ekološki prihvatljivi. Vrednosti CIE $L^*a^*b^*$ i K/S vrednosti obojenih tkanina merene su pomoću spektrofotometra. Pored toga, testovi postojanosti pranja, znojenja i trljanja primenjeni su na obojene tkanine. Rezultati pokazuju da se tkanine mogu bojati dovoljno postojano korišćenjem grana drveta pistacija.

Ključne reči: grana pistacija, tekstil, prirodne boje, biootpad, ekološki prihvatljiv, održivost.

1. INTRODUCTION

These days, eco-friendly products are critical to both commercial and academic study. Green products and production processes, as well as techniques to lessen pollution in the environment, are the focus of intense efforts. In this regard, the topic of agricultural wastes and their valuation is among the most fascinating recent developments. It is well known that a large amount of agricultural waste is created daily to meet the growing demands of the fast growing population [1]. By-products of the production and processing of agricultural goods, agricultural wastes may contain components that are valuable to humans. Pistachio tree (*Pistacia vera* L.) waste can be an important industrial and agricultural waste. The tree, also known as the cashew family, is widely planted throughout the Mediterranean region and is native to the arid regions of Central and West Asia [2]. Commercial pistachio cultivation occurs in the USA, Türkiye, Iran, Iraq, Italy, Tunisia, and other nations [3]. Hosseinzaei et al. (2022)[4] report that the production of pistachios reached a peak of 1.1 million tons worldwide in 2020. In previous studies, shells, a waste of pistachios, have been used to color woven cotton fabrics [5] and carpet yarns [6], as well as as a bio-mordant [7-8]. Unlike other studies, in this study, pistachio tree branches were used as a dye source to color woolen fabrics. Türkiye is one of the world's leading producers of pistachios, and this modern agricultural cultivation can leave behind a sizable amount of waste. Concurrently, one of Türkiye's most significant industrial sectors is the textile industry. Using the information collected as a result of this study, it is expected to suggest a different source of natural dyestuffs to dyehouses across the country and to show how their wastes can be a useful resource for companies that grow pistachios. The primary objectives of the study were to determine whether pistachio tree branches could be used as a source of color for textile products.

2. MATERIAL AND METHODS

2.1. Materials

A 150 g/m² 100% wool and 220 g/m² 100% cotton fabric that was ready for dyeing was used in this investigation. The pistachio tree's bio-waste branches (Figure 1) were used in

this investigation as a natural color source. All of the branches were dried and powdered before being dyed. All dyeing processes directly utilized this powdered form.

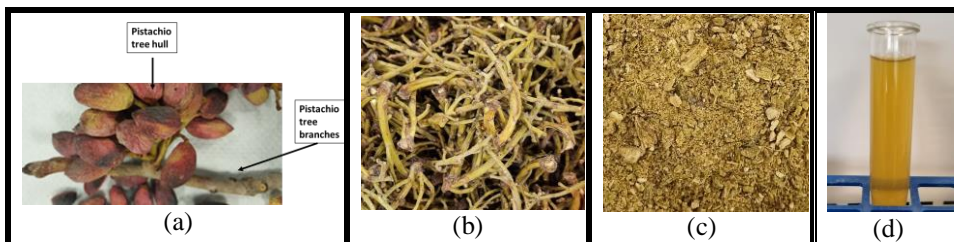


Figure 1: Pistachios (a), branches (b), ground form (c), and dye solution (d)

2.2. Mordanting & Dyeing Procedure

The kind and concentration of the mordant, as well as the coloring agent, are significant factors in natural dyeing studies. It is well known that employing a mordant and raising the dye concentration will intensify the colors produced. Various mordant substances were used in dyeing wool and cotton fabrics. For this, iron (II) sulfate and alum were used at concentrations of 3% and 30% (owf), respectively. In addition to metal salts, many different sources are also used as biomordants [9]. The dyeing process took place together with the mordanting process (simultaneously mordanting). All procedures in this research were performed for one hour at 100°C with a constant liquor ratio of 1:40.

