Next generation biofuel ButyFix has burst onto the scene and is changing the face of biobutanol processing

Disruption hits biobutanol production

Bioethanol shares 80 million tonnes annual consumption around the world.

However, some of the inherent properties of ethanol, such as high water solubility and low energy density, set the limit of its blend ceiling to 10% in petrol. Moreover, using sugar or starch in the ethanol fermentation process could affect the food supply stability and price, globally.

To facilitate a more aggressive goal in greenhouse gas (GHG) reduction, developing advanced biofuels, which deal with those ethanol issues, is essential to the future growth of biofuel production.

Superior alternative?

Among many candidates of second generation biofuels, n-butanol is considered a better choice for several reasons. The additional two carbons of butanol not only improve the energy density, but also decrease the polarity of the molecule. This means butanol's fuel properties are very similar to those in petrol and increase the blend ratio by 60% compared with ethanol.

In addition, butanol is less corrosive than ethanol, which renders it a more compatible fuel toward the existing petrol-based engines and pipelines for fuel transportation.

Despite providing all of these superior properties, biobutanol is not currently used in the fuel market, mainly due to its high production cost. In traditional ABE fermentation, used to produce biobutanol, one third of the carbons in sugar are wasted by forming CO_2 in the anaerobic fermentation of the working microorganisms. Besides, other metabolic pathways and by-products, such as acetone and ethanol, are competing in the process to further lower the yield of biobutanol production to 0.21g/g-sugar. The low yield of butanol increases the production cost, therefore making it less competitive than bioethanol.

Today, a more cost effective way for biobutanol production is essential for introducing this advanced biofuel to the global fuel market.

A disruptive biobutanol technology

Green Cellulosity (GC) is a spin-off company from Industrial Technology Research Institute (ITRI) in Taiwan. Last year, ITRI developed a proprietary technology under the trade-named ButyFix, which increases the butanol yield from sugar to 0.53g/g-sugar. The ButyFix technology comprises three stages: cellulose hydrolysis, sugars fermentation to butyric acid and the chemical conversion of butyric acid to butanol.

The carbon conversion rate, which is as high as 86%, is 2.5 times the traditional ABE process and the a result of ButyFix fermentation technology. ButyFix also demonstrates a higher cellulose adaptability. When a C5 sugar such as xylose is used, the carbon conversion rate of ABE process is generally low. However, ButyFix can retain a yield of over 60%, which is close to the theoretical upper limit of traditional fermentation processes. The high yield represents a more effective utilisation of the feedstock, which would translate to a lower production cost and carbon emission.

The cellulose hydrolysis part of ButyFix uses an environmentally friendly organic solvent with mild acid to break the cellulose. The approach can solve the problems of low reaction rate in enzymatic hydrolysis, or expensive equipment needed in strong acid hydrolysis. Preliminary calculations show that production cost of butanol from ButyFix technology is lower than that of ethanol, without taking the 30% energy gain into the equation.

ButyFix technology produces butyric acid as an intermediate of the butanol production process.

Based on the results of a feeding experiment using 13C labelling substrates, it was found that carbons, which are expected to be lost in the form of CO_2 emissions in the ABE process were re-captured, at least partially, into the fermentation system and incorporated in products (Figure 1).

This observation provides a basis for the explanation

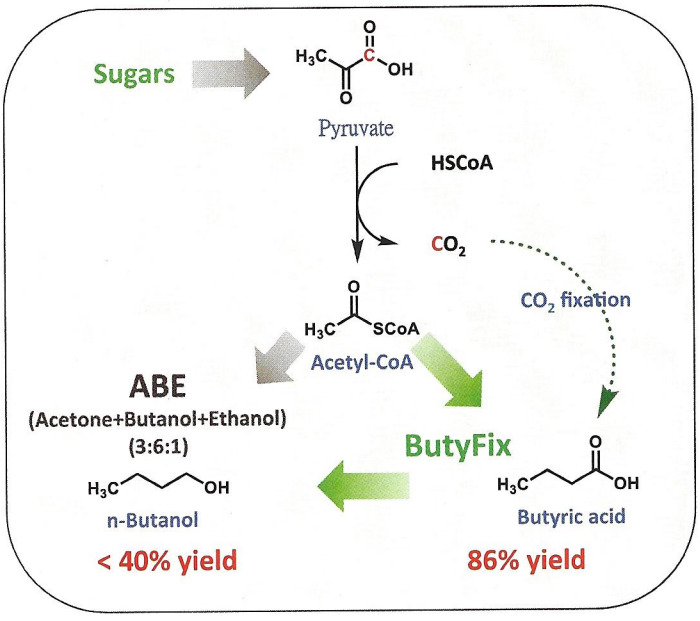

Figure 1: In traditional ABE process, sugar is first converted to pyruvate followed by decarboxylation to generate acetyl-CoA and the carbon of carbonyl functional group (in red) is emitted in the form of CO_2 gas, this natural pathway limits the theoretical yield of ABE fermentation process to 66%. In contrast, experimental results reveal that the "lost carbon" is incorporated into products through CO_2 fixation when using ButyFix technology to perform butyric acid fermentation. This novel technology exceeds the limitation of ABE process, and carbon conversion yield from sugar to butanol is 89% in the lab

A fermentor is a bioreactor used for containing and controlling fermenter microorganisms

of why ButyFix is capable of reaching a yield way above the theoretical limiting yield of 66% in the ABE fermentation process. In addition to the carbon conversion rate, microbes in ButyFix are stable in fermentation broths. In the laboratory, microbes in the immobilised cells of a 2 L fermenter have endured a continuous run of over one year without changing cells, while maintaining a steady average carbon yield of 82% in sugar fermentation.

Furthermore, if the inherent low CO_2 emission in this fermentation process is combined with cellulose hydrolysis, the greenhouse gas (GHG) emission can be reduced by over 80% as compared to that of petrol. This GHG reduction has met US Renewable Fuel Standard's requirement as an advanced biofuel.

Current progress

The three parts of ButyFix technology are at different stages of readiness. The chemical conversion of butyric acid to butanol is considered a commercially ready process, followed by the fermentation and then the cellulose hydrolysis processes. In order to minimise the risk during commercialisation of ButyFix technology, Green Cellulosity (GC), a spin-off company from Industrial Technology Research Institute (ITRI), is focusing on improving the readiness of fermentation. After fine-tuning these fermentation results in repeated experiments and large-scale production, cellulose hydrolysis will be integrated in the system to complete this new 'waste-to-fuel' technology.

Currently, the fermentation technology has been demonstrated in different scales of fermenters, from 2 L to 5,000 L, and the carbon conversion yields are invariably above 80% at all times. Encouraged by the promising results of lab experiments and small scale-ups, a demonstration plant is planned to start construction next year. The cellulose hydrolysis stage is also undergoing a scale up in the lab, to achieve a biomass load of 200kg. Total sugar yield of over 90% can be achieved by using a single recipe over many different biomasses. The commercialisation of cellulose hydrolysis is expected to come a year after the fermentation stage is implemented.

ButyFix has a similar engineering process to fermentation, used to produce bioethanol. This makes the technology relatively easy to adopt. Retrofitting existing bioethanol plants, for example, can increase profit margins significantly with only limited investment.

For more information:
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