https://doi.org/10.56038/oprd.v1i1.173

Research Article

Determination of The Effect of Dyeing and Finishing Processes on Physical, Mechanical, Handle, Comfort and Functional Properties of Cotton Knitted Fabrics

M. Fatih Yüksel[1], Durul Büşra Dilden[2*], Seda Keskin[3], Uğur Ergünay[4], Rıza Atav[5]

[1]Eren Retail Company, 59930, Ergene/Tekirdağ, Türkiye, Orcid Id: 0000-0003-4239-3212
[2]Eren Retail Company, 59930, Ergene/Tekirdağ, Türkiye, Orcid Id: 0000-0003-xxxx-xxxx
[3]Eren Retail Company, 59930, Ergene/Tekirdağ, Türkiye , Orcid Id: 0000-0002-9381-4278
[4]Tekirdağ Namık Kemal University, Çorlu Engineering Faculty, 59860, Çorlu/Tekirdağ, Türkiye, Orcid Id: 0000-0002-2955-4686
[5]Tekirdağ Namık Kemal University, Çorlu Engineering Faculty, 59860, Çorlu/Tekirdağ, Türkiye, Orcid Id: 0000-0002-5807-4542
*correspondence: durulbusra.dilden@erenperakende.com

(First received September 02, 2022 and in final form December 28, 2022)

2nd International Conference on Design, Research and Development
December 14 - 17, 2022

Reference: Yüksel M. F., Dilden, D. B., Keskin, S., Ergünay, U., Atav, R. Determination of The Effect of Dyeing and Finishing Processes on Physical, Mechanical, Handle, Comfort and Functional Properties of Cotton Knitted Fabrics. Orclever Proceedings of Research and Development,1(1), 167-177.

Abstract

As it is known, the most widely used dye class for dyeing cotton fabrics is reactive dyes. However, the reactive dyeing process itself and various finishing processes applied after dyeing affects the physical, mechanical, handle, comfort and functional properties of the fabrics. Therefore, the main aim of this study was to determine the dyeing and finishing processes on the quality-performance characteristics of the cotton knitted fabrics. For this aim, physical (weight, wale/course density), mechanical (bursting strength, pilling, abrasion resistance), handle (bending rigidity), comfort *(thermal comfort, air permeability, water vapor permeability) and functional (Ultraviolet protective functionality and flame retardancy of the fabrics) properties of fabrics were tested before and after dyeing and finishing processes. Fabric weight and bursting strength values increases after dyeing and finishing processes due to the shrinkage of the fabrics during wet processing. On the other hand, the pilling and abrasion resistance values of fabrics are not significantly affected by dyeing and finishing processes. Another important result obtained is that the bending length and bending stiffness of the fabrics decrease after dyeing/finishing processes. The thickness values of the fabrics decrease after dyeing-finishing processes and therefore the thermal resistance decreases. It was observed that the air permeability of the fabrics significantly decreased after dyeing-finishing processes. However, the water vapor permeability of the fabrics was decreased very slightly after dyeing and finishing processes. UPF ratings were increased after dyeing and finishing processes.*

Keywords: Cotton, dyeing, color, functionality, permeability

1. INTRODUCTION

Cotton is defined as the seed hair of a wide variety of plants in the Gossypium family. It is one of the fibers found in nature (Tang and Kan, 2020). Since the ecology of few countries in the world is suitable for cotton farming, nearly 80% of world production is carried out by a small number of countries, including Turkey (Atav et al, 2022).

The cotton fabric characteristically exhibits excellent physical and chemical properties in terms of water absorbency, dyeability and stability (Fang et al, 2013). The demand for cotton is increasing day by day due to its unique comfort, good strength, moisture absorption, wicking properties, beautifulness and availability around the world (Paul et al, 2017). Cotton has got much more attention also because of its biodegradability and biocompatibility properties (Irfan et al, 2018).

For dyeing of cotton goods reactive dyes are so much suitable and extensively used in the textile dyeing industries. They have good color fastness properties and a wide range of shade can be achieved with this dye class (Paul et al, 2017). The ability of producing brilliant and fast colors makes them to be more important among all other dyes. It forms a covalent bond with cotton fiber which results in excellent fastness properties (Irfan et al, 2018).

