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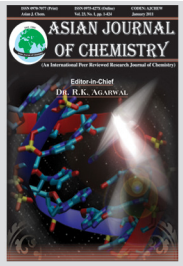

Effects of Commercial Laccase Enzyme on Appearance and Light Fastness of Lingocellulosic Jute Yarn

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In this paper, a commercial laccase enzyme Denilite II S was applied on jute yarn. In comparison to control yarn, the enzyme treated sample shows declined in whiteness, yellowness, brightness index and reflectance characteristics. Because of poor light fastness of this type of fiber due to phenolic lignin component, the effect of laccase enzyme on properties of jute yarn was examined. Enzyme treated yarn shows higher light fastness while lower yarn count and tenacity, because the amount of lignin decreased. The FTIR spectroscopy of bio-treated yarn exhibited oxidation of -CH_3 and -CH_2- groups into consideration and the amount of carboxylic or ester groups were less than control yarn.

Key Words: Jute, Laccase enzyme, Appearance, Physical properties, Light fastness.

INTRODUCTION

Jute fiber is a bast fiber obtained from the bark of jute plant containing three main categories of chemical compounds namely cellulose (58-63 %), hemicellulose (20-24 %) and lignin (12-15 %) and some other small quantities of constituents like fats, pectin, aqueous extract. Jute fiber is composed of small units of cellulose surrounded and cemented together by lignin and hemi-cellulose. The low cellulose content, coarseness, stiffness, low extensibility, low grip performance and some other disadvantages seriously restrict the raw jute fiber from processing[1].

Cellulose-based fibers are intrinsically polar owing to the presence of hydroxyl and carboxylic groups (due to the presence of lignin and hemi-cellulose containing peripheral COOH in the jute fiber) in their structure[2]. Lignin is relatively hydrophobic and aromatic in nature.

When jute is exposed to light and air, all main components undergo degradation. An aqueous extract of the exposed material contains reduction substances, which may be aldehydes of low molecular weight derived from the cellulose by main chain fission, because the copper number of jute is increased by exposure. In addition, the aqueous extract is more acid than from unexposed jute. Part of acid seems to come from degraded polyuronides and the remainder from lignin, which loses methoxyl groups during irradiation. Their loss may lead to the formation of *o*-diphenols and, ultimately, *o*-quinones. These seem to be the main cause of the discolouration, which jute suffers during exposure to light and air[3].

Laccase (EC 1.10.3.2) is capable of oxidizing phenols and aromatic amines[4]. Laccase enzyme is particulary abundant in white-rot fungi and it is assumed to comprise a lignin biodegradable complex[5]. From among other microorganisms it is the best lignin degrader[6]. Laccase seems to be one of the most important enzymes in lignin degradation[7] since it can attack polymeric lignin, degrade the framework structure loosely, introduce additional hydrophilic groups and produce water soluble material[8]. Pre-treatment with laccase complex from *Cerrena unicolor* provides a high level of water sorption capabilities in linen fabrics[9]. Some researchers investigated about loss weight and changes of yarn count[10,11]. We have investigated the effect of laccase enzyme on appearance and light fastness of jute yarn.

EXPERIMENTAL

Commercially available tossa jute yarn with a yarn count of 4306.2 dTex was used throughout the study. Laccase enzyme (Denilite II S) used was purchased from commercial enzyme supplier Novozyme. Enzyme activity is expressed as units per gram (U/g), where one unit is defined as amount of enzyme required to oxidize one micromole of syringaldazine per minute at pH 7.5 and 30 ºC. Enzymatic activity of Denilite

was measured by Ossalla *et al.*[11] and was about 80 U/g. A basic dye (bezacryl red GRL 180) was purchased from Benzema Deutcheland.

Enzymatic treatment: Enzymatic treatment of jute yarn was performed in a bath with concentration of laccase enzyme 20 g/kg (over weight of yarn) of a preparation with 80 U/g, equivalent to 1600 U/kg of yarn in the optimal following condition: pH 7.5 (phosphate buffer), temperature of 30 ºC, time 2 h and liquid ratio 20:1. Enzyme inactivation occurred in water bath at a temperature of 98 ºC.

FTIR spectroscopy: The FTIR spectra of raw and surface treated jute fibers were recorded with Bruker Tensor 27 spectrophometer (Bruker Corporation, Germany) using KBr pellet technique. The dried fiber samples were crushed to a size that was finer than 20 meshes before pelleting with KBr. The test KBr pellet contained about 1 % powdered fiber. Untreated and treated jute fibers were analyzed by FTIR spectroscopy.

