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MATERIALS SCIENCE

Influence of modification methods on colour properties of a linen fabric dyed with direct dyes

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Abstract. Linen textiles appear to be some of the oldest in the world. Nowadays flax fibres are coming back to the fashion industry thanks to their freshness, comfort, and innovative technologies providing the elegance of and demand for linen clothing. Direct dyes are popular for dyeing cellulosic fibres due to their reasonable price and easy use. As the first synthetic dyes they are currently used for dyeing textile materials in order to repair and consolidate the threads. Unfortunately, these dyes have only moderate fastness properties. Many studies have been conducted to improve substantivity of anionic direct dyes for cellulosic materials. In most cases the suggested methods are expensive and technologically complicated. We examined the colour properties of the fabric dyed with direct dyes in the case the linen fabric was modified by alkali and enzyme BEISOL PRO treatment. To evaluate the modification effect, the colour characteristics before and after light test were used, and the fastness to rubbing as well as mechanical properties were determined. The colour characteristics of dyed fabrics and the fastness to rubbing differed depending on the used dye. The wet fastness to rubbing was lower than the dry fastness. The tensile strength and elongation in the warp direction were superior in all cases and did not depend on the used dye. The influence of modification type on fabric light resistance was not significant.

Key words: linen fabric, alkali, enzyme, pretreatment, colour characteristics, rubbing fastness, mechanical properties.

1. INTRODUCTION

Linen textiles appear to be some of the oldest in the world. Their history goes back many thousands of years. Nowadays flax textiles are used again in the fashion industry thanks to their freshness, comfort, and innovative technologies providing the elegance of and demand for linen clothing. Another trend is to use linen for the repair and consolidation of threads in restoration [1].

The term *direct dyes* arose from the fact that such dyes possess direct substantivity for cellulosic fibres. They are popular for dyeing cellulosic textiles due to the available broad colour range, competitive price, and easy use. Easy use means a certain preparation of fabric, lower required water quality, and simpler dyeing process (liquor ratio, time, temperature rising rate, electrolyte and other chemical additives, pH etc.) control compared to other dyes. Unfortunately, these dyes have only moderate dye fastness [2]. Many studies have been devoted to improvement of the substantivity of anionic direct dyes for cellulosic materials. The latest investigations in most cases show that the process is expensive and technologically complicated [2–4].

The aim of the present study is to examine the influence of modification of linen fabric on colour properties of the textile dyed with direct dyes. For fabric modification the well-known alkali method [2], which causes changes in the physical structure of cellulose, and a comparatively new enzyme treatment [5–7] were used. The methods were compared and their influence

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on the colour characteristics of a linen fabric before and after the light test, its fastness to rubbing, and its mechanical properties were studied. For textile finishing a promising alternative to the replacement of chemicals, whose disposal causes problems to the environment, is the use of a wide selection of enzymes [7].

2. MATERIALS AND METHODS

2.1. Materials and chemicals

For experiments bleached, plain-weave 100% linen fabric (linear density 167.7 g/m^2) was used. The modification methods and the used direct dyes together with the designation of the different samples are shown in Table 1.

Chemicals: sodium hydroxide (NaOH), sodium sulphate (Na_2SO_4), acetic acid (CH_3COOH), enzyme Beisol PRO (CHT BEZEMA), washing agent Felosan NOF (CHT BEZEMA).

Direct poly-azo dyes: Solophenyl Yellow GLE, Solophenyl Blue 220%, and Solophenyl Scarlet BNLE 200% (all from Huntsman International LLC).

2.2. Methods of production

The fabric with no tension was treated with alkali solution (200 g/L; bath ratio VM 50 at 16 °C for 1 min). A rinse and a neutralization with acetic acid solution (10 g/L, at 16 °C for 1 min) and a second rinse followed.

Another method used for fabric pretreatment was with a 4% solution of enzyme Beisol PRO and 1% Felosan NOF (VM 25 at 55 ± 2 °C for 15 ± 1 min with rinse).

The dyeing of the fabric was performed according to the recommendation of the direct Solophenyl dye producer [8] (Fig. 1) with VM 50 applied.

