Biological Stripping Technology for Recycling of Faulty Dyed and Old Waste Cotton Fabrics

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Stripping is desirable to remove dyes/color from the dyed fabric in order to correct the faulty or uneven dyeing and to re-dye the waste fabric in different shades and colors for reuse. Chemical stripping is the traditionally used process called as "back stripping" or "destructive stripping". Chemical stripping liquids do not have universal acceptance in the dyeing industries as none of them can be used on various blends of fabric and dyes and each system has to be individually designed, depending on the nature of dye to be removed and the type of fabric. Many of the stripping liquids have alkaline pH values often higher than 9 that could be harmful to the fabric material and the stripped fabric is very difficult to re-dye.

Due to stringent environmental legislations and regulations, it is inevitable to develop new strategies for dye color removal that should not be only environmental friendly, but also cost effective. In recent years many studies have focused on microorganisms that are capable of degrading dyestuffs in environment friendly and cost effective processes. Ligninolytic white rot fungi (WRF) are the most promising and versatile microorganisms, characterized by their derivative abilities towards broad spectrum of structurally different dyes due to their highly oxidative and non-specific enzymatic system. In recent years a number of studies have been reported on biodegradation of textile dyes and bioremediation of dye containing textile industry effluents using different WRF strains. However, there was not even a single attempt reported on removal of dyes fixed on cotton fabrics. This work was, therefore, the first attempt to develop an economical and environmentally acceptable biochemical stripping technology for cotton fabric dyed with C.I. Reactive Black B dye using crude enzyme extract from a white rot fungus IBL-05.

Description of Invention

Dyeing of Fabric

The grey fabric was bleached for half an hour at 50 ^{0}C and dyed with Reactive black B (hetero-bifunctional) dye to 2, 4 & 6% shade strengths on the basis of weight of the fabric (WOF). Dyeing was carried out using exhaust dyeing method at 45 ^{0}C for 15 minutes, followed by at 55 ^{0}C for 50 minutes.

Biological Stripping Protocol

Preparation of fungal inoculum

Pure culture of indigenous white rot fungus IBL-05 isolated from decaying soft wood (Fig.1) was used for biological stripping of dyed cotton fabric. The flasks containing basal nutrient medium (100mL) were adjusted at pH 4.5 and autoclaved at 121 ^{0}C for 15 min. The flasks were inoculated with loopful fungal spores and placed in shaking incubator (120 rpm) at 30 ^{0}C for 3 days to get homogenous fungal inoculum.

Fig.1 The indigenous white rot fungus IBL-05 growing on decaying soft wood

Biological stripping procedure

Triplicate flasks containing 100 mL basal medium, wheat bran as carbon source, peptone as nitrogen source, $MnSO_4$ as meditor, $ZnSO_4$ as activator and 5×5 inch dyed fabric pieces of respective three shade strengths (2, 4 and 6%), were adjusted to pH 4.0 with M NaOH/M HCl and autoclaved. The stripping flasks were inoculated with IBL-05 fungus and incubated at 35 ^{0}C in shaking incubator at 120rpm for 15 days. The control flasks contained fabric pieces and basal nutrient media but did not receive fungal inoculum. After 15 days the triplicate flasks were harvested and fabric pieces were washed, dried, labeled and evaluated for color stripping.

Optimization of biological stripping process

The biological stripping process was optimized by studying the effect of different physical (pH, temperature) and nutritional factors (carbon nitrogen source, mediators and metal ions) on production of ligninolytic enzymes and stripping of dyed cotton fabric by IBL-05 using Resistance Surface Method (RSM).

Biological stripping of fabric using ligninolytic enzymes

Cotton fabrics dyed to 2, 4 and 6% shade strengths were stripped by *enzymes produce*d by IBL-05 under the process conditions optimized for 2% shade strength. In biological process 90.4, 73.7 and 69.7% color stripping was achieved for 2, 4 and 6% shade strengths, respectively (Fig. 2).

