Ultrasound

An Environmentally Friendly Tool for the Textile Industry

Most people associate ultrasound technology with obstetricians, not textile manufacturers. But that may change in the near future, at least in the world of cotton processors, because of work being done by chemical engineer Val Yachmenev and his colleagues at the Agricultural Research Service.

Yachmenev, who works in the Cotton Textile Chemistry Research Unit (CTCRU) at ARS' Southern Regional Research Center in New Orleans, Lousiana, has found that ultrasound can boost enzymatic activity during several different types of treatments to cotton fibers.

Enzymes are protein molecules that can speed up complex chemical reactions. They act as catalysts—substances that start or accelerate chemical reactions without themselves being affected. Human saliva, for example, contains amylase, an enzyme that helps break down starchy foods into sugars.

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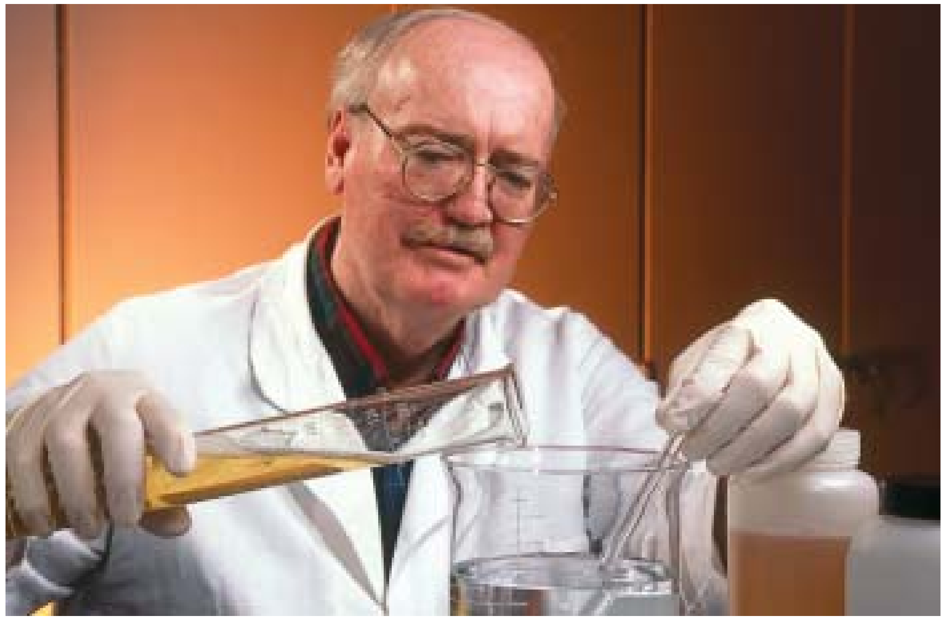

Chemical engineer Allan Lambert prepares an enzyme processing solution before treating fabric.

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Chemical engineer Val Yachmenev inspects a sample of cotton fabric after an enzyme-ultrasonic treatment.

"Use of enzymes in the cotton industry has become more popular in recent years," says Yachmenev, "because scientists have developed highly specific enzymes that perform textile-processing tasks." Enzymatic treatments have been used for a long time to remove the starch size that's added to cotton yarns to smooth and protect them from breaks during weaving. But new processing applications have been developed for scouring (removing natural waxes, pectins, and fats from the surface of cotton fibers), biofinishing (removing fiber fuzz and pills from fabric surface), and biostoning (removing color and softening denim fabrics for a stone-washed effect). Enzymes are also used in laundry detergent, to remove fiber fuzz and various stains, and in bleach cleanup after scouring to eliminate problems during the dyeing process.

Yachmenev says that enzymes use significantly less water, less energy, and fewer chemicals than traditional methods. In addition, wastewater from enzymatic treatments is readily biodegradable and does not pose an environmental threat.

Gene Blanchard, CTCRU's research leader, describes differences between traditional and enzymatic scouring methods: "To scour cotton fibers the old-fashioned way, you boil them in a highly alkaline solution at temperatures of 100˚C. Afterwards, you're left with alkaline wastewater that must be neutralized with an acid or diluted with large amounts of fresh water.

