First generation ethanol plants must employ new technologies and innovations to keep abreast in the changing market

Keeping competitive and seizing opportunities

The production of bioethanol has been around for a number of years and efficiencies have grown leaps and bounds. But what can the industry do in order to stay ahead of the curve and not fall behind? One of the best ways to make sure of that is consistent operations. This may sound like an easy thing to do, but in fact may be one of the most difficult to control. Of course there will be day to day fluctuations in plant operations, but in order to stay competitive in the marketplace, the goal should be to minimise the up and down swings of operation. Things such as preventative maintenance, implementing troubleshooting techniques, updated SOPs, operator training, etc. are keys to maintaining a consistent operation.

One of the easiest ways to lose efficiency and yield is through fermentation. Why is that? If a good handle over yeast health is not kept, there could be potentially big financial losses due to lack of ethanol production, contamination, etc. Fermentation is the only place within the system where you can potentially make money (through yield increases, etc.).

One of the main aspects of maintaining consistency as described above is to make sure the given plant is as hygienically clean as possible. This means performing various hygiene audits throughout the year to make sure there are no potential places for contamination to occur, and if there are, corrective actions to fix them are applied as soon as possible.

Bacterial growth

For various financial and engineering reasons, fuel ethanol plants are not designed to operate aseptically like pharmaceutical plants. Therefore, there will always be the risk of bacterial contamination from numerous sources, including the feedstock and other ingredients, the plant environment, as well as the microflora harboured within the plant equipment itself.

This situation creates the opportunity for organisms competing for the same food, glucose. Yeast and bacteria will feed on the glucose, both to grow while producing their by-products – ethanol from yeast or lactic/acetic acid from bacteria. Since bacteria grow faster than yeast, antibiotics are used in order to control growth and to ensure that bacterial infection does not take over the fermentation. Contamination happens when the population of bacteria reaches a critical mass, producing more and more of the undesirable lactic and acetic acid. When these levels get too high, the yeast will go into preservation mode and try to protect itself instead of producing alcohol or more yeast cells. Due to this, the fermentation can get stuck or slow down. This results in yield loss due to direct bacterial consumption of the glucose combined with poor fermentation performance. Also there will be unfermented sugars that negatively affect yield.

There are many ways to try and combat bacterial growth. One is by having a hygienically designed plant, like breweries and pharma, but 98% of ethanol production facilities are not designed in this manner. The second way is to use some sort of microbial agent to control the growth of these bacteria. One of the most effective methods to eliminate bacteria is through the use of antibiotics. However, there can be many issues with the use of these control agents. One of the main drawbacks is that not all regions of the world can or will use antibiotics.

Ethanol producers will have to and are running more efficiently than before. The increased attention that is paid to hygiene is taking place. Through the use of hygiene audits, there is more emphasis on determining sources of contamination and its prevention, such as removal of dead legs, proper cleaning techniques, etc. The result is a definite improvement in the productivity of ethanol plants. There is no "silver bullet" when it comes to the use on antimicrobial agents. The best antimicrobial is a clean plant and healthy yeast population. Antibiotics are generally used less if these issues are addressed. As seen in figure 1, the resulting contamination event can cause severe financial losses and in these times of tight margins, any loss of yield can spell disaster for operations.

Mechanical and chemical innovation

Another area where operators can look at to increase operational efficiency is in

Viable bacteria in mash at fermentor fill (CFU/ml)	Ethanol loss (%/v)	Ethanol loss* (US gal)	Revenue loss ($2US/gal)
100,000	0.1-0.2%	1,387	$2,774
1000,000	0.2-0.4%	2,774	$5,548
10,000,000	0.6-1.0%	6,935	$13,870
100,000,000	0.9-1.2%	8,760	$17,520
1,000,000,000	1.0-1.5%	10,950	$21,900

Figure 1: Financial impact of contamination

the mechanical equipment they are using in the plant. Equipment such as mills and centrifuges are vital for separating components and getting the most starch or available substrate obtainable in order for the rest of the process to work. Without properly getting the substrate into a state where it can be broken down further, yield improvement will never take place. Enhancements and newer generations of these types of equipment can be expensive, but generally will pay for themselves in better yield and efficiency over time compared to older equipment.

