Designing textile accessories from coffee ground

DOI: 10.35530/IT.073.03.202049

AVCIOĞLU KALEBEK NAZAN

ABSTRACT – REZUMAT

Designing textile accessories from coffee ground

Excessive consumption of natural resources restricts raw material production and threatens future generations' access to these resources. Therefore, most of the famous fashion and textile brands are used bio-based materials such as orange, banana, pineapple, coffee ground, etc. In this study, buttons are designed from the coffee waste collected from a local coffee house from an automatic espresso coffee machine located in Turkey for the completion of garments in the fashion industry. Coffee grounds are mixed with corn starch, glycerine, bio-epoxy resin and hardener with adequate concentrations. Bio-waste button is designed according to a mostly used circular shape. Colour fastness tests are performed to evaluate the quality of fabric such as appearance, stain release, water resistance, and colour fastness to domestic laundering and drying procedures. As a result, designed natural accessories can be adopted not only as environmentally friendly but also as cost-effective solutions for manufacturing other accessories used in the fashion industry. At the end of the domestic laundering, at the first three washing cycles, it is observed that there is no visible wear discolouration, flexibility or deformations.

Keywords: *bio-based materials, environmentally friendly, fastness properties, fashion industry, recycling*

Proiectarea accesoriilor pentru produsele textile din zaț de cafea

Consumul excesiv de resurse naturale restrânge producția de materii prime și amenință accesul generațiilor viitoare la aceste resurse. Prin urmare, majoritatea brandurilor renumite de modă și produse textile utilizează materiale bio precum portocala, banana, ananasul, zațul de cafea etc. În acest studiu, nasturii sunt proiectați din deșeurile de cafea colectate de la un automat de cafea espresso situat în Turcia, pentru realizarea produselor de îmbrăcăminte din industria modei. Zațul de cafea este amestecat cu amidon de porumb, glicerină, rășină bio-epoxidică și agent de întărire cu concentrații adecvate. Nasturii din deșeuri biologice sunt proiectați într-o formă circulară, aceasta fiind cel mai des utilizată. Testele de rezistență a culorii sunt efectuate pentru a evalua calitatea țesăturii, cum ar fi aspectul, rezistența la pătare, rezistența la apă și rezistența culorii la procedurile de spălare și uscare casnică. Prin urmare, accesoriile naturale concepute pot fi adoptate nu numai ca fiind prietenoase cu mediul, ci și ca soluții rentabile pentru fabricarea altor accesorii utilizate în industria modei. La sfârșitul spălării casnice, la primele trei cicluri de spălare, se observă că nu există decolorări vizibile la purtare, flexibilitate sau deformări.

Cuvinte-cheie*: materiale bio, ecologic, proprietăți de rezistență a culorii, industria modei, reciclare*

INTRODUCTION

Nowadays, with the rapid increase of the population, natural resources are consumed unconsciously. Excessive consumption of natural resources restricts raw material production and threatens future generations' access to these resources [1]. Therefore, within the framework of waste management, the European Union has been determined to prevent waste generation, reuse waste and recycle [2]. Economical control of waste management can only be managed by reducing waste generations. Reduction of waste generation can be accomplished by recycling. If it is not recycled, it remains like garbage. Any litter that does not participate in the recycling left in nature causes serious problems for the future. In the world and also in Turkey, plastic bags are started being offered to the consumer for a fee to be environmentally conscious.

Bio-based materials, some or all of which are obtained from biomass, contribute to sustainability by using the fashion and textile industry. The silk-like cellulose-based fabric was produced from the citrus wastes in the fruit juice sector, which is a bio-waste raw material by Orange Fiber. Another example produced from bio-wastes was produced by the company Singtex, which was named "S-Cafe" from coffee wastes. In addition to being sustainable, this fabric also performs many functions such as anti-bacterial and antiseptic by emitting coffee scents [3]. In addition, many garments were produced by the global giant companies such as sportswear, Timberland, New Balance, North Face, Puma and Nike by the French clothing company Eider Action Wear to reduce environmental pollution. A fibre called "Azlon" is produced from protein-based edible soy fibre, which is 100% eco-friendly and is a good alternative to silk and cashmere. It is used in making sweaters, jackets and blankets by being mixed with wool due to its natural antibacterial and harmonious structure. The yarn obtained from pineapple fibre with its porous and irregular structure is used in home textile production where the strength properties such as carpet and curtains should be high. The banana fibre obtained from the bark and leaves of bananas is among the innovative natural fibres that have attracted attention recently. Banana wastes inevitably contribute to both nature and the economy by converting them into high-added value products [4]. Vasquez and Vega studied the sustainable life cycle used biodegradable materials to embed electronics. The electronic circuit is embedded into mycelium skin to produce an accessory. After the accessory has been worn, the electronic circuit is reused and the mycelium skin is composed. As a result, this material provides new possibilities for alternative wearable technology fields such as accessories [5]. Cao and et. al. developed from plant oils and natural fibres water-resistant and breathable eco-leather for shoes and coats. Wear tests and questionnaire surveys were conducted on female college students. At the end of the study, if the design and style met their requirements, the participants expressed they would like to buy footwear and apparel made from environmentally friendly leathers [6]. Cimatti et al. demonstrated some sustainable methods and techniques, such as eco-design and recycling for fashion manufacturing companies. A life cycle assessment of traditional products of the company is presented to enhance the significant aspects of sustainability in the fashion industry [7].