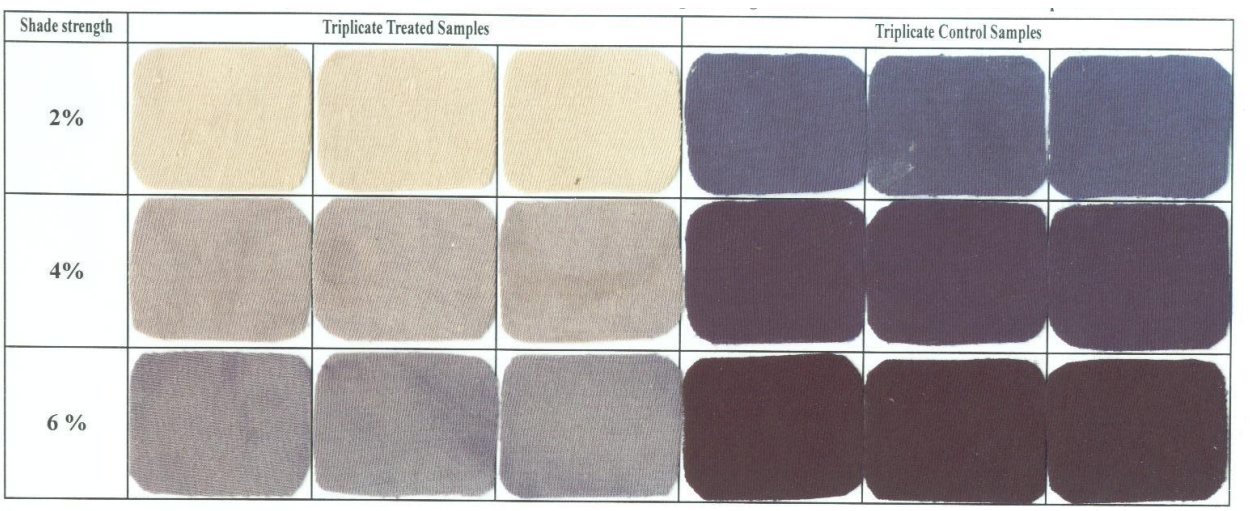

Fig.2 Samples of biologically stripped cotton fabric dyed with C.I. Reactive black 5 to different shade strengths under optimum process conditionsChemical Stripping

Chemical stripping of dyed fabric was carried out according to the conventional method employed in textile industries as reported by Ogulata and Balci (2007) with some modifications. The percent color stripping achieved by chemical process was 63.09, 55.50 and 32.97 for 2, 4 and 6% shade strengths of fabric, respectively (Fig.3).

