Effect of Enzymatic Treatment on Dyeing and Finishing of Cellulosic Fibers: A Study of the Basic Mechanisms and Optimization of the Process

Project: A96-1

Principal Investigators

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Goal

The objectives of this project are to study the mechanism of the enzymatic hydrolysis and to establish optimum conditions for a combined process of enzymatic treatment and dyeing/finishing which is applicable to various types of cellulosic fibers.

Abstract

The treatment of cellulosic goods with cellulase enzymes has developed into a finishing process of increasing importance over the past few years. Cellulases are nontoxic and thus environmentally friendly. They are capable of improving the hand properties of the textile materials as well as increasing the color brightness by removing surface fibrils. The enzymatic reaction consists of a series of complex steps and the mechanism is not yet fully understood. Enzymatic finishing is often performed prior or subsequent to dyeing and finishing. It is therefore very important to study the interaction of cellulases and dyes/finishing compounds in their effect on each other as well as on the cellulosic substrate. Developing a combined process will render an efficient procedure for the textile industry. Simultaneously, information could be acquired about fundamental mechanistic aspects of this interesting reaction.
Technical Approach

Cellulase enzymes are proteins of large molecular size. They affect accessible amorphous areas and crystallite surfaces of the cellulose substrate. Most decisive factors from the point of view of the textile material are therefore internal surface area, pore dimensions, crystallinity, and degree of polymerization. Cellulosic substrates of different origin, such as cotton, linen, ramie, jute, or regenerated cellulose, with varying structural parameters and differences in chemical composition will thus show different accessibility for the enzymes. Besides, compounds like lignin, hemicelluloses, gums, and other by-products will also influence the overall result of the enzymatic reaction. A thorough characterization of the starting materials as well as of the products after the enzymatic treatment is therefore essential.

Dyes for cellulosic goods enter the amorphous areas of the fiber through water-filled porous channels and attach themselves, depending on the dye class, by various types of intermolecular forces. They will consequently interfere with the enzymatic reaction to a larger or lesser extent. Fiber-reactive dyes, forming covalent bonds with the hydroxyl groups of the cellulose, are expected to have a larger influence since they change the substrate for the enzymatic recognition in areas of accessibility. Direct dyes and pigment-type dyes, such as vat dyes, might have less impact on the result of the cellulytic treatment. Studying the enzymatic hydrolysis in the presence of various different dyes will yield important information on prime attacking sites of the cellulase complex.

It is generally observed that enzymatic surface polishing by reduction of fabric fuzziness increases the color brightness through diminished light scattering. To achieve this effect, considerable mechanical action is necessary during the treatment with cellulases. This aspect will be addressed separately in order to differentiate it from the degradative effect of the enzymes. In terms of dye uptake and dye fixation it will possibly make a difference whether the textile material was enzymatically treated prior to the dyeing process which in turn might also influence the resulting color shades. Therefore it is necessary to study both treatment sequences. Again, different dye classes are expected to behave differently (see above).
Surface polishing of the enzymes by removal of surface fibrils yields a softer hand and easier fabric bending properties. This effect is based on altered friction between fibers and yarns due to reduced fiber diameters and smoother fiber surfaces. A crosslinking treatment for the purpose of improved wrinkle recovery usually renders the fabric stiff and harsh to the hand. The question is whether an enzymatic treatment will be able to complement this effect.

The reaction with a crosslinking resin can be carried out in the dry, moist and wet state of the textile material. The application conditions chosen will determine the final lengths of the bridges between the cellulose chains. Short links produce good wrinkle recovery but high tensile strength losses. With longer links medium crease recovery and strength reduction can be expected. It will be interesting to apply cellulases before the finishing treatment to study the resulting softening effect. The resin will be applied to the fabric containing different amounts of humidity. With the enzymatic pretreatment it is possible that less finishing chemicals will be sufficient to reach the same level of wrinkle recovery.

**Current Activities**

Due to the late start of this project, only the experimental conditions for the enzymatic hydrolysis and for the dyeing procedures with direct and reactive dyes have been established in preliminary experiments. The conditions for the enzymatic treatment are as follows:

- Plain-weave 100% cotton sheeting fabric (obtained from Testfabrics, Inc.) was treated with an aggressive acid cellulase (86 FPU) at pH 4.8 (acetate buffer) and 37°C at different concentrations and for various lengths of time (1 to 24 h). In a second set of experiments another, less active cellulase (74 FPU) was applied under identical conditions, either alone (concentration 5-10% owf) or in a mixture with cellobiase (2-5% owf). Weight losses obtained were in the range of 1-12% depending on incubation duration and enzyme system used.