2.3. Methods of testing

Following ISO 105-JO3:2009 [9], colour properties were determined in the spectral width of 400 to 700 nm with an Easy Colour QA device (Pocket Spec. Technologies Inc., USA; design colour sensitivity >16.5 million colours, standard deviation ΔE^*ab 0.1) on both sides of the fabric, using a red, green, and blue light (RGB) system in CIELAB-76 colour space, which allows determination of the coordinates of colour vectors a^* and b^*, as well as the degree of lightness in the colour space L^* [6].

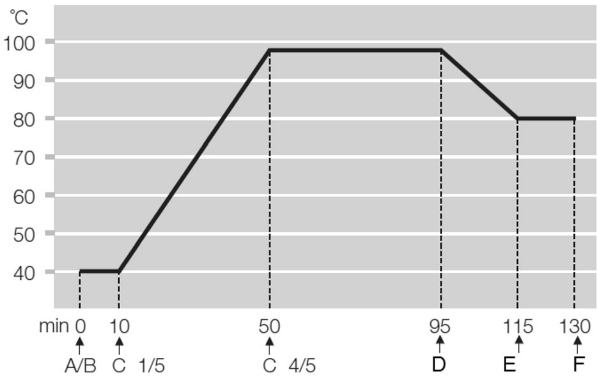

Fig. 1. Standard method for dyeing cellulose textiles with Solphenyl dyes [8]. A – Auxiliary Felosan NOF 1 g/L; B – Solophenyl dye 1%; C – Na_2SO_4 (10 g/L) in portions (1/5 and 4/5); D – scaling down temperature for 20 min; E – dyeing for 15 min; F – the finish of dyeing. Rinsing in hot/cold water follows.

Table 1. Designation of linen fabric samples used in experiments

Designation	Modification			Solophenyl dye		
	Untreated	Enzyme	Alkali	Yellow GLE	Blue 220%	Scarlet BNLE 200%
U	+					
E		+				
Ley			+			
UY	+			+		
UB	+				+	
UR	+					+
EY		+		+		
EB		+			+	
ER		+				+
LeyY			+	+		
LeyB			+		+	
LeyR			+			+

Colour fastness to rubbing was assessed by a standard white fabric against the dyed sample under wet and dry conditions using Crocmeter 238 A of SDLA (Shirley Development Laboratories Atlas Inc., USA) according to LVS EN ISO 105-X12:2016 [10].

Mechanical properties of the samples (width 2.5 cm, length 16 cm) in the warp and the weft direction were tested according to LVS EN ISO 13934-1:2013 [11] on an INSTRON dynamometer (Instron Ltd, UK; the length between clamps 100 mm, test speed 100.0 mm/min).

Colour fastness to artificial light of the dyed samples was checked in a light chamber (Q-SUN, Xenon Test Chamber, mod. Xe-1-B, Q-LAB) after 24, 48, and 72 h exhibition at 55 °C (intensity of radiance 1.1 W/m^2) according to LVS EN ISO:105-B02:2014 [12].

3. RESULTS AND DISCUSSION

The colour properties are presented in Figs 2–4. The rubbing fastness of the tested fabric can be found in Table 2. The mechanical properties of the tested unmodified and modified dyed linen fabric are illustrated in Figs 5 and 6.

3.1. Colour characteristics

To characterize colour the main indices were used. Lightness (L) defines the range from dark (0%) to fully illuminated (100%). Any original hue has the average lightness level of 50%. Saturation (S) defines the range from the pure colour (100%) to grey (0%) at a constant lightness level. A pure colour is fully saturated [13].

In all cases the saturation and lightness of yellow samples were higher in comparison to the blue and red samples (Fig. 2). No significant influence of fabric modification was observed. The influence of modification can be better seen from results of lightness difference (Fig. 3) and hue (Fig. 4). For all dyes the modification with alkali was more effective. For samples with alkali pretreatment the common colour difference was higher for all coloured linen fabrics than with enzyme pretreatment, especially for yellow samples. A slight increase of hue was observed (Fig. 4) for all colour samples with alkali pretreatment while enzyme pretreatment decreased the hue. A notable increase of hue difference was observed for all samples, especially in the case of alkali pretreatment.

