J. Chem. Chem. Eng. 8 (2014) 686-691

Color Fastness of Dyed Raw Linen Cloth Modified with Enzymes

Bernava Aina[1*], Borisova Anna[1], Strazds Guntis[2] and Reihmane Skaidrite[1]

1. Institute of Polymer Materials, Riga Technical University, Riga LV-1048, Latvia

2. Forest Industry Competence Centre, Riga LV-1006, Latvia

Abstract: Green thinking looks to develop alternatives with higher environmental advantage that traditional materials or processes. The present experimental studies are directed to investigation of dyeing the linen fabric prepared with modification with enzymes. In the research, 1% and 2% solution of cellulase enzyme Beizym ENC-SB (garment auxiliary of enzymes mixture of CHT R. BEITLICH GmbH/BEZEMA AG) and pectinase Beisol PRO (enzymes mixture for cleaning cellulose fibers of CHT R. BEITLICH GmbH) enzyme solutions were used. The main objective of this work is focus on results studies of enzyme influence on dyeing of flax fabric with direct Solphenyl dye triade Blue FGLE (economical, fairly good light fast blue, main trichromatic component for medium shades with high wash fastness), Scarlet BNLE (economical scarlet, main trichromatic component for medium to dark shades) 200%, and Yellow GLE (very bright neutral yellow, main trichromatic component for high wash fastness requirements). The dye-bath exhaustion, color fastness to rubbing and washing were estimated. The color parameters before and after tests were calculated.

Key words: Raw linen cloth, pectinase, cellulase enzymes modification, direct dye, color fastness.

1. Introduction

Following a few decades of almost total abandonment, flax fibres are revaluated by the fashion industry and increasingly appreciated owing to the freshness, comfort and elegance [1]. Seventy percent of European Union produced long fibres have been exported, therefore long flax fibres products are considered as potential chance for Latvian textile industry development.

Flax is one of the oldest plants grown in Latvia. Flax industry was very important for the development of Latvia economy in the 20th century. At the end of the thirties was produced 215,000 tons of flax per year due to flax fibres and seeds application for various products production [2]. Nowadays, flax has a great importance as a raw material in the production of food, medicaments and building materials [3]. The export to European Union is 85%-90% [4]. With the best and original properties, obtained by new technologies of finishing flax was used for the high quality fashion products and technical application.

One of the directions of technologies improvement is enzymes application. Enzymes use in start stages of bast fibre processing like retting, cottonization, improving pre-treatment, de-sizing, scouring and others are partly investigated [5]. The dyeing process of flax can be performed mainly by exhaustion, using direct or reactive dyes. Only few researches are devoted to the influence of different pre-treatment of dyeing results of vegetable fibres [6], the increase of lightness and removing the surface fibre (i.e., depilling or bio-polishing) after dyeing to change the lightness of the cellulase enzyme treated cotton fabric is observed [7].

The textile processing industry is one of the major environmental polluters. The World Bank estimates that 17%-20% of industrial water pollution comes from textile dyeing and treatment [8]. It is the problem

*Corresponding author: Bernava Aina, M.Sc, Researcher, research fields: innovative weaved textile structures processing and textile materials modification for ordinary textiles and composite materials. E-mail: aina.bernava@inbox.lv.

for textile manufacturers. The use of the enzymes—high molecular proteins in a wide selection for textile finishes is positive alternative to replace chemicals, whose disposal into the environment causes problems [5].

In the preliminary research [9], we conclude that enzyme influence on raw linen fabric color parameters and whiteness is insignificant, meaning that enzymes do not act on natural pigments, which are responsible for color characteristics of natural fibres.

The present experimental study is focused on enzyme influence studies on dyeing/dye bath exhaustion/of enzymes modified raw flax fabric dyed with direct dyes and dyeing results (colour parameters, color fastness to rubbing and washing) with the aim to look for new, shorten, more economical and ecological technology.

