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NATURAL DYEING OF BULDAN HANDWOVEN FABRICS WITH PLANT SHELL EXTRACTS: A STEP TOWARDS SUSTAINABLE TEXTILE

Derya TATMAN, Technical High school of Servergazi BIST, Turkey, deryatatman@gmail.com
(0000-0001-8498-2512)

Gizem KARAKAN GÜNAYDIN*, Pamukkale University /Buldan Vocational School,Fashion and Design Programme, Turkey , ggunaydin@pau.edu.tr
(0000-0001-9164-3391)

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*Corresponding author
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Abstract

Sustainable textile production has become widespread among the world due to high consumption of energy and water in the conventional textile methods. Traditional handwoven Buldan fabrics may be one of the alternatives as sustainable textile products which may be also naturally colored with the environmentally friendly natural dye sources. This study has been performed to reveal that handwoven naturally colored Buldan fabrics with different plant extracts such as walnut, acorn shell and onion skin may provide satisfying tensile and fastness properties. According to the test results; The fabric tenacity results indicated that a prominent deterioration was not observed with the natural dyeing process among the fabric samples. Tear strength results varied regarding to the fabrics' raw material but did not vary significantly according to applied natural dye extract. A slight decrement for washing, water and perspiration fastness results was observed when the undyed samples were compared with their dyed counterparts. Samples dyed with onion skins generally revealed lower washing, water and perspiration fastness results compared to those dyed with walnut and acorn shell for each fabric type. Dry rubbing fastness results were more satisfying than wet rubbing fastness results.

Keywords: Sustainable textiles, natural dyeing, fastness properties, Buldan woven fabrics

BULDAN KUMAŞLARININ BİTKİ KABUĞU EKSTRAKTLARI İLE BOYANMASI: SÜRDÜRÜLEBİLİR TEKSTİLE DOĞRU BİR ADIM

Özet

Geleneksel tekstil terbiyesinde yüksek enerji ve su tüketiminden dolayı daha az su ve enerji kullanarak tekstil üretimi yapmak sürdürülebilirlik açısından önemli hale gelmiştir. Sürdürülebilir tekstil ürünlerine örnek olabilecek geleneksel Buldan el dokuma kumaşları çevre dostu olduğu düşünülen doğal boya kaynakları ile boyanabilmektedir. Bu çalışma ceviz kabuğu, meşe palamudu kabuğu ve soğan kabuğu özü gibi bitki ekstraktları ile boyanan Buldan el dokuması kumaşlarının tatmin edici düzeyde mukavemet ve haslık özelliği gösterebileceğini aktarmak için gerçekleştirilmiştir. Test sonuçlarına göre, doğal boyama işlemi ile kumaşlarda mukavemet kaybı gözlenmemiştir. Yırtılma mukavemet değerleri kumaş hammaddesine göre farklılık göstermiş ancak kullanılan doğal boyar madde türüne göre belirgin olarak değişim göstermemiştir. Boyanmamış kumaşlar boyanmış karşılıkları ile kıyaslandığında yıkama, su ve ter haslıklarında az da olsa düşüş kaydedilmiştir. Soğan kabuğu ile boyanmış kumaşların ceviz ve meşe palamudu kabuğu ile boyananlara göre daha düşük yıkama, su ve ter haslığı gösterdiği belirlenmiştir. Kuru sürtme haslık değerleri yaş sürtme haslık değerlerine göre daha memnun edici bulunmuştur.

