The development of yeast strains plays an integral role in improving ethanol yields

Yeasts yield results

In ethanol economics it is no secret that the feedstock results in roughly 80% of the plant's costs. Most emphasis is placed on the sugar or the starchy biomass, yet down the cost scale few pay attention to the importance of yeast in improving ethanol fermentation.

Yeast cost is by far less than 1%. 'If alcohol is around $2/gallon (€1.49/gallon), yeast costs are less than $0.003, and enzyme cost is around $0.03/4,' Chris Richards, global sales manager at Lallemand Ethanol Technology, says. 'In summary, the order of a plant's ingredient/utility cost is feedstock, energy, enzymes, chemicals and then yeasts,' Richards concludes.

So if yeasts are a negligible cost, why worry about the need to optimise? The yeasts make it all happen and in a simple science lesson: better yeasts make better ethanol yields.

The need to optimise

During first generation ethanol production (grains to ethanol) typically starch is broken down to simple sugars, which yeast helps to convert to ethanol, and distilled up to 94-5% alcohol with a molecular sieve, which makes up the alcohol content to 100%. Following this, producers blend 2-5% denaturant so that the fuel ethanol does not fall under alcohol duty regulations.

There are two main types of fermentation process. It either falls under either continuous or batch production. Distillation can be one of following categories: vacuum, low pressure or pressured. The lower the pressure (vacuum lowest and pressure highest), the lower the boiling point and hence lower energy requirements. The ratio of continuous to batch fermentation is more balanced in Europe, with an approximate 50/50 share. A decade ago the US market comprised a similar ratio, but nowadays it is typically 85% batch and 15% continuous. This is to do more with design and engineering groups building the plant and the use of new technology. Continuous fermentation plants possess more traditional technology, which is usually more efficient. The high efficiency is due to plant utilisation – batch plants have down time for cleaning and emptying. However, batch plants can achieve higher alcohols (utilising higher solids) and hence better energy efficiency.

Optimising the fermentation process increases profitability. As mentioned approximately 80% of the cost of ethanol is the feedstock, so anything to reduce the cost by increasing the yield generates a higher profit.

When the price of feedstock is low and ethanol prices are high, producers want to run the plant as fast as possible. In the current market feedstock prices are up and ethanol prices are relatively low, so producers are focused more on yield than throughput.

'The volume of alcohol can be increased if the process is made more efficient,' Richards says. 'Most plants leave a small amount of residual sugars behind that could have been converted to alcohol. Lallemand Ethanol Technology has knowledge of how to use yeast and control stresses and contamination, which allows yeasts to ferment better.'

If producers lift the yield they can get higher alcohol or use less feedstocks to get the same amount of alcohol. Most opt for higher alcohol because they save on energy costs by doing so.

The strain bank

Feedstocks and the yeasts needed to ferment the sugars come in different forms. There are myriad strains of yeasts with different attributes in the strain bank. For potable alcohol, for instance, Scotch whisky yeast must be able to ferment higher levels of maltose instead of glucose. Meanwhile yeasts for sugar beet fuel ethanol must be optimised for high levels of sucrose as opposed to glucose, so a balance is required. A correct strain is essential in fermenting the correct sugar profile over the course of fermentation rather than at the beginning.

There are three types of yeast: dry yeast, cake yeast and liquid yeast. Liquid needs less processing by the yeast manufacturer, therefore it has undergone less stress and reduced opportunity for contamination. Dry yeast goes through more drying processes and as a result is more exposed to stresses and contamination. Cake yeast, requiring less drying, is in between liquid and dry in terms of process steps during manufacture.

For instance, cake yeast may have been filtered on a drum filter to create 35-38% solid cake which is almost like a clay. Dry yeast has been filtered and extruded and dried to 95% solid, 5% moisture – the extrusion and drying processes are highly stressful to yeast cells and with every additional process step the risk of contamination increases. Yeast shelf life is determined by the production methods and subsequent storage conditions. Dry yeast has the longest shelf life and unstabilised liquid yeast the least.

'Every industry that utilises yeast has migrated from dry to liquid where local production is available,' Richards remarks. 'The fuel ethanol industry has started to go through this process as liquid yeast is easily automated to reduce manual handling and is easier to optimise.'

The packaging of yeast could also be an issue. Dry yeast comes in bags weighing 10-20kg. The main problem is that the optimal dosage rate is limited by the pack size. 'Liquid yeast can be dosed in fractions of a kilo in optimisation along with the fresh format enabling the yeast to start quicker,' Richards explains.