2. Materials and Experimental Methods

For experiments, the raw linen fabric modified with cellulase and pectinase enzymes, and dyed with Triade of the direct SOLOPHENYL dyes Blue FGLE (economical, fairly good light fast blue, main trichromatic component for medium shades with high wash fastness), Scarlet BNLE (economical scarlet, main trichromatic component for medium to dark shades) 200% and Yellow GLE (very bright neutral yellow, main trichromatic component for high wash fastness requirements), was used.

2.1 Raw Material

The raw 100% linen plain weave fabric (company "Larelini" Ltd., Latvia production) with surface density 162.8 g/m^2 was used. The designation of the sample without treatment is UN.

2.2 Method of Pretreating

Before modification, the raw linen fabric was prewashed at 75 ^{o}C temperature in water for 15 min. Following procedure was treatment of fabric with washing agent Felosan NOF (CHT R Beitlich GMBH) solution in distilled water (2 g/L) for 1 h with following rinse in cold/warm water. The designation of the sample is PR.

2.3 Method of Enzyme Modification

Modification of linen fabric was realized with 1% and 2% cellulase Beizym ENC-SB (designation of sample C1, C2**)** and pectinase Beisol PRO (designation of sample P1, P2) enzymes as described in previous publication [9].

2.4 Dyeing Technology

The dyeing was realized according to the recommendation of the direct Solophenyl dye producer (Fig. 1). The liquid ratio M 50 was applied.

(1) Auxiliary Felosan NOF 1 g/L;

(2) SOLOPHENYL dye 1%;

(3) Glauber's saltsolution (10 g/L) in two portions (1/5 and 4/5) [10].

2.5 Testing of Rubbing Fastness

Color fastness to rubbing was assessed by a standard white fabric against the dyed sample under wet or dry conditions with rubbing fastness testing equipment AATCCM (American Association of Textile Chemistsand Colorists) 238 AA of SDLA (Shirley Development Laboratories tlas Inc. USA), according to ISO (International Organization for Standardization) standard 105-X12:2002.

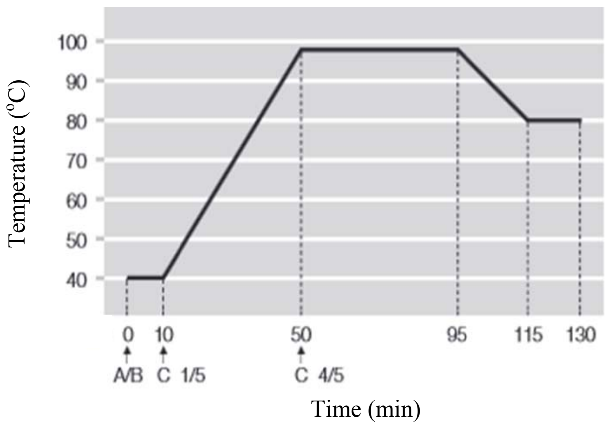

Fig. 1 Standard method for cellulose textiles dyeing with Solphenyl dyes.

2.6 Stability to Washing

The dyed samples were washed (5 and 10 cycles), according to ISO 105-C10:2006 standard.

2.7 Examination of Dye-Bath Exhaustion

The dye-bath ER (exhaustion rate, %) according to ISO 105-Z10:2001 standard was calculated:

$$ER = \frac{A_0 - A_t}{A_0} \times 100\% \quad (1)$$

where, A_0—Absorbance of the initial dye-bath and A_t—dye-bath after dyeing is marked.

2.8 Colour Testing

The samples were analyzed with Easy Colour QA (Quality Assurance**)** device (Pocket Spec. Technologies Inc. USA) on 16 points on both sides, using RGB (red, green and bluelight) system in CIELAB-76 color space, using L^* axis with maximum 100 (a perfect reflecting), L^* minimum 0 (black) and color coordinates a^* and b^* (adopted 1976).