Anahtar Kelimeler: Sürdürülebilir tekstiller,doğal boyama, haslık özellikleri, Buldan dokumaları

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1. Introduction

Textile has always been as one of the main income source of Turkish economy with its main production areas such as İstanbul, Bursa, Çorlu, Denizli etc. Buldan, "town of Denizli" which is famous for its handwoven products is located in the northwest of Denizli city centre. Textile history of Buldan dates back to ancient times, to the B.C. in the 6th centuries. Anatolian Seljuk State ruled this region in 1215. They combined the local weaving culture with their own weaving techniques. Weaving is the most important source of livelihood in the region both in the past and today. The weaving with primitive hand looms continued until 1779 and after that the looms woven with the yarn count between Ne 10/1 and Ne 20/1 were utilized. The motorized looms began to be utilized from since 1952 in the town in addition to the handlooms. It is known from the literature source of town's chamber of commerce (BTO, Buldan Chamber of Commerce) that most important income source in the town is still provided from textile hand weaving. Buldan handwoven products may be accepted as sustainable textile products where human power is required instead of electrical energy [1-4].

It is possible to summarize sustainability as ensuring the continuity of today's resources and quality of life, diversity, and productivity, without endangering the continuity of future generations. Sustainability principles, which are based on three pillars, environmentally, socially, and economically, are considered as a whole. In addition, it is necessary to increase awareness of not only a segment of the society but also each individual. Textile industry is one of the important contributors for threatening the environment with production of 60 billion kilogram of fabric annually and utilizing up to 9 trillion gallons of water [5,6]. Sustainability has been considered also in textile production as in all sectors due to increase of environmental pollution. There are large amounts of utilized chemicals, water and energy in textile processes. New sustainable methods should come forward more. Today in the famous textile brands, consumers are encouraged to buy sustainable clothes where their raw materials are recycled or all production processes are performed with a sustainable manner. The use of natural fibers, recycled fibers, the sustainable pre-treatment and dyeing methods in the textile industry makes great contributions to the sustainability issue in textiles [7-15].

During coloration, large amount of unfixed dyestuff is released into water sources. Additionally, as the number of synthetic dyes used in textile sector has increased, effluent ratio in the environment sourcing from textile dyeing process has also displayed an upward trend. In the 1980s, natural dyeing gained importance with the determination that most of the synthetic dyes are toxic, carcinogenic and cause environmental pollution [16]. Another reason for natural dyeing to be put forward was their becoming biodegradable and compatible with the environment. Natural dyes are the colorants provided from various natural sources such as vegetables, animals and minerals. Since the vegetables offer more color choice they are more widely preferred. Roots, leaves, bark and fruit of plants may be used for coloring leather, textile materials. Especially wastes from agriculture, food, medicine, forest food enterprises can also be recycled as natural dyes. Although there are some lack of fastness and durability, natural dyeing may provide a sustainable alternative to conventional dyes. The advantage of natural dyes may be sorted as: Production of soft, lustrous and rare colours, extraction from renewable sources, biodegradability, ease of disposal, reduced carbon emissions, lack of environmental threats. However, beside all these advantages, less availability, low color yield, inadequate fixation, necessity of mordants may be listed as the limitations of natural dyes [17-24]. The shells of the natural dyes utilized within our study can also be thrown away to the nature without giving any damage to the environment.

Buldan fabrics may be naturally colored with extracts of natural sources such as walnut, acorn, onion, pomegranate peel etc. which are cultivated in the large farming areas of the town. In this respect, Buldan fabrics are even more advantageous in terms of sustainability. The literature revealing that natural extracts from plants may be utilized for coloring woven fabrics with high fastness and emphasizes a possible contribution to the issue of sustainability. Sharma and Grover (2011) conducted a study related to dyeing of cotton yarns with walnut bark dye in order to evaluate the color fastness of dyed material against light, crocking, perspiration and washing. The authors concluded that walnut shell dye can be used for dyeing for cotton with sufficient fastness values [25]. Sarı and Akduman performed a study related to naturally coloring of Buldan fabrics with madder and walnut shells using different mordant. The authors declared that the natural extracts such as walnut shells may be used for coloring handmade woven fabrics where the color fastness results were satisfying [26]. Two different natural dye sources, heather (Calluna Vulgaris) and madder root were utilized in different combinations for obtaining naturally colored Buldan clothes with different color shades. The authors concluded that sufficient fastness properties could be achieved with the combination of

