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The Influence of pH of Float on the Dyeability of Polyester Fabric

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Summary: Disperse dyes are essentially non – ionic, exhibit poor solubility in water, and they can be used in the form of water dispersion. Polyester fibres are resistant to dilute aqueous acids and alkaline solutions and pH value does not provide a crucial impact on the dyeing mechanism; however, many disperse dyes undergo degradation if the pH is uncontrolled during aqueous dyeing. In order to minimize the possibility of dye hydrolysis, the dyeing is carried out in a slightly acidic medium, and pH is usually adjusted with acetic acid. In this work, the quantity of disperse dyes (Sinten Gelb P-5GL and Sinten Scharlach P-3GL) applied to polyester knitwear was investigated as a function of pH. The sorption capacity of polyester knitwear was monitored by using reflection curves and CIELab system, according to Swiss software Sandoz (based on spectrophotometry). The acetic acid was used for dyebath pH adjustment. The results showed that the maximum uptake of Sinten Gelb P-5GL and SintenScharlach P-3GL dyes by polyester knitwear occurred at pH 4.64 (0.2924%) and 6.20 (0.1860%), respectively. According to reflection curves in the range (λ_{max} = 400-700 nm), the effect of pH on the sorption of Sinten Gelb P-5GL was more significant than one for Sinten Scharlach P-3GL, when concentration of dye is constant (0.4%). The CIELab values for three illuminants (daylight, light – bulb and incandescent) showed a significant dependence between pH float and hue and intensity of polyester knitwear dyeing with disperse dyes.

Key words: Disperse dyes, Polyester knitwear, pH of float.

Introduction

Polyester is one of the most important and most commonly used polycondensation polymers derived from dicarboxylic acids (sometimes other types of acids) and diols. Polyester is a polymer that contains a functional group of esters on a polymer chain. The term polyester is often used for polyethylene terephthalate (PET), despite the numerous polyester forms present [1, 2].

This polymer is processed in various forms, such as fibers, fabrics, composites, resins, dendimers, films, membranes, in various fields such as textiles, automobiles, electronics, construction. Polyester can be made by the polycondensation process, ring opening polymerization, and polyaddition. Polyester can be recycled by physical (mechanical) or chemical (hydrolysis, methanolysis, and glucose reaction) methods [1, 2].

Polyester can be classified into two groups: thermoplastic polyester and thermosetting (unsaturated, polyester resin) polyester. Thermoplastic polymers can be classified as linear aromatic polyesters (fiber and film polyesters), elastomers (block copolyesters), liquid crystal polyesters, engineering plastics, aliphatic polyesters, and poly (hydroxyl alkanoates) [3].

Disperse inks have poor water solubility and, in order to be used, must be ground into very small particle sizes and sprayed in water using a surfactant or carrier that must be added during dyeing or printing [4–7].

Disperse dyes are economical, easy to apply and have an exceptional ability to cover the morphological and chemical structure of the fibers. Disperse dyes have a good ability to dye in dark shades. Some of them have good leveling and migration properties [8].

A fine uniform dispersion is necessary in order for the dye to be evenly distributed in the dyeing bath and to prevent the dye from being filtered by the fibers that have already been dyed, and also to make a large surface area of dye particles that soon dissolve. Synthetic fibers, such as nylon, triacetates, polyester, and acrylic hydrophobicity from acetate, would be very difficult to dye if it were not for dispersed dyes [8].

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Dyeing of polyester fabrics is usually performed in a slightly acidic medium. Although the polyester is resistant to dilute aqueous acids and alkaline solutions, many disperse dyes can be degraded if the pH is uncontrolled during aqueous dyeing. This can be related to the chemical structure of disperse dyes. Namely, some of disperse dyes contain hydrolysable groups (i.e., ester groups) which makes them particularly sensitive to hydrolysis, especially in alkaline medium. In order to minimize the possibility of dye hydrolysis, dyeing is carried out in a slightly acidic medium, usually in the pH range of 4.5–5.56 [9, 10].