ΔL^* is the difference of lightness coordinates between standard and sample, Δa^* is the difference of redness-greenness coordinates between standard and sample, Δb^* is the difference of yellowness-blueness coordinates between standard and sample. ΔE is the total color difference between reference and sample. Chroma (C) is a measure of intensity or saturation of color. The values of L^*, a^*, b^* and C of any one sample before dyeing were used as the standard. Lightness difference (ΔL^*), common color differences (ΔE) and chroma (C) were calculated following ISO 105-JO3:2010 standard.

The designations of samples used for demonstration of experimental results are summarized in Table 1.

3. Results and Discussion

3.1 Results of Dye Exhaustion

Experimental results (Fig. 2) show that exhaustion rate is dependents of applied dye and better seen for untreated fabric. While for pre-treated fabrics, better dye exhaustion is observed with cellulase pretreated fabric in case of dye Scarlet BNLE 200%.

3.2 Results of Rubbing Fastness

The fastness to wet and dry rubbing was evaluated for dyed fabrics (Table 2). As expected in catalogue of Solophenyl dye [10], the better color fastness was obtained for dry rubbing. The best result to dry rubbing (4/5-5) and lower stability to wet rubbing (3/4) were foruntreated fabrics. After fabric treatment, the small decrease of dry fastness practically in all cases of treatments is observed. At the same time, fastness to wet rubbing increases. Better stability to dry and wet rubbing shoves Blue FGLE samples with both enzymes modification. It suggests that the influence of used dye is significant.

3.3 Color Characteristics

Full analysis of color characteristics of dyed linen fabric before washing was made. The same test of color parameters at the same conditions of dyed samples after 5 and 10 washing cycles was determined as well (Tables 3-5).

Table 1 Designation of samples used for experiments preliminary treatment.

				Used Dyes			Washing					
							5 cycles			10 cycles		
		Designation of sample	Concentration of chemical	Blue FGLE (B)	Scarlet BLE 200% (R)	Yellow GLE(Y)	B	R	Y	B	R	Y
Without treatment		UN		UN_B	UN_R	UN_Y	UN_B_5	UN_R_5	UN_Y_5	UN_B_10	UN_R_10	UN_Y_10
With pre-treating		PR		PR_B	PR_R	PR_Y	PR_B_5	PR_R_5	PR_Y_5	PR_B_10	PR_R_10	PR_Y_10
With pre-treating and modification with	Cellulase Enzyme	C	1%	C1_B	C1_R	C1_Y	C1_B_5	C1_R_5	C1_Y_5	C1_B_10	C1_R_10	C1_Y_10
			2%	C2__B	C2_R	C2_Y	C2__B_5	C2_R_5	C2_Y_5	C2_B_10	C2_R_10	C2_Y_10
	Pectinase Enzyme	P	1%	P1_B	P1_R	P1_Y	P1_B_5	P1_R_5	P1_Y_5	P1_B_10	P1_R_10	P1_Y_10
			2%	P2_B	P2_R	P2_Y	P2_B_5	P2_R_5	P2_Y_5	P2_B_10	P2_R_10	P2_Y_10