2.3. Evaluation of colors and fastness

Using a Konica Minolta 3600d spectrophotometer, color strength (K/S) and CIE $L^*a^*b^*$ values of dyed wool and cotton materials were determined. Kubelka-Munk equation 1 was used to calculate the K/S values [10].

$$\frac{K}{S} = \frac{(1 - R)^2}{2R} \quad eq. (1)$$

where " R " is the highest color reflectance of the cloth, given as a decimal percentage. " K " stands for the absorption coefficient and " S " for the scattering coefficient. In addition, washing [11], rubbing [12], and perspiration [13] fastness tests were applied to dyed woolen and cotton fabrics. In the meantime, for visible region the VWR UV-3100PC spectrophotometer was used to evaluate the extracts.

3. RESULTS AND DISCUSSION

Pistachios are a major industrial agricultural crop, and Türkiye is one of the world's leading producers of pistachios for snacking. Despite the fact that wild pistachio trees can be found almost anywhere in Türkiye, the majority of these plants are located in the southeast [14]. Türkiye holds the top spot on the globe as of 2021, with 389.5 thousand hectares of land used for pistachio harvesting. Plant waste may include a considerable amount of tree branches and the hard and soft shells of pistachios as a result of this enormous production,

processing, and consumption. In our previous study, the hard and soft shells of pistachios were used as a dye source [5].

In this study, pistachio tree branches were used as a dye source for the first time. In the study, two different environmentally friendly metal salt and mordant-free dyeing processes were carried out, and the color photos obtained from these studies are presented in Table 1. The colors of wool and cotton dyed without mordant are pink and have light ecru tones. The color strengths (K/S) in the no-mordanting technique were discovered to be excessively low, indicating inadequate dyeing in the absence of any mordant. In the dyeing made with tree branches, a color strength of 2.13 for wool and 0.34 for cotton was determined. Although the lightness values for wool and cotton were determined to be 75.2 and 81.5, respectively, both samples were too light. The a^* (1.56) and b^* (1.6) values as well as sample images showed variations in color. However, the application of mordants resulted in modest color alterations. In addition, it was found that when alum salt was used, both wool and cotton were dyed in yellow hues. When iron salt was used, the color tones were quite dark, with wool dyed gray and cotton dyed blue. When wool was used with alum, the a^* value measured from the sample dyed without using any mordant changed from 1.56 to -3.1. When cotton was used with alum, the a^* value measured from the sample dyed without using any mordant changed from 1.6 to -3.1. When wool was used with iron (II) sulfate, the a^* value measured from the sample dyed without using any mordant changed from 1.56 to 2.2. When cotton was used with iron (II) sulfate, the a^* value measured from the sample dyed without using any mordant changed from 1.6 to 2.2. The color obtained from wool dyeing using alum mordant is clearly yellow (b^* : 32.2). A distinct blue hue was obtained in cotton dyeing using iron salt (FeSO_4). The hue angle (h° : 323) clearly shows this. The highest L^* values in both wool and cotton dyeing were obtained from experiments with Fe-based mordants and were determined to be 50 and 58.5, respectively. No significant relationship was found between mordant changes in terms of color tone.

Table 1: Photographs of dyed samples and color values

Fabric type	Mordant type	Dyed samples	Color Values					
			K/S	L^*	a^*	b^*	C^*	h°
Wool	Unmordanted		2.13	75,2	1,56	19,1	19,1	85
	$KAl(SO_4)_2 \cdot 12H_2O$		1.79	80.9	-3.1	32.2	32.3	96
	$FeSO_4 \cdot 7H_2O$		2.94	50	2.2	5.8	6.1	69
Cotton	Unmordanted		0.34	81.5	1.6	7	7	77
	$KAl(SO_4)_2 \cdot 12H_2O$		0.44	86.2	-3.1	19.4	19.7	99
	$FeSO_4 \cdot 7H_2O$		0.98	58.5	2.2	-1.7	2.8	323



Some color fastness tests were performed on dyed wool and cotton fabrics. In general, the results of all fastness tests were obtained in the range of 4-5 points, and it can be stated that the results are very good. However, it was also determined that the fastness values of fabrics dyed without mordant were half a point lower. In general, wet rubbing fastness values were half a point lower among themselves.