heather and madder natural dyes [27]. Eser et al. (2015) investigated the dyeability of wool fabrics with walnut leaves extract in the presence of various acids including acetic acid, citric acid, maleic acid, oxalic acid, and formic acid. The authors revealed that wool fabrics revealed satisfying color fastness properties when dyed with walnut extract in the presence of citric acid pre-treatment [28]. Ayele et al. made a research related to natural dyeing of cotton fabric with extracts from mango tree. Natural coloring agents were extracted using an aqueous extraction technique. The extracts were used for dyeing the cotton fabric followed by mordanting. The authors concluded that dyes extracted from various part of mango plant such as mango leaves, mango fruits could be an efficient coloring agent for cotton fabrics [29]. Deo and Desai performed a study related to dyeing of cotton and jute fabrics with aqueous extract of tea, containing tannins. It was observed that wash and light fastness of the dyed fabrics were good to excellent. The deep shades were also found satisfying [30]. Kulkarni et al. investigated cotton dyeing with natural dye extracted from Pomegranate (Punica granatum) peel. The fabrics dyed with pomegranate peel gave different shade of yellow, brown and black [31]. Sood et al. revealed that combination of litchi and apricot dye combination exhibit excellent color fastness to washing, crocking and light and good perspiration fastness [32]. Sankat and Siddique et al. studied dyeing of cotton fabric with the natural dye obtained from cultivated Poppy petals (Papaver orientale L.). Three different eco-friendly metallic mordants; alum [Al2 (SO4)3], CuSO4 and FeSO4 are used. The results for dyeing were very encouraging [33].

The present study focuses on the sustainable textile production and natural dyeing of handwoven Buldan fabrics with utilization of acorn, walnut shell and onion skin extracts. The purpose is also to increase the awareness of Buldan handwoven fabrics which are healthy, natural and reflect the cultural identity. It is also aimed that traditional handwoven Buldan fabrics may be colored with natural dye extracts enhancing the sufficient fastness and strength results.

2. Material and Method

2.1. Material

In order to present a sustainable alternative for the woven fabrics, Buldan handwoven fabrics were specially preferred as the materials to be evaluated for tearing strength, seam strength, fabric tenacity, and also to be evaluated for color fastness results. Buldan fabrics made of different raw materials were produced on a handloom as plain weave. %100 cotton, cotton blends of linen, cotton blends of viscose and polyester blends of linen staple yarns at yarn count of Ne 20/1 were selected as the warp-weft yarns of each woven sample. Combed yarn production line was utilized during the production of all staple yarns. The woven fabrics were exposed to desizing and soft washing processes but were not to exposed to bleaching before dyeing. Samples were dyed with 3 different natural dye sources where extracts of walnut shells, acorn shells and onion skins were used. The experimental design is summarized in table 1.

Table 1. Experimental Design

Fabric code	Fabric composition	warp density (thread/cm)	weft density (thread/cm)	Fabric weight (g/m^2)	Applied natural dye extract
PLU	%50 polyester %50 Linen	20	20	87	undyed
PLW				100	Walnut shell
PLA				103	Acorn shell
PLO				100	Onion skin
CLU	%50 cotton %50 Linen	25	20	92	undyed
CLW				105	Walnut shell
CLA				109	Acorn shell
CLO				103	Onion skin
CU	%100 cotton	25	15	113	undyed
CW				130	Walnut shell
CA				134	Acorn shell
CO				129	Onion skin
CVU	% 50 cotton %50 viscose	17	17	84	undyed
CVW				104	Walnut shell
CVA				100	Acorn shell
CVO				142	Onion skin

2.2. Method

Dyeing with natural dyestuff extracts

Walnut shells *(Juglons regia L.),* acorn shells (Quercus ithaburensis Decaisne) and onion skins *(Allium cepa L.)* were provided from high plateaus of Buldan. The natural dye sources preferred in the study are shell parts that were separated from the plants during harvest and cannot be used for food industry. It is declared in the literature that walnut shells have been used as an important dyestuff and an antimicrobial source since the ancient times. The plant includes "Juglon" substance as the colorant. Walnut is a direct or substantive dye, which means that no mordant is necessary when used for dyeing protein (animal) fibers or fabric. There are some tannins in the hull, but that is considered secondary to the strong juglone [34, 35].

