TECHNICAL BULLETIN

6399 Weston Parkway, Cary, North Carolina, 27513 • Telephone (919) 678-2220

ISP 1003

ENZYME TECHNOLOGY FOR COTTON PRODUCTS

This report is sponsored by the Importer Support Program and written to address the technical needs of product sourcers.

INTRODUCTION

Fashion dictates that certain types of casual cotton apparel, such as denim and canvas, should have a worn, broken-in appearance and soft hand, even when these garments are brand new. These characteristics can be achieved by stonewashing, in which garments are tumbled in a bath with abrasive stones, or by enzyme treatment, or sometimes by a combination of the two. An alternative objective of enzyme treatment is to remove surface cotton fibers to yield a smoother, cleaner appearance that is evident even after multiple home launderings. Many laundry detergents contain enzyme additives to achieve this effect. Enzyme treatment can be done in either fabric or garment form.

In recent years, enzyme technology in the textile industry has been rapidly expanding, as more and more garments and fabrics are enzyme treated to improve their marketability. Advancements in biotechnology have broadened the application versatility of enzymes for textile wet processing. This report is intended to provide a basic overview of enzyme technology as it is used in the textile industry today, with specific emphasis on cellulase enzymes.

ENZYME BASICS

Enzymes are specialized proteins found in all living organisms, and are essential to the existence of life. These complex, three-dimensional compounds work synergistically as biochemical catalysts to alter fabric surfaces during wet processing.

A catalyst is a substance, usually present in small amounts relative to the reactants, that accelerates the rate of a chemical reaction without being consumed in the process. In textile processing, these compounds accelerate reactions at fabric surfaces that would naturally occur at much slower rates in the absence of enzymes, as well as reacting themselves with the fabric surface.

There are several types of enzymes that are currently used in textile wet processing:

ENZYME TYPE	END USE
Amylase	used to hydrolyze* starch for desizing
Cellulase	used to hydrolyze cellulose
Protease	used to hydrolyze proteins
Catalase	used to hydrolyze hydrogen peroxide
Laccase	used to decolorize indigo

*hydrolyze- to decompose by reaction with water

Enzymes are used because they accelerate reactions under mild conditions. They are effective at relatively low temperatures and environmentally benign processing conditions, and they can be used to replace harsh solvents and other organic compounds.

Enzymes are used to alter specific substrates, such as the surface of a fabric. For an enzyme to be effective with a particular substrate, the two must be able to “fit” together. There must be a reactive site available on the substrate that is compatible with the enzyme being used. After a certain period of time, the enzyme can be removed or rendered inactive. An enzyme can be rendered inactive by changing processing conditions so that enzyme activity is no longer favored, and is typically achieved by increasing pH (raising alkalinity), increasing temperature, or by strong ionic changes.

CELLULASE ENZYME BASICS

In the 1980’s, cellulase enzymes came into wide use as a denim washing aid to achieve a faded, worn look similar to a stonewash finish on indigo denim jeans. Today, this is still the most common and most widely researched area of cellulase enzyme use in textile wet processing. Denim fabric is constructed of indigo dyed cotton warp yarns and natural undyed cotton filling yarns. The warp yarns are dyed by a special process that deposits the dye on the surface of the yarn, facilitating easy removal of the dye for a washdown appearance. The consumer can achieve this washdown appearance over time as a garment is repeatedly worn and washed, or it can be achieved immediately by cellulase enzyme treatment.

In recent years, supplier variations in the composition of cellulase have provided more effective cellulases, reduced back-staining (redeposited indigo dye on the backside) of denim, reduced strength loss, and an expanded range of optimum processing conditions.

Other types of fabrics, including lighter weight fabrics, can be cellulase enzyme treated to achieve a cleaner, smoother surface by removing surface cotton fibers. This effect will remain evident even after multiple home launderings.

Cellulase is a complex natural mixture of different components, which work synergistically to degrade cellulose to glucose. Classification of cellulases is usually by the pH range (acidity or alkalinity) at which they are most effective:

CELLULASE TYPE	pH
Standard Acid	4.0-6.5
Modified Acid	5.0-6.5
Endo-Enriched Acid	4.5-6.0
Mono-Component Acid	4.5-6.0
Neutral Cellulase	5.5-8.0

Operational guidelines and optimum processing conditions are specific to each type of cellulase, as well as to the type of fabric being processed. Where aggressiveness is needed for heavy, sturdy fabrics, standard acid cellulase may be the best choice. For less back-staining of denim products, modified acid or neutral cellulases perform better, but the amount of washdown desired must be considered. Endo-enriched and neutral cellulases are less aggressive and are used where strength loss is a major concern. The evolution of cellulase choices has made cellulase selection more complicated, but has given the textile processor a wider choice of products for more specific results.