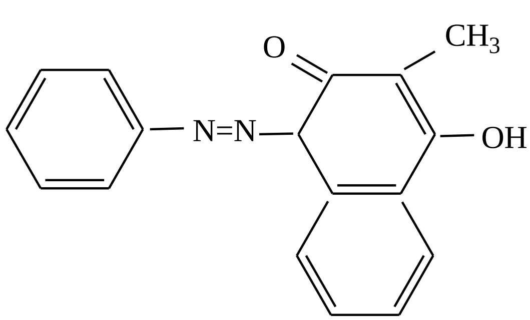
The aim of this paper is to examine the influence of pH values on the resistance of disperse dye on a sample of polyester knitwear based on the reflection curves, CIELab values, and the accepted database. The most accurate results were obtained during the examination of the database, on the basis of which it is possible to see exactly how much dye was applied to the sample of polyester knitwear at the appropriate pH values of the float.

Experiment

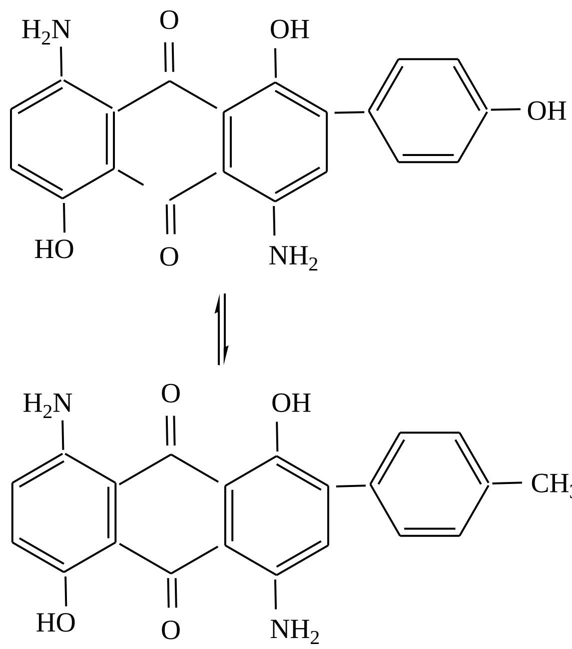
Undyed polyester (100% PET) knitwear, produced by Nitex (Niš) was used and its characteristics are shown in Table 1. The weight of the sample was 10 g. Disperse dyes Sinten Gelb P-5GL (manufacturer) and Sinten Sharlach P-3GL were obtained from (manufacturer) and used without further purification. The chemical structures of these dyes are shown in Fig 1a (Sinten Gelb P-5GL) and Fig 1b (Sinten Sharlach P-3GL).

Table-1: Characteristics of undyed polyester knitwear.

Characteristic	Amount
Horizontal density (cm^{-1})	**15**
Vertical density (cm^{-1})	**18.5**
Square meter mass ($g\ cm^{-1}$)	**130**
Shrinking in the process of boiling:	
in length (%)	**1**
in width (%)	**1.5**



a)



b)

Fig. 1: Chemical structure of a) Sinten Gelb P-5GL and b) SintenSharlach P-3GL.

Polyester knitwear was cleaned in a bath containing a solution of 1 g/dm^3 Na_2CO_3, 1 g/dm^3 NaOH, washing agent (Jugopon 50). The material was placed in a float and processed for 30 minutes at a temperature of 343-345 K, and then washed by squeezing. The ratio of the float was 30:1. In order to neutralize the rest of the preparation float, 0.1 g/dm^3 CH_3COOH was added in the last wash.

The dyeing float consisted of a certain amount of dye, i.e., 0.4% by weight of material and CH_3COOH (0.1 g/dm^3), where the pH value was 4. The ratio of the dye float was 30:1. Powder dyes were dispersed in 10-20 times more water at a temperature of 303 K with intensive mixing. Dyeing started at 323 K, and after 50 minutes, the temperature of the float was raised to 398-408 K, and maintained at that temperature for 60-90 minutes depending on the intensity of the shade. After dyeing, the float was cooled to 363-368 K, the polyester was washed with warm water. The sample was washed again at 343 K with 1 g/dm^3 of washing agent (Jugopon 50) added and washed again.

The residues of non-fixed paints on polyester were removed by washing and alkaline cleaning. The material was processed with 1 g/dm^3 of Jugopon 2N and 0.5 g/dm^3 of soda ash for 15-20 minutes at 343-353 K, and thoroughly washed. Dark and medium dyes were processed in a reductive alkaline float (3 g/dm^3 NaOH, 2 g/dm^3 $Na_2S_2O_4$, 3 g/dm^3 Jugopon 2N), achieving optimal dye fastness and facilitating further processing of polyester fibers.

