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One-Bath Dyeing and Finishing Process of Polyester Fabrics

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ABSTRACT

The purpose of this study is to provide some finishing properties of polyester fabrics in dyeing baths. One bath dyeing and finishing process of 100% polyester fabrics are carried out with exhaust method. A commercial finishing agent is added with different concentrations in the dyeing baths. Fabrics are evaluated concerning hydrophilicity, volumetric resistivity, colour measurement, colour fastness, soil-releasing and fabric performance tests like bending strength, crease recovery, air permeability and thickness. Test results are analyzed by Kruskal Wallis Analysis using version 25 of IBM SPSS Statistics. As a result, the addition of a finishing agent to the dyeing bath has improved hydrophilicity, soil-release, crease recovery and bending strength properties of the fabrics, but has not affected the colour fastness of the fabrics. As the concentration of the finishing agent has increased, the air permeability and the surface resistance of the fabrics have decreased and the thickness has increased.

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Polyester, One-Bath, Dyeing, Finishing, Colour

1. INTRODUCTION

Polyester (PES) dominates the world market for synthetic textile fibers [1]. The use of polyester fibres in many textile applications is growing very rapidly due to their high strength, good elastic recovery, dimensional stability after heat setting, as well as suitability for blending with natural fibres. However, the main drawbacks in polyester-based textiles, for example, low moisture content, static accumulation, soiling, uncomfortable feel, pilling tendency, and difficulty in dyeing, attributed to their high crystallinity, compactness, hydrophobic nature, and absence of chemically reactive groups. Therefore, considerable efforts and technical developments have been done to upgrade their quality and usefulness, for example, antistatic finish, soil-release finish, water-repellent finish, anti-pilling finish, flame-retardant finish, and silk-like finish [2].

Moreover the combined dyeing and finishing processes offer a saving in energy and water consumption, which is important from both an economical and ecological point of view [3]. Dyeing and finishing of polyester fabrics were applied in one bath to give some finishing properties during disperse dyeing of polyester fabrics in this study. Disperse dyes have very limited solubility in water at room temperature and have substantivity for one or more hydrophobic fibres; e.g., polyesters and nylons. A general rule of thumb has the starting temperature about 70-80°C, the rate of temperature rises at 1.5-2 °C per minute, the dyeing temperature between 115-130°C and the time of dyeing at temperature from 15-60 minutes [4]. Most disperse dyes have a high exhaustion on polyester, often achieving 95% or higher. However, to achieve the best levels of wet-fastness, it is necessary to remove the residual dye from the polyester surface after dyeing to prevent it from staining other fibres. This is normally achieved by a

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reduction clearing treatment using caustic soda and hydrous (sodium dithionite), which reduces the surface dye [5].

Studies in the literature are focused on dyeing of polyester / cotton fabrics in one bath [6-8]. In one of the studies, the effects of corona discharge (CD) and chitosan treatment on the dyeability of polyester / cotton blends with direct and reactive dyes were investigated. The results have opened up the possibility of a new method for dyeing polyester / cotton blends in a single bath using a class of dyes commonly used for dyeing textile material of cellulosic origin [6]. In another study, the dyeing process of polyester / cotton fabrics using disperse / reactive dyes in one-bath dyeing method was examined. It was pretreated in NaOH solutions to improve the adhesion of chitin to the surface of polyester / cotton fibers. The colour and friction fastness properties of the chitin deposited polyester / cotton fabrics were evaluated. The colour difference between the stained voids and the stained voids in the NaOH and / or different viscosity chitin treatment was estimated. The data obtained show that it is possible to dye polyester / cotton fabrics finished with chitin with only one dispersion / reactive dye. The rubbing and washing colour fastness of the dyed samples were found to be good [7]. Maeda et al. conducted an experimental study on dyeing polyester / cotton blends with reactive disperse dyes in one bath. Supercritical carbon dioxide (SC-CO_2) was used as solvent in the range of 353 to 393 K and 10 to 20 MPa, and a successful result was achieved in dyeing polyester / cotton blends in one bath. The dyeing behavior was compared with the thermosol dyeing method using the same dye, and the colour fastness properties of the fabrics dyed with SC-CO_2 gave a better result than the fabrics dyed with the thermosol dyeing method [8]. Afifi and Sayed carried out an experimental study aimed at researching and developing a one-bath dyeing process for the most common blended fibers that would replace the traditional two-step process to dye each fiber component individually. They applied the dyeing of polyester / wool mixture with disperse dyes in a single bath, aiming to save raw materials, dyes, auxiliary substances and energy [9].