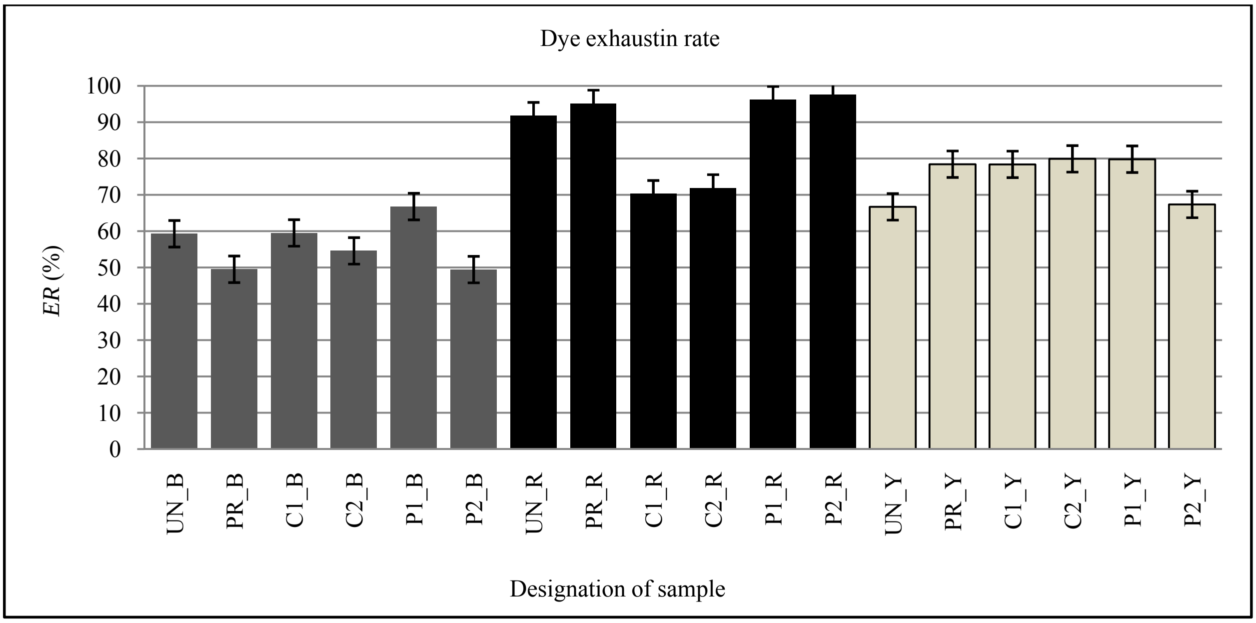

Fig. 2 The exhaustion rate of solophenyl dyes with different fabric pre-treating.

Understandable is lightness difference ΔL^* for different dyes. Therefore, for fabric pre-treatment characterisation, we prefer comparison of color difference ΔE and saturation intensity C. The pre-treating influence on color difference and saturation intensity is evident. The obtained test results about used enzymes influence on color characteristics are different depending on used dyes. The effect of modification concentration is more significant than specific enzyme applying. In all cases, insignificant decrease of lightness and color difference is observed after washing for samples dyed with Solophenyl Blue FGLE (Table 3). It causes the small increase of chroma. As well as insignificant decrease of lightness and color difference after washing are obtained for samples dyed with Solophenyl Scarlet BNLE 200% (Table 4) and Yellow GLE (Y) (Table 5).

Some no significant selective influence of enzyme treatment on dyeing characteristics and dyeing fastness properties is observed.

The lightness difference is higher with lower concentration of bough enzymes (cellulase and pectinase). The influence on color difference and chroma is alike. For pre-treated samples changes of color difference and chroma after washing were observed, while lightness difference was insignificant.

The influence of cellulase enzyme modification on color parameters works sparing, especially after 10 cycles with concentration of enzyme 2%.

The enzyme modification positively influences the washing fastness properties of dyed samples (Tables 3-5). The most significant influence to color parameters stability to washing observed with pectinase enzyme modification. The enzyme modification positively influences the washing fastness properties of dyed samples.

Table 2 Rubbing fastness of samples dyed with Blue FGLE, Scarlet BNLE 200% and Yellow GL.

Sample	Dry	Wet	Sample	Dry	Wet	Sample	Dry	Wet
UN_B	5	3/4	UN_R	4/5	3/4	UN_Y	5	3/4
PR_B	3/4	4	PR_R	4/5	4	PR_Y	4/5	4
C1_B	4	4	C1_R	4	3/4	C1_Y	4	3/4
C2_B	5	4/5	C2_R	4	4/5	C2_Y	4/5	4/5
P1_B	4	4/5	P1_R	4	4/5	P1_Y	4	4/5
P2_B	4	4	P2_R	3/4	4/5	P2_Y	4/5	4

Table 3 Color parameters of samples dyed with Blue FGLE (B) and after 5 and 10 washing cycles.

