An optimal conversion process in biofuel production depends on the type and quality of the raw material

VOGELBUSCH Biocommodities focuses on the production of ethanol from starch and sugar crops

Fermentation strategies in biofuel production

VOGELBUSCH Biocommodities is acknowledged worldwide for proprietary technologies and tailor-made plant designs for the bio-based industries and offers solutions for a range of fermentation processes, including technologies and equipment for the production of yeast, organic acids, bioethanol as well as potable alcohol.

Bioethanol is a sustainable and renewable source of energy, produced from sugar or starch-containing crops or lignocellulosic materials and plays an essential role in the reduction of greenhouse gas (GHG) emissions. Lignocellulose processing plants offer the possibility to produce bioethanol by using energy crops or green waste but the economic benefit of using grain or sugar based plants often outweigh the former until today.

In its alcohol division, VOGELBUSCH Biocommodities focuses on the production of ethanol from starch crops (e.g. wheat, corn), molasses and sugar syrups or by-products of the starch industry.

Process adaptations for novel raw materials (e.g. pea starch, a side product of pea protein production) are tested at its in-house research facilities before they are implemented on an industrial scale.

Analysis work and fermentation tests are carried out if the raw material quality plays a major role in plant performance.

This is essential for molasses or side products of the starch industry, like B and C starch.

Raw material preparation and fermentation processes are decisive for the profitability of a bioethanol plant. Therefore, these process steps have to be adapted to the individual raw material properties in order to achieve optimal yields, product quality and plant efficiency.

Grain-based fermentation

The efficiency of grain-based ethanol fermentation and consequently its competitiveness is already defined before the fermentation is even started. Accurate application of appropriate pre-processing, suited to the used raw material, affords the opportunity to generate high yields at low investment costs.

When using wheat, rye or triticale as a raw material, overall hydraulic load and steam consumption may be significantly reduced by the application of bran separation techniques at the beginning of the production process.

Dry brans are separated from the ground grain and directly mixed with wet distiller's grain solubles (WDGS) before entering the dryer unit.

Besides saving equipment costs and electrical energy due to the decreased