Fan et al. (2019) for the antistatic properties of polyester fabric, demonstrated that dyeing and antistatic finishing in which a new functional disperse dye is doped with graphene oxide can be obtained simultaneously with a single bath method. Functional dyes were used to dye polyester fabric by a high-temperature, high-pressure dyeing method. The dyeing concentration of the disperse dye for polyester fabric was 2%. The concentrations of GO were 0.5%, 1%, 2%, 3%, and 4% respectively. The original disperse Dye, GO, and the Dye-GO-treated polyester fabric were characterized by scanning electron microscopy. Raman spectrum, the colour performances of dyed polyester fabrics and effects of GO concentration and reduction time on antistatic properties were analysed. Increase in the amount of GO in functional disperse dye in terms of rubbing and washing fastness when tested, washing fastness of polyester fabric while it is at a good level, it was observed that the friction fastness decreased a little. The surface electrical resistance of the dyed fabric was obtained at a condition of 2% GO with a reduction time of 30 min and achieved an excellent antistatic standard. **It means that the dyeing and antistatic finishing can be simultaneously obtained by a one-bath method** [10].

In a study conducted in 2019, the simultaneous alkali deweighting and dyeing of polyester fabric was carried out in one-bath and one-step process. In the study, three highly alkali-resistant (HA) disperse dyes were successfully applied to the simultaneous alkali deweighting and dyeing of polyester fabric by a one-bath and one-step process. All the dyeing and finishing experiments were carried out in sealed and conical flasks immersed in a universal dyeing machine using a 50:1 liquor ratio. Colour measurement, mechanical performance, scanning electron microscopy observation, fastness to washing and rubbing were evaluated according to related standards. HA disperse dyes had very good dyeing performance and good fastness on polyester fabrics. Compared to the traditional method one-bath and one-stage process it has been determined that it has the potential to increase production efficiency. Thus, water, chemical and energy consumption decreases it is thought that economic and environmental benefits can be achieved [11].

Touhid et al. (2020) investigated a dyeing process that can provide functional properties to polyester fabric. In the study in question, a production-scale semi-continuous dyeing process was used for the production of reduced graphene oxide (rGO) and titanium dioxide (TiO_2) on polyester fabric. The micro-flowers (MFs) were successfully decorated on the fiber surface through a simple binder-free approach. The MFs blessed fabric showed improved adhesion and washing stability for antibacterial performance using eco-friendly cold O_2 plasma technique. Surface morphology analysis and elemental analysis such as FTIR analysis, X-ray diffraction analysis, Raman spectra analysis, Thermal analysis (TGA-DTG), XPS spectra analysis were performed experimental samples. The hydrophilicity of the as plasma modified polyester fabric was analyzed before and after surface modification. After treatment with pristine TiO_2 and rGO-TiO_2 the water contact angle (WCA) was increased from 20° to 85°, 115°, 125°, and 135° respectively. The antibacterial performance for the functionalized polyester fabric was analyzed. The antibacterial performance of the resultant fabric coated of TiO_2- rGO was enhanced from 60□ 99.5 % with the increase of GO and TiO_2 content % as compared to a pristine coated fabric. The overall efficiency of TiO_2-rGO MFs against the gram-positive (S. aureus) and gram-negative (E. coli) bacteria was recorded 99.5 % and 98.0 %, respectively [12].

Dyeing and finishing processes of 100% polyester fabrics with disperse dyestuff are carried out using the exhaust dyeing method in one bath in this study. Fabrics are evaluated concerning hydrophilicity, volumetric resistivity, colour measurement, colour fastness, soil-releasing test and fabric performance tests like bending strength, crease recovery, air permeability and thickness. Test results are analyzed by Kruskal Wallis Analysis using version 25 of IBM SPSS Statistics.

2. MATERIAL AND METHOD

2.1 Material

2.1.1. Fabric

100% polyester fabrics that are prefinished are obtained from Zorlu Textile (Turkey). The physical properties of the fabric are given in Table 1.

2.1.2. Disperse dye

Disperse Blue 79, whose chemical structure is shown in Figure 1, is provided by Setaş Chemical Company (Adana, Turkey).

2.1.3. Finishing agent

A commercial finishing agent (Reapret SR) is provided from Bozetto Group (Izmir, Turkey). The finishing agent gives softness, slipperiness, anti-static, dirt/stain resistant and hydrophilic properties to the polyester fabric. FT-IR analysis of the finishing agent is given in Figure 2.