The most widely consumed beverage of coffee grounds is also used for colouring fabrics. After colouring, the colour and surface properties of fabrics were investigated using spectrophotometry (CIELAB, Hue and Value/Chrome), colour fastness to laundering and crocking. As a result, natural dyes used in coffee grounds can be a good alternative to synthetic dyes in the textile and dyeing industries. Dyed fabrics were significantly different shades of brown in appearance [8–10]. Coffee grounds (0.074 mm) mixed with 100 gr corn-starch, 5 gr glycerine and 2 gr distilled water. After mixed up, the samples were brought to the microwave for heating under a power of 40 W for 6 minutes. Then, this mixture is deposited into polyacrylic moulds at 32°C in an oven. Differential scanning calorimetric, thermo-gravimetric and morphological analyses are performed. As a result, coffee ground reinforced materials did not change to thermal stability and have better mechanical tensile strength [11]. Many researchers have also used the coffee grounds for dyeing with different mordant. These mordants are zinc sulphate ($ZnSO_4 \cdot 7H_2O$), zinc acetate ($Zn(CH_3CO_2)_2 \cdot 12H_2O$) aluminium potassium sulphate ($AlK(SO_4)_2 \cdot 12H_2O$), copper (II) acetate ($Cu(CH_3CO_2)_2 \cdot H_2O$) [12], copper (II) sulphate pentahydrate ($CuSO_4 \cdot 5H_2O$), tin (II) chloride pentahydrate ($SnCl_2 \cdot 5H_2O$) and iron (II) sulphate heptahydrate ($FeSO_4 \cdot 7H_2O$)) [13], and natural (ash water, iron water, cow dung and lemon juice) [14]. Good colour shades and visibly more intense colours were recorded with different mordant used.

As a result of the literature search, it was seen that studies are focused on bio-based materials such as orange, tea, banana, etc., recycling, and eco-friendly textile materials. For textile accessories, coffee grounds were not produced and used before. In this study, two and four holed buttons are designed from the coffee waste collected from local coffee shops for the completion of garments in the fashion industry. These buttons are sewn on the mostly used woven fabrics. Domestic washing and drying tests were applied to the standards.

MATERIAL AND METHOD

Material

The coffee grounds used in this study were Brazilian coffee beams collected from a coffee house from an automatic espresso coffee machine located in Gaziantep/Turkey. Collected used coffee grounds were completely dried in a container for four days without open-air circulation not directly to the sun as soon as possible getting. Then these are turned into powder by grinding from the mill. Coffee grounds are mixed with corn starch, glycerine, bio-epoxy resin and hardener in the concentration given in table 1 for reinforcements. Then it was pressed into a silicone mould with the shape circular. The size of the button is 24 and the length is 15.2 mm. The prepared mixture was cured in a laboratory-type furnace. The buttons were removed from the silicone moulds for applications.