Acorns are provided from Valonia oak. Acorns contains tannins as the colorant. Tannins can be removed by soaking chopped acorns in several changes of water, until the water no longer turns brown [36]. Onion skins are also rich in tannins. Tannins work similar to a mordant in the sense that they assist dyes to adhere to fibre, and may improve the strength and color-fastness of the dye [37]. Figure 1 indicates the image of three different natural materials utilized within the study.

The outer green shells of walnuts were separated during harvesting then dried in an open airy place where they were not exposed to any light. Acorn cones were separated during harvesting and dried in the same way with the walnut. The outer skins of the onions were also dried after harvesting. All plant shells were powdered by using electrical grinder. 100 grams of powdered materials were boiled for 60 minutes at 100°C by using 3 litre of water. Natural dyestuff solution was obtained after filtration. Dyeing liquor ratio was 1:20. The dyeing process for each fabric began at room temperature in the cauldrons and was increased by 3 °C/min up to the optimum dyeing temperature of 100°C and maintained at this temperature for 60 minutes. It was then reduced to 25°C, and the dyeing procedure was completed. The dyed samples were rinsed and conditioned for 24 hours. Table 2 indicates the undyed samples and samples dyed in accordance with the experiment plan.

Figure 1 Sources of natural materials utilized in the study (a: walnut shell, b: acorn shell, c: onion skins)

Table 2 Undyed (ecru variant) and dyed samples with natural extracts

	Cotton/ Cotton	Polyester/ Linen	Cotton/ Viscose	Linen/ Cotton
Undyed fabric				
Acorn				
Walnut shell				
Onion skin				

Fabric Tenacity, Tear Strength, Seam Strength and Fastness Properties

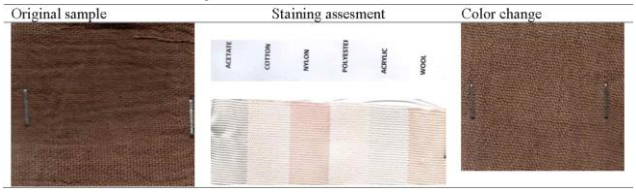
Today, some modern comfortable clothes such as dresses, shirts, blouses, peshtemals may be produced from Buldan woven fabrics. Hence the naturally colored Buldan samples were considered to be evaluated in terms of some mechanical and color fastness properties.

Prior to fabric tenacity, tear strength, seam strength and fastness properties tests including rubbing, perspiration, washing and water fastness; All fabrics were conditioned for 24 hours in standard atmospheric conditions. To examine the potential changes in the tensile properties of the Buldan fabric samples, fabric tenacity test was conducted in warp and weft direction by using Titan Universal Testing Machine according to ISO13934-1 standard. [38]. Tear strength was considered as an important parameter for the naturally colored fabrics since those fabrics may be used for daily wear such as shirting fabrics. A tearing area called “del zone” is generated as a result of the applied load and the sequential breakage of yarn groups along the fabric sample [39,40]. Tear strength results of the 16 different fabric samples were provided by means of Prowhite Elmendorf test device. Dynamic tear strength tests for the warp and weft wise were performed according to ISO 13937-1:2000-Textiles-Tear properties of fabrics - Part 1: Determination of tear force using ballistic pendulum method (Elmendorf) standard (ISO 13937-1, 2000) [41]. Seam slippage strength is a kind of failure results from a yarn movement at either side of the seam creating a gap. The displacement of the yarns in fabric forms an opening in the fabric [16]. Rectangular specimens of 350 mm length and 100 mm width were prepared. 5 specimens (350*100) with their long sides

parallel to the weft of the fabric for determining warp slippage and with their long sides parallel to the warp of the fabric for determining the weft slippage according to ISO 13936-1: 2004 test standard by using Testometric 5 kN device. The two force elongation curves were obtained from the unsewn and sewn sample and the force required to open the seam opening distance (3 mm) was determined by using the horizontal separation between the curves [42-44].