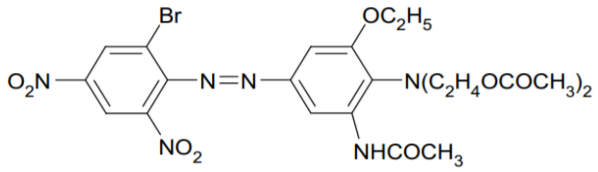

Figure 1. C.I.Disperse blue 79 (Şahin vd. 2007)

Table 1. Physical properties of polyester fabric

Weave Structure		Satin
Weight (g/m^2)		160
Density (yarns per cm)	Weft	25
	Warp	56
Linear Densities of Yarns (denier)	Weft	300
	Warp	100

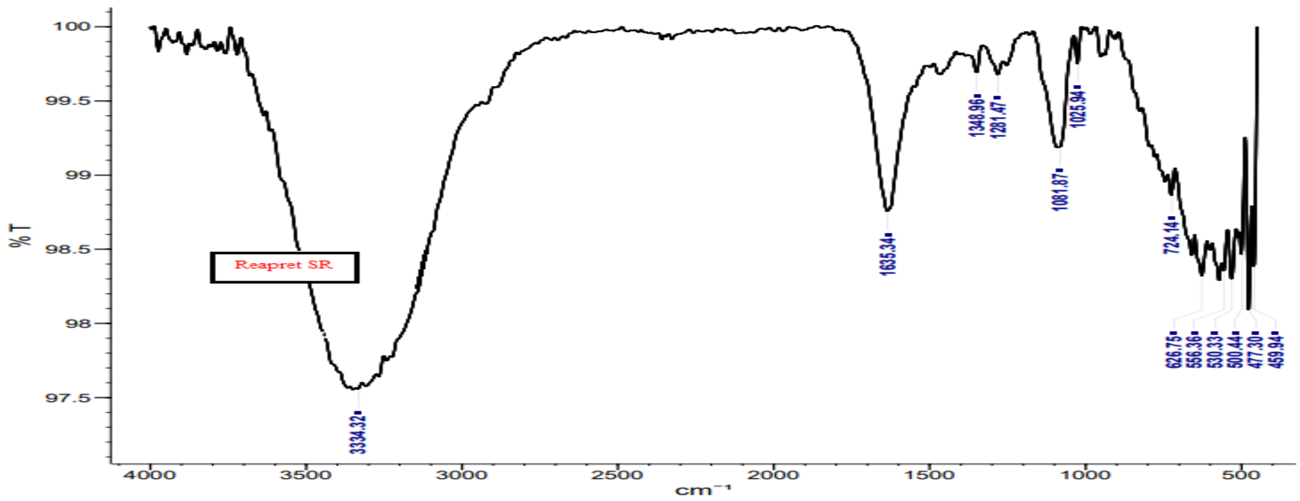

Figure 2. FT-IR analysis of the commercial finishing agent (Reapret SR)

In FT-IR analysis (Figure 2), wide O-H H_2O band at 3300 cm^{-1}, C = O at 1600 cm^{-1} and etheric bond C-O-C peaks at 1100 cm^{-1} are seen. The chemical structure of the commercial finishing agent is given in Figure 3.

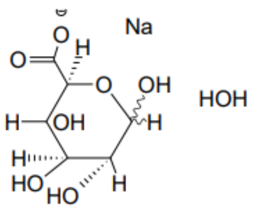

Figure 3. Chemical structure of the commercial finishing agent (Reapret SR)

The chemical structure of this material, used to reduce the static electrification of polyester fabric and to give it a hydrophilic feature, is given in Figure 3. This material, in the form of light brown cloudy liquid, is thought to be a water-based material. While the OH group in the structure gains hydrophilicity, conductivity is provided with H_2O and Na (due to its ionic character).

2.1.4. Auxiliary chemicals

Dispergator and pH regulating agent (Belsit Emu), anti-creasing agent (Belfalt Oyt) and wetting agent (Belwett-Mr-Ex) are provided by Belice Chemical Company (Gaziantep, Turkey).

2.2 Method

100% polyester fabrics are treated in dyeing baths containing different concentrations of a commercial finishing agent. The finishing agent is added in different concentrations to the dyeing bath. Some properties of the fabrics are tested after the dyeing process. Hydrophilicity, volumetric resistivity, colour measurement, colour fastness, soil-release and some performance properties (bending strength, crease recovery, air permeability, thickness) are tested respectively.

2.2.1. Disperse dyeing

Disperse dyeing processes containing different concentrations of a finishing agent are carried out with exhaust method. C.I. Disperse Blue 79 dyestuff is used in all dyeing processes. The finishing agent is added to the dyeing bath as 2%, 4% and 6% owf (on the weight of fabric). Disperse dyeing recipes are given in Table 2.

Disperse dyeing baths are prepared according to four different recipes as shown in Table 2. Fabric weights are taken as 10 grams. The pH values of the dyeing solutions are adjusted to 5 with acetic acid. Dyeing processes are carried out for 60 minutes at 130°C. Disperse dyeing processes for all samples are carried out in a laboratory-type dyeing machine (Ataç HT) at 20:1 liquor ratio (Figure 4).

Figure 4. Laboratory-type dyeing machine [13]

Reductive washing processes of samples are carried out with exhaust method after the dyeing process. Reductive washing recipes are prepared with hydrosulphite (2 g/L) and sodium hydroxide (2 g/L). Reductive washing processes are carried out for 20 minutes at 85°C in a laboratory-type dyeing machine (Figure 4) at 20:1 liquor ratio. Samples are neutralized for 10 minutes at 50°C in the neutralizing solution prepared by 1 g/L acetic acid after reductive washing processes.