The most dangerous time in fermentation is the first two hours because the yeast usually has a lag phase and is not fermenting actively. This reduces the competitiveness

Yeast storage life

Type	Solids	Packaging	Storage	Shelf life
Liquid	15-20%	Bulk	Refrigerate	2 weeks
Cake	30-40%	Unprotected	Refrigerate	2-6 weeks
Instant dry	94-96%	Protected	Room temp	3 years
Stabilized liquid	19-26%	1,000 L totes	Refrigerate	3 months

Source: Lallemand Ethanol Technology

with the bacteria that could be present in the mash as well. Bacteria multiply much quicker than the yeast thus taking away sugars needed for ethanol production and resulting in decreased yield. The propagation stage can be a hot-bed for contamination. If producers could eliminate the propagation stage and thus a potential contamination point, by going direct pitch with liquid yeast, this could result in significant savings at the plant. However this uses a lot more yeast, but can be justified by increased yield gain.

Lallemand Ethanol Technology's Thermosacc Gold yeast, released this summer, helps to increase yield by leaving lower residual sugars glucose at the end of fermentation. 'This yeast is in the crumble (cake) form because our local manufacturing presence makes it possible in the North American market. The US market is the biggest market for us, but we have every intention to move the Gold strain to Europe and Asia eventually,' Craig Pilgrim, global marketing and product development manager, comments.

There is a wide range of beliefs into the effectiveness of yeast dosage rates. In the US, 25kg yeast represents a break-even value in relative alcohol content of 0.01% by weight volume. It is so small it is almost impossible to measure and impossible to detect the change in the fermentor. Hence yeast can be seen as a very cost effective process aid that can add significant value if optimised for yield.

For a 100mgy plant (375mly) the yeast volume per fermentor ranges from 50kg to 200kg in rare cases through propagation. Predominantly 50-80kg (per propagation) are more common figures. In direct pitch there can be much higher dosing numbers.

'Some plant managers now optimise yeast costs. Others see yeast is the last place they want to optimise as it so cheap relative to the potential for increased yield,' Richards says.

In the field

In 2010 Lallemand Ethanol Technology worked with one ethanol plant in North America which had regular contamination issues. Lallemand undertook a full hygiene audit of the whole front end process – just after milling to just before distillation. The report went through 35 pages worth of key recommendations including to invest money to change the design of the fill line cooling layout. For example, in some of the plants in order to save money on installation a less than optimal hygienic layout of piping and cooling equipment was used. The location of the problem was between the enzymatic conversion (185°F/85°C) step and fermentation (95°F/35°C). The main issue was to save on one heat exchanger using complicated piping and reducing the cleaning frequency. The plant made the change and improved its contamination issues significantly.

Lallemand Ethanol Technology also worked with other plants through yield improvement programme, improving hygiene and lowering contamination levels, resulting in improved yield. Fermentation becomes more efficient, and bacteria are not consuming glucose and making lactic and acetic acid. The most optimal hygiene in a plant is a healthy yeast population. Lallemand will also work to assist plants to optimise milling grind size to achieve the right size particulate matter, reduce yeast stress and increase throughput and yield thus increasing profits.

Further aspects under evaluation include temperature control, bacteria control, yeast propagation parameters, and pH levels. 'We have worked with ethanol plants on yield improvement and taken up the yield by 0.01 gallons per bushel, equating to over $400,000 a year depending on the plant. A rise of 0.1gallons per bushel represents a 4% yield increase, worth $4 million to a 50mgy plant.

Enhancing the future

Currently the US produces around 13 billion gallons of ethanol a year and is hitting the blend wall for E10. Legislation has been in the spotlight and the EPA recently granted a partial waiver for E15 for certain types of vehicles. And now eyes are turning to non-food-based feedstocks for ethanol.

Currently there is no cost-effective second generation organism that is naturally-occurring. 'We can make ethanol from C6 (six carbon) sugars derived from cellulose now. What the industry needs to do is to engineer a combination for converting C5 and C6 sugars,' Pilgrim states.

A lot of investment is needed for research and development if the industry is to really grow second generation ethanol. There is much discussion about pre-treatment for cellulosic ethanol, with high temperatures and acidification steps in many processes resulting in more stressful fermentation conditions for yeast.

There is a drive towards genetically-enhanced products primarily because companies are almost at the wall in terms of the benefits of natural yeast, so genetically-enhanced yeasts are needed for both second generation ethanol production and to make a significant improvement in conventional first generation processes. 'We will see a divergence of yeast abilities as people introduce intellectually-protected, more novel yeasts or organisms,' Richards remarks. 'This will create a higher price for yeast, but free up much higher revenues for yield owing to the benefits of these new yeasts.' ●

For more information:
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