As it is known, the most widely used dye class for dyeing cotton fabrics is reactive dyes. However, the reactive dyeing process itself and various finishing processes applied after dyeing affects the physical, mechanical, handle, comfort and functional properties of the fabrics. Therefore, the main aim of this study was to determine the dyeing and finishing processes on the quality-performance characteristics of the cotton knitted fabrics. For this aim, physical (weight, wale/course density), mechanical (bursting strength, pilling, abrasion resistance), handle (bending rigidity), comfort (thermal comfort, air permeability, water vapor permeability) and functional (UV protective functionality) properties of fabrics were tested before and after dyeing and finishing processes.

2. MATERIAL AND METHOD

In this study, Ne 44/2 100% combed cotton yarn made from 100% white Greek cotton was used. Knitted fabric in the form of tube was produced from this yarn in a pique construction on the Shima Seiki SFF 152-T machine. Then, the processes of raw opening → gauze → bleaching → rinsing → dyeing (in green and brown colors) → washing → softening → open width drying → sanforization were applied to the fabrics.

All fabric samples, both in raw form and after dyeing and finishing processes were subjected to technical (color, fastness, weight, wale/course density, bursting strength, pilling, abrasion resistance, bending rigidity, thermal comfort, air permeability, water vapor permeability, UV protective functionality and flame retardancy of the fabrics) performance tests.

- Color yield and CIE L*a*b* values: In order to determine the color efficiency (K/S) values, %R (remission) values of the fabric samples were measured in the spectral region of 400-700 nm at the maximum absorption wavelength by using the Datacolor Spectro 1000 spectrophotometer (D 65/10°). Then K/S values were calculated according to the Kubelka-Munk formula;

$$K/S \; = (1-R)^2 / \, 2R$$

R: Reflection value at maximum absorption wavelength
K: Absorption coefficient
S: Diffusion coefficient

The CIE L*a*b* values of the samples were also measured with the spectrophotometer.

L*: The lightness-darkness value (0: ideal black, 100: ideal white)
a*: Redness-greenness value (+ more red, - more green)
b*: Yellowness-blueness value (+ more yellow, - more blue)

- Fastness values: Washing (at 60 °C), rubbing (dry and wet), perspiration (acid and alkali) and light fastness tests of dyed samples were made according to ISO-105 C06 (ISO 2010), ISO 105-X12 (ISO 2016), ISO 105-E04 (ISO 2013) and ISO 105 B02 (ISO, 2014), respectively.

- Fabric weight: 5 samples of each 100 cm^2 were taken from different parts of the fabrics conditioned and then fabric weight values were determined according to the TS EN 12127 (TSE 1999) standard.

- Fabric wale& course density: Tests were carried out based on the TS 250 EN 1049-2 (TSE 1996) standard.

- Bursting strength: In the measurement of bursting strength, tests were carried out according to the standard ISO 13938-2 (ISO 2019).

- Pilling: Fabric pilling test was carried out in 2000 cycles in Martindale test device according to TS EN ISO 12945-2 (ISO 2021) standard.

- Abrasion resistance: It was carried out according to TS EN ISO 12947-2 (ISO 2017) in the Martindale test device.

- Bending rigidity: The bending height of the samples (in cm) was measured in a Shirley hardness tester according to TS 1409 (TS 1973) standard. In addition, bending stiffnesses in the course and wale directions were calculated considering the bending heights and fabric weight as follows;

$$G = 0.1 \; x \; W \; x \; L^3$$

G: bending stiffness (mg.cm), W: fabric weight (g/m^2), L: bending length (cm).

- Thermal comfort: The thermal properties of the fabrics were measured in the ALAMBETA device.

- Air permeability: Air permeability of conditioned fabrics was measured in the Prowhite Airtest 2 device according to TS 391 EN ISO 9237 (ISO 1999) standard.

- Water vapor permeability: The water vapor permeability of conditioned fabric samples was measured based on the BS 7209 (BS 1990) standard.

- ***UV protection factor (UPF)***: UPF values of fabrics were determined according to ASTM D6603 (ASTM 2019) standard.

3. RESULTS AND DISCUSSION

3.1.Color and Fastness Results

Color measurement results of fabrics are given in Table 1.

Table 1: Color yield and CIE L*a*b* values of fabrics

Treatment	Color Yield	L*	a*	b*	C*	h°
After dyeing into	2.51	58.00	10.38	20.31	22.81	62.92
After dyeing into	1.17	68.28	1.88	17.64	17.74	83.91

When Table 2 is examined, it is seen that the L* value of the brown fabric is smaller, that is, the color is darker. At the same time, the a* and b* values are greater than the green fabric, meaning that its color is more red and more yellow.

Washing, rubbing, light and perspiration fastness values of fabrics are given in Table 2 and 3.