The color fastness tests were evaluated in terms of washing fastness, water fastness, rubbing fastness, perspiration fastness. James Heal's Color Fastness Tester "GyroWash" for washing fastness, James Heal's Crock Master instrument for wet and dry rubbing; Jame Heal's perspirometer instrument for perspiration and water fastness were used for the fastness tests. Dry and wet rubbing fastness values were determined according to TS EN ISO 105-X12 and washing fastness values were determined according to TS EN ISO 105-C06/A1S. Perspiration fastness was determined according to ISO 105 EO4. The grey scale was benefited from for determining the fastness grades. According to Grey Scale, 1-2-3-4-5 are rating classes also half rating values can be used like 4-5 (1- very poor, 2-poor, 3-fair, 4-good and 5-excellent). Table 3 is given below for an example view for the change assessment of the original fabric and grey scale staining assessment for washing fastness.

Table 3. Washing fastness evaluation of 100% cotton dyed with walnut shell



2. Results and Discussion

Fabric Tenacity

Fabric tenacity values of undyed woven fabrics and those dyed with natural dyestuffs were revealed in figure 2. According to figure 2, polyester linen fabrics dyed with three different natural extracts indicated similar fabric tenacity results in the warp wise however samples dyed with walnut and acorn shells revealed slightly higher weft tenacity compared to undyed samples and onion skin dyed samples. Additionally, it was prominently observed that the warp wise tenacity measurements were higher than the weft wise tenacity measurements among the polyester linen blended samples.

Among the cotton-linen samples, maximum warp tenacity was obtained from samples dyed with walnut shell extract while maximum weft tenacity was provided from samples dyed with acorn shell extract. Considering the cotton fabrics, undyed samples indicated the maximum warp tenacity while cotton samples dyed with acorn shell extract provided the highest weft tenacity. There was not a prominent change between the fabric tenacity values of undyed and naturally dyed samples among the cotton-viscose blended fabrics in warp and weft wise. Tenacity values fluctuated between a certain interval for each sample and did not show any dramatic changes regarding to the utilized natural dye extract type.

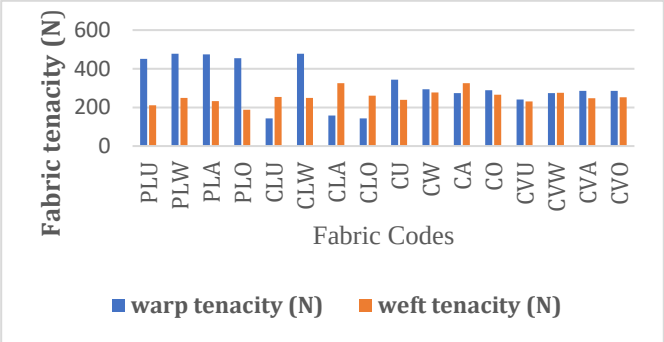


Figure 2. Fabric Tenacity

Tear Strength

Tear strength values of dyed woven samples in warp and wise were indicated in figure 3. Among the polyester linen samples, it was understood that there is not a prominent difference for tear strength values in warp and weft wise between the undyed woven samples and those dyed with natural dye extracts. However, warp tear strength results were much higher than weft tear strength results among polyester linen fabrics.