Table 2. Rubbing fastness of the examined dyed samples. For designation, see Table 1

	UY	LeyY	EY	UB	LeyB	EB	UR	LeyR	ER
Dry	5	4/5	4	4/5	4/5	4/5	2/3	3/4	4
Wet	4/5	3/4	3/4	4	3/4	3/4	2	2/3	3/4

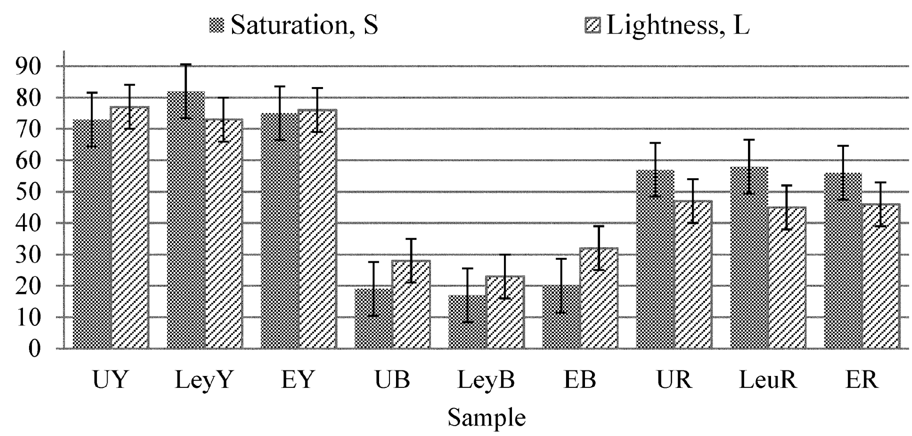

Fig. 2. Saturation and lightness of the examined samples. For designation of samples, see Table 1.

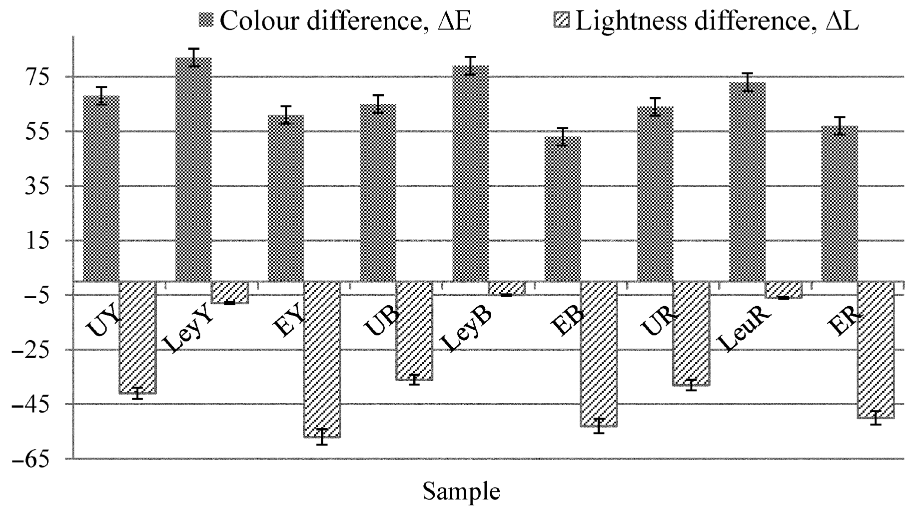

Fig. 3. Colour difference and lightness difference of the examined samples. For designation of samples, see Table 1.