2.2.2. Hydrophilicity test

Hydrophilicity tests are performed according to TSE 866 [14].

2.2.3. Volumetric resistivity tests

Volumetric resistivity measurements are carried out on the samples through a two-probe method using Keithley 6517B Electrometer/High resistance meter. Keithley 6517B electrometer is a multifunctional electrometer that usually works with low current and high resistance. This electrometer can be controlled through interfacing. Volumetric resistivity tests are performed according to ASTM D257-14 [15]. Test parameters are given in Table 3.

2.2.4. Colour measurement

Colour measurements of fabrics are made using a spectrophotometer (X-Rite Ci 4200UV) according to the CIE Lab system with d/8° measurement geometry and D65 daylight.

2.2.5.Colour fastness tests

Colour fastness tests to rubbing, washing and water are carried out according to TS EN ISO 105-X12, TS EN ISO 105-C06 and TS EN ISO 105-E01 respectively [16-18].

2.2.6. Soil-release tests

Soil-release tests are performed according to ASTM D4265 [19]. Firstly samples are contaminated with standard soils as seen in Table 4.

White circles 2,5 cm in diameter are drawn on the fabrics. Drawn areas are contaminated with the standard soils (Figure 5).

Table 2. Dyeing recipes

Dyeing Recipes	Reference	2% finishing agent	4% finishing agent	6% finishing agent
Weight of fabric (g)	10	10	10	10
Liquor ratio	1:20	1:20	1:20	1:20
Finishing agent (%) (Reapret SR)	**0**	**2**	**4**	**6**
Disperse dyestuff (%)	1	1	1	1
Dispergator and pH regulating agent (g/L)	1	1	1	1
Anti-creasing agent (g/L)	1	1	1	1
Wetting agent (g/L)	1	1	1	1

Table 3. Volumetric resistivity test parameters

Pre-discharge (s)	10
Bias voltage (V)	100
Bias time (s)	1
Measure voltage (V)	500
Measure time (s)	60

Table 4. Standard soil types

Soil	Standard Soil Types	Applied Amount (g)
Soil 1	%75 Tomato paste +%25 Pure olive oil	0.5
Soil 2	Mustard sauce	0.5
Soil 3	Ink	0.056

Figure 5. Samples contaminated with soil 2 (mustard sauce)

Soils transferred onto fabric samples are kept for 10 minutes under standard atmospheric conditions. Samples are washed 5 minutes under tap water at 29° dH hardness and left to dry at room temperature. Colour measurements of the samples are made with a spectrophotometer and the colour differences between the samples after and before soil-release tests are obtained.

2.2.7. Fabric performance test

Bending strength, crease recovery, air permeability and thickness tests are performed according to TS 1409, TS 390 EN 22313, TS 391 EN ISO 9237 and TS 7128 EN ISO 5084 respectively [20-23].

3. RESULTS AND DISCUSSION

3.1 Hydrophilicity Test Results

Hydrophilicity is the duration of absorbed drops by the fabric dropped onto the fabric. Hydrophilicity test results are given in Table 5. The hydrophilicity values given for each sample are the average value of 10 measurements.

As seen in Table 5, the hydrophilicity value of the reference sample (dyed without the finishing agent) is found as 5.87 seconds. It can be said that the addition of the finishing agent to the dyeing bath has improved the hydrophilicity of the fabric. 71%, 86%, 90% better hydrophilicity obtained than the reference sample respectively with the addition of 2%, 4% and 6% finishing agent to the dyeing bath. Test results are analyzed using version 25 of IBM SPSS Statistics.

The compliance of the data to the normal distribution is tested with Kolmogorov-Smirnov and Shapiro-Wilk. Test results are given in Table 6.

Table 5. Hydrophilicity test results

Samples	Hydrophilicity (s)
Reference	5.87
2% finishing agent	1.70
4% finishing agent	0.80
6% finishing agent	0.53

Table 6. Kolmogorov-smirnov and shapiro-wilk test results of hydrophilicity values

Sample Code	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Reference	.375	10	.000	.682	10	.001
2% finishing agent	.285	10	.021	.757	10	.004
4% finishing agent	.213	10	.200*	.920	10	.354
6% finishing agent	.154	10	.200*	.935	10	.494

*. This is a lower bound of the true significance.
a. Lilliefors Significance Correction

Since some data groups don't conform to a normal distribution and the number of samples is insufficient, a non-parametric test is used. Kruskal Wallis k-independent sample test is a nonparametric test that evaluates whether more than two groups are different from each other. It is used to reveal the difference between the groups with different concentrations (reference, 2% finishing agent, 4% finishing agent and 6% finishing agent) and the following hypothesis are established.

