Chemo-Enzymatic Modification of High-Kappa Kraft Pulps with Laccase (2003)

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Abstract: As research in pulp and paper has progressed, emphasis has shifted towards creating a wider range of uses for pulps that are produced in higher yields such as high-kappa (50+) grades typically employed for the production of linerboard. Unfortunately, high-yield kraft pulp fibers possess inferior hydrogen bonding capabilities due to their high-surface lignin content. Enzymes that react with fiber lignin such as laccase have been shown to have only limited positive effects on the physical properties of mechanical pulps, however, it has been demonstrated that laccase can co-polymerize phenolic compounds to lignin when all of the reactants are in the solution phase.

In this research project, a novel system was developed where laccase catalyzed the coupling of water-soluble compounds to high-kappa kraft pulp fibers to improve their properties. The conditions where the system tended to function most effectively in improving paper strength properties were also revealed.

The initial treatments employed syringic, vanillic and 4-hydroxybenzoic acid (4-hba) as water-soluble phenols to react with laccase in the presence of high kappa kraft pulps. These studies investigated the feasibility of employing the laccase-facilitated coupling system to alter the properties of high-kappa (90) kraft pulps. It was demonstrated that the reaction with 4-hba resulted in the highest amount of incorporated phenol. Lignin was determined as the chief target of the laccase-facilitated modification. Treatment of high-kappa kraft pulps with laccase and 4-hba resulted in increases in surface and bulk acid groups, increases in molecular weight of pulp surface material, and modest increases in paper strength.

Further studies investigated the effects of employing laccase to facilitate the coupling of phenols with amine functionalities and quaternary-amines possessing a cationic charge. Once again, laccase was shown to alter pulp fiber surface material by the coupling of these compounds with the pulp; however, these reactions had only minimal effects on paper strength properties.

Finally, laccase was reacted with gallic acid, a water-soluble phenol that reacts at a faster rate with laccase than 4-hba. The reaction of laccase with gallic acid in the presence of high-kappa pulp was shown to impart increases in dry and wet-strength properties. The improved strength properties observed during laccase and gallic acid treatments were most likely due to a combination of decreasing the fiber contact angle with water and coupling of phenoxy radicals within the paper sheets.