Sample	Lightness difference (Δ*L**)	Δ*a**	Δ*b**	Color difference (Δ*E*)	Chroma (*C*)
UN_B	-34.24	-2.96	-15.62	37.75	15.89
UN_B_5	-32.33	-2.87	-16.96	36.62	17.20
UN_B_10	-31.45	-1.06	-14.16	34.50	14.20
PR_B	-31.34	0.82	-12.63	33.80	12.66
PR_B_5	-29.60	1.92	-13.70	32.67	13.84
PR_B_10	-28.61	3.91	-14.35	32.24	14.87
C1_B	-31.89	-3.63	-16.80	36.23	17.19
C1_B_5	-31.54	-3.42	-18.27	36.61	18.59
C1_B_10	-30.28	-2.17	-18.68	35.64	18.80
C2_B	-33.33	-3.97	-16.49	37.39	16.96
C2_B_5	-31.25	-3.59	-17.80	36.14	18.16
C2_B_10	-30.78	-1.46	-18.32	35.84	18.38
P1_B	-32.39	-3.63	-16.87	36.70	17.25
P1_B_5	-31.29	-3.40	-18.24	36.38	18.55
P1_B_10	-30.15	-0.98	-18.74	35.52	18.77
P2_B	-34.40	-2.78	-16.09	38.07	16.33
P2_B_5	-31.71	-3.01	-14.28	34.91	14.60
P2_B_10	-31.52	-1.17	-18.13	36.38	18.17

Table 4 Color parameters of samples dyed with scarlet BNLE 200% (R) and after 5 and 10 washing cycles.

Sample	Lightness difference (Δ*L**)	Δ*a**	Δ*b**	Color difference (Δ*E*)	Chroma (*C*)
UN_R	-22.66	32.20	10.18	40.67	33.77
UN_R_5	-21.65	30.30	9.32	38.39	31.70
UN_R_10	-20.81	31.89	9.31	39.20	33.22
PR_R	-21.63	35.33	14.17	43.78	38.07
PR_R_5	-20.11	34.91	13.46	42.48	37.42
PR_R_10	-18.73	36.36	13.77	43.15	38.88
C1_R	-22.47	30.16	10.64	39.08	31.98
C1_R_5	-21.76	30.14	9.60	38.40	31.63
C1_R_10	-20.61	31.79	10.92	39.43	33.61
C2_R	-21.62	30.74	11.56	39.32	32.85
C2_R_5	-21.49	30.20	9.62	38.29	31.69
C2_R_10	-20.17	31.55	11.19	39.08	33.47
P1_R	-21.49	30.25	10.07	38.45	31.88
P1_R_5	-21.49	29.00	8.67	37.12	30.27
P1_R_10	-20.51	30.65	9.97	38.20	32.23
P2_R	-21.64	32.05	11.92	40.47	34.20
P2_R_5	-21.45	30.48	9.23	38.97	31.85
P2_R_10	-20.81	32.14	9.98	39.57	33.65

Table 5 Color parameters of samples dyed with Yellow GLE (Y) and after 5 and 10 washing cycles.

Sample	Lightness difference (Δ*L**)	Δ*a**	Δ*b**	Color difference (Δ*E*)	Chroma (*C*)
UN_Y	-4.77	-3.74	41.37	41.81	41.54
UN_Y_5	-5.13	-4.88	38.67	39.31	38.98
UN_Y_10	-3.71	-3.67	38.88	39.23	39.05
PR_Y	-0.93	0.09	45.75	45.76	45.75
PR_Y_5	-2.65	-0.18	46.77	46.84	46.77
PR_Y_10	-0.89	-0.02	43.61	43.61	43.61

(Table 5 continued)

