Ethanol
PRODUCER MAGAZINE

Step 1: Quality Cook

FROM THE MARCH ISSUE: Liquefaction should be the first focus area in yield improvement efforts. Understanding enzyme enhancements and proper indicators are key to evaluating a plant's process.

By Susanne Retka Schill | February 12, 2018

Keeping yeast well-fed and happily producing ethanol starts in liquefaction, or cook. It begins the process of breaking down the long carbon chains of starch in ground corn into the simple sugar glucose that yeast consume, using heat and enzymes. Getting liquefaction right is the first step to maximizing yields.

In cook, ground corn is mixed with fresh water and recycled process streams to make a slurry to gelatinize, or dissolve, the starch. A home cook does this when making gravy, diluting corn starch in warm water and gently stirring. "Industrial operations call for a very heavy slurry and much faster speed," says Loren Chen, president of Shanghai East Tide Science and Technology and a representative for Hydro-Thermal Corp. Jet cooking is used to speed up the process and, in recent years, more has been learned about how heat and mechanical shear work together. For several years, there was a trend to turn off jet cookers, Chen explains, primarily because energy conservation measures recovered steam that could be used for slurry heating. "After a couple of years of this new practice, a 'big data' review of residual carbohydrates versus cooking practice prompted turning the Hydroheater back on, and a more satisfactory residual carbohydrate level gradually came back."

The industry had long evaluated cook solely through temperature, Chen says, thus overlooking the mechanical shear function in the patented Hydroheater. "The Hydroheater is uniquely designed to channel streams of steam and corn slurry to collide with exact quantity and adjustable force, resulting in nearly 100 percent gelatinization." In one experiment where he adjusted the mechanical shear force, he determined the effectiveness of optimized shear force can be the equivalent of an increase of 15 percent in the enzyme dose. More importantly, the enzymes were able to get at all the starch to do their work.

Chen and his colleagues at Hydro-Thermal are now examining ways to evaluate cook material immediately, rather than waiting to the end of the process, some three days later, as is done currently by looking at data correlations between ethanol yields and cook operations. One promising method showing good correlations with the level of mechanical shear is to test the liquefaction liquor for speed of filtration. Meanwhile, he continues his work on optimizing jet cooking. "We are still in the process of collecting data to tell the story in a statistically significant way," he adds. "There are many factors impacting ethanol yields in addition to cook. Thus, correlations are often confounded with other factors and we can only do this with long-term analysis."

Monitoring Liquefaction

Enzymes are the other critical component of liquefaction. "There are four goals to liquefaction," says Stephanie Gleason, regional application development leader for DuPont Industrial Biosciences. "Solubilize the starch, reduce viscosity to make the corn mash pumpable and break down the starch molecule to make it available for enzymatic hydrolysis to glucose so it can be fermented." Alpha-amylase enzymes help with those three, along with the fourth, which is to recycle process streams successfully.

As changes are made to improve operations, it's important to know the plant's baseline, using solid measurement protocols, she says. "For liquefaction, a couple of good key performance indicators (KPI) are viscosity and dextrose equivalents, or DEs." Viscosity can be measured by monitoring pump pressures or with viscometers and, while not all plants measure DE, she says, the wet chemistry step is a good measurement for liquefaction performance. Dextrose equivalent gives a measurement of the average starch chain length, she explains, and consistency is important. "As the

alpha-amylase is solubilizing the starch, it generates reducing ends, which is where the glucoamylase can act in fermentation."

Monitoring KPIs in liquefaction also helps with early identification of process upsets that can be caused by accumulating levels of fusels or organic acids in the recycled process streams. While bacteria don't survive the temperatures in liquefaction, she points out, the products of contaminants—organic acids—can, and high levels will stress yeast. Recycled process streams do have benefits, she adds, as most alpha-amylases require cations such as sodium and calcium that are found in backset for good performance.

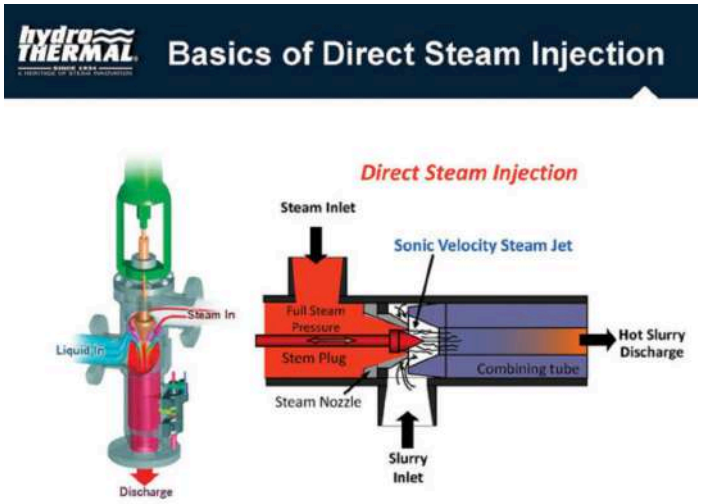
Knowing the baseline, establishing solid performance indicators and achieving consistent operations are fundamental in evaluating enzyme performance—important in a time when enzyme providers are offering new lines of improved enzymes and plants want to determine if they are getting the expected results. "As new alphas are developed, we're getting molecules that can operate in a wider range of cation levels and a wider range of temperatures," Gleason says. A good liquefaction, she stresses, sets the stage for successful fermentation.

Enzyme Advancements

Just as alphas are being improved to work under broader conditions, new, improved glucoamylases are being introduced to improve fermentation, along with new accessory enzymes. Proteases have been developed that break down protein in the corn mash that can't be utilized by the yeast into free amino nitrogen that can. Trehalase is a new enzyme that breaks down trehalose, a sugar produced by yeast, into glucose, which conventional yeast can consume.

Running trials on new enzymes can be tricky, particularly to verify small gains in a large volume, says Laurie Duval, director of technical services, biofuel for Novozymes. "We were running a trehalase trial that took a three-month evaluation at all the customers' sites so they could prove to themselves and see the performance of the trehalase. And, then they redid a baseline without to be sure that's what they saw. When you're going for that 1 percent of yield, you really have to make sure you're making the right product choice."

An important step in working with plants on yield maximization is understanding the plant's goals, Duval says. For many, location determines the best focus for optimization efforts. It affects the prices paid for corn and received for ethanol and corn oil, she points out.



SHEAR POWER: The patented Hydroheater combines steam with mechanical shear to heat and open the starch molecule for enzymes to do their work.
ILLUSTRATION: HYDRO-THERMAL CORP.

"They really need to be true to themselves as for what the right KPI is for the best profitable business for them. And given the process they have, they need to run good trials on products to make the best decision to deliver on the benefit they're looking for."

When it comes to enzymes, there are many such decisions to make, weighing the cost versus benefit. "We have come a long way with adding new enzyme activities and getting more ethanol yield, higher throughput, more corn oil and finding ways to simplify the process," Duval says. "And we've been able to reduce the leftover sugars not going to ethanol." Starches and sugars that make it through the process unconverted, ending up in the distillers grains, are getting down to increasingly low levels, she says. "The majority of plants are getting much less than 5 percent residual sugar and, in some cases now, less than 2 percent."

Enzyme advancements offer even more opportunity, Duval says. "With these advanced enzymes, we can get 2 to 5 percent more yield. And there's other things we can get to around fiber that can get us another 10 percent." Even a 1 percent yield improvement across the industry calculates into major gains, Duval points out. "Looking at the 16.3 billion gallons produced in 2017, a 1 percent gain at today's relatively low ethanol prices would contribute a little over $200 million in revenue to the ethanol industry."

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