Squeezing More Sugar From Cane

ARS researcher makes problematic sugarcane dextran easier to swallow.

It's a shame that something so sweet can be fraught with such bitter difficulty. But that's how the cookie crumbles when it comes to satisfying America's enormous appetite for sugar.

About 45 percent of our sugar in the United States comes from cane. In factory milling stations, these 10-foot-tall plant stalks are pressed and squeezed, their juice laboriously heated, clarified, evaporated, and crystallized until raw sugar is formed. This sugar is the basis for those familiar feather-light, white crystals we all know and love.

But the 200-year-old process of converting cane into sugar has its share of hang-ups. From the moment cane is planted to the time its natural syrups are crystallized into sugar, U.S. growers and processors are beset by challenges. These include devastating hurricanes, sudden freezes, diseases, and the detrimental feeding of insects and nuisance critters, like raccoons and rats.

Adding to the trouble is the fact that humans, small animals, and insects aren't the only ones interested in getting at cane's precious sugars. In Louisiana, the second-largest sugar-producing state in the country, a combination of humidity and cane damage can bring about a microbial feeding frenzy that's capable of inflicting serious economic loss to an industry that typically adds more than $1.5 billion annually to the state's economy.

For this reason, these bacterial sugar robbers, *Leuconostoc mesenteroides,* are considered by U.S. growers and processors to be the greatest cause of cane deterioration.

Fortunately, ARS researchers in New Orleans, Louisiana, are finding ways to give sugar growers and processors the upper hand in the ongoing battle against *Leuconostoc.* Already, ARS chemist Gillian Eggleston, who works at the agency's Southern Regional Research Center, has uncovered simple technologies for alleviating the burden of these costly bacteria—and Louisiana factories are eating them up.

Chemist Gillian Eggleston (right) demonstrates the simple, rapid enzymatic mannitol test to Hedgardo M. Centella, a factory laboratory technician at Alma Sugarcane Factory, Lakeland, Louisiana. A spectrophotometer is required for the test.

Dismal Dextrans

Like most microbes, *Leuconostoc* bacteria don't need much coaxing when it comes to capitalizing on their favorite food source.

"Any time sugarcane is cut, injured, or damaged," says Eggleston, "*Leuconostoc* are there, ready to invade." They seize on damage inflicted by temperature extremes—from the burning of cane that's done to ease harvest to the freezing weather that occasionally hampers Louisiana, the northernmost cane-growing region in the world.

Cane is also vulnerable just after it's been cut. In the humid, dog days of late summer and early fall, just-harvested cane may sit for several hours in fields before it's loaded onto trucks and shuttled to the factory. It may even have to wait in the factory yard before it's crushed.

"And while it's not especially common, the combination of a sudden freeze followed by an especially warm and humid thaw-out period can spell disaster for cane," says Eggleston. Just as roadways suffer cracks and potholes due to weather extremes, sugarcane is also prone to fissure-like wounds caused by widely swinging temperatures. Always the opportunists, *Leuconostoc* bacteria invade these broken-tissue areas to access dead tissues and sugars.

As they feed, the bacteria turn cane's simple sugars into clunky compounds that are chemically much different from sucrose. While most of this activity is occurring on a minute scale, growers do have one red flag signaling a bacterial invasion: Patches of crimson-stained plant tissue, often found along the cane plants' vulnerable bamboo-like joints, indicate that the cane is deteriorating.

One bacterial byproduct is dextran—a viscous polysaccharide that represents huge headaches for processors. Because of its bulky, unwieldy structure, dextran makes it harder for factories to process cane. It's also a bitter pill to swallow, economically.

For factories, the more dextran there is in cane, the less sucrose there is for turning into sugar. There are also penalties to contend with—mostly from the refiners who clarify raw sugar until it takes the shape of fine, white crystals.

Another significant cost? Having to purchase an expensive enzyme that can break down stubborn dextran into more easily processed sugar material. But this response isn't even a straight-

forward solution, because the path for processors trying to apply the enzyme—called "dextranase"—in an efficient manner has hardly been crystal clear.

A Less Enigmatic Enzyme

"For years, factories have been operating on faith," says Eggleston, "assuming that the dextranase they're using will do the job. But the reality is that the strength and activity levels of commercially available dextranases vary widely."