H_0: There is no difference between the groups that are treated with different concentrations of finishing agent

H_1: There is a difference between the groups that are treated with different concentrations of finishing agent

Kruskal Wallis test results of hydrophilicity are given in Table 7.

It is seen that comparison of groups treated with different concentrations of finishing agents in terms of hydrophilicity in Table 7. A statistically significant difference is found between the groups in terms of hydrophilicity values ($p <0.05$). Mann-Whitney U test is used for the pairwise comparison of groups (Table 8). According to Table 8, there is a difference in pairwise comparison between groups treated with different concentrations of finishing agents.

3.2. Volumetric Resistivity Test Results

Volumetric resistivity test results are given in Table 9. The volumetric resistivity value given for each sample is the average value of 4 measurements.

As seen in Table 9, the group dyed with 6% finishing agent has the lowest volumetric resistivity. The increase in concentration has reduced the surface resistivity, in other words, has increased the conductivity. However, we can say that the fabric is still insulating since it does not fall below the value of $5x10^{10}$.

3.3. Colour Measurement Results

Colour measurements of fabrics are made using a spectrophotometer (X-Rite Ci 4200UV) according to the CIE Lab system with d/8° measurement geometry and D65 daylight. The L, a, b, ΔE values obtained for each sample are the average values of 3 measurements taken on the same fabric sample. Colour measurement results are given in Table 10.

Table 7. Kruskal Wallis test results of hydrophilicity values

Sample Code	n	p	x^2
Reference	10	0.000	28.561
2% finishing agent	10		
4% finishing agent	10		
6% finishing agent	10		

Table 8. Mann-Whitney U test results of hydrophilicity values

Sample Code	p	Mann-Whitney U	Wilcoxon W
Reference-2% finishing agent	0.049	24.000	79.000
Reference-4% finishing agent	0.000	2.000	57.000
Reference-6% finishing agent	0.000	0.000	55.000
2% finishing agent-4% finishing agent	0.029	21.000	76.000
2% finishing agent-6% finishing agent	0.000	1.500	56.500
4% finishing agent-6% finishing agent	0.001	8.000	63.000

Table 9. Volumetric resistivity test results

Samples	Volumetric Resistivity (ohm.cm)
Reference	$363x10^{11}$
2% finishing agent	$67.2x10^{11}$
4% finishing agent	$11.8x10^{11}$
6% finishing agent	$2.18x10^{11}$

Table 10. Colour measurement test results

Sample Code	L*	a*	b*	C*	h	ΔE*	K/S
Reference	26.20	0.95	-19.34	19.36	272.82		
2% finishing agent	25.80	1.37	-18.94	18.99	274.14	0.58	102.20
4% finishing agent	25.84	1.09	-19.48	19.51	273.20	0.29	102.94
6% finishing agent	24.76	1.62	-18.13	18.20	275.10	1.44	111.30

Colour differences between the group dyed with 2% finishing agent, the group dyed with 4% finishing agent, the group dyed with 6% finishing agent and the reference group is calculated as 0.58, 0.29 and 1.44 respectively. These colour differences are within acceptable limits for production in the textile industry. As the finishing agent concentration has increased, the colour strength (K/S) values have increased, as expected.

3.4. Colour Fastness Test Results

Colour fastness tests to washing and water are carried out using the relevant standards. Here, colour change on the fabric and colour staining on the multifiber fabric (acetate, cotton, polyamide, polyester, acrylic and wool) are investigated. Test results are given in Table 11.

Colour change values for all samples is found as 5 levels. In other words, no change is observed in the colour of the samples after colour fastness tests to washing and water. When the values of colour staining on the multifiber is examined, it is observed that the values are generally at the level of 4/5 and 5. It can be said that the highest colour staining value is to wool fibre.

Colour fastness to rubbing tests is made in two ways, dry and wet. Colour fastness test results to rubbing are given in Table 12.

As seen in Table 15, the colour staining values in the weft and warp directions are 5 levels for all samples in the dry rubbing fastness test. When the wet rubbing fastness test results is examined, it is seen that the fastness values of all samples are at the level of 4/5. As expected, the wet rubbing fastness values of the fabrics are slightly lower than the dry rub fastness values. As a result, it can be said that the increase in finishing agent does not affect the colour fastness of the fabrics.

3.5. Soil-Release Test Results

Soil-release tests are performed according to ASTM D4265. Colour measurements of the samples are made with a spectrophotometer after soil release treatment with soil 1, soil 2 and soil 3 to observe changes in colours of the fabrics. The L, a, b, ΔE values for each sample are the average values of 3 measurements taken on the same fabric (Table 13).