Table 2: Washing, rubbing and light fastness values of fabrics

Treatment	Washing Fastness (Staining)						Rubbing Fastness		Light Fastness
	WO	PAC	PES	PA	CO	CA	Dry	Wet	
After dyeing into brown color & finishing	4/5	4/5	4/5	4/5	4/5	4/5	5	4/5	4
After dyeing into green color & finishing	5	5	5	5	5	5	5	4/5	3/4

Table 3: Acidic and alkali perspiration fastness values of fabrics

	Acidic Perspiration Fastness (Staining)						Alkali Perspiration Fastness (Staining)					
Treatment	**WO**	**PAC**	**PES**	**PA**	**CO**	**CA**	**WO**	**PAC**	**PES**	**PA**	**CO**	**CA**
After dyeing into brown color & finishing	4/5	4/5	4/5	4/5	4/5	4/5	4/5	4/5	4/5	4	4/5	4
After dyeing into green color & finishing	5	5	5	5	5	5	5	5	5	5	5	5

When Table 2 and 3 are examined, it can be said that washing, rubbing and perspiration fastness values of both the green and brown dyed fabrics are high. However, their light fastness values were moderate.

3.2.Results Related to The Physical and Mechanical Properties

The physical and mechanical properties of the fabrics dyed in two different colors are given in Table 4.

Table 4: The physical and mechanical properties of the fabrics

Treatment	Weight (g/m²)	Density (Wale/Course)		Bursting Strength (kPa)	Pilling	Abrasion Resistance
Greige	170	8.8	11	621	4	4-5
After dyeing into brown color & finishing	179	9.8	12	609	4	4
After dyeing into green color & finishing	189	9.6	12	619	4	4-5

First of all, it is seen that the weight values of the greige fabric was 170 g/m², while it increased to 179-189 g/m² after dyeing and finishing processes. The reason for this is the shrinkage of the fabrics during wet processing. Parallel to this, a slight increase trend was observed in the wale/course density of the fabrics after wet processing. When the bursting strength values are examined, it can be said that dyeing and finishing processes cause a slight decrease in fabric strength. On the other hand, the pilling and abrasion resistance values of fabrics were not significantly affected by dyeing and finishing processes. These results are parallel with our previous study (Atav et al., 2022).

3.3.Results Related to The Handle and Comfort Properties

Bending rigidity properties of fabrics are given in Table 5.

Table 5: Bending rigidity properties of fabrics

Treatment	Bending Length (cm)		Bending Stiffness (mg.cm)	
	Course	Wale	Course	Wale
Greige	3.20	3.35	151.95	152.7
After dyeing into brown color & finishing	3.30	3.20	86.95	87.25
After dyeing into green color & finishing	3.05	3.05	71.80	71.85

When Table 5 is examined, the first thing that draws attention is that the bending length and accordingly the bending stiffness of the fabric in the wale direction is higher compared to the course direction. Another result obtained is that the bending length and bending stiffness of the fabrics decrease after dyeing and finishing processes.

Thermal comfort properties of fabrics are given in Table 6.

Table 6: Thermal comfort properties of fabrics

Treatment	Thermal Conductivity (W/mK)	Thermal Diffusivity (m^2/s)	Thermal Absorptivity ($Ws^{1/2}/m^2K$)	Thermal Resistance (m^2K/W)	Thickness (mm)	Heat Flow Rate
Greige	**60.9**	**0.143**	**161.4**	**15.2**	**0.93**	**1.80**
After dyeing into brown color & finishing	**60.0**	**0.107**	**184.0**	**11.7**	**0.70**	**1.71**
After dyeing into green color & finishing	**59.6**	**0.109**	**180.4**	**12.0**	**0.72**	**1.70**

When Table 6 is examined, the first thing that draws attention is that the thickness values of the fabrics decrease after dyeing and finishing processes. As it is known, the thickness of the clothing material is one of the most important factors determining the thermal conductivity of the clothing. As the thickness of the material and therefore the amount of air it contains increases, the thermal resistance of the material increases and its permeability decreases (Marmaralı et al., 2006). Therefore, after dyeing and finishing processes for each of 2 fabrics, the thermal resistance decreased.

Air and water permeability properties of fabrics are given in Table 7.

Table 7: Air and water permeability properties of fabrics

Treatment	Air Permeability	Water Vapor Permeability
Greige	1426.6	30.02
After dyeing into brown color & finishing	988.8	29.43
After dyeing into green color & finishing	767.6	29.02

When Table 7 is examined, it is seen that the air permeability of the fabrics significantly decreased after dyeing and finishing processes. As it is known, some shrinkage occurs in fabrics during wet processing, which leads to an increase in fabric density, as can be seen from Table 4. This explains the reason for the decrease in air permeability. However, the water vapor permeability of the fabrics was decreased very slightly after dyeing and finishing processes.