Dyeing of polyester knitwear was carried out at a constant dye concentration (0.4%), a constant weight of polyester knitwear (10 g), as well as a constant volume of float. The acetic acid was added in different volumes, so the influence of pH on dyeing process could be monitored. Used volumes of acetic acids and pH values are given in Table 2.

The reflectance spectra of treated polyester knitwear samples were recorded with an UPDATE COLOR EYE 3000 spectrophotometer (ICS – TEXICON). For the dyed samples, they were expressed in terms of reflectance (%) in the visible spectral range ($\lambda = 400 - 700$ nm). The color properties of the samples were expressed in terms of CIELab values. The CIELab coordinates were estimated by applying the metric program "Super Match 6 Supplement" [9-11].

Results and Discussion

Figs 3 and 4 show the relationship between the amount of dye (%) applied to polyester knitwear and the pH value of the float, while Table 2 shows the used volumes of acetic acids and pH values.

As it can be seen, the influence of pH values of dyeing float on dye concentrations of polyester knitwear is rather changeable, and its dependence is irregular. The highest concentration (0.2924%) of Sinten Gelb P-5GL applied on polyester knitwear was at pH 4.64, while the lowest concentration (0.0204%) was at pH 6.03 (Fig 2). At pH 6.20, dye Sinten Sharlach P-3GL was applied in the highest amount (0.2654), while the lowest concentration (0.1924) was at pH 4.61 (Fig 3). As it can be seen, the acid float is more suitable for dyeing polyester knitwear with Sinten Gelb P-5GL, while the dyeing efficiency of Sinten Sharlach P-3GL is higher at slightly acidic condition.

The reflection dependence on wavelength for both dyes is shown in Fig 4,5. Fig 4 shows the reflection curves for polyester knitwear dyed by Sinten Gelb P-5GL. Compared to standard (reflection curve at pH 7.78, without acetic acid), other reflection curves are above and below the standard reflection curve, suggesting a higher or smaller amount of applied dye, and a significant influence of pH on the dyeing process, since the beam of reflection curves is large.

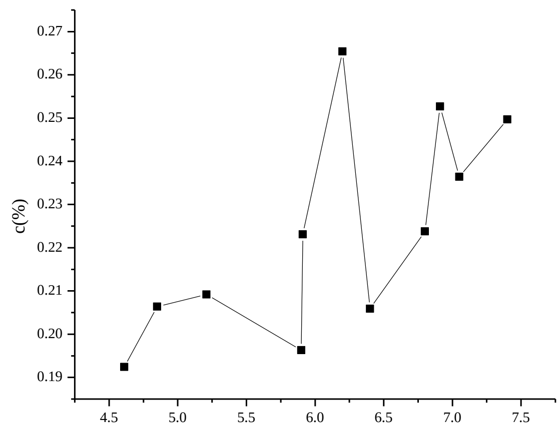


Fig. 2: Dependency between the amount of dye Sinten Gelb P-5GL and the pH value of the float.

Table-2: The impact of pH values of dyeing float on dye concentrations of polyester knitwear.

Sinten Gelb P-5GL		Sinten Sharlach P-3GL	
pH value of float	**Dye concentration (%)**	**pH value of float**	**Dye concentration (%)**
7.78	**0.0377**	**7.40**	**0.2497**
7.08	**0.0364**	**7.05**	**0.2364**
6.92	**0.0770**	**6.91**	**0.2527**
6.61	**0.0718**	**6.80**	**0.2238**
6.30	**0.0478**	**6.40**	**0.2059**
6.19	**0.0359**	**6.20**	**0.2654**
6.03	**0.0204**	**5.91**	**0.2231**
5.99	**0.0316**	**5.90**	**0.1963**
5.40	**0.1550**	**5.21**	**0.2092**
4.80	**0.2412**	**4.85**	**0.2064**
4.64	**0.2924**	**4.61**	**0.1924**

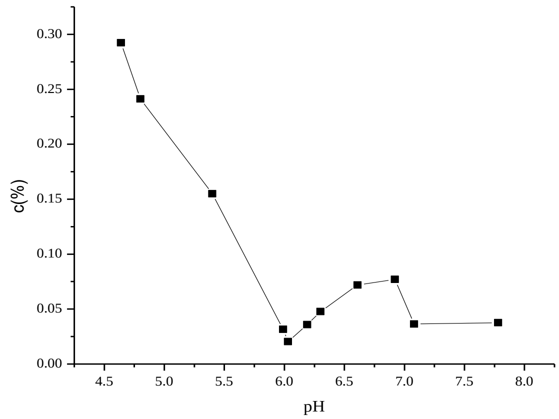


Fig. 3: Dependence of the amount of dye SintenSharlach P-3GL in relation to the pH value of the float.