Table 11. Colour fastness test results to washing and water

Fastness	Colour fastness to washing				Colour fastness to water			
	Reference	2% finishing agent	4% finishing agent	6% finishing agent	Reference	2% finishing agent	4% finishing agent	6% finishing agent
Colour change	5	5	5	5	5	5	5	5
Colour staining								
-Acetate	5	5	5	5	5	5	5	5
-Cotton	5	5	5	5	5	5	5	5
-Polyamide	5	5	5	5	5	5	5	5
-Polyester	5	4/5	4/5	4/5	5	5	5	5
-Acrylic	5	5	5	5	5	5	5	5
-Wool	4/5	4/5	4/5	4/5	5	4/5	4/5	4/5

Table 12. Colour fastness to rubbing

Sample Code	Colour staining			
	Dry		Wet	
	Warp	Weft	Warp	Weft
Reference	5	5	4/5	4/5
2% finishing agent	5	5	4/5	4/5
4% finishing agent	5	5	4/5	4/5
6% finishing agent	5	5	4/5	4/5

Table 13. Colour measurement test results after soil-release treatment

Soil Type	Sample Code	L	a	b	ΔE*
Soil 1	Reference	21.70	1.10	-12.50	
	2% finishing agent	22.50	1.08	-15.09	2.71
	4% finishing agent	23.51	0.83	-16.26	1.57
	6% finishing agent	23.65	1.14	-18.67	2.43
Soil 2	Reference	23.39	1.17	-19.16	
	2% finishing agent	22.67	1.30	-18.57	0.94
	4% finishing agent	22.43	1.54	-19.45	0.94
	6% finishing agent	24.45	1.03	-19.57	2.09
Soil 3	Reference	23.45	3.94	-18.68	
	2% finishing agent	24.85	2.72	-19.96	2.26
	4% finishing agent	25.74	2.61	-20.53	1.06
	6% finishing agent	24.79	2.44	-20.50	0.97

The group dyed with 4% finishing agent also have the lowest colour difference after the soil release test which is done with soil 1 (%75 Tomato paste +%25 Pure olive oil). The group dyed with 2% finishing agent and the group dyed with 4% finishing agent have the lowest and acceptable colour difference values after the soil release test which is done with soil 2 (mustard). It can be said that 2% finishing agent impregnation is enough to get soil release effect for mustard. As the concentration of the finishing agent has increased, the colour difference has decreased. The minimum colour difference with the reference group is observed in the sample which added 6% finishing agent to dyeing bath for soil 3.

3.6. Fabric Performance Test Results

Fabrics are evaluated concerning bending strength, crease recovery, air permeability and thickness. The bending strength value for each sample is a value calculated with these data obtained by measuring the droop lengths of 16 samples in the warp and weft directions. The crease recovery value for each sample is the average value of the measurement obtained from 10 samples in the warp and weft directions. Air permeability and thickness values represent the average value of 5 measurements for each sample. Fabric performance test results are given in Table 14.

Bending strength is the degree of deviation from the horizontal axis of the fabric with its weight. When the bending strength of fabric increases, stiffness of fabric also increases but drape and softness of fabric decrease. As seen in Table 14, the reference sample has the highest bending strength. As the concentration of the finishing agent has increased, the bending strength has decreased and softness has increased. Crease recovery angle can be defined as the ability to revert fabric folded for a certain period under a given force. The high crease recovery angle means that the wrinkle properties of the fabric are good. Generally, it can be said that increased finishing agent concentration increased the crease recovery angles of the samples compared with the reference sample. It means that the addition of a finishing agent to the dyeing bath has improved the crease recovery property of the fabrics. Air permeability expresses the passing ability of air through fibers and yarns constituent of a fabric [24]. Air permeability is calculated as the time required for a certain volume of air to pass through the fabric. High air permeability values mean deterioration of the air permeability property of the fabric. As seen in Table 14, a certain volume of air has passed through the reference sample in the lowest time. It is observed that this sample has had the lowest thickness and the best air permeability. As the concentration of the finishing agent has increased, the thickness of the samples has increased and has deteriorated the air permeability of the samples slightly.

The compliance of the data to the normal distribution is tested with Kolmogorov-Smirnov and Shapiro-Wilk tests. Tests of normality of fabric performance test results are given in Table 15.