3.4.Results Related to The Functional Properties

UV protection functionality of fabrics were tested. Results are given in Table 8.

Table 8: UV protection functionality of fabrics

Treatment	Mean UV-A (315-400 nm)	Mean UV-B (290-315 nm)	Mean UPF	Standard Deviation of UPF average	Standard Error	UPF Range	UPF Rating
Greige	0.03322	0.03439	30	4.58	1.62	Very Good	26
After dyeing into brown color	0.0308	0.03204	32	2.41	0.8512	Very Good	30
After dyeing into green color	0.0216	0.02242	45	5.12	1.8091	Excellent	41

As can be seen from Table 8, greige fabric has already very good UV protection functionality. However, UPF ratings are increased after dyeing and finishing processes especially for fabric dyed into green color. The reason for this is the increase in fabric weight and wale/course density after dyeing and finishing processes.

4. CONCLUSION

According to experimental results it can be concluded that;
- fabric weight and bursting strength values increase,
- the pilling and abrasion resistance values do not change significantly,
- the bending length and bending stiffness values decrease,
- the thickness values and consequently the thermal resistance values decrease,
- the air permeability significantly decreases,
- the water vapor permeability slightly decreases and
- UPF ratings increase

after dyeing and finishing processes.

REFERENCES

[1] Atav, R., Yüksel, M. F., Dilden, D. B., & İzer, G. (2022). Colored cotton fabric production without dyeing within the sustainablity concept in textile. *Industrial Crops and Products*, *187*.
[2] ASTM D6603 Standard Specification for Labeling of UV-Protective Textiles 2019.
[3] BS 7209 Specification for water vapour permeable apparel fabrics 1990.
[4] Fang, L., Zhang, X., & Sun, D. (2013). Chemical modification of cotton fabrics for improving utilization of reactive dyes. *Carbohydrate polymers*, *91*(1), 363-369.
[5] Irfan, M., Zhang, H., Syed, U., & Hou, A. (2018). Low liquor dyeing of cotton fabric with reactive dye by an eco-friendly technique. *Journal of Cleaner Production*, *197*, 1480-1487.
[6] ISO 105-C06 Textiles test for colour fastness. Part C06: Color fastness to domestic and commercial laundering. 2010.
[7] ISO 105-X12 Textiles tests for color fastness. Part X12: Color fastness to rubbing. 2016.
[8] ISO 105-E04 Textiles-Tests for color fastness, Part E04: Color fastness to perspiration. 2013.
[9] ISO 105-B02 Textiles-Tests for color fastness, Part B02: Color fastness to artificial light. 2014.
[10] ISO 13938-2 Textiles - Bursting properties of fabrics - Part 2: Pneumatic method for determination of bursting strength and bursting distension. 2019.
[11] Marmaralı, A., Dönmez, S., Özdil, N., Oğlakçıoğlu, N. (2006). Giysilerde Isıl Konforu Etkileyen Parametreler, *Tekstil ve Konfeksiyon*, 4, 241-246.
[12] Paul, D., Das, S. C., Islam, T., Siddiquee, M. A. B., & Al, M. A. (2017). Effect of alkali concentration on dyeing cotton knitted fabrics with reactive dyes. *J. Chem*, *11*, 162-167.
[13] Tang, A. Y., & Kan, C. W. (2020). Non-aqueous dyeing of cotton fibre with reactive dyes: A review. *Coloration Technology*, *136*(3), 214-223.
[14] TS EN 12127 Textiles- Fabrics- Determination of mass per unit area using small samples.1999.
[15] TS 250 EN 1049-2 Textiles-Woven Fabrics-Construction-Methods of Analysis-Part 2 Determination of Number of Threads Per Unit Length. 1996.

[16] TS EN ISO 12945-2 Textiles - Determination of fabric propensity to surface pilling, fuzzing or matting - Part 2: Modified Martindale method 2021.
[17] TS EN ISO 12947-2 Textiles- Determination of abrasion resistance of fabrics by the Martindale method- Part 2: Determination of specimen breakdown 2017.
[18] TS 1409 Stiffness Determination of Woven Textiles 1973.
[19] TS 391 EN ISO 9237 Textiles-Determination of permeability of fabrics to air 1999.