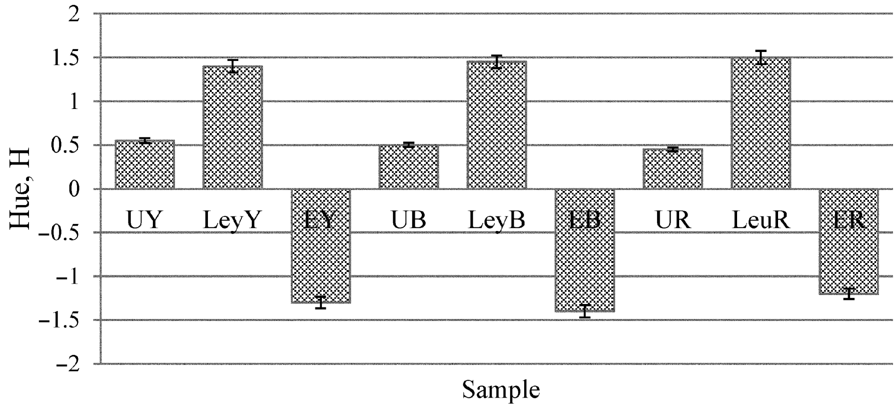

Fig. 4. Hue of the examined samples. For designation of samples, see Table 1.

3.2. Rubbing fastness

The rubbing fastness mostly depended on the used dye (Table 2). The modification of fabric was not effective for improving rubbing fastness. This can be explained by the influence of modificators, which change the physical structure of linen fabric so that the fibres become more 'open'. As the direct dyes form with cellulosic fibres only physical bonds, greater accessibility to the structure can reduce the fastness to rubbing.

3.3. Mechanical properties

Higher tensile strength values can be observed for all samples in the warp direction (Fig. 5). Higher elongation occurred in the weft direction (Fig. 6) except for alkali treated fabrics (designation Ley). Note that alkali treatment was performed without tension, which causes serious elongation (in the warp direction 37.5–41.5%, in the weft direction 19.5–22.8%). This means that the elasticity of the fabric increases considerably and thus it would be interesting to know if this method is used for dyeing threads. The mechanical properties of the dyed samples were influenced by the modification method as well as by the used dye.

3.4. Colour fastness to light

The light fastness is an important characteristic of dyed textiles. For the investigated fabrics after 72 h in an artifical light chamber a small decrease of lightness

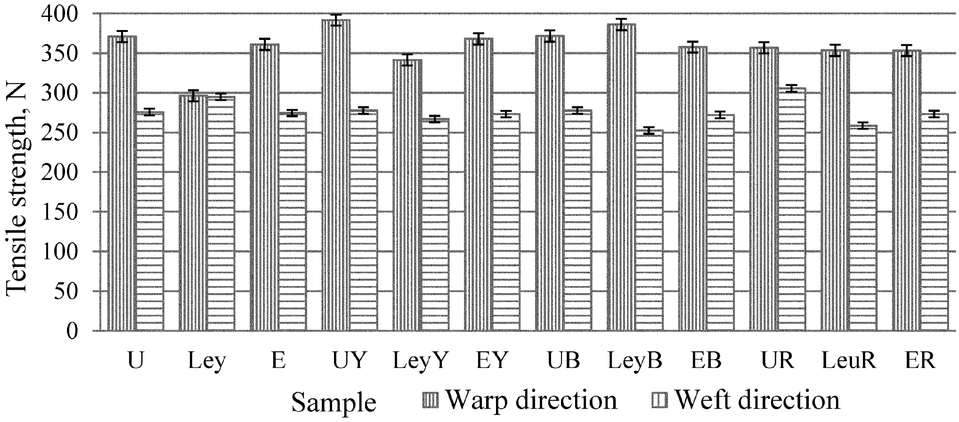

Fig. 5. Tensile strength of the examined samples. For designation of samples, see Table 1.