Table 14. Fabric performance test results

Samples	Bending Strength (mg.cm)	Crease Recovery Angle (°)	Air Permeability (s)	Thickness (mm)
Reference	28.92	139.50	144.80	0.31
2% finishing agent	26.73	136.35	154.20	0.32
4% finishing agent	25.93	141.00	156.40	0.32
6% finishing agent	16.16	144.55	172.80	0.33

Table 15. Kolmogorov-smirnov and shapiro-wilk test results of fabric performance values

Test Tesults	Sample Code	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
		Statistic	df	Sig.	Statistic	df	Sig.
Bending Length (Weft Direction)	Reference	.194	16	.109	.902	16	.085
	2% finishing agent	.169	16	.200*	.947	16	.438
	4% finishing agent	.217	16	.043	.873	16	.031
	6% finishing agent	.269	16	.003	.725	16	.000
Bending Length (Warp Direction)	Reference	.137	16	.200	.960	16	.659
	2% finishing agent	.174	16	.200	.934	16	.287
	4% finishing agent	.259	16	.005	.898	16	.075
	6% finishing agent	.274	16	.002	.671	16	.000
Crease Recovery (Weft Direction)	Reference	.217	10	.200*	.931	10	.458
	2% finishing agent	.205	10	.200*	.881	10	.133
	4% finishing agent	.209	10	.200*	.922	10	.376
	6% finishing agent	.191	10	.200*	.865	10	.088
Crease Recovery (Warp Direction)	Reference	.274	10	.032	.785	10	.010
	2% finishing agent	.208	10	.200*	.941	10	.567
	4% finishing agent	.132	10	.200*	.965	10	.843
	6% finishing agent	.120	10	.200*	.968	10	.869
Air Permeability	Reference	.347	5	.048	.857	5	.217
	2% finishing agent	.249	5	.200*	.844	5	.177
	4% finishing agent	.252	5	.200*	.943	5	.685
	6% finishing agent	.294	5	.183	.822	5	.121
Thickness	Reference	.300	5	.161	.833	5	.146
	2% finishing agent	.243	5	.200*	.894	5	.377
	4% finishing agent	.300	5	.161	.833	5	.146
	6% finishing agent	.246	5	.200*	.956	5	.777

When Table 15 is examined, it is seen that some data groups aren't distributed normally. Since there are groups with an abnormal distribution within the groups and the number of samples is insufficient, it is deemed appropriate to perform the Kruskal Wallis test among non-parametric tests. Bending length and crease recovery values are used in statistical analysis in warp and weft directions. The following hypothesis are established.

H_0: There is no difference between the groups that are treated with different concentrations of finishing agent

H_1: There is a difference between the groups that are treated with different concentrations of finishing agent

Kruskal Wallis test results are given in Table 16.

It is seen that comparison of groups treated with different concentrations of the finishing agent in Table 16. A statistically significant difference isn't found between the groups (the reference group, the group dyed with 2% finishing agent, the group dyed with 4% finishing agent and the group dyed with 6% finishing agent) in terms of the bending length values (weft direction) ($p = 0.137 > 0.05$) and the thickness values ($p = 0.177 > 0.05$). A statistically significant difference is found between the groups for the other fabric performance values, such as the air permeability values ($p = 0.016 < 0.05$).

Mann-Whitney U test is used for the pairwise comparison of groups (Table 17). According to Table 20, there is a significant difference in pairwise comparison between groups (especially the group dyed with 4% finishing agent and the group dyed with 6% finishing agent).

Table 16. Kruskal Wallis test results of fabric performance values

	Sample Code	N	p	x^2
Bending Length (Weft Direction)	Reference	16	0.137	5.535
	2% finishing agent	16		
	4% finishing agent	16		
	6% finishing agent	16		
Bending Length (Warp Direction)	Reference	16	0.000	29.006
	2% finishing agent	16		
	4% finishing agent	16		
	6% finishing agent	16		
Crease Recovery (Weft Direction)	Reference	10	0.009	11.557
	2% finishing agent	10		
	4% finishing agent	10		
	6% finishing agent	10		
Crease Recovery (Warp Direction)	Reference	10	0.005	12.688
	2% finishing agent	10		
	4% finishing agent	10		
	6% finishing agent	10		
Air Permeability	Reference	5	0.016	10.371
	2% finishing agent	5		
	4% finishing agent	5		
	6% finishing agent	5		
Thickness	Reference	5	0.177	4.926
	2% finishing agent	5		
	4% finishing agent	5		
	6% finishing agent	5		

