A COMPARISON BETWEEN ENZYMATIC SCOURING AND ALKALINE SCOURING OF COTTON

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Introduction

Alkaline scouring of cotton is a mature technology and one that has become standardized over the two hundred years of its development and practice (10). Essentially, cotton is boiled for several hours at atmospheric or elevated pressures with 2 percent sodium hydroxide. Enzymatic scouring presents an opportunity to effect the desired changes in cotton's surface structure and its subsequent absorbency properties by a means that gives possibilities for less environmental impact and significant energy savings (12, 13). This article discusses the two methods of scouring in terms of their basic chemistry, the changes in cotton that they engender, and the implications for industry if the results from laboratory work can be translated into industry practice.

Cotton Surface Structure

Cotton has a specific surface structure. Under the scanning electron microscope (SEM), a mature cotton fiber presents a longitudinal view of smooth parallel ridges and grooves (5, 12, 13). The smooth outer covering is comprised of amorphous non-cellulosic substances, mainly waxes, proteins and pectins (2, 3). These non-cellulosic substances, accounting for about 2.5 percent of total fiber weight (2, 12, 13), are probably in a layered structure, as is the fiber structure itself. The outermost layer is believed to be wax. Cotton wax is a mixture of long chain fatty alcohols and acids (3, 4, 9, 11). Proteins and pectins are located between the wax layer and the primary wall cellulose layer (2, 3, 4, 8), with their relative distribution in the layer structure unknown. Primary wall cellulose accounts for about 2.5 percent of the total fiber weight and is much less crystalline with shorter molecular chains than the cellulose making up the secondary wall (1), the fiber's main body.

Alkaline Scouring of Cotton

The basic mechanism of alkaline scouring of cotton is the solubilization of oils and fats, the saponification of waxes, and the breakdown of proteins and pectins into sodium salts of smaller molecular fragments. The removal of these impurities is accompanied by a corresponding loss of weight of up to 5-7 percent. This purification process can be rather long if a high degree of purification is desired. The end result of thorough alkaline scouring is exposure of the microfibrils in the primary wall, organized in layers. A near complete purification requires several cycles of alternative extraction with boiling dilute alkaline solution and hot water washing for several hours (14). Complete removal of surface non-cellulosic constituents will expose the lattice structure of the primary cellulose layer, but this needs repeated extraction with dilute alkali for several hours (6).

About eight hours of industrial alkaline scouring is needed to obtain highly absorbent and whitened goods (7, 9). The scouring processes for preparing goods for dyeing are shorter (usually in 1-2 hours), varying in accord with color shades required (15). The purpose of the shorter processes is to prepare goods to absorb subsequent dyeing and finishing agents. In addition, complete removal of wax is usually not desirable, since spinnability will be lowered (if stock scoured) and the fabric hand will be worsened (7). In summation, industrial alkaline scouring is the most important preparatory step to further wet processing, one whose degree of completion should be controlled according to the nature of the subsequent steps.

Adequate water absorbency of cotton is a prerequisite for cotton goods to be well prepared, since water is the common carrier of chemicals in wet processing. Adequate water absorbency is usually understood in industrial experience as a fabric wetting time not longer than 1 second (9). This definition of wetting time corresponds to AATCC Test Method 39-1980 (Evaluation of Wettability). The treatment necessary to acquire adequate water absorbency by alkaline scouring is a relatively long procedure. Figure 1 shows how the wetting times of a knitted cotton fabric were achieved by some alkaline treatments. The results are in agreement with common industrial alkaline scouring experience in preparing goods for dyeing.

Enzymatic Scouring of Cotton

In treatments of cotton with cellulases, pectinases, proteases and lipases, both cellulases and pectinases turned out to be very effective in changing the cotton surface structure in terms of treatment times and enzyme dosages (12, 13). The basic mechanisms of the treatments are, in a limited treatment time, cellulases digesting primary wall cellulose, pectinases catalyzing the hydrolysis of pectins in the primary wall, and both actions resulting in destruction of the overall primary wall structure. One of the direct impacts of such treatments is the exposure of cellulose fibrils under the non-cellulosic covering. A high degree of enzymatic purification of cotton cellulose may involve several cycles of treatments with several species of enzymes, or a complicated long procedure. It is, however, relatively easy to obtain adequate water absorbency by enzymatic treatments with cellulases and pectinases. This means that the cotton surface is relatively easily changed by such enzymatic treatments if adequate water absorbency of cotton

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is held as a judgement of openness of the cotton structure. Figure 2 shows how cellulases change the absorbency (wetting time) of a knitted fabric.

Alkaline Scouring and Enzymatic Scouring of Cotton in Perspective

1. **Alkaline scouring of cotton is a well-developed technique**. There, however, exist serious drawbacks of this technology.

   a. Harsh chemicals result in wastes that can contribute to environmental problems.
   b. Alkaline conditions are incompatible with enzyme desizing processes.
   c. For polyester/cotton blends, caustic scouring at the boil for prolonged durations can cause damage to polyester. For the same reason, caustic scouring is not suitable for wool/cotton blends.
   d. Caustic scouring, as well as alkaline oxidative desizing, may cause pH adjustment at later stages to be more difficult to control.