Sample	Lightness difference (ΔL*)	Δa*	Δb*	Color difference (ΔE)	Chroma (C)
C1_Y	-4.77	-3.74	41.37	41.81	41.54
C1_Y _5	-4.45	-5.18	40.27	40.84	40.60
C1_Y_10	-4.59	-4.78	39.20	39.75	39.49
C2_Y	-3.68	-4.53	43.61	44.00	43.84
C2_Y_5	-4.40	-5.41	40.27	40.87	40.63
C2_Y_10	-2.88	-5.10	41.13	41.55	41.45
P1_Y	-3.93	-4.64	41.86	42.30	42.12
P1_Y _5	-4.32	-5.50	38.82	39.44	39.20
P1_Y_10	-3.93	-4.64	41.86	42.30	42.12
P2_Y	-2.93	-4.91	42.86	43.24	43.14
P2_Y_5	-3.54	-4.74	39.07	39.52	39.36
P2_Y_10	-2.94	-4.78	39.18	39.58	39.47

4. Conclusions

The raw flax fabric modified with cellulase and pectinase enzymes was dye with direct Solphenyl dyes. The obtained experimental results of enzymes pre-treatment influence on dye-bath exhaustion rate, color parameters as well as color fastness to rubbing and washing was investigated.

The obtained test results about influence of used enzymes on exhaustion rate and color characteristics are different, depending on used dyes and fabric modification method.

The effect of modification is more significant factor on color fastness to rubbing, especially with higher concentration of cellulase enzyme.

The changes of color parameters better are observed for Blue FGLE dye with modification of cellulase enzyme, while pectinase influence in case of Yellow GLE and Scarlet BNLE 200% dye.

References

[1] Ossola, M.; Galante, Y. M. Scouring of Flax Rove with the Aid of Enzymes. *Enzyme and Microbial Technology* **2004,** *34(2),* 177-186.

[2] Komlajeva, L.; Adamovics, A.; Stramkale, V. *Evaluation of Yielding Abilities of Latvian Flax Varieties and Its Outlook* [Online], http://ilga.cs.llu.lv/homepg/energija/wpcontent/uploads/2011/06/Evaluation of yielding abilities Komlajeva.pdf (accessed May 14, 2013).

[3] Komlajeva, L.; Adamovics, A. The Perspective of Latvian Flax (*Linum usitatissimum*) for Biofuels. *Agronomy Research, Biosystem Engineering* **2011,** *1,* 107-113.

[4] Stramkale, V.; Stramkalis, A.; Komlajeva, L.; Selecka, M.; Vikmane, M.; Stalazs, A. In *Evaluation of Latvian Flax Varieties by Seed Yield and Quality, Environment, Technology and Resources,* Proceedings of the 7th International Scientific and Practical Conference, 2009.

[5] Marek, J.; Antonov, V.; Bjelkova, M.; Smirous, P.; Fischer, H.; Janosik, S. In *Enzymatic Bioprocessing—New Tool of Extensive Natural Fibre Source Utilization*, Proceedings of International Conference on Flax and Other Bast Plants, Saskatoon, Canada, July 21-23, 2008.

[6] Fakin, D.; Ojstrs, A. Colour of Flax Fibres in Regard to Different Pretreatment and Dyeing Processes. *Coloration Technology* **2008,** *124,* 216-222.

[7] Vishnu, V. K. J.; Selvakumar, N. Biopolishing Enzymes and Their Influence on the Properties of Cotton Materials. *Colourage* **2006,** *53(12),* 45-52.

[8] Muntean, S. G.; Paska, O.; Coseri, S.; Simu, G. M.; Grad, M. E.; Ilia, G. Evaluation of a Functionalized Copolymer as Adsorbent on Direct Dyes Removal Process. *Journal of Applied Polymer Science* **2013,** *127(6),* 4409-4421.

[9] Bernava, A.; Reihmane, S. Usage of Enzymatic Bioprocessing for Raw Linen Fabric Preparing. *Textiles and Light Industrial Science and Technology* **2013,** *2(3),* 131-136.

[10] http://www.textile-dyes.co.uk/solophenyl.pdf, **May 2007**, 1-32 (accessed September 30, 2014).