Table 17. Mann-Whitney U test results of fabric performance values

	Sample Code	p	Mann-Whitney U	Wilcoxon W
Bending Length (Warp Direction)	Reference-2% finishing agent	0.423	106.500	242.500
	Reference-4% finishing agent	0.128	87.000	223.000
	Reference-6% finishing agent	0.000	14.500	150.500
	2% finishing agent-4% finishing agent	0.445	107.500	243.500
	2% finishing agent-6% finishing agent	0.000	16.000	152.000
	4% finishing agent-6% finishing agent	0.000	16.000	152.000
Crease Recovery (Weft Direction)	Reference-2% finishing agent	0.190	32.000	87.000
	Reference-4% finishing agent	0.009	16.500	71.500
	Reference-6% finishing agent	0.001	9.500	64.500
	2% finishing agent-4% finishing agent	0.853	47.500	102.500
	2% finishing agent-6% finishing agent	0.190	32.000	87.000
	4% finishing agent-6% finishing agent	0.052	24.000	79.000
Crease Recovery (Warp Direction)	Reference-2% finishing agent	0.023	20.000	75.000
	Reference-4% finishing agent	0.029	21.500	76.500
	Reference-6% finishing agent	0.393	38.500	93.500
	2% finishing agent-4% finishing agent	0.035	22.500	77.500
	2% finishing agent-6% finishing agent	0.007	15.000	70.000
	4% finishing agent-6% finishing agent	0.023	20.000	75.000
Air Permeability	Reference-2% finishing agent	0.69	10.500	25.500
	Reference-4% finishing agent	0.056	3.00	18.000
	Reference-6% finishing agent	0.008	0.000	15.000
	2% finishing agent-4% finishing agent	0.421	8.500	23.500
	2% finishing agent-6% finishing agent	0.095	4.000	19.000
	4% finishing agent-6% finishing agent	0.008	0.000	15.000

4. CONCLUSION

In this study, simultaneous dyeing and finishing processes of 100% polyester fabrics are carried out in one bath using exhaust method. A commercial finishing agent is added with different ratios (2%, 4% and 6% owf) in the dyeing bath. Fabrics are evaluated concerning hydrophilicity, volumetric resistivity, colour measurement, colour fastness, soil-releasing test and fabric performance tests like bending strength, crease recovery, air permeability and thickness. Test results are analyzed by Kruskal Wallis test using version 25 of IBM SPSS Statistics. Mann-Whitney U test is used for the pairwise comparison of groups.

The hydrophilicity value of the reference sample (dyed without a finishing agent) is found as 5.87 seconds. It can be said that the addition of a finishing agent to the dyeing bath is improved the hydrophilicity property of the fabric. 71%, 86%, 90% better hydrophilicity is obtained than the reference sample respectively with the addition of 2%, 4% and 6% finishing agent. It isconcluded that samples dyed with 6%, 4% and 2% finishing agents are statistically different from each other in terms of hydrophilicity. Samples dyed with 6% finishing agent has the lowest volumetric resistivity value. The increase in the concentration of the finishing agent has decreased the surface resistance, in other words, it has increased the conductivity.

Colour differences between the group dyed with 2% finishing agent, the group dyed with 4% finishing agent, the group dyed with 6% finishing agent and the reference sample are calculated as 0.58, 0.29 and 1.44 respectively. These colour differences are within acceptable limits for production in the textile industry. As the finishing agent concentration has increased, the colour strength (K/S) values have increased, as expected. No change is observed in the colour of the samples after colour fastness tests to washing and water. When the values of colour staining on the multifiber is examined, it is observed that the values are generally at the level of 4/5 and 5. Colour staining values in the weft and warp directions are found to be at the level of 5 for all samples in the dry rubbing fastness test. When the wet rubbing fastness test results are examined, it is seen that the fastness values of all samples are at the level of 4/5. It can be said that the increase in finishing agent concentration has not affected the colour fastness of the fabric.

The group dyed with 4% finishing agent also has the lowest colour difference after the soil release test which is done with soil 1 (%75 Tomato paste +%25 Pure olive oil). The group dyed with 2% finishing agent and the group dyed with 4% finishing agent have the lowest and acceptable colour difference values after the soil release test which is done with soil 2 (mustard). It can be said that 2% finishing agent impregnation is enough to get soil release effect for mustard. As the concentration of the finishing agent has increased, the colour difference has increased. The minimum colour difference with the reference sample is observed in the sample which added 6% finishing agent to dyeing bath for soil 3.

When the fabric performance properties are examined, the reference sample has the highest bending strength. As the concentration of the finishing agent has increased, the bending strength has decreased so that the softness of the samğles has increased. Generally, it can be said that increased finishing agent concentration has increased the crease recovery angles of the samples compared with the reference sample. It means that the addition of a finishing agent to the dyeing bath is improved the crease recovery property of the fabrics. When air permeability values are examined, a certain volume of air has passed through the reference sample in the shortest time. As the concentration of the finishing agent has increased, the air permeability of the fabrics has decreased and the thickness values have increased.

The finishing agent gives softness, slipperiness, anti-static and dirt/stain resistant and hydrophilic properties to the polyester fabric. The addition of a finishing agent to the dyeing bath has no effect on the colour fastness of the fabrics. The difference in colour values with finishing agent application is within the acceptable range. The addition of a finishing agent to the dyeing bath has improved the soil-release properties of the fabrics. When the fabric performance properties are examined, the addition of a finishing agent to the dyeing bath improves crease recovery and bending strength properties of the fabrics.

Future Works: Similar to this study, the results can be compared by making a similar application in fibre and yarn form. It can be observed how the performance properties of the fabric are affected by trying different finishing processes after dyeing. It can be compared by applying chemicals produced by different manufacturers for similar purposes.

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