In fact, Eggleston's studies revealed that there's about a 20-fold difference in activity among them. Worse still, this variance isn't always reflected in unit price. And factories haven't really known where in the process it's most effective to add the enzyme: Do you add it to the cane juice or syrup? How much should you add? And how should you add it?

With so much confusion surrounding the dextranases currently on the market, Eggleston agreed to help factories optimize their dextran-targeting schemes.

Working alongside factory personnel, like Adrian Monge at Louisiana's Cora Texas Manufacturing Company in White Castle, Eggleston has developed a quick factory laboratory test that should help take the mystery out of dextranase usage. Her simple titration method allows operators to measure an enzyme's actual potency and to track its performance during the sugar-making season.

And Eggleston has helped answer other questions. In her studies at factories such as Cora Texas and Alma Plantation in Lakeland, she determined it's actually more economical to add concentrated versions of the enzyme, rather than the nonconcentrated ones most factories were using.

"To increase contact between concentrated dextranase and its substrate, dextran," says Eggleston, "we learned that it's best to add larger volumes of a concentrated enzyme that's been diluted with inexpensive tap water."

Mannitol: The Best Measure

Factories have immediately benefited from the new measurement tool and knowledge about when and where to add dextranase. Louisiana factories that have adopted the technology are seeing as much as a 95-percent reduction in dextran in their cane juice.

And of the state's 12 raw sugar factories, 5 are optimizing their dextranase usage, thanks to Eggleston's research, which was funded partly by the American Sugar Cane League, a Thibodaux-based commodity group representing the nation's cane growers and processors.

But that wasn't enough for Eggleston. "Factories still needed a way to determine whether certain batches of cane coming into their facilities were of good enough quality to be processed in the first place," she says.

Economically, it may not be worthwhile to process a highly damaged truckload of cane. Not only can poor cane quality impinge on profitability, it could also trigger an overall factory shutdown by stopping crystallization.

Now, Eggleston has developed a method that can reduce the risks of processing unacceptable cane. In just a few minutes, it can tell factory operators exactly how deteriorated a batch of cane is.

Finding a sensitive indicator of cane deterioration has been a goal of ARS scientists for nearly 30 years. Ben Legendre, who had a 31-year career with ARS but now works at the Louisiana State University Agricultural Center in St. Gabriel, tells how he and a fellow ARS researcher worked three decades ago to diffuse the damage caused by dextran.

"ARS's Jim Irvine was the first to find a way to analyze dextran," says Legendre. And while this compound is a surefire way of knowing if *Leuconostoc* have been destructively feeding on cane, the test for detecting it was simply too time consuming. "It just wasn't practical for factories to evaluate numerous cane samples daily when each one was taking 6 to 8 hours to analyze," he says.

Measuring dextran alone may be too laborious, complicated, and expensive, but Eggleston knew that the bacteria producing this compound are also making another chemical—one that's an even better indicator of cane damage: mannitol.

Mannitol is a sugar alcohol that Eggleston and her colleagues realized could be easily and quickly measured. In fact, she developed an enzyme-based test that can measure the substance in 4 minutes.

PEGGY GREB (D695-1)

ARS technician Eldwin St. Cyr (right) shows Belisario Montes, fabrication superintendent of Alma Sugarcane Factory, Lakeland, Louisiana, the dextranase activity titration method for use at the factory.

PEGGY GREB (D700-1)

Benjamin Legendre, sugarcane specialist at Louisiana State University Agricultural Center, holds a sugarcane stalk showing signs of deterioration. The red discoloration represents the plant's reaction to injury or damage.

In the time since her mannitol test was developed, international factories have been readily adopting it, including some in Argentina, Morocco, and Guatemala. Sugar beet producers, who must also contend with scavenging *Leuconostoc* bacteria, are also interested in Eggleston's findings.

As a long-term solution against deteriorated cane, breeders can use the mannitol test for screening diverse cane germplasm. Their aim? To develop superior sugarcane lines that can fend off the voracious bacteria that try to rob us all of our sweet sugar.—By **Erin Peabody,** ARS.

This research is part of Quality and Utilization of Agricultural Products, an ARS National Program (#306) described on the World Wide Web at www.nps.ars.usda.gov.

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PEGGY GREB (D699-1)

A core press burrows into a shipment of green sugarcane. The sample will be tested for amount of deterioration.

PEGGY GREB (D698-1)

Alma factory manager and owner David Stewart and Gillian Eggleston inspect sugarcane at the factory core press.