Usage of Enzymatic Bioprocessing for Raw Linen Fabric Preparing

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Abstract

Enzymatic treatment application in textiles preparing processes extends due to the offer of new enzyme products, improvement of processing results and ecology of technologies. Enzymes are high molecular protein biocatalysts specific in their action. In presented research, cellulase and pectinase enzymes are used for preparing raw linen fabric with emphasis on colour characteristic changes. Colour coordinates of experimental samples have been evaluated in RGB system. As well the whiteness of the linen fabric was measured. Determinated coordinates of colour vector in a colour space a*, b* and L* and calculated lightness difference (∆L*), common colour differences (∆E), colour saturation (C), hue (H) show that enzyme type and modification method have influence on raw linen colour parameters and whiteness is insignificant. If the higher whiteness as 29 % is required, the additional chemical bleaching is necessary.

Keywords

Linen Fabric; Bioprocessing; Enzymes; Pectinases; Cellulases

Introduction

Classical textiles wet processing contains three stages: pretreatment (or preparing), coloration (dyeing and/or printing) and finishing. Any operation for improving the appearance or usefulness of the fabric is necessary, but it is well known that the final result is closely connected with pretreatment processes and technologies. One of the oldest techniques applied in the textiles field (Roy Choudhury A.K., Wei Q)-treatment in aqueous solutions till nowadays stays as main. The first step before dyeing is raw materials pretreating for impurities and natural pigments removal, which differs accordingly in raw material and requirements.

The enzymes– high molecular protein biocatalysts can be safely used in a wide selection of textile processes such as de-sizing, scouring, bleaching, dyeing and finishing, where the alternatives are chemicals whose disposal into the environment causes many problems. Textile processing with enzymes aims to provide the textile technologist with an understanding of enzymes and their use for textile materials (Marek J.).

Enzymes are generally globular proteins with long linear chains of amino acids that fold to produce three-dimensional product, making specific structures with unique properties. At present, more than 2000 enzymes have been isolated and characterised, among which 50 have industrial applications. A typical feature of enzymes is its selectivity. Most of the textile enzymes catalyze the digestion or hydrolysis of certain large organic molecules like starch, cellulose and protein (Shaikh M. A.).

The enzyme products, in general, are easy to use and treatment can be adapted to run on existing equipment and at different stages of textile wet processes; in addition, mild treatment conditions (i.e. temperature and pH) can be employed. Enzymes completely biodegradable, fail to accumulate in the environment; and they save chemicals and energy with the capability to reduce processing time as well as improve the surface properties and texture of cellulose-based fabrics. Furthermore, novel techniques can improve the characteristics of enzymes, e.g. thermostability of cellulases (Montazer M.).

Alkaline pectinases are generally produced by bacteria. Pectinolytic enzymes have been applied for the degumming of jute, sunn hemp, flax, ramie and coconut fibers for textile application to remove the non-cellulosic gummy material of pectin and hemicellulose. Bioscouring is an alternative and more environmentally friendly method to remove non-cellulosic “impurities” from raw cellulose fibers by specific enzymes to make the surface more hydrophilic (Rasheedha Banu A., Biscaro Pedrolli B.D.). Pectins are responsible for the hydrophobic properties of raw cotton and its degradation with pectinolytic enzymes has been suggested to facilitate the removal of waxes.
and thus leading to a considerable reduction rate of water and chemicals consumption. Treatment with pectin degrading enzymes would not affect the cellulose backbone and thus avoiding a fiber damage (Rasheedha Banu A.). Our group first results of pectinases enzymes used for hemp retting and results of the obtained fibers colour difference show that pectinase treatment causes colour characteristics (Bernava A.).

The cellulases enzyme treatment of jute fabrics resultes in increase of whiteness index (Kozlowsky R.). The information about cellulases used in the textile industry to create a fashionable stonewashed appearance and biofinishing of linen and other bast fibres are known (Miettinen–Oinonen A). One of the reasons for the wide use of cellulases is their comparatively low price (Miettinen–Oinonen A).

The aim of this research is examination of some cellulase and pectinase enzymes treatment having influence on colour characteristics of raw linen fabric.

**Materials and Methods**

**Materials**

Raw 100% linen plaine weave fabric (characteristic in Tab.1) produced by the company “Larelini” Ltd, Latvia, was used for experiments.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Linear density of warp</td>
<td>50 tex</td>
</tr>
<tr>
<td>Linear density of weft</td>
<td>50 tex</td>
</tr>
<tr>
<td>Density of warp/10cm</td>
<td>174 yarns</td>
</tr>
<tr>
<td>Density of weft/10cm</td>
<td>138 yarns</td>
</tr>
<tr>
<td>Weight of fabric</td>
<td>162.8 g/m²</td>
</tr>
</tbody>
</table>

**Treatments**

The commercially available products pectinase enzyme Beisol PRO (CHT BEITLICH GmbH, Germany) earlear used for hemp retting (Bernava A.) and cellulase enzyme Beizym ENC-SB (CHT BEITLICH GmbH, Germany) were choosed for investigations.