Colour spectroscopy analysis: The colour strength of dyed samples was determined from the values K/S calculated from the sample reflectance (R):

$$K/S = (1-R)^2 / 2R \quad (1)$$

The reflectance R of dyed samples were measured on a X-rite colour eye 7000 A spectrophotometer measurement system, at the wavelength of minimum reflectance, under CIE Illumination D65 and d/10º illumination/observation. The whiteness index, yellowness index and brightness index were calculated by the Hunter Lab-scale, ASTM E313-73 and ISO-2470-77 formula, respectively.

$$WI = 100 - \sqrt{[(100-L)^2 + a^2 + b^2]} \quad (2)$$

$$YI = 100 \times [1-(0.847Z/Y)] \quad (3)$$

BI = [Reflectance value of substrate at 457 nm/Reflectance value of the standard white tile at 457 nm] × 100 (4)

Light fastness: The light fastness of treated and untreated samples was test on fad-o-meter (Sima Nassaj co. Iran) after partially exposing the samples to the Xenon arc lamp for 2 h. The colour change estimated with calculating ΔE* which is defined by the following equation.

$$\Delta E^* = \sqrt{[(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2]} \quad (5)$$

where ΔL*, Δa* and Δb* are colour difference between before and after exposing the sample to the xenon arc lamp.

Mechanical properties: Mechanical properties was measured by using a material tensile tests (Testometric materials testing machines winTest™ Analysis, England) according to ASTM D 2256-97 with an effective specimen length of 250 mm (clamped distance) and a test speed of 300 mm/min, pretension 0.5 %, at room temperature. The values given are the means from at least five individual samples.

RESULTS AND DISCUSSION

Fiber characterization: The FTIR spectra of untreated and treated jute fiber are shown in Figs. 1 and 2. The band at 3240 cm^{-1} in spectrum of untreated jute is assigned to H-bonded OH stretching vibration after enzymatic treatment of jute yarn this band shift 3411.72 cm^{-1}. The bands range 3000-2800 cm^{-1} are due to CH stretching vibration. After enzymatic treatment this band decreased from 2918 to 2910 cm^{-1}. This may be explained by taking the oxidation of $-CH_3$ and $-CH_2-$ groups into consideration.

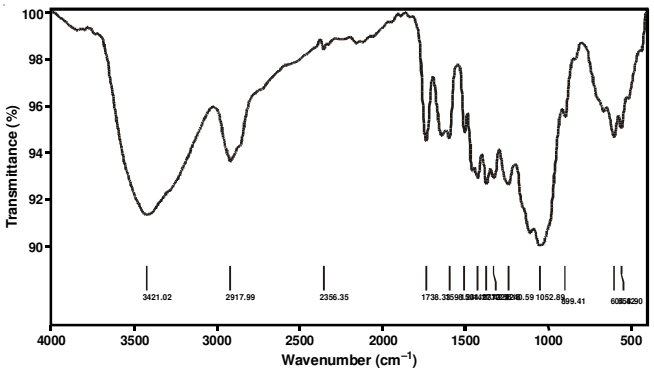

Fig. 1. Fourier transform infrared spectra of untreated jute yarn

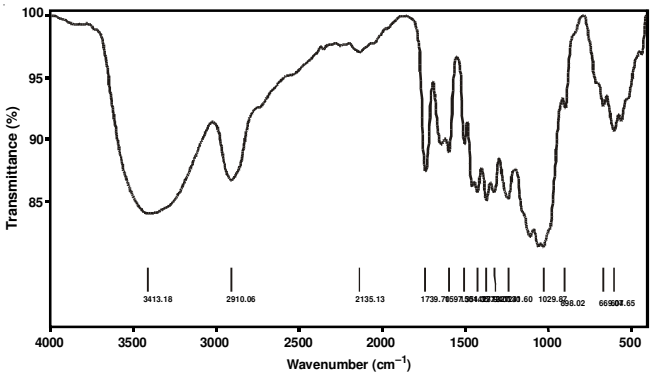

Fig. 2. Fourier transform infrared spectra of laccase enzyme treated jute yarn

Carbonyl group appears at *ca.* 1740 cm^{-1} and carboxyl group appears at *ca.* 3400 cm^{-1}. The ratio of transmittance of carboxyl group to carbonyl group in bio treated yarn is high compare to control yarn. As a result in bio-treated yarn the amount of carboxylic or ester groups are less than control yarn. Thus, bio-treated yarn has low amount of hemi-cellulose in composition compare to control yarn.

Effect of enzymatic treatment on appearance of jute yarns: Table-1 shows the shade of control and bio-treated jute yarns. The relatively lower L* value in bio-treated jute indicates the presence of less white and higher a* and b* values indicate the presence greater red and yellow components in the colour. Enzyme treatment leads to more exposure of lignin

TABLE-1
EFFECT OF ENZYMATIC TREATMENT ON SHADE OF THE RAW JUTE YARNS

Sample	L*	a*	b*	K/S	Whiteness index	Yellowness index	Brightness index
Untreated	60.124	5.454	18.092	4.733	55.873	42.998	22.169
Bio-treated	59.911	6.633	18.289	4.638	37.009	43.616	21.879

on the surface of the treated jute fibers[10] causing a higher increase in colour strength (K/S) and yellowness index of yarn, in other hand whiteness index and brightness index decreases. Fig. 3 shows that the reflectance characteristics of enzyme treated jute yarn shows a decreasing trend. Perhaps due to this effect in paper industries some values of mediator were added to enzyme combination in pulp stage accompanied by plasma treatments[12]. After laccase enzyme treatment the surface of treated yarn become rougher and more porous (decreasing in yarn count next section). Therefore decreasing of reflectance characteristics of laccase treated jute yarn may attributed to the rough surface of the treated yarn.