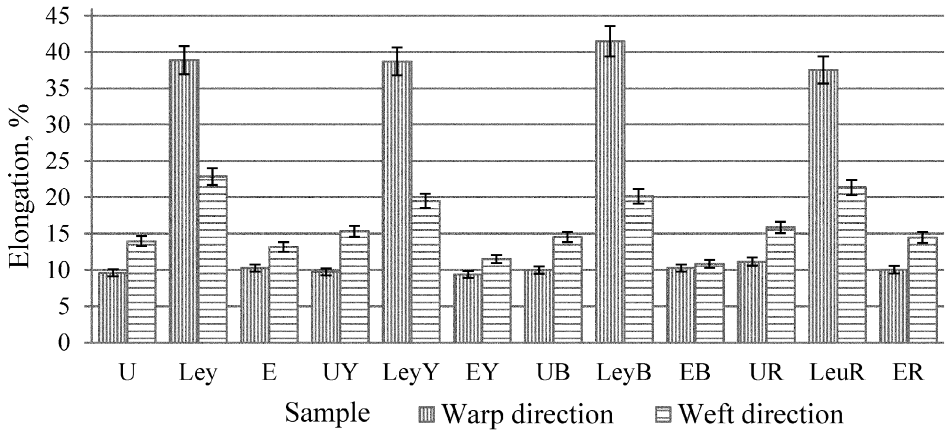

Fig. 6. Elongation of the examined samples. For designation of samples, see Table 1.

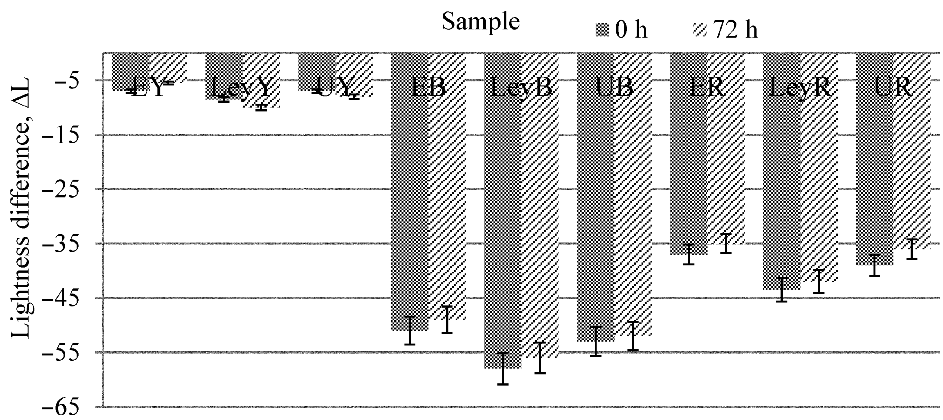

Fig. 7. Lightness difference of the examined samples. For designation of samples, see Table 1.

difference was observed for blue and red samples (Fig. 7). No significant changes of the hue were observed for any (unmodified and modified) samples (Fig. 8). For all samples a small common colour difference was observed (Fig. 9). The results of tests indicate good colour fastness to light.

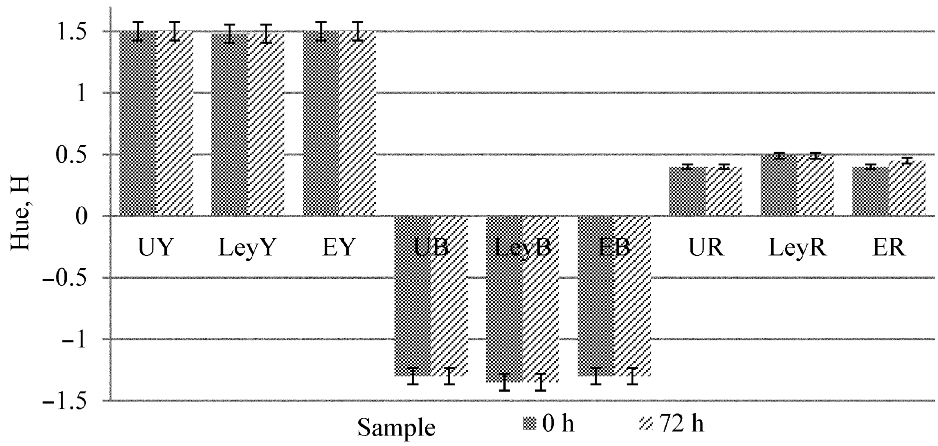

Fig. 8. Hue of the examined samples. For designation of samples, see Table 1.