**Methods of Treating**

Conditions of treating and designations of samples are presented in table 2.

**Methods of Testing**

1) Determination of Testing Samples Changes

The mass differences of samples after conditioning were fixed.

<table>
<thead>
<tr>
<th>Enzyme Enzyme</th>
<th>Treatment conditions</th>
<th>Designation</th>
</tr>
</thead>
<tbody>
<tr>
<td>-</td>
<td>Without treatment</td>
<td>No-washed</td>
</tr>
<tr>
<td>-</td>
<td>Washing in water (M 50) at 75°C for 15 min. with after treatment (M 50) in washing agent Felosan NOF 2 g/l water solution at 100°C for 60 min with following rinse in cold/warm water</td>
<td>Pre-washed</td>
</tr>
<tr>
<td>Cellulase Enzyme Beizym ENC-SB</td>
<td>M 50, concentration of enzyme 1%, at 45-50°C, for 60 min, followed by rinse with cold/warm water</td>
<td>C1</td>
</tr>
<tr>
<td>Pectinase Enzyme Beisol PRO</td>
<td>M 50, concentration of enzyme 2%, at 55°C, for 15 min, followed by rinse with cold/warm water</td>
<td>P1</td>
</tr>
<tr>
<td>M 50, concentration of enzyme 2%, at 55°C, for 15 min, followed by rinse with cold/warm water</td>
<td>P2</td>
<td></td>
</tr>
</tbody>
</table>

2) Colour Testing

The samples representing variations of enzymes modification were analyzed on 8 points of each side of sample, using RGB system (CQA Easy Color V3.0 Pocketspec Technologies Inc, USA) which allows determining coordinates of colour vector a*, b* and L*-lightness in CIELab- 76 colour space. Lightness difference (ΔL*), common colour differences (ΔE), colour saturation (C) and hue (H) were calculated following common formulas:

\[ \Delta L^* = L^*_{sample} - L^*_{standard} \]
\[ \Delta a^* = a^*_{sample} - a^*_{standard} \]
\[ \Delta b^* = b^*_{sample} - b^*_{standard} \]
\[ \Delta E = \sqrt{(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2} \]
\[ C = \sqrt{(a^*)^2 + (b^*)^2} \]
\[ H = \arctan\left(\frac{b^*}{a^*}\right) \]
Linen fabric without washing was used as the standard.

3) Testing of Whiteness

Whiteness of the linen fabric surface was determined with Rhopoint Novo-Shade Duo 45/0° reflectometer (Rhopoint Instrumentation Ltd, UK). Preparing and testing of samples according to user manual (Rhopoint) was performed.

4) Microscopy of Surface

The linen fabric surface investigation with the image of optical microscopy (microscope Leica Microsystems GmbH, Germany, magnification 50x) was used.

### Results and Discussion

There are practically no changes of mass of linen fabric after pectinase enzyme treatment; and insignificant mass lose (0.1-0.5%) of investigated samples has been observed in cellulase enzyme treatment case. Obviously, main masses of impurities are removed in prewashing process and action of enzymes is impossible to determine by simple weight method.

The values of calculated colour parameters are shown in Table 3. The values of a* and b* coordinates (Tab.3) of all samples are positives. Pre-washed linen fabric a* parameter is slightly higher in comparison with no-washed (standard). With both enzymes treating a* coordinate is higher than standard; meaning that colour of samples is slightly redder.

The value of coordinate of standard b* is 3.8. Pre-washed and both enzyme treated samples parameters of b* are lower than standard. Δa* of pre-washed linen fabric is 0.2, Δb*-0.1. Δa* and Δb* after cellulase enzyme treatment in all cases are positive; and small differences causes used kind of enzyme.