"If you use an enzymatic treatment," Blanchard continues, "you only have to heat the solution to about 50˚C for optimum enzyme performance. You don't expend as much energy, you do less damage to the textile, and the resulting wastewater is biodegradable."

Although enzymatic processing offers many advantages, there are a few drawbacks when compared to traditional methods—namely, expensive processing costs and relatively slow reaction rates. "These drawbacks could impede widespread use of enzymes by the textile industry," says Yachmenev.

But ultrasound technology may help make up for enzymatic processing's shortcomings.

Enzymatic treatments supplemented with ultrasonic energy resulted in shorter processing times, less consumption of expensive enzymes, less fiber damage, and better uniformity of treatment to the fabric.

Yachmenev and his SRRC colleagues have found that introducing ultrasonic energy during enzymatic treatments of cotton fabric significantly improves enzyme efficiency without affecting the strength of the fabric.

It's In the Bubbles

Ultrasound can be defined as sound waves with frequencies above 20,000 oscillations per second, which is above the upper limit of human hearing. In liquid, these high-frequency waves cause the formation of microscopic bubbles, or cavitation. They also cause insignificant heating of the liquid.

When fabric is placed in an enzymatic solution, enzyme molecules, which are relatively large, make their way to the fabric and are adsorbed onto the surface. The enzymatic reaction—biostoning, scouring, etc.—occurs when the enzymes reach the place where solid and liquid meet, the "solid/liquid interface."

Although this seems like a straightforward process, it can take awhile because of the enzymes' large size. Yachmenev says, "These bulky molecules don't move toward the interface very quickly. And their size makes it hard for them to penetrate the nearly immobile layer of liquid that sits right next to the fabric surface."

Yachmenev decided that the best way to accelerate the transport of enzymes through this liquid barrier was to shake things up. He chose ultrasound as his tool.

"Ultrasound causes cavitational bubbles to form in liquid. When the bubbles collapse, they generate tiny but powerful shock waves. I knew we needed to agitate the border layer of liquid to get the enzymes through the barrier more quickly, and these shock waves seemed like the perfect stirring mechanism," he says.

Some scientists had speculated that ultrasonic energy would be too powerful to use as a stirring tool—that it would tear apart the large, yet fragile, enzyme molecules. To prevent this from happening, Yachmenev and Blanchard diffused the ultrasound energy uniformly through a solution with low enzyme concentrations.

The experiment was a success. Enzymatic treatments supplemented with ultrasonic energy resulted in shorter processing times, less consumption of expensive enzymes, less fiber damage, and better uniformity of treatment to the fabric.

Factory-Grade Ultrasound

All of Yachmenev's experiments were conducted in a laboratory that houses a small-scale ultrasound machine. Some textile manufacturers have expressed interest in the technology, but they would need large, industrial-grade equipment to achieve similar results at the mass-production level. Unfortunately, most ultrasound manufacturers produce only smaller machines for the medical and research communities.

Yachmenev has contacted manufacturers from around the world trying to generate interest. He says it would be a good investment because the technology's usefulness isn't limited to just the textile industry. "It can be used to intensify enzymatic treatments in any solid/liquid system," he says.

"For example, the paper industry would be an excellent candidate for using ultrasound. Paper producers have had problems in the past with meeting environmental standards, and they have been moving toward enzymatic treatments. Ultrasound would make these treatments more cost-effective," says Yachmenev.

"I believe enzymatic treatments are the wave of the future," he continues. "Governments worldwide are calling for a reduction in the quantity and toxicity of wastewater, and using enzymes would help factories and manufacturers achieve this goal. Ultrasound will help them achieve it at lower costs."

An article about Yachmenev's work appeared in the *Journal of Chemical Technology and Biotechnology* in May 2002.—By **Amy Spillman,** ARS.

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Chemist Gene Blanchard (left) observes as chemical engineer Val Yachmenev prepares cotton samples for enzyme-ultrasonic treatment.