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Note from the field

Xylano-pectinolytic synergism from a bacterial isolate for ecofriendly processing of jute fabric

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ABSTRACT

The application of xylano-pectinolytic enzymes produced concurrently by a bacterial isolate on raw jute fabrics was investigated in the present study. For efficient removal of non-cellulosic impurities from raw jute fabric, different process conditions were optimized. Bioscoured jute fabrics showed an increase of 19.50% in whiteness, 33.65% in brightness, 21.08% in tensile strength and 14.35% decrease in yellowness as compared to alkaline scoured fabric. Bleaching of bioscoured fabrics further improved whiteness, brightness and tensile strength in comparison to the bleaching of chemically scoured fabrics. Use of these concurrently produced xylano-pectinolytic enzymes completely replaced the conventional alkaline scouring and hence makes the process environment friendly. This is the first report on the use of xylano-pectinolytic enzymes produced simultaneously by a bacterial isolate in the processing of jute.

1. Introduction

Natural fibres mainly consist of cellulose which account for 30–40% of floral cell walls (Loow et al., 2015). They are surrounded by a hydrophobic layer of natural impurities, which must be removed to make the fibre soft, hydrophilic and suitable for industrial applications. In conventional scouring, high temperature and alkaline chemicals are used to remove non-cellulosic impurities. These alkaline chemicals also attack on the cellulosic part of the fabric which causes weight and strength loss of the fabric and also generate highly polluted wastewater with high BOD, COD and TDS values (Ledakowicz et al., 2007; Battan et al., 2012). A cost-effective strategy that can reduce the impact on the environment is required. Bioscouring is an ecofriendly method which employs enzymes to remove these impurities. This process preserves the fibre's structure, strength and avoids the high energy consumption and severe pollution problems that are associated with conventional alkaline treatments. Xylano-pectinolytic enzymes remove xylan and pectin and make the fibre softer. Xylanase and pectinase produced by different microorganisms have been used in combination for jute treatment (Dutta et al., 2000; Chattopadhyay et al., 2006; Samanta et al., 2008; Vigneswaran and Jayapriya, 2010; Zolriasatein and Yazdanshenas, 2014). No data is available till date on simultaneous production of these enzymes by a bacterial isolate and their application in the processing of jute fabric.

Abbreviation list: °C, degree centigrade; µl, microlitre; µmol, micromole; AATCC, American Association of Textile Chemists and Colorists; ASTM, American Society for Testing and Materials; BOD, biological oxygen demand; C, control; COD, chemical oxygen demand; EDTA, ethylene diamine tetra acetic acid; g/L, gram per litre; h, hour; H_2O_2, hydrogen peroxide; ISO, International Standard Organization; IU, International Unit; kg, kilogram; KH_2PO_4, monopotassium phosphate; KNO_3, potassium nitrate; M, molar; mg/g, milligram per gram; $MgSO_4$, magnesium sulphate; min, minute; mL, millilitre; MLR, material to liquid ratio; mM, millimolar; MTCC, Microbial Type Culture Collection; NaCl, sodium chloride; NaOH, sodium hydroxide; nm, nanometre; pH, potential of hydrogen; rpm, rotation per minute; s, second; SPSS, Statistical Package for Social Sciences; T, test; TDS, total dissolved solids; UV, ultraviolet; W, weight.

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2. Materials and methods

2.1. Materials

A cellulase free xylano-pectinolytic enzymes producer, *Bacillus pumilus* AJK (MTCC Accession No. 10414) was routinely subcultured on nutrient agar medium (g/L) (pH 7: peptone, 5.0; NaCl, 5.0; beef extract, 3.0; and agar, 15.0) and maintained at 4 °C. Xylan and

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polygalacturonic acid were purchased from Sigma chemicals. All other chemicals used were of analytical grade. Jute samples were kindly provided by the Technological Institute of Textile and Sciences, Bhiwani, India.

2.2. Methods

2.2.1. Enzyme production and assay conditions

The 50 ml basal medium (g/L: peptone, 5.0; yeast extract, 5.0; KNO_3, 5.0; KH_2PO_4, 1.0; $MgSO_4$, 0.1; pH 8.0) supplemented with 2% wheat bran and 2% citrus peel in 250 ml Erlenmeyer flasks was inoculated with 2% inoculum of 24 h old and incubated at 37 °C for 48 h. The cells were removed by centrifugation and the clear supernatant was used for enzymes assay. Birchwood xylan 1% and polygalacturonic acid 0.5% were used for estimation of xylanase and pectinase activities respectively. The enzymes activity was measured after enzyme–substrate reaction using dinitrosalicylic acid reagent (Miller, 1959). To 490 μl of respective substrate prepared in glycine–NaOH buffer (0.1 M, pH 8.5), added 10 μl of appropriately diluted enzyme and was incubated at 55 °C for 10 min and the release of sugars was measured. One unit of xylanase and pectinase is the amount of enzyme that catalyses the release of 1 μmol of reducing sugar equivalent to xylose and galacturonic acid respectively per minute.