The colour parameters of tested samples are characterized with common colour difference ΔE (Fig.1), colour saturation C (Fig.2), hue H (Fig.3) and lightness difference ΔL* (Fig.4), all of which give information about colour of fabric. In preparing processes, most significant parameters are ΔE, ΔL* and whiteness.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Sample</th>
<th>No-washed</th>
<th>Pre-washed</th>
<th>C1</th>
<th>C2</th>
<th>P1</th>
<th>P2</th>
</tr>
</thead>
<tbody>
<tr>
<td>a*</td>
<td>4.5</td>
<td>4.7</td>
<td>5.4</td>
<td>5.5</td>
<td>5.1</td>
<td>4.9</td>
<td></td>
</tr>
<tr>
<td>b*</td>
<td>3.8</td>
<td>3.7</td>
<td>3.5</td>
<td>3.4</td>
<td>3.6</td>
<td>3.8</td>
<td></td>
</tr>
<tr>
<td>L*</td>
<td>59.4</td>
<td>0.2</td>
<td>60.4</td>
<td>60.1</td>
<td>60.1</td>
<td>60.1</td>
<td></td>
</tr>
<tr>
<td>Δa*</td>
<td>0.2</td>
<td>3.6</td>
<td>3.6</td>
<td>3.8</td>
<td>3.9</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Δb*</td>
<td>-0.1</td>
<td>5.2</td>
<td>5.4</td>
<td>4.9</td>
<td>4.7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lightness difference, ΔL*</td>
<td>57.4</td>
<td>60.2</td>
<td>59.9</td>
<td>59.9</td>
<td>59.9</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Common colour difference, ΔE</td>
<td>57.6</td>
<td>60.5</td>
<td>60.2</td>
<td>60.2</td>
<td>60.2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Colour saturation, C</td>
<td>5.9</td>
<td>0.9</td>
<td>6.7</td>
<td>6.4</td>
<td>6.2</td>
<td>6.1</td>
<td></td>
</tr>
<tr>
<td>Hue, H</td>
<td>-0.6</td>
<td>0.6</td>
<td>0.6</td>
<td>0.7</td>
<td>0.7</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**FIG. 1. COMMON COLOUR DIFFERENCE OF PRE-WASHED AND ENZYME TREATED LINEN FABRICS**
Common colour difference (Tab.3, Fig.1) of pre-washed linen fabric is 57.6. Insignificant increase of $\Delta E$ after enzyme treatment independently of kind and treatment conditions has been observed.

Colour saturation (Tab.3, Fig.2) of no-washed linen fabric is 5.9. Saturation decrease is remarkable for pre-washed linen fabric (0.9). Colour saturation returns to no-washed sample level after enzyme treatment independently of enzyme kind and treatment conditions.

Hue (Tab.3, Fig.3) of pre-washed linen fabric is -0.6. Values of hue for samples after enzymes treating are positives, which means that insignificant colour and colour saturation differences are connected with hue of
linen fabric.

For comparison and explaining the obtained results, the another index-whiteness of surface was determined with Rhopoint Novo-Shade Duo 45° reflectometer, designed to assess the shade of any flat surface from black (0%-no reflectance) to brilliant white (100%-full reflectance) was used.

The results of experiments together with ΔL* parameters are shown in fig.4. insignificant growth of lightness difference ΔL* and whiteness after enzyme treatment independently of kind and treatment conditions has been observed. The correlation between lightness difference ΔL* and whiteness is evident (fig.4).

The investigation results of microscopy images of fibres surface (Fig.5-7) show treatment influence on fabric surface. Enzyme treatment causes some splitting of the yarns, and the effect is more remarkable in the case of cellulase enzyme.

**FIG. 5 MICROSCOPY OF SURFACE OF PRE-WASHED LINEN FABRIC**

**FIG. 6 MICROSCOPY OF SURFACE OF PECTINASE (P2) TREATED LINEN FABRIC**

**FIG. 7 MICROSCOPY OF SURFACE OF CELLULASE (C2) TREATED LINEN FABRIC**

**Conclusions**

Enzyme type and modification method having influence on raw linen colour parameters and whiteness are insignificant, meaning that enzyme don’t act on natural pigments responsible for colour characteristics of natural fibers. If the higher whiteness as 29% is required, the additional chemical bleaching is necessary. The correlation between lightness difference and whiteness obtained with different experimental methods has been observed. Splitting of the warp and weft yarns after enzyme treatment appears.

**REFERENCES**


CieL*a*b* color Cscale; Inside of Color Vol.8, Nr7; ©Copyright; 1-4, 2008.


Reihmane Skaidrite, Dr.Sc. Eng., Prof. Born in Latvia, Bauska district 28 of February 1945. Dipl. Eng. qualification of Riga Polytechnical Institute Faculty of Chemistry in specialty chemical technology and equipment of textiles treatment, 1968; Dr. Sc. Engineering 26 of June 1992, Riga, Riga Technical University (RTU) in the field of chemical technology of fiber materials. Head of Department of Polymer Materials Chemical Technology of RTU, lecture courses at Riga Technical University connected with textile materials, their modification and use in composites. Leading researcher of collaborative international and national scientific projects, more than 120 research publications connected with textile materials finishing and application.