2. **Enzymatic scouring of cotton is a new concept**. Our results are at the laboratory scale. Work is in progress to move to pilot and industrial scales. The following advantages, however, suggest themselves:

   a. Environmental costs will be lower because of the mild conditions of the enzymatic treatments and the savings of energy by using lower temperatures.
   b. Enzymatic scouring can be incorporated with enzymatic desizing processes to form a new technique of one-step enzymatic preparation of cotton.
   c. It can be a safe process for polyester in polyester/cotton blends and for wool in wool/cotton blends.
   d. It will not significantly influence pH adjustment at later stages.

Work in enzymatic treatment of textiles at The University of Georgia includes collaboration between scientists in Textile Sciences, Biological and Agricultural Engineering, and Biochemistry, as well as the USDA Richard B. Russell Research Center. Areas of study include the fate of motes in enzymatic scouring, achieving improved whiteness in enzymatically scoured fabrics, the influence of enzymatic scouring on other stages of wet processing, retting of bast fibers, composting of cellulosic and protein fibers, and decolorization of textile wastewater.

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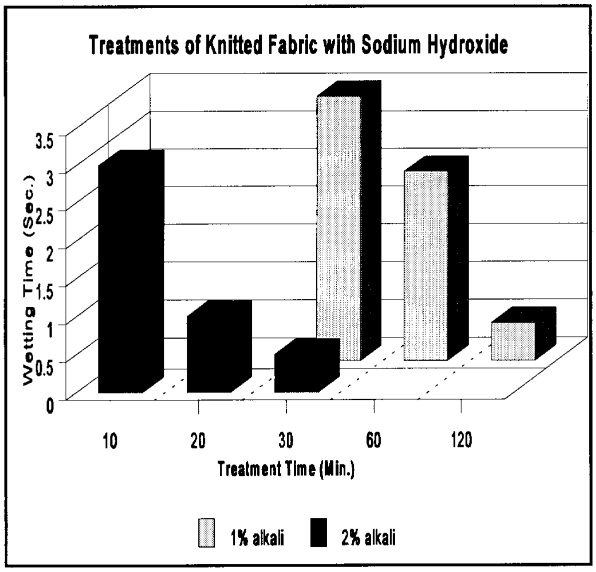

Figure 1. Influence of alkaline treatment time and alkali concentration on fabric wetting time (treatments conducted in beakers at boil)

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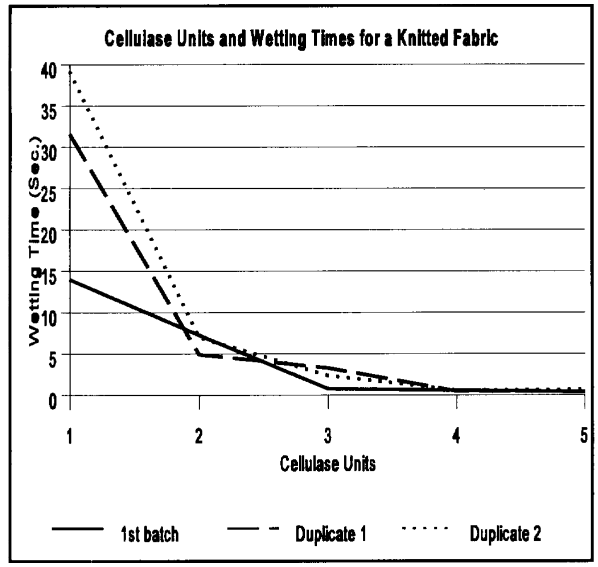

Figure 2a. Influence of cellulase concentration on the wetting time of treated fabric. Treatment conditions: 50 C; pH 4.0; mild agitation; 20 minutes; specimen 0.5 g; liquor ratio 40 ml/g; cellulase (c1184) from Sigma Chemical Company & 0.1% Freesol non-ionic surfactant. See cited references (12, 13) for the detailed experimental steps and an explanation of enzyme units.

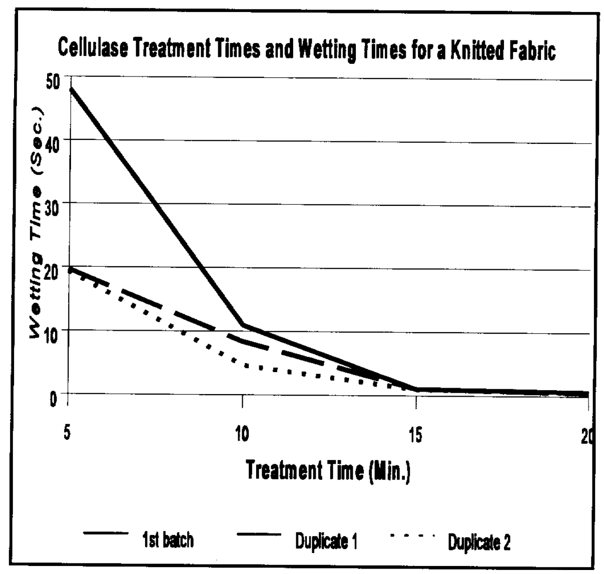

Figure 2b. Influence of cellulase treatment time on the wetting time of treated fabric. Treatment conditions: cellulase c1184=4 units; others same as in Figure 2a.