Furthermore, advances in enzyme technology allow for better breakdown of the substrates in liquefaction and saccharification/ fermentation. These advances include increased enzyme activity, specific activities for specific substrates, and increased rates of reaction. Enzymes have become more concentrated and specific than they ever have before. Modern enzyme plants are becoming more efficient and able to produce lower cost enzymes. Techniques in modern biotechnology have allowed them to target certain types of enzymes and activities to introduce better enzymes for yield improvement and consistency in operations.

Innovation present and future

For those supplying "fermentation ingredients" to ethanol production facilities, new technology and innovation is necessary in order to stay ahead of the curve. There are varying technologies in the marketplace and in order to ensure that this technology is current and relevant, we must have strong partnerships not only with the production facilities themselves, but technology (research) providers as well. Having a relationship as partners instead of just vendors (suppliers) goes a long way in securing critical evaluation and introduction of new technology, which will not only make the process faster but also more streamlined. Having an expert in various parts of the operations gives operators a resource they can tap into in order to solve existing and prevent future problems that could negatively affect operations from occurring.

The next likely change in ethanol production will come in various forms ranging from biotech yeasts to the so called second generation type of production or cellulosic processes. In the past few years, there have been many advances in biotech yeast. The economics of the production of ethanol from biomass feedstocks like corn and sugarcane are dramatically influenced by the yield of fuel ethanol that can be produced from the feedstock. This is because the input costs to the process (feedstock purchase, energy, fermentation inputs, labour…) are divided by the amount of product produced from those inputs. Although there is variation among them, traditional yeast strains used to carry out these fermentation processes have a ceiling to the ethanol yield they can achieve (mass of ethanol produced per mass of sugar fermented). However, the tools of genetic engineering can fundamentally alter the height of this ceiling.

The development of new genetically modified yeast strains for fuel ethanol production has also been pursued extensively. In particular, methods of increasing the yield of ethanol by reducing by-product glycerol formation, enzyme expression, and accessing new types of sugars not normally fermented by yeast (e.g. xylose) have all been demonstrated. Until recently, however, none of these technologies had been implemented during commercial production of ethanol.

There have been two new enhanced biotech yeasts introduced to the North American fuel ethanol market. One was a strain of industrial yeast that produced an important enzyme for breaking down starch into simple sugars that is added to the corn to ethanol process, called glucoamylase (GA). This product allows the yeast to produce it inherently instead of relying on exogenous addition of expensive enzyme. The second one, called TransFerm Yield+, takes that same GA-producing technology and combines it with an introduction of an alternative glycerol reduction pathway. Instead of making glycerol, the yeast will take it down the alternative pathway to produce ethanol instead. These two technologies have resulted in major financial savings and yield benefits. Yield increases anywhere from 1-5% have resulted in increased revenue and more consistent operations from the same amount of substrate.

Advances in cellulosic yeast technology have made it possible for second generation bioethanol to become a reality instead of a dream or being always five years away. The introduction of two types of yeast (C5 FUEL and XyloFerm) has allowed producers to choose which product works better under their conditions. Each one of these products has been engineered with a different pathway for xylose consumption. Newer and alternative pathway versions are becoming more and more commonplace. These types of yeast could also be used in first generation systems to get some of the C5/C6 sugars that are released through the conventional process or with some slight mechanical or enzymatic breakdown as well. This will result in even further increased yields for the "conventional" process operations that are used today.

In processes that use pre-treatment technology, it will be even more critical to monitor yeast health. In biotech yeasts, these will call upon certain pathways to be changed to increase yield and decrease variability within fermentation. The industry will have to ensure that these yeasts are properly maintained within fermentation and provide enough nutrients to maximise their intended benefits, in second generation. Pre-treatment processes have to rely upon large amounts of high heat or acid to break apart the structure of the substrate in order to get to the fermentable sugars. They can also form somewhat toxic substances to the yeast, which can affect fermentation performance. New nutrient packages will have to be introduced to compliment the new yeast that will ferment C5 sugars in a much harsher environment than in starch or sugar-based fermentation. Also, these lignocellulosic hydrolysates (unlike corn or starch based substrates) are often devoid of essential nutrients, so nutrition will again be essential and play a key role in this type of fermentation.

In these times of tough margins, any type of advantage to help maintain consistency in operations and potentially increase yield is essential. There are numerous factors plants can monitor and improve upon in order to gain an advantage over their competition and increase revenue. Working closely together with various partners and suppliers is key. Keeping abreast of technology and implementing when and where necessary will also help to keep one ahead of the curve. ●

For more information:
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