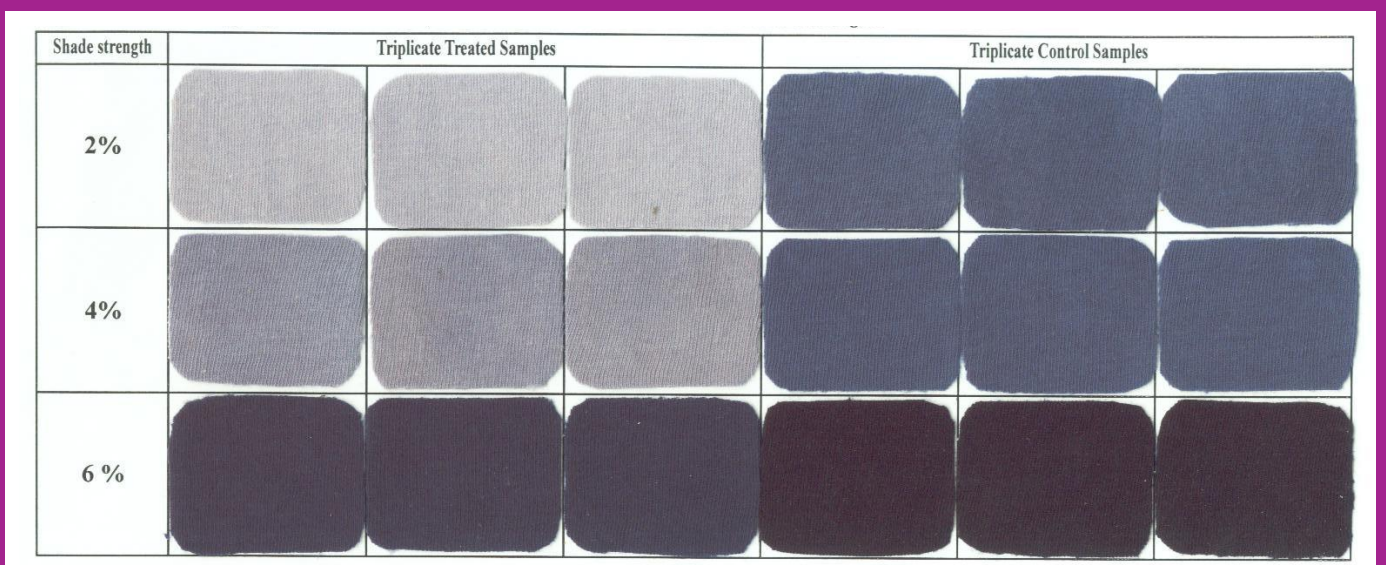

Fig.3 Samples of chemically Stripped cotton fabric samples dyed with C.I. reactive black 5 to different shades

Comparison of Chemical and Biological stripping

Using LiP (944 U/mL), MnP (472 U/mL) and laccase (94 U/mL) produced by the fungus caused 90.6, 73.7 and 59.7% color stripping for cotton fabric dyed to 2, 4 and 5% shade strengths (Table 1; Fig.2) in 11 days, whereas percent stripping achieved by chemical process was 53.09, 55.50 and 32.97%, respectively (Fig.3) in 5 days .

Fabric Quality after Stripping

The quality of biologically and chemical stripped, and un-stripped fabrics was evaluated by determining the Bursting strength, Pilling and Weight loss, following the methods of American Association of Textile Chemists and Colorists (AATCC, 2000). The biological stripping proved to be superior to chemical stripping as it did not deteriorate the fabric quality. The bursting strength of biologically stripped cotton fabric dyed to 2%, 4% and 6% shade strength was 889, 874 and 890 KPa, respectively (Table 1). Whereas, the bursting strength values for chemically stripped fabrics were 845, 839 and 853 KPa, respectively. The resistance to pilling was 4 for biologically stripped fabrics for light (2% shade), medium (4% shade) and dark (6%) shade strengths, respectively, where as chemically stripped cotton fabric samples had values of 3, 3/4 and 3, respectively. The loss in weight % of biologically stripped cotton fabric samples was 1.45, 1.34 and 1.47% for light, medium and dark shades, respectively as compared weight losses of 3.13, 3.70 and 3.01% for chemically stripped fabrics, respectively (Table 1). The higher weight losses of the chemically stripped fabric indicate the damaging effects of chemical treatment that might be attributed to structural losses due to harsh chemicals. In contrast to chemical treatment, biological stripping is gentle and less damaging treatment causing the less structural damages.

Table 1. Fabric quality parameters for biologically and chemically stripped fabric

Quality Parameter	Untreated Fabric	Biologically and chemically stripped fabric					
		2% Shade strength		4% Shade strength		6% Shade strength	
		BS*	CS**	BS	CS	BS	CS
Bursting Strength (kPa)		889±14.7	845±13.3	874±19.2	839±18.9	890±13.54	853±15.8
Pilling	4/5	4	3	4	3	4	3
Weight loss (%)	---------	1.45±0.01	3.13±0.03	1.34±0.03	3.70±0.02	1.47±0.02	3.01±0.03

*BS: Biologically stripped
**CS: Chemically stripped

Conclusions

1. The biological process almost completely removed dye from the fabric in 5 days without deteriorating the fabric quality because the nutrient medium does not contain any harsh chemicals and the fungus does not secrete any significant cellulases
2. The biological stripping process is cost effective as compared to traditional chemical stripping because it involves a cheaper nutrient medium for white rot fungus IBL-05.
3. The newly developed process should be named as "Biological Stripping Technology" to be used for stripping of cotton fabrics dyed with reactive textile dyes