

Enzymatic Biobleaching of Recalcitrant Paper Dyes

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Abstract: Modern manufacturing processes assume efficient utilization and recycling of natural resources whenever possible. Over the past decade paper recycling has progressed from 33.5% in 1990 to just above 48% in 2002. Indeed, for certain select grades, (newspaper and old corrugated containers) greater than 70% is currently being recycled. In contrast, mixed office waste and colored directory papers are often underutilized. A major difficulty in recycling these grades of paper is the problems associated with decolorizing the dyes present in the paper. Of the commonly used paper dyes, the stilbene dye Direct Yellow 11 and methine dye Basazol 46L are notorious for poor bleachability with the commonly used chemical bleaching agents including chlorine dioxide, oxygen, hydrogen peroxide and sodium dithionite.

The ability of white-rot fungi to decolorize colored effluents containing textile dyes is currently the subject of intensive research efforts. The secreted enzymes involved in dye decolorization include manganese peroxidase, lignin peroxidase and laccase. Laccase, a lignolytic enzyme, has also been studied for many years for the biobleaching of wood pulps. The ability of laccase to delignify pulp is greatly enhanced by the addition of small molecule mediators such as 2-2' azinobis (3-ethylbenzthiazoline-6-sulfonate) (ABTS) and 1-hydroxybenzotriazole (HBT).

This research project focused on applying laccase combined with a mediator to decolorize C.I. Direct Yellow 11 and Basazol 46L. Three mediators were tested: ABTS, HBT and violuric acid. Laccase/ABTS was most effective with 60% of the color being removed. The level of color removal was maintained at 60% even when ABTS concentration was lowered from 5 mM to 0.01 mM. When laccase/1 mM ABTS was applied to Direct Yellow 11 in solution, the majority of color loss occurred within 60 minutes.

The ability of soybean (SBP) and horseradish (HRP) peroxidases and laccase to decolorize Direct Yellow 11 and Basazol 46L in solution was also examined. The results demonstrated that these two recalcitrant dyes could be effectively decolorized by enzymatic treatments by horseradish peroxidase, soybean peroxidase, and laccase with ABTS as mediator. SBP is effective from pH 4.5 to 8.5. The stilbene dye Direct Yellow 11 responded to both SBP and laccase/ABTS. For the methine dye Basazol 46L, SBP was a more effective treatment than HRP or laccase/ABTS. Basazol 46L responded quickly to SBP treatment with 74% reduction in signal intensity within 5 minutes.

To evaluate the effectiveness of laccase/ABTS treatment, pulp dyed with Direct Yellow 11 and three commercial colored pulps were subjected to seven different bleaching treatments. These treatments consisted of 1)laccase/ABTS; 2)laccase/ABTS followed by alkaline extraction; 3)laccase/ABTS followed by bleaching with sodium dithionite; 4)oxygen bleaching; 5)oxygen bleaching followed by dithionite treatment; 6)alkaline hydrogen peroxide bleaching; and 7)alkaline peroxide bleaching followed by dithionite treatment. The best results were obtained by including reductive bleaching with sodium dithionite. For Direct Yellow 11 dyed pulp, laccase/ABTS followed by dithionite yield comparable reduction in color to oxygen or peroxide followed by dithionite.