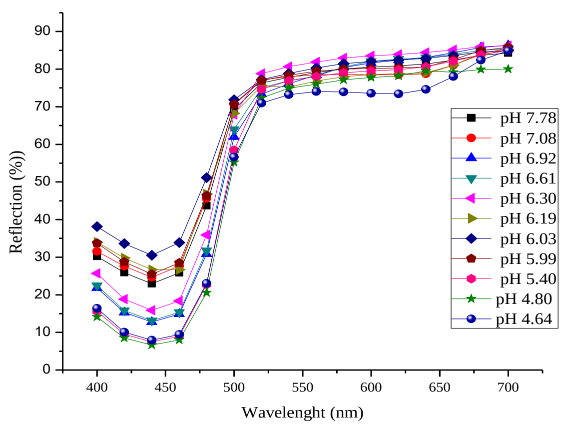


Fig. 4: Dependence of the reflexion on wavelength in polyester sample dyed by Sinten Gelb P-5GL at different pH.

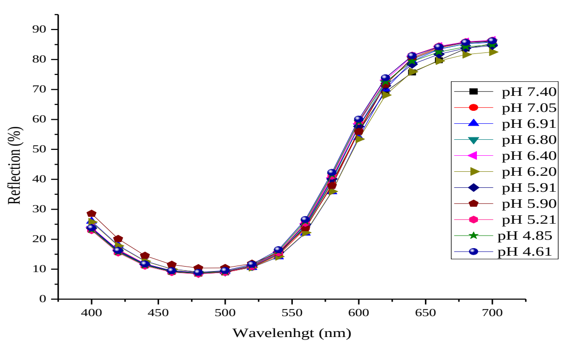


Fig. 5: Dependence of the reflexion on wavelength in polyester sample dyed by SintenSharlachP-3GL at different pH.

For Sinten Sharlach P-3GL, Fig 5 shows a very small deviation of reflection curves calculated at different pH and compared to the standard sample (pH=7.40). This can be attributed to metamerism and a very small difference in the hue of dyed samples.

The color properties of the dyed knitwear samples, expressed in terms of the CIELab system are listed in Tables 3 and 4.

According to the CIELab system for color, dyed samples have visible differences in total color value (L*), lightness/darkness component (A* - the green-red axis) and the (B* - the blue - yellow axis), chroma (C*) and hue (H*). Such a difference indicates the amount of bonded color, and its shade. Different qualities of coloring can also be attributed to the chemical structure of applied dyes. The difference in lightness/darkness components is characteristic for all samples, and has positive values. This means that the control sample is lighter than the dyed one, as was expected. The highest difference is observed in the polyester dyed sample with Sinten Gelb P-5GL at pH 7.78 (very acid conditions, light source D65), while the lowest difference is achieved in the polyester dyed sample with SintenSharlach P-3GL at pH 7.40, which can be explained by the fact that Sinten Sharlach P-3GL is an azo dye. However, the negative values of A* (D65-10 and TL84-10) for polyester samples dyed with Sinten Gelb P-5GL at different pH imply more green than red tones in color. In the second case with Sinten Sharlach P-3GL, positive values were obtained. Differences in hue are visible for all polyester samples, and have positive and high values for both dyes. The data obtained indicates that chemical structure has no effect on the hue parameter because no correlation can be achieved or determined.

Differences in color between standard at pH 7.78, and colored polyester with Sinten Gelb P-5GL at different pH values are shown in Table 5. As noted, at slightly acidic conditions lower than standard (pH 7.78), negative values were obtained, which was expected. This is due to the fact that Sinten Gelb P-5GL can only be dyed with polyester in very acidic conditions in order to get good results. The ΔE color difference of the following pairs of colors is approximately similar for all three sources of light, as well as the values of lightness (ΔL).