Considering the cotton linen samples, highest warp tear strength values was obtained from cotton-linen samples dyed with onion extract. The weft tear strength results of the cotton linen samples dyed with different natural dye extracts did not seem to be differing regarding to the natural dye type. In contrary to polyester linen samples, weft tear strength results of cotton-linen samples were higher compared to warp tear strength results among the cotton linen woven samples. The similar situation was observed among the cotton samples where the weft tear strength results were by far higher than the warp tear strength results. Additionally, warp and weft tear strength results of cotton sample dyed with walnut shell were found lower than its counterparts dyed with other natural extracts.

When it comes to cotton-viscose blended fabric samples, undyed samples and those dyed with onion skin extract exhibited the similar warp and weft tear strength values. Warp tear strength values were higher than the weft tear strength values among the cotton-viscose woven fabrics dyed with walnut shell extract and among those dyed with acorn shell extract. On the other hand, cotton viscose woven samples dyed with walnut shells revealed the lowest warp and weft tear strength.

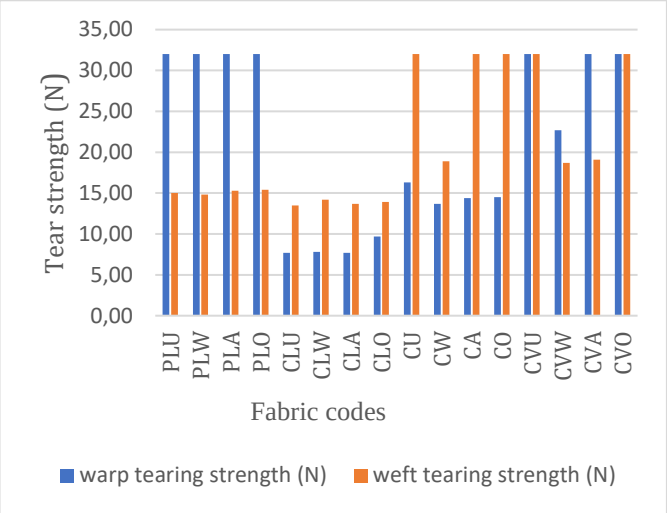


Figure 3. Tear Strength results

Seam Strength

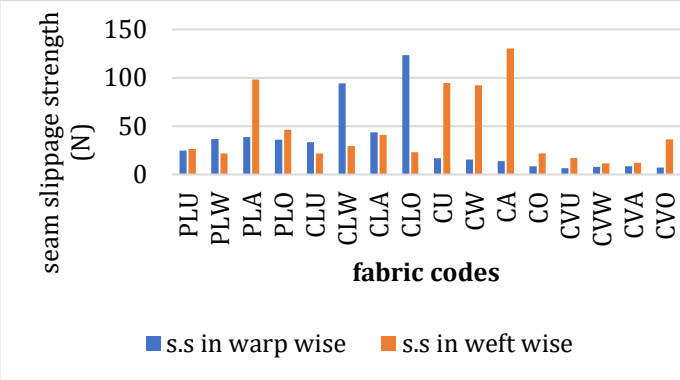


Figure 4. Seam slippage strength results

Figure 4 indicates the seam slippage strength results of the handwoven samples. Among the polyester-linen fabrics, seam slippage strength in warp wise were close to each other. Seam slippage strength of samples dyed with acorn shell revealed higher values by far compared to other samples in weft wise. When the cotton-linen samples were evaluated, it may be observed that samples dyed with walnut shell and dyed with onion skin indicated higher seam slippage strength in warp wise. Additionally, it may be added that seam slippage strength in warp wise was higher than weft wise among the cotton-linen samples. The opposite situation was observed among the cotton woven samples where the weft seam slippage strength values were higher than the warp slippage strength values. The highest weft seam slippage strength value was obtained from 100% cotton samples dyed with acorn shell extract while the minimum value was found among the samples dyed with onion skin. The warp seam slippage strength values of 100% cotton samples were similar to each other. The warp and weft seam slippage strength did not vary prominently regarding to utilized natural dye among the cotton-viscose fabrics however seam slippage strength of samples dyed with onion skin indicated the maximum value in weft wise.