Table 1

CONCENTRATION OF MIXED COFFEE GROUNDS

Ingredients	Content (%)
Coffee Ground	80
Corn Starch	8
Glycerine	3
Bio-epoxy	6
Hardener	3

Method

Bio-waste button is designed according to mostly used circular shape according to two and four holed [15, 16] from the coffee ground. Colour fastness tests are performed by TS EN ISO 105 C06: Colour Fastness to Domestic and Commercial Laundering. The aim of performing this test is to evaluate the quality of fabric such as appearance, stain release, and colour fastness to domestic and commercial laundering procedures. Test samples 100*40 mm dimensions are sewed between multi-fibre standard test samples (Acetate, Cotton, Polyamide, Polyester, Polyacrylic, and Wool). ECE detergent (4 g) (non-phosphate reference detergent) and sodium carbonate (1 g) were added to the one litre of distilled water. A gentle washing program at 40°C for 30 min. without stainless steel ball was performed. After the washing cycle was completed, the samples were dried by hanging on a line in a room without sunlight. The average temperature inside the room was 24°C. At the end of the test, visible wear discolouration, unrecoverable deformation the occurrence of an error, and accessories flexibility corruption has been observed. Three washing cycles are performed.

Test materials are examined according to ISO 105-A04:1989; Textiles – Tests for Colour Fastness – Part A04: Method for the Instrumental Assessment of the Degree of Staining of Adjacent Fabrics with grayscale at the end of the test. The transference of colour from the test specimen to an adjacent specimen is commented with grayscale for staining and colour change. Five standard pairs are used. One half of each standard is white, and the second half ranges from white (no staining) to grey with the chroma value of the test specimen (a great deal of staining). A value of 5 corresponds to virtually no staining, whereas 1 indicates poor colour-fastness. The observer conditions are under the D65 daylight.

The changes in the colours of the designed button samples were investigated for each washing cycle using a photoelectric Minolta, İstanbul). The CIELab values provide L^* ("0" black, "100" white), the higher the L values, the lighter the colour. Also, the a^* value indicates red ($+a^*$) and green ($-a^*$), while the b^* value indicates yellow ($+b^*$) and blue ($-b^*$). The colour change (ΔE) value was calculated from the L^*, a^* and b^* values by using illuminant D65 and 10° standard observer conditions. L^*, a^* and b^* were calculated as follows, respectively;

$$L^* = 116\,(Y/Y_n)^{1/3} \quad (1)$$

$$a^* = 500[(X/X_n)^{1/3} - (Y/Y_n)^{1/3}] \quad (2)$$

$$b^* = 200[(Y/Y_n)^{1/3} - (Z/Z_n)^{1/3}] \quad (3)$$

where X, Y, and Z are CIE tristimulus values, and X_n, Y_n, and Z_n are CIE tristimulus values to the reference white under the source used. The ΔE value indicates the differences between the reference and the sample [9, 17].

In addition, colour strength, K/S, was calculated from the reflectance values using the Kubelka–Munk equation [18, 19] about the maximum absorption at 520 nm as follows:

$$K/S = (1 - R)^2 / 2R \quad (4)$$

where R is the reflectance of the dyed fabric and K/S (colour depth) is the ratio of the absorption coefficient (K) to scattering coefficient (S); the higher the value, the greater the colour strength.

EXPERIMENTAL STUDY

Coffee ground (80%), corn starch (8%), glycerine (3%), bio-epoxy resin (6%), and hardener (3%) are mixed. After being mixed up, the mixture was brought to the consistency of dense flowing. The preparing the mixture with adequate plastic consistency pours into two and four holed silicone moulds. In the silicone mould, each button is approximately 20 g each one. In the mould, the mixture is vibrated by a shaker in order not to let air bubble with homogenous distribution of natural components prepared with the coffee ground. The prepared mixture was cured in a laboratory-type furnace at 65°C temperature for 1 hour. After, they were left in the open air at 32°C with no air circulation for one day. The buttons were removed from the silicone moulds and made ready for testing (figure 1).

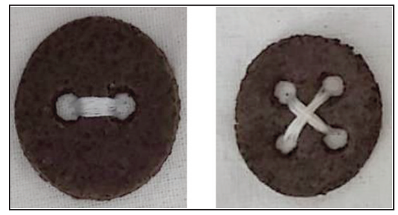


Fig. 1. Designed buttons

Buttons are sewed to three different woven fabrics. First fabrics technical properties are 98/2% cotton/lycra 150 gr/m^2, 40/1 Ne, 48 end/cm (weft), 30 end/cm (warp) plain (1/1) woven fabric. Second one is 100% Polyester 160 gr/m^2, 34/1 Ne, 46 end/cm (weft), 28 end/cm (warp) twill (2/1) woven fabric. Last fabric is 100% wool with 120 gr/m^2, 50/1 Ne, 32 end/cm (weft), 30 end/cm (warp) twill (2/1). Sewing thread is selected from 100% white colour polyester to have been chosen to avoid discolouration of white woven fabric.

