

Laundry equipment has come a long way since the Maytag Gyro-foam rescued our great-grandmothers from labor-intensive agitators and wringers in 1922.

As washing technology has advanced, so have the tools of textile science. Take microscopes as a case in point.

The scanning electron microscope (SEM) was developed in 1942 and has been commercially available since the early 1960s. It uses electrons to scan a sample's surface and form images, in much the same way a television does. This microscope allows researchers to look at fiber samples three-dimensionally, providing valuable information about morphological structure.

Wilton R. Goynes used an SEM to confirm that small, undyeable clumps of cotton fibers—known in the textile industry as white-speck neps—are the result of underdeveloped cotton. Goynes is a chemist in the Cotton Fiber Quality Research Unit at ARS' Southern Regional Research Center (SRRC) in New Orleans, Louisiana.

His finding proved what researchers had suspected since the 1940s. For under an SEM, white-speck neps appeared as mats of ribbonlike material, giving researchers proof of their origin.

Cotton fibers are usually made up of a thin primary cell wall and a thicker secondary one. It's the secondary wall that gives the fiber a rounded, tubelike shape and makes for easy dyeing. Without that secondary cell wall, the fibers look flat—like the ribbons that are revealed by the SEM.

Cotton grading systems such as HVI (high-volume instrumentation) can track neps, but not all neps produce white specks. Technically, neps are tangles of fiber. A tangle of mature fiber can still take up dye.

A CLOSE-UP LOOK AT WHITE-SPECK NEPS IN COTTON



Underdeveloped cotton fiber magnified about 1,400x.

It's just the tangles of very immature fibers that become undyeable white-speck neps.

"The white-speck problem actually comes from the field, when plants or growing conditions don't allow the fibers to mature properly," says Goynes. "Neps can sneak up on mills: The money is spent to dye the fabric, and it comes out spattered with white specks where the dye didn't take."

Bales of high-quality cotton can be blended with lower grades to use more of the cotton crop. However, if

a bad growing season produces bales with a large number of undeveloped fiber clumps, blending cannot solve the problem.

Now Goynes' verification that the white-speck neps are really the result of underdeveloped fibers allows him and other researchers to focus on solutions. Some will involve improving conditions in the field.

Others will be directed toward detecting immature white-speck neps before they reach the dye bath. For example, since the clumps of undyeable flat fibers reflect light differently from mature cotton, Goynes says there may be a way to use special lighting to detect these immature fibers before money is wasted on trying to dye them.

In a recent paper, Goynes, Patricia D. Bel-Berger, Eugene J. Blanchard, and other SRRC cotton researchers tracked white-speck neps from the field through processing, including their occurrence in dyed and enzyme-treated fabrics. It won the American Association of Textile Chemists and Colorists' top prize in last year's Inter-Section Technical Paper Competition.

The paper was full of new research. For example, Blanchard, who is a chemist in SRRC's Cotton Textile Chemical Research Unit, reported on enzyme pretreatments that could help reduce the number of white-speck neps.

Goynes and Blanchard explored whether enzymes such as cellulase can modify undeveloped fibers to improve fabric dyeability. Even with cotton varieties that were prone to white-speck neps, Blanchard saw reductions of 33 percent.

It's not enough that fabric dyes well. Consumers also want lasting color for their clothes. Detergent makers now add enzymes to reduce pilling, but there is a risk of fading the color and weakening the fabric.



Materials engineer Patricia Bel-Berger and chemists Bill Goynes (center) and Eugene Blanchard examine scanning electron micrographs (SEMs) that show the structure of a white-speck nep.

The electron microscope lets researchers see fiber wear long before consumers can—so industry can choose treatments that keep clothing looking good and lasting longer. It also helps chemists like Blanchard prove that experimental enzyme treatments are effective in controlling neps. And, Blanchard found, some dyes may work better with enzymes than others.

“There are various dyes for cotton, including direct and reactive classes,” he says. “Since reactive dyes chemically bind to fabrics, their colors stay

true with enzyme detergents. Some direct dyes, which are just positioned within the fiber structure, may fade after several washes. It also appears that some dyes—both direct and reactive—actually limit enzyme damage,” Blanchard adds.

Bel-Berger, a textile engineer in the SRRC’s Cotton Fiber Quality Research Unit who also worked on the award-winning paper, has found that mechanical processing can play a role in white-speck nep control.

Cotton mills clean and straighten fibers using a process known as

carding, in which the fiber is run through a large drumlike roller with combing wires. Most mills use two carding cylinders—to perform tandem carding.

Bel-Berger’s surprising find was that when cotton has lots of underdeveloped fiber neps, single carding is better than tandem carding, which tends to open and separate the white-speck neps, making the problem appear worse. Her image analysis of dyed fabrics showed tandem-carded white-speck neps to be larger and more numerous than single-carded ones and to result in a higher percentage of white on the dyed fabrics.

Bel-Berger is now working with industry collaborators to confirm her results. If the findings prove true, mill operators can pre-test their cotton and process it accordingly.

For the Good of the Environment

All this research is good news for industry—and consumers—because it allows for less wasted material and a higher quality product. But textile makers, like all other industries, have to also be concerned about their impact on the environment.

The scientists at SRRC are looking for new ways to process cotton that are kinder to the environment. And, as with white-speck nep control, SEMs provide scientists another way to look at this problem.

“Cotton fibers come from the plant with waxes, pectins, and proteins on their surfaces. Mills have to remove waxy materials to dye fabric,” says Goynes. “But the alcohols and chlorinated solvents once favored by industry are now restricted because of environmental concerns. We’d like to see if biodegradable enzymes can do the job—and using electron microscopes is one way to find out.”

Another example of how Goynes’ work with SEMs has benefited the

environment is his study of non-woven fabrics. These materials are often used in disposable cloth products such as diapers, moist towelettes, and personal care products. Consumers fill U.S. landfills with them, so these products need to be biodegradable.

Goynes and coworkers found that cotton degraded faster than synthetic materials often used in these disposable products. He was able to confirm this, because electron microscopy allowed him to see and assess the speed and degree of decomposition over time.

Much has been done with fiber research, thanks to the electron microscope. But light microscopes, which normally have a maximum magnification of 1,000 times, also have a place in Goynes' laboratory. Sometimes those lower-tech tools reveal things the more advanced equipment can't.

Meanwhile, other SRRC scientists use SEMs not only for cotton research, but for projects on rice, peanuts, and corn as well.



Scanning electron micrograph shows a coiled cotton fiber with flattened, twisted areas that formed as the fiber dried. Magnified about 65x.



Scanning electron micrograph of a white-speck nep in a typical plain-weave cotton fabric. Magnified about 125x.

Technology advances are not stagnant. Newer instruments, like the atomic force microscope, are being used by the center. These scientific tools have their own special advantages and will lead to more discoveries in the future.—By **Jill Lee**, ARS.

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