2.2.2. Experimental procedure

2.2.2.1. Bioscouring. To obtain best bioscouring condition, 1 g fabric samples were treated at different pH (7.0–9.5) and buffer molarity (10–100 mM). The material to liquid ratio in the range of 1:15 to 1:40 was also optimized to obtain the best treatment conditions. Different enzyme doses (1.0–10.0 IU of xylanase and 0.8–8.0 IU of pectinase) per gram fabric were used for different treatment time periods (15–150 min) at temperature varying from 40 to 60 °C and agitation speed ranging from 50 to 75 rpm. Different concentrations (0.1–5.0 mM) of EDTA were also used to improve various properties of the fabrics. To improve the water absorbancy, different wetting agents and concentration of most effective wetting agent were also optimized in the range of 0.1–2.0%. For control treatments, the fabrics were treated under the same reaction conditions but in the presence of inactivated enzymes.

2.2.2.2. Chemical scouring. Scouring was carried out according to the method of Ibrahim et al. (2010) with slight modification. A solution containing NaOH (10 g/L) and Tween 80 (2 g/L) was used. The reaction was carried out at 90 °C for 60 min. The MLR was adjusted as optimized for bioscouring treatment.

2.2.2.3. Bleaching. Bleaching of bioscoured and scoured fabrics was carried out according to the method given by Ibrahim et al. (2010) with slight modification. A solution containing H_2O_2 (10 g/L, 30%), soda ash (2 g/L), sodium silicate (5 g/L), EDTA (1 g/L) and Tween 80 (2 g/L) was used for bleaching at 90 °C for 90 min.

2.2.2.4. Analysis of jute fabrics treated filtrates. After each treatment, the fabrics were removed from the reaction mixture and the filtrates were used for estimation of reducing sugars and lignin. Reducing sugars were measured using dinitrosalicylic acid (Miller, 1959) and the release of lignin was determined by measuring the absorbance at 280 nm. The UV spectra of filtrates with respect to their control were taken using UV–vis spectrophotometer.

2.2.3. Analysis of bioscoured and scoured jute fabrics

2.2.3.1. Weight loss. Weight loss of fabric samples was measured after drying the sample at 45 °C before and after a particular treatment. The following formula was used to calculate the % weight loss of the fabric samples.

$$\%\text{Weight loss} = (W1 - W2) \times 100/W1$$

$W1$ and $W2$ are the dry weights of the fabric samples before and after treatment, respectively (Aly et al., 2004).

2.2.3.2. Physical, microscopic and statistical analysis. The whiteness index on the Hunter scale (Hunter, 1975), brightness on the ISO 2470 scale (ISO 2470, 1977) and yellowness on the ASTM-E-313 scale (ASTM-E-313, 1974) were measured by Macbeth Color-Eye® spectrophotometer. Tensile strength of the fabric samples was determined using digital tensile strength tester Paramount. Microscopic characterisation of raw, bioscoured and scoured fibres was examined using light microscope at 1000× (Sharma et al., 2011). All experiments were performed in duplicate and results were expressed as mean ± standard error. The Student's *t*-test for calculating the statistical significance and standard error was calculated using SPSS 16.0.

2.2.3.3. Water absorbancy test. Evaluation of wettability of the samples was tested using AATCC Test methods 39-1980 (AATCC Technical Manual, 1980). The time (in seconds) between the contact of water drop with the fabric and its disappearance into the fabric was measured.

3. Results and discussion

3.1. Optimization of bioscouring conditions

Physical properties of fabrics were affected by different variables of bioscouring. Effect of bioscouring was more at pH 8.5 of 50 mM buffer solution. Enzymes were found to be most efficient at MLR of 1:20 (Table 1). An enzyme dose of 2.5 IU of xylanase and 2.0 IU of pectinase per gram fabric was found to be optimum. Maximum removal of non-cellulosic impurities was achieved after treatment period of 60 min at temperature 50 °C (Table 2). Agitation speed of 60 rpm and 0.5 mM EDTA was found to be optimum (Table 3). Addition of EDTA into the enzyme solution enhanced the removal of impurities. Many researchers confirmed the addition of EDTA during bioscouring accelerated the degree of hydrolysis significantly (Csiszar et al., 2004; Foulk et al., 2008; Garg et al., 2013). Different wetting agents were used in order to improve the water absorbancy of the fabrics. Tween 80 at a concentration of 1% was optimized for getting the maximum bioscouring efficiency (Table 4). Li and Hardin (1998) studied the effects of surfactants, agitation, enzyme selection and concluded that the effect of surfactants and agitation depend on the enzyme structure and the characteristics of the fibre. After enzymatic treatment, the whiteness and brightness of bioscoured fabrics were increased by 7.30 and 19.45% as compared to control (without enzymatic treatment). A decrease of 4.22% in yellowness of jute fabrics was also observed (Table 5).

Use of combination of enzymes for jute treatment has been reported by several workers (Dutta et al., 2000; Chattopadhyay et al., 2006; Samanta et al., 2008; Vigneswaran and Jayapriya, 2010; Zolriasatein and Yazdanshenas, 2014). Samanta et al. (2008) reported the use of cellulase, xylanase and pectinase for the treatment of jute fibre at 55 °C, pH 4.8 for 120 min, which resulted in higher brightness of the fibre. Bioscouring of jute fabric with xylanase along with EDTA and Tween 20 resulted in an increase of 9.63, 4.28 and 10.71% of reducing sugars, whiteness and brightness respectively as compared to conventional process (Garg et al., 2013).

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