Washing fastness

Fabrics with buttons are washed in the domestic laundry three times. This test aims to evaluate the quality of fabric such as appearance, stain release, and colour fastness to domestic and commercial laundering procedures. For all washing cycles, standard ECE detergent is used at 40°C for 30 minutes. After each cycle, the differences obtained between the control fabric and the multi-fibre, before and after washing was visually controlled with the grayscale to obtain the colour change and staining according to ISO 105-A03:1993. The rating scale is 1 (very poor) to 5 (excellent). Test results are shown in table 2.

As can be seen in the tables, there is no visible wear discolouration from button to fabric, deformation of button and flexibility of accessories. All fabrics sewed buttons produced from the coffee ground showed superior colour fastness (4 or higher and 5 grade). Table 2 also shows that very little colour transfer (colour staining) occurred from acetate, cotton, polyamide, polyester and wool fabrics, while no colour transfer to polyacrylic to the adjacent multi-fibre fabric for cotton/lycra. This result indicates that coffee ground would be a suitable natural dye for various fabrics and/or blends manufactured of acetate, polyamide, and polyacrylic. This is important since most commercial fabric blends contain 2 or more fibre types e.g., polyester/cotton. Colour transfer (colour staining) in cotton, polyester and wool is considered acceptable, with a rating of 4. According to the International Organization of Standardization

Table 2

TEST RESULTS AFTER WASHING										
Colour Change		**Cotton/Lycra**			**Polyester**			**Wool**		
		1.Cycle	2.Cycle	3.Cycle	1.Cycle	2.Cycle	3.Cycle	1.Cycle	2.Cycle	3.Cycle
	Colour staining	5	4/5	4	4/5	4	4	5	4/5	4
Acetate		4/5	4/5	4/5	4	4	4	4/5	4	4
Cotton		4	4	4	4	4	4	4/5	4	4
Polyamide		4/5	4/5	4	4–5	4	4	4	4	4
Polyester		4	4	4	5	5	5	4	4	4
Polyacrylic		5	5	4/5	4	4	4	4	4	4
Wool		4	4	4	4/5	4/5	4	5	5	5

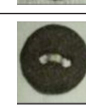
(ISO) for textile materials, it is considered acceptable in the condition of a grade of 4 or higher for colour change and 3 or higher for staining. Dyeing with the coffee ground is acceptable according to standard. The ratings were >4.5 for acetate, polyamide and polyacrylic, showing excellent fastness to staining. While very little colour transfer (colour staining) occurred from acetate, cotton, polyamide, polyacrylic and wool fabrics, no colour transfer from polyester to the adjacent multi-fibre fabric for polyester fabric. There is no colour transfer (wool) is occurred for wool fabrics. This result indicates that button all fabric is excellent fastness to colour change and staining.

CIE Lab

CIELAB L^*, a^*, b^*, *K/S*, ΔE values for the buttons manufactured from the coffee ground at the end of each washing cycle were shown in table 3. When the button was washed with standard conditions, L^* values were found to be lower. While the highest L^* value belongs first washing cycle, the lowest L^* is obtained with 51.879 for the last washing cycle. It means deeper shades of brown colour for the last washing cycle. As a result of repeated washing, the colour on the button caused a deeper brown tone, contrary to what was expected. With this result, it has been concluded that the buttons can be washed easily.

Also, when the buttons were washed, a^* and b^* values were found to be lower. It was evident that it lost its brown bright colour and gained a matte appearance. When we look at the colour fastness values, we obtained results supporting this interpretation. Staining on the multi-fibre standard test fabric, a slight change was observed in all fibres (acetate, cotton, polyamide, polyester and wool) except polyacrylic fibre. During this staining, the brown colour on the button was stained while at the same time reducing the brightness and providing a matte appearance. The colour change of buttons is shown also in table 3. According to the washing test results, there is a little colour change is occurred. Furthermore, the total colour change (ΔE) values of natural brown colour on buttons were lower with each washing cycle (ΔE = 6.84, 4.75 and 3.10 respectively). It is good excellent colour absorption depending on three washing cycles. Therefore, analysing CIELAB values with washing cycles will inform researchers and textile sectors about natural colours. Based on table 3, buttons produced from the coffee ground showed that washing cycles increased Colour Strength (K/S) from 9.070 for the first washing to 30.381 for the last washing. Maximum colour strength is obtained at the end of the third washing cycle. The obtained values (table 3) show that buttons' colour after washing cycles is becoming darker and duller. It means darker and duller brown colour. The reason for this result can be explained by the aqueous solution that helps set the brown colour to buttons. Also, it can be explained that aqueous solution tends to form strong