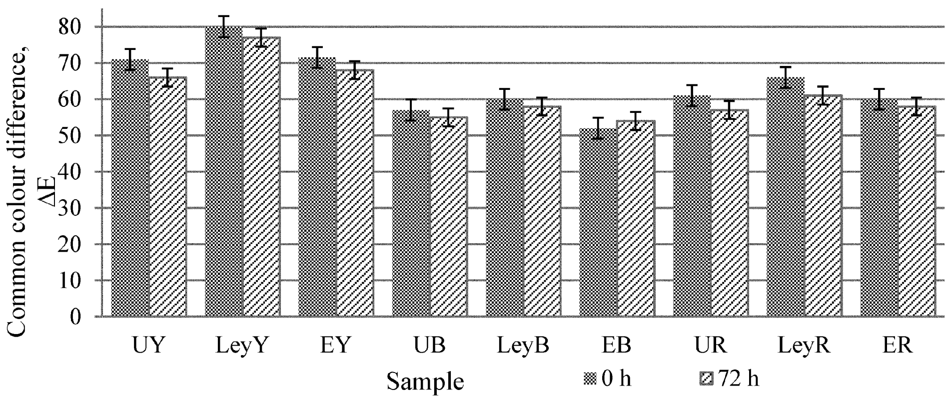

Fig. 9. Common colour difference of the examined samples. For designation of samples, see Table 1.

4. CONCLUSIONS

Comparison of dyed linen fabric samples (untreated and modified with alkali and enzyme) show that

- the used dye is the main factor influencing colour characteristics and rubbing fastness of dyed fabrics;
- both modifiers changed the colour characteristics of textile and the influence was different depending on the used dye; the changes were not significant;
- the wet resistance to rubbing was lower than the dry resistance;
- the tensile strength in the warp direction was superior to the tensile strength in the weft direction in all cases;
- the influence of alkali modification was significant on elongation (elasticity) regardless of the used dye;
- the changes of colour characteristics after the light fastness test in definite conditions were not significant.

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Linase riide eelneva modifitseerimise meetodi mõju otsevärvidega värvitud kanga värvuse omadustele

Aina Bernava ja Skaidrite Reihmane

Linane kangas ja sellest valmistatud tooted on ajalooliselt ühed vanimad tuntud tekstiilmaterjalid. Kuid nende kasutamine tänapäeval on toimunud vahelduva eduga, mis on seotud sünteetiliste ja tehiskiudude turule tulekuga. Siiski on linane tekstiilmaterjal teatud perioodilisusega taaskasutusel, sest loodusliku kiuna on sel omadusi, mis puuduvad teistel kiududel, suurendades turu nõudlust linase kui loodusliku materjali järele.

Linase materjali kasutamisel näiteks rõivatööstuses on tähtis värvus. Linase materjali värvimisel on olnud kasutatavamaks värviklassiks otsevärvid. Kuid nende puuduseks on suhteliselt nõrk värvipüsivus (pleekimiskindlus) kiududel. Selle puuduse olemust on palju uuritud. Enamikul juhtudel on väljatöötatud meetodid anioontüüpi otsevärvide värvipüsivuse tõstmiseks kallid ja tehnoloogiliselt keerukad. Seetõttu on käesolevas artiklis uuritud, kuidas linase kiu otsevärviga värvimise tulemusi parendada kiu värvimisele eelneva töötlemisega (modifitseerimisega), kasutades selleks aluselist lahust ja ensüümi BEISOL PRO. Modifitseerimise efektiivsust mõõdeti kolorimeetriliselt, võrreldes värvuskarakteristikuid enne ja pärast valguskambris kiiritamist. Katsekehadele määrati ka vastupidavus hõõrdumisele ja nende tõmbetugevuse muutumine. Leiti, et värvitud kangaste värvuskarakteristikud ja värvi hõõrdumiskindlus sõltusid kasutatud värvainest. Märghõõrdumise tulemused olid madalamad kui kuivhõõrdumisel saadud. Kõikide katsekehade tugevus ei sõltunud kasutatud värvaine liigist. Kokkuvõttes leiti, et linase materjali värvipüsivus ei sõltu modifitseerimise viisist.