Color Fastness

Table 4 indicates the change assessment of the original fabric and grey scale staining assessment for washing fastness and for water fastness as well as perspiration fastness. The washing fastness results were generally satisfying in the manner of staining and color change evaluation among the natural dyed woven fabrics. The washing fastness properties of the natural dyed samples varied between 3 and 5 for the staining on different fabrics and for sample change assessment. Staining grades for washing fastness obtained from wool were generally lower than those provided from other staining clothes. Among the polyester-linen fabrics, samples dyed with walnut shell extract and samples dyed with onion skin indicated lower washing fastness grades compared to fastness results of other sample groups in the manner of change assessment (Table 4). Among the cotton-linen samples, there is not a prominent difference of washing fastness values between the fabrics due to the fabric type. The washing fastness grades fluctuated between fair grade to excellent grade. However, water fastness results of these samples deteriorated a little bit with the natural dyeing process. Among the cotton linen samples, minimum change assessment grade for washing and water fastness was found among the samples dyed with onion skins. Undyed 100% cotton fabric generally revealed better washing fastness results compared to its dyed counterparts. Cotton samples dyed with acorn shell extract and the samples dyed with onion skin extracts revealed lower change assessment grades for washing fastness and water fastness. The similar situation was observed among the cotton-viscose blended woven fabrics where the change assessment grades of the samples dyed with acorn and onion extract were found lower than the others for washing and water fastness evaluation (Table 4). This may be an expected result since onion's outer shell (Allium cepa) belongs to the Lilliaaceae family and these dyes are known as

pelargonidin which work like acid dyes that can dye protein fibres much better than cellulosic fibres such as cotton and its blends [23].

As a general result it may be emphasized that natural dyeing of Buldan clothes with walnut extract provided higher washing fastness grades compared with others. Our result was supported with Eser et al.'s study where the high washing fastness results of walnut dyed fabrics was attributed to "Juglone", the main colorant of walnut leaves [28]. Enez also emphasized in his study that natural coloring of cotton, wool etc. with walnut shell may provide satisfying fastness results without using any extra chemical additives [45].

When acidic and alkaline perspiration was evaluated; fair to good resistance to staining and change assessment was observed among the polyester-linen samples dyed with 3 natural dye extracts. Fair to good resistance to staining and change assessment was observed among the cotton-linen fabric due to acidic and alkaline perspiration. The most unsatisfying perspiration grades were obtained from the samples dyed with onion skin extract among the cotton-linen and among the 100 % cotton samples. Poor to good level for resistance to staining and color change assessment due to acidic and alkaline perspiration was observed among the cotton viscose blended samples dyed with natural extracts. As a general evaluation for perspiration fastness, natural dyeing process had a slight negative contribution on the perspiration resistance of the samples in acidic and alkaline conditions. Grades for resistance to color staining and to color change were generally observed to be similar due to acidic perspiration and due to alkaline perspiration for each fabric sample (Table 4).

Table 4 washing fastness, water fastness of the undyed and naturally dyed samples