Table 3

CIELAB VALUES							
Washing cycle	**L^***	**a^***	**b^***	**K/S**	**ΔE**	**Colour**	**Accessory**
1.Cycle	74.477	5.049	25.158	9.070	6.84	Dark Brown	
2.Cycle	60.254	5.002	16.037	14.289	4.75	Brown	
3.Cycle	51.879	4.576	14.308	30.891	3.10	Brown	

Note: L^*= lighter the colour, a^*= red values, b^*= yellow values, K/S = colour strength, ΔE = total colour change bonds to coffee ground. Thus, consequently, a colour change is to be a darker shade. It can be concluded that buttons can be produced from natural sources such as coffee grounds as an alternative to plastics, wood and metals.

DISCUSSION AND CONCLUSION

Accessories used in the fashion industry like button is mostly produced from wood, plastics or metals. A huge amount of residue is generated annually while producing petroleum-based. Therefore, the idea of manufacturing buttons from the bio-waste coffee ground is an innovative and good alternative for future generations.

The experimental results of this study are summarized below:

- New natural textile accessories designed can contribute to developing another bio-waste alternative for buttons with cost-effective and high availability of materials.
- It is also demonstrated that recycled coffee grounds, which are still recognized as bio-waste can be possible materials.
- Designing buttons from bio-waste coffee grounds can help to contribute to long-term economic potential and promote suitable environmental management to minimize negative effects caused by the use of petroleum-based buttons like plastics instead of coffee ground buttons.
- Developed natural accessories can be adopted not only as environmentally friendly but also as cost-effective solutions for manufacturing other accessories used in the fashion industry as buckles, broach, tie pins, punch, claps, etc.
- At the end of the domestic laundering, at the first two washing cycles, it is observed that there is no visible wear discolouration, flexibility or deformations. However, after three washing cycles, there is only little invisible deformation. This is acceptable for buttons in the fashion industry.
- The washing colour fastness of button samples produced from the coffee ground showed 4 (good), 4/5 (very good) and 5 (excellent) resistances to colour staining for multi-fibre standard test samples This may be not only due to the strong combination to the coffee ground and also suitable for all fibres (acetate, cotton, polyamide, polyester, polyacrylic, wool). According to the International Organization of Standardization (ISO) for textile materials, it is considered acceptable in the condition of a grade of 4 or higher for colour change.
- High washing fastness values might be due to the migration of coffee-based materials firmly attached to the buttons. Because water molecules were not removed easily some water-soluble dyes (coffee ground) by the action of washing conditions.
- Buttons produced from coffee ground alter the washing fastness ratings into positive as well as makes them insoluble with water and ultimately improve washing fastness properties.
- The reason for choosing three different fabric types (%98 cotton/%2 lycra, %100 polyester and %100 wool woven) are alternatives for outwear for example coat, jacket and duster.
- K/S values increased in the order of 3.Cycle> 2.Cycle>1.Cycle for buttons produced from the coffee ground. It is remarkable that at the end of the 3. washing cycles have higher K/S values. This may be associated with the setting of brown colour value into the accessory by washing.
- Bio-waste materials with genuine characteristics offer innovative ideas for designers.
- Recycling coffee grounds is still recognized as industrial waste not only for the textile industry but also in other industries like agriculture, construction, food, chemistry, etc.
- One of the important characteristics gained during using the fabric is that naturally protect against bed smell like perspiration, cigarette, cooking, etc. The natural aroma of the coffee is spread during the production, using and washing of the fabric.

REFERENCES

[1] Tufaner, F., *Investigation of Effects of Informative Activities on Collection Efficiency of Recyclable Wastes*, In: Weather Changes and Environment, 2019, 4, 1, 33–40

[2] Meriç, D., *The Use of Biobased Materials Textile and Fashion Design Fields as an Example of Sustainable Approaches*, In: Usak University Journal of Socia Sciences, 2019, 12, 2, 111–121

[3] Bayer, İ.S., Guzmanpuyol, S., Herediaguerrero, A., Ceseracciu, L., Pignatelli, F., Ruffilli, R.,Cingolanis, R., Athanassiou, A., *Direct Transformation of Edible Vegetable Waste into Bioplastics*, In: Macromolecules, 2014, 47, 15, 5135–5143, https://doi.org/10.1021/ma5008557