Table 2: Color fastness test results of dyed fabrics

Fabric type	Mordant type	Washing Fastness		Rubbing Fastness		Perspiration Fastness			
		Sta.	C.C.	Dry	Wet	Acidic		Alkaline	
						Sta.	C.C.	Sta.	C.C.
Wool	Unmordanted	4/5	4/5	4/5	4	4/5	5	4/5	5
	$KAl(SO_4)_2 \cdot 12H_2O$	5	5	5	4/5	4/5	5	5	5
	$FeSO_4 \cdot 7H_2O$	4	4/5	4/5	4	4	4	4/5	4
Cotton	Unmordanted	4/5	4/5	4/5	4	4/5	5	4/5	5
	$KAl(SO_4)_2 \cdot 12H_2O$	5	5	5	4/5	4/5	5	5	5
	$FeSO_4 \cdot 7H_2O$	4	4/5	4/5	4	4	4	4/5	4

Sta.: Staining of wool; C.C.: Color Change

The dye source was evaluated in terms of the visible region. Following dilution, the absorbance curve depicted in Figure 2 was produced, and no notable peak was found within the range of the visible region. As shown in Figure 1 (d), the color of the blind dye bath obtained from the branches is beige. This solution dyes wool and cotton in different colors with different mordant substances. The absorbance curve of the solution obtained at a certain dilution ratio is shown in Figure 2, and no notable peak was observed in the visible region in the range of 400–700 nm.

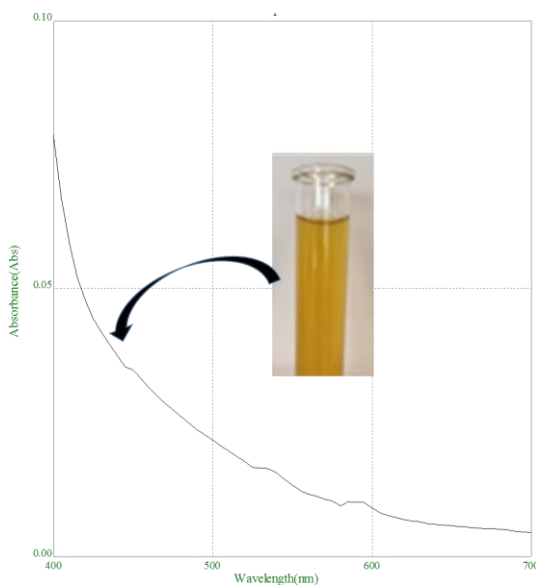


Figure 2: Absorbance curve of the Pistachio tree branch extract after 1:50 dilution

The idea of recycling waste should work toward encouraging a sustainable way of living in the future, not just because it helps the environment but also because it creates new jobs, sources of income, and technological advancements. Crop leftovers, including leaves, maize stovers, rice, wheat, oats, barley straws, and seed pods, are among the wastes generated in agricultural areas. Crop wastes have historically been utilized to create paper, matchsticks, compost, animal feed, roof thatch, and fuel [1]. However, there are currently a number of additional uses that can be mentioned.

4. CONCLUSION

The one discussed in this study uses waste materials to naturally dye cotton and wool. Pistachio tree (*Pistacia vera* L.) branches were used to dye cotton and wool for this purpose. The branches were employed in dye baths without first going through an extraction procedure during this procedure. The outcomes thus show how these wastes could be used to dye cotton and wool. In the meantime, various color shifts were noticed, depending on the type of mordanting and the mordanting chemical utilized. The results showed that the fastness values for the washing, rubbing, and perspiration fastnesses were good to ideal. A few minor variations were noted based on the dyeing parameters, but no systematic impact of these parameters was noted. Further investigation into the application of various solvents and/or extraction techniques to improve *K/S* would be intriguing. It is believed that the application of these wastes in the coloring of various fibers may be intriguing for future research, and concurrently, the potential application of these wastes in the functionalization of textiles may also be a worthwhile area of study.



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