Fabric code	Washing fastness							Water fastness		Perspiration fastness			
	Staining on acetate	Staining on cotton	Staining on polyamide	Staining on polyester	Staining on acrylic	Staining on wool	Change assesment	Staining on cotton	Change assesment	staining		Change assesment	
										acidic	alkaline	acidic	alkaline
PLU	4/5	4/5	4/5	4/5	4/5	4/5	4/5	4/5	4/5	4/5	4/5	4/5	4/5
PLW	4	3/4	3	3/4	4	3/4	3/4	3/4	4	4	3/4	4	4
PLA	4/5	4	4	4	4/5	3/4	4	4/5	4	3/4	3/4	4	3/4
PLO	4/5	4	4	4	4/5	3/4	3/4	4	4	4	4	3/4	3/4
CLU	4/5	4/5	4/5	4/5	4/5	4/5	4/5	4/5	4/5	4/5	4/5	4/5	4/5
CLW	4/5	4	3/4	4	4/5	3/4	4	4	4	4	4	3/4	4
CLA	4/5	4	4	4	4/5	3	3/4	4	4	3	3	4	4
CLO	4/5	4	4	4	4/5	3/4	2/3	4	3	4	4	2/3	2/3
CU	4/5	4/5	4/5	4/5	4/5	4	4/5	4/5	4/5	4/5	4/5	4/5	4/5
CW	4/5	4	3/4	4	4/5	3/4	3/4	4	4	4	4	3/4	4
CA	4/5	4	4	4	4/5	3/4	3	4	3/4	4	4	4	4
CO	4/5	4/5	4/5	4/5	4/5	3/4	3	4/5	3/4	4	4/5	2/3	3
CVU	4/5	4/5	4/5	4/5	4/5	4/5	4/5	4/5	4/5	4/5	4/5	4/5	4/5
CVW	4/5	4	3/4	4/5	4/5	4	4	4	4/5	4/5	4/5	3	3/4
CVA	4	4	4	4	4	3	3	4	4	3	3/4	3	4
CVO	4/5	4	4	4	4/5	4	3	4	2/3	4/5	4	2	2

As the rubbing fastness values were investigated (table 5), dry rubbing fastness results were found as much more satisfying compared to wet rubbing fastness results among all samples. Our results were consisted with the early study of Ala and Bakıcı where the researchers found lower wet rubbing fastness results compared to dry rubbing values (18). It may be also anticipated that natural dyeing process led to decrement of rubbing fastness results as it is observed in table 5.

Table 5 Rubbing fastness

Fabric code	Dry	Wet
PLU	5	4/5
PLW	4	3
PLA	4/5	4
PLO	4	3/4
CLU	5	4/5
CLW	4	3
CLA	4/5	3/4
CLO	4/5	4
CU	5	4/5
CW	3/4	3
CA	4/5	4
CO	4	3/4
CVU	5	4/5
CVW	4/5	3/4
CVA	4/5	4
CVO	4/5	4

4. Conclusion

This study has been conducted to reveal that naturally colored Buldan handwoven fabrics made of different raw materials provided sufficient tensile values and fastness results in terms of washing, water, perspiration and rubbing fastness. Comfortable Buldan clothes such as shirts, dresses, blouses may be provided from these Buldan fabrics which may be proposed good alternatives for sustainable textile production.

Fabric tenacity results revealed that natural dyeing process did not give much damage to the fabric strength. As an expected result, the fabric tenacity results varied in accordance with the fabric raw material. Although there are some fluctuations for the fabric tenacity values due to the applied natural dye type for each fabric type, there is not a prominent variation in general due to the natural dye type. Tear strength results revealed that natural dye process did not seriously influence the tearing behaviour of the yarns consisting the woven fabrics. Such a result may show that naturally dyed handwoven fabrics utilized in the study may be utilized for ready to wear products with a sustainable manner where there is less chemical usage and water consumption. Regarding to washing and water fastness results, polyester linen fabrics, revealed more satisfying results when the results are generally evaluated. Among all fabric types, woven samples dyed with onion skin revealed lower fastness results especially in terms of color change assessment. When the perspiration fastness results are evaluated, change assessment values of the dyed fabrics are lower than their undyed counterparts. There is not a prominent difference between the perspiration fastness values of all fabric samples with different raw material however the natural dye extract type is observed to be influencing the perspiration fastness values slightly.

Human health is given more importance than ever before nowadays. As a result, naturally colored Buldan fabrics with sufficient tensile and fastness properties should be supported for a more widespread utilization among the textile consumers which may be an opportunity to reduce the pollutants for a sustainable textile production.

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