Differences in color between standard at pH 7.40 and colored polyester with Sinten Sharlach P-3GL at different pH values are shown in Table 6. As noted, at slightly acidic conditions lower than standard (pH 7.40), negative values were obtained, which is expected. This is due to the fact that Sinten Gelb P-5GL can only be dyed with polyester in very acidic conditions in order to get good results. The ΔE color difference of the following pairs of colors is approximately similar for all three sources of light, as well as the values of lightness (ΔL).

Table-3. CIELab dye difference coordinates for polyester samples dyed with Sinten Gelb P-5GL at various pH.

Source of light	L*	A*	B*	C*	H*
		pH 7.78			
D65-10`	89.01	-8.87	47.36	48.18	100.61
A - 10`	90.55	0.3	45.87	45.88	89.34
TL84-10`	90.11	-4.96	51.35	51.59	95.51
		pH 7.08			
D65-10`	88.86	-10.08	44.55	45.68	102.75
A - 10`	90.17	-0.8	42.82	42.83	91.07
TL84-10`	89.8	-6.13	48.2	48.59	97.25
		pH 6.92			
D65-10`	87.96	-7.9	63.88	64.36	97.05
A - 10`	90.15	2.67	62.02	62.07	87.54
TL84-10`	89.55	-3.93	69.2	69.31	93.25
		pH 6.61			
D65-10`	88.26	-8.61	63.24	63.82	97.75
A - 10`	90.35	2.17	61.18	61.22	87.97
TL84-10`	89.76	-4.18	68.44	68.57	93.46
		pH 6.30			
D65-10`	89.71	-9.84	59.85	60.65	99.34
A - 10`	91.59	0.78	57.76	57.76	89.23
TL84-10`	91.1	-5.54	64.77	65.01	94.89
		pH 6.19			
D65-10`	88.2	-7.55	41.02	41.71	100.43
A - 10`	89.63	0.93	39.97	39.98	88.66
TL84-10`	89.19	-4.14	44.61	44.8	95.3
		pH 6.03			
D65-10`	89.9	-7.33	38.58	39.27	100.75
A - 10`	91.26	0.82	37.65	37.66	88.75
TL84-10`	90.86	-4.01	42.04	42.23	95.45
		pH 5.99			
D65-10`	89.24	-8.99	44.01	44.92	101.54
A - 10`	90.65	0.03	42.61	42.61	89.97
TL84-10`	90.25	-5.29	47.75	48.04	96.32
		pH 5.40			
D65-10`	87.3	-10.05	75.88	76.54	97.54
A - 10`	89.56	1.38	72.65	72.65	88.91
TL84-10`	89.04	-5.83	81.83	82.04	94.07
		pH 4.80			
D65-10`	86.27	-9.53	77.35	77.94	97.02
A - 10`	88.6	1.69	74.13	74.15	88.7
TL84-10`	88.11	-5.46	83.45	83.63	93.74
		pH 4.64			
D65-10`	85.39	-11.01	71.82	72.66	98.72
A - 10`	87.43	0.24	68.61	68.61	89.8
TL84-10`	86.98	-7.11	77.42	77.74	95.25

Table-4: CIELab dye difference coordinates for polyester samples dyed with Sinten SharlachP-3GL at various pH

Source of light	L*	A*	B*	C*	H*
		pH 7.40			
D65-10`	59.95	42.03	35.37	54.94	40.08
A - 10`	66.7	41.03	48.3	63.89	49.12
TL84-10`	63.33	38.89	40.82	57.08	45.65
		pH 7.05			
D65-10`	60.02	43.71	34.51	55.9	38.3
A - 10`	66.95	43.51	47.85	64.67	47.72
TL84-10`	63.46	41.46	40.02	57.63	43.98
		pH 6.91			
D65-10`	59.1	43.95	30.6	53.55	34.85
A - 10`	65.93	43.72	43.93	61.98	45.14
TL84-10`	62.45	41.68	35.85	54.68	40.7
		pH 6.80			
D65-10`	60.59	43.15	36.08	56.24	39.91
A - 10`	67.51	42.98	49.28	65.39	48.9
TL84-10`	64.04	40.94	41.64	58.4	45.49
		pH 6.40			