[4] *Elbisenizi Neli Alırsınız, Muzlu, Hindistan Cevizli, Sütlü*?, In: Tübitak Bilim ve Teknik, 2014, 6, 63–67

[5] Vasquez, E.L., Vega, K., *Myco-accessories:Sustainable Wearables with Biodegradable Materials*, In: Proceedings of the 2019 International Symposium on Wearable Computers (ISWC), 9–13 September, 2019, London/United Kingdom

[6] Cao, H., Wool, R.P., Bonanno, P., Dan, Q., Karamer, J., Lipschitz, S., *Development and Evaluation of Apparel and Footwear Made From Renewable Bio-Based Materials*, In: Interantional Journal of Fashion Design, Technology and Education, 2013, 7, 1, 21–30

[7] Cimatti, B., Campana, G., Carluccio, L., *Eco Design and Sustainable Manufacturing in Fashion: A Case Study in the Luxury Personel Accessories Industry*, In: Procedia Manufacturing, 2017, 8, 393–400

[8] Nam, C., Xiang, C., *Natural Dyeing Application of Used Coffee Grounds as a Potential Resource*, In: International Journal of Fashion Design, Technology and Education, 2019, 12, 3,335–345, https://doi.org/10.1080/17543266.2019.1640291

[9] Lee, Y.H., Dyeing, *Fastness, and Deodorizing Properties of Cotton, Silk, and Wool Fabrics Dyed with Coffee Sludge (Coffee arabica L.) Extract*, In: Journal of Applied Polymer Science, 2007, 103, 251–257, https://doi.org/10.1002/app.25221

[10] Hong, K.H., *Effects of Tannin Mordanting on Colouring and Functionalities of Wool Fabrics Dyed with Spent Coffee Grounds*, In: Fashion and Textiles, 2018, 5, 33,1–11, https://doi.org/ 10.1186/s40691-018-0151-3

[11] Gazonato, E.C., Mala, A.A.D., Moris V.A.S., Palva, J.M.F., *Thermomechanical Properties of Corn Starch Based Film Reinforced with Coffee Ground Waste as Renewable Resource*, In: Materials Research, 2019, 22, 2, 4–16, https://doi.org/10.1590/1980-5373-mr-2018-0416

[12] Lee, J., Ko, J., *The Characteristic of Natural Dyeing with Mulberry Leaf and Coffee Powder using Zinc Mordant*, In: Textile Colouration and Finishing, 2016, 28, 2, 118-123, https://doi.org/10.5764/TCF.2016.28.2.118

[13] Repon, M.R., Islam, M.T., Mamun, M.A., *Ecological Risk Assessment And Health Safety Speculation During Colour Fastness Properties Enhancement Of Natural Dyed Cotton Through Metallic Mordants*, In: Fashion and Textiles, 2017, 4, 24, 1–17, https://doi.org/10.1186/s40691-017-0109-x

[14] Janani, L., Winifred, D., *Suitability of Dyes from Mulberry and Coffee Leaves on Silk Fabrics using Eco-Friendly Mordants*, In: International Journal of Scientific and Research Publications, 2013, 3, 11, 1–4

[15] Qian, X., *Customized Button Design Platform Construction and Implementation*, In: International Journal of Science, 2020, 7, 7

[16] Das, S., *Study on Trims and Accesories of Same Garments*, Supervisor: Hossain, K.R., B.Sc Thesis, Daffodil International University, Faculty of Engineering, Department of Textile Engineering, Dakka, Bangladesh, 2019

[17] CIE, *Technical Report Colourimetry*, Vienna, Austria: CIE, Central Bureau, 2004

[18] Vankar, P.S., Srivastava, S., Dumitrescu, I., Mocioiu, M., *Enzyme Treated Dyeing of Cotton, Silk and Wool with Bixa Orellana*, In: Industria Textila, 2012, 63, 6, 327–333

[19] Kubelka, P., *New Contributions to the Optics of Intensely Light-Scattering Materials. Part II: Nonhomogeneous Layers*, In: Journal of the Optical Society America, 1954, 44, 330–335

Author:

AVCIOĞLU KALEBEK NAZAN

Gaziantep University, Fine Art Faculty, Textile and Fashion Design Department,
University Avenue, 27310, Şehitkamil/Gaziantep, Turkey

Corresponding author:

AVCIOĞLU KALEBEK NAZAN
e-mail: nkalebek@gantep.edu.tr