CELLULASE ENZYME PROCESSING

A number of factors impact cellulase activity during processing, and these factors can be classified as mechanical or chemical:

MECHANICAL	CHEMICAL
Equipment Type	Cellulase Type
Equipment Design	Cellulase Amount
Process Time	Process Time
Load Size	Process Temperature
Liquor Ratio	Process pH
Machine Speed	Auxiliary Chemicals
Auxiliary Products	Pre-treatments

To optimize the application of cellulase to fabrics or garments, consideration must be given to how these individual factors will collectively retard or accelerate cellulase activity. Mechanical action varies from machine to machine, depending upon the type and design. Most fabrics are processed in jets, jigs, or high-speed air-tumbling units for surface modifications. Overflow jets provide low mechanical action, requiring use of the more aggressive, standard acid cellulase. Soft-flow jets deliver more mechanical action, so either the modified acid or standard acid cellulase could be used. With the higher mechanical action present in the high-pressure jets or air-tumbling units, any one of the cellulases could be used. Garments are enzyme processed in rotary drum or paddle machines, typically used for garment washing and dyeing. The mechanical action of the garments in these machines, including garment-to-garment abrasion, further enhances surface fiber removal, color washdown, and softness.

Process times for cellulase treatment typically range from 0.5-2.0 hours. Delicate, lightweight fabrics/garments are processed for shorter time periods. When carefully controlled, the desired surface modifications can be achieved within 30 minutes, without excessive strength loss. Heavier fabrics, such as denim, normally require longer processing times at specific cellulase concentrations to achieve the standard washdown of color reduction, seam abrasion, and softness. Backstaining of indigo denim is usually resolved by switching from standard acid to modified acid or neutral cellulase. Other options to reduce backstaining include the use of anti-redeposition agents, balancing enzyme amount/time factors, or reducing the load size.

Temperature control throughout the cellulase enzyme cycle is important for both quality control and reproducibility. Due to the narrow temperature range (normally 45-60°C) for optimum cellulase utilization, most operations choose to run the procedure at just below the maximum temperature of 60°C. Further reduction in temperature may be employed when lightweight fabrics are treated or when the cycle time is extended. Sometimes, lowering the reaction temperature will broaden the effective pH range, an attractive strategy when ideal conditions are not achievable.

As with temperature, pH level affects cellulase performance. For each cellulase type, an optimum pH exists where activity is maximized. Precise control is difficult due to the many inherent variables, but operating within a realistic range is crucial for quality control and reproducibility. A buffer system of phosphate, citrate, or acetate is recommended to maintain pH during the entire cycle due to the typical release of alkalinity from garments during processing.

Most textile operations process knit and woven fabrics at a 10:1 ratio of cellulase solution to fabric, while garments are treated at lower ratios of 5:1. Often times, lower ratios require less cellulase usage, but care must be taken to achieve uniform results.

Often overlooked auxiliary chemicals can have a dramatic impact on the activity of cellulase. Strongly ionic substances reduce cellulase activity. Generally, nonionic surfactants tend to boost enzyme activity.

Dyestuffs and fabric finishes may have an impact on cellulase enzyme activity, and allowances should be made for their effects. Vat dyes generally do not inhibit cellulase activity, but pigments bound with film-forming acrylics will block cellulase access, therefore extended time may be needed for acceptable washdown. Direct dyes, particularly those aftertreated with fixing agents, and reactive dyes inhibit cellulase activity. Fabric finishes, such as finishes for wrinkle resistance, reduce the effectiveness of cellulase by limiting accessibility to the internal fiber structure. However, a large number of wrinkle-resistant garments are being successfully post-washed with cellulase.

CONCLUSIONS

Garment manufacturers, retailers, and consumers often want cotton apparel to have a more casual appearance. This look can be achieved by textile wet processors using modern enzyme technology. If enzyme processing is done using carefully selected cellulase enzymes, under well-controlled processing conditions with suitable fabrics or garments, a quality product should result. Cellulase enzymes can also be used to remove surface fuzz from a fabric, creating a smoother, cleaner look.

Over the last two decades, enzyme technology in the textile industry has expanded dramatically. This is especially evident in the processing of cotton garments and fabrics, where cellulase enzymes are used to enhance cotton products without adversely affecting the environment. In the future, enzyme technology will continue in importance as biochemists and textile chemists strive to create new product and processing innovations to further revolutionize textile processing.

Importer Support Program

The Cotton Board and Cotton Incorporated are funded by U.S. upland cotton growers and importers of cotton and cotton products (this includes raw cotton, piece goods, and finished apparel). A percentage of the importer funds are devoted for importer specific programs organized under the Importer Support Program. Examples of projects funded from this fund include training schools, educational programs, focus groups, economic meetings, and research initiatives.

Selected technical issues have been identified by importer members as relevant to their business. This report is a condensed, less technical report of those issues intended to provide the reader with basic, yet useful information on the topic.

For more information contact:

ELIZABETH KING
VICE PRESIDENT
IMPORTER SERVICES
COTTON BOARD
PHONE: 973-378-7951
FAX: 973-378-7956
eking@cottonboard.org

DENNIS P. HORSTMAN
SENIOR DIRECTOR
ACCOUNT MANAGEMENT
COTTON INCORPORATED
PHONE: 919-678-2336
FAX: 919-678-2231
dhorstman@cottoninc.com

Visit our website at: www.cottoninc.com

COTTON INCORPORATED