D65-10`	**61.12**	**42.99**	**36.22**	**56.21**	**40.12**
A - 10`	**68.02**	**42.86**	**49.39**	**65.39**	**49.05**
TL84-10`	**64.57**	**40.77**	**41.78**	**58.38**	**45.7**
		pH 6.20			
D65-10`	**58.87**	**42.83**	**30.42**	**52.54**	**35.38**
A - 10`	**65.55**	**42.51**	**43.47**	**60.8**	**45.64**
TL84-10`	**62.18**	**40.72**	**35.6**	**54.08**	**41.16**
		pH 5.91			
D65-10`	**60.69**	**42.36**	**36.05**	**55.62**	**40.4**
A - 10`	**67.5**	**42.17**	**49.06**	**64.69**	**49.32**
TL84-10`	**64.1**	**40.19**	**41.55**	**57.81**	**45.96**
		pH 5.90			
D65-10`	**60.54**	**42.92**	**28.79**	**51.69**	**33.85**
A - 10`	**67.18**	**42.69**	**41.83**	**59.77**	**44.42**
TL84-10`	**63.8**	**40.75**	**33.85**	**52.97**	**39.71**
		pH 5.21			
D65-10`	**61.21**	**43.34**	**38.14**	**57.74**	**41.35**
A - 10`	**68.21**	**43.16**	**51.43**	**67.14**	**50**
TL84-10`	**64.73**	**41.14**	**43.85**	**60.13**	**46.83**
		pH 4.85			
D65-10`	**61.36**	**42.26**	**37.79**	**56.69**	**41.81**
A - 10`	**68.22**	**42.09**	**50.8**	**65.97**	**50.36**
TL84-10`	**64.82**	**40.08**	**43.41**	**59.08**	**47.28**
		pH 4.61			
D65-10`	**61.88**	**42.38**	**37.57**	**56.63**	**41.56**
A - 10`	**68.76**	**42.25**	**50.61**	**65.93**	**50.14**
TL84-10`	**65.34**	**40.16**	**43.17**	**58.96**	**47.07**

Table-5: Color differences between a standard (pH 7.78) and a polyester sample dyed with Sinten Gelb P-5GLat at different pH , according to the CIELab system.

Source of light	**ΔL**	**ΔA**	**ΔB**	**ΔE**
		pH 7.08		
D65-10`	**0.1 Darker**	**-1.2**	**-2.8**	**3.1**
A - 10`	**0.4 Darker**	**-1.3**	**-1.3**	**3.4**
TL84-10`	**0.3 Darker**	**-1.2**	**-3.1**	**3.4**
		pH 6.92		
D65-10`	**1.0 Darker**	**+1.0**	**+16.5**	**16.6**
A - 10`	**0.4 Darker**	**+2.1**	**+16.1**	**16.3**
TL84-10`	**0.6 Darker**	**+1.0**	**+17.9**	**17.9**
		pH 6.61		
D65-10`	**0.7 Darker**	**+0.3**	**+15.9**	**15.9**
A - 10`	**0.2 Darker**	**+1.6**	**+15.3**	**15.4**
TL84-10`	**0.3 Darker**	**+0.8**	**+17.1**	**17.1**
		pH 6.30		
D65-10`	**0.7 Lighter**	**+1.0**	**+12.5**	**12.5**
A - 10`	**1.0 Lighter**	**+0.2**	**+11.9**	**11.9**
TL84-10`	**1.0 Lighter**	**-0.6**	**+13.4**	**13.5**
		pH 6.19		
D65-10`	**0.8 Darker**	**+1.3**	**-6.3**	**6.5**
A - 10`	**0.9 Darker**	**+0.4**	**-5.9**	**6.0**
TL84-10`	**0.9 Darker**	**+0.8**	**-6.7**	**6.9**
		pH 6.03		
D65-10`	**0.9Lighter**	**+1.5**	**-8.8**	**9.0**
A - 10`	**8.3Lighter**	**+0.3**	**-8.2**	**8.3**
TL84-10`	**9.4Lighter**	**+0.9**	**-9.3**	**9.4**
		pH 5.59		
D65-10`	**0.2Lighter**	**-0.1**	**-3.3**	**3.4**
A - 10`	**0.1Lighter**	**-0.5**	**-3.3**	**3.3**
TL84-10`	**0.1Lighter**	**-0.3**	**-3.6**	**3.6**
		pH 5.40		
D65-10`	**1.7 Darker**	**-1.2**	**+28.5**	**28.6**
A - 10`	**1.0 Darker**	**+0.8**	**+26.8**	**26.8**
TL84-10`	**1.1 Darker**	**-0.9**	**+30.5**	**30.5**
		pH 4.80		
D65-10`	**2.7 Darker**	**-0.7**	**+30.0**	**30.1**
A - 10`	**2.0 Darker**	**+1.2**	**+28.3**	**28.3**
TL84-10`	**2.0 Darker**	**-0.5**	**+32.1**	**32.2**
		pH 4.64		
D65-10`	**3.6 Darker**	**-2.1**	**+24.5**	**24.8**
A - 10`	**3.1 Darker**	**-0.3**	**+22.7**	**22.9**
TL84-10`	**3.1 Darker**	**-2.2**	**+26.1**	**26.3**