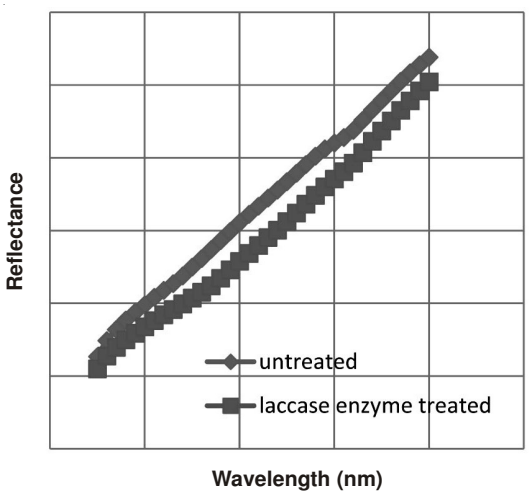

Fig. 3. Reflectance characteristics of the raw jute and laccase treated jute yarn

Effect of enzymatic treatment on the yarn count: Yarn count (dTex) is proportional to yarn diameter therefore a thin yarn would result from more removal of impurities from the yarn. Table-2 shows the results of yarn count comparing the control and enzymatic treatment. It is evident from Table-2 that enzymatic treatment gives low yarn count value. Thus, bio-treated yarn is thinner than control yarn. A low yarn count value indicates a thin yarn, thus greater removal of impurities (lignin) from the yarn. Similar results obtained from scouring flax rove with the aid of enzyme[11].

TABLE-2
YARN COUNT BEFORE AND AFTER TREATMENT WITH LACCASE ENZYME

Sample	Yarn count (dTex)
Before enzymatic treatment	4306.2
After enzymatic treatment	4255.7

Effect of enzymatic treatment on light properties: One of the major problems that restrict the application of jute products is that jute suffers seriously from light-induced discolouration. Lignin is highly sensitive to action of light. When UV-light falls upon jute fiber, the phenolic hydroxyl groups of lignin in jute created free radicals. These free radicals undergo transformation into quinoid structures and showed yellowing on surface of fibers[2].

Table-3 shows that the light fastness of bio-treated yarn improved to a great extent from $\Delta E^* = 3.444$ to $\Delta E^* = 1.996$ which can be attributed to remove impurities. Laccase is the most efficient degrader of lignin which oxidizes phenolic compounds to give phenoxy radical and quinines. Enzyme treated jute yarn contains minor amount of lignin. Therefore after enzymatic treatment when the fiber subjected to light in presence of atmospheric oxygen, photo yellowing can not be accelerated as much as control jute yarn.

TABLE-3
LIGHT FASTNESS OF TREATED AND UNTREATED SAMPLES AFTER EXPOSING THE SAMPLES TO XENON ARC LAMP FOR 2 h

Sample	ΔE*
Untreated jute yarn	4306.2
Bio-treated jute yarn	4255.7

Effect of enzymatic treatment on mechanical properties: It is evident from Table-4 that enzymatic treatment causes the great loss in yarn strength since lignin chain in the fibers were partially oxidized. These changes in the breaking tenacity were related to removal of lignin. Oxidative effect of laccase enzyme on jute fiber is led to loosen the cement agent in the fiber matrix and caused to loss in strength.

TABLE-4
MECHANICAL PROPERTIES OF TREATED AND UNTREATED JUTE YARNS

Sample	Initial modulus (g/dTex)	Tenacity at rupture (g/dTex)	Strain at rupture (%)
Untreated	50.290	1.527	3.376
Bio-treated	30.813	1.253	4.155

Conclusion

Carbonyl group appears at *ca.* 1740 cm^{-1} and carboxyl group appears at *ca.* 3400 cm^{-1}. The ratio of transmittance of carboxyl group to carbonyl group in bio treated yarn is high compare to control yarn. As a result in bio-treated yarn the amount of carboxylic or ester groups are less than control yarn. Thus, bio-treated yarn has low amount of hemi-cellulose in composition compare to control yarn.

Enzyme treatment leads to more exposure of lignin on the surface of the treated jute fibers causing a higher increase in colour strength (K/S) and yellowness index of yarn, in other hand whiteness index and brightness index decreases.

Laccase is the most efficient degrader of lignin which oxidizes phenolic compounds. Therefore after enzymatic treatment when the fiber subjected to light in presence of atmospheric oxygen, photo yellowing can not be accelerated as much as control jute yarn. In other hand, oxidative effect of laccase enzyme on jute fiber is led to loosen the cement agent in the fiber matrix and caused to loss in strength.

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