Table-6: Color differences between a standard (pH 7.40) and a polyester sample dyed with Sinten SharlachP-3GL at different pH , according to the CIELab system.

Source of light	ΔL	ΔA	ΔB	ΔE
		pH 7.05		
D65-10`	0.1 Lighter	+1.7	-0.9	1.9
A - 10`	0.2 Lighter	+1.7	-0.5	1.8
TL84-10`	0.1 Lighter	+1.6	-0.8	1.8
		pH 6.91		
D65-10`	0.9 Darker	+1.9	-4.8	5.2
A - 10`	0.8 Darker	+1.9	-4.4	4.8
TL84-10`	0.9 Darker	+1.8	-5.0	5.4
		pH 6.80		
D65-10`	0.6 Lighter	+1.1	+0.7	1.5
A - 10`	0.8 Lighter	+1.2	+1.0	1.7
TL84-10`	0.7 Lighter	+1.0	+0.8	1.5
		pH 6.40		
D65-10`	1.2 Lighter	+1.0	+0.8	1.7
A - 10`	1.3 Lighter	+1.0	+1.1	2.0
TL84-10`	1.2 Lighter	+0.9	+1.0	1.8
		pH 6.20		
D65-10`	1.1 Darker	+0.8	-5.0	5.1
A - 10`	1.1 Darker	+0.7	-4.8	5.0
TL84-10`	1.2 Darker	+0.8	-5.2	5.4
		pH 5.91		
D65-10`	0.7 Lighter	+0.3	+0.7	1.0
A - 10`	0.8 Lighter	+0.4	+0.8	1.2
TL84-10`	0.8 Lighter	+0.3	+0.7	1.1
		pH 5.90		
D65-10`	0.6Lighter	+0.9	-6.6	6.7
A - 10`	0.5Lighter	+0.9	-6.5	6.5
TL84-10`	0.5Lighter	+0.9	-7.0	7.0
		pH 5.21		
D65-10`	1.3 Lighter	+1.3	+2.8	3.3
A - 10`	1.5 Lighter	+1.3	+3.1	3.7
TL84-10`	1.4 Lighter	+1.2	+3.0	3.6
		pH 4.85		
D65-10`	1.4 Lighter	+0.2	+2.4	2.8
A - 10`	1.5 Lighter	+0.3	+2.5	2.9
TL84-10`	1.5 Lighter	+0.2	+2.6	3.0
		pH 4.61		
D65-10`	1.9 Lighter	+0.3	+2.2	2.9
A - 10`	2.1 Lighter	+0.4	+2.3	3.1
TL84-10`	2.0 Lighter	+0.3	+2.4	3.1

Conclusion

The pH value of the Sinten Gelb P-5GL dye float affects the displacement of the reflection curves relative to the standard, which means that there are larger or smaller amounts of dye applied to the polyester sample.In the case of Sinten Scharlach P-3GL, the effect of pH on the displacement of the reflection curve samples in relation to the standard is negligible, because it is about the metamerism of the samples in relation to the standard. Based on CIELab values, brightness curves, and dye curves, it is noticeable that the pH value of the dyeing float affects the hue and intensity of the dyed polyester sample.

The most accurate results were obtained using an accepted database on the basis of which the influence of the pH value of the dyeing float on the amount of applied dye on the polyester sample was observed from the graphs. For Sinten Gelb P-5GL, the maximum amount of applied dye is 4.64 and amounts to 0.2924% of the dye. For Sinten Scharlach P-3GL, the maximum amount of applied dye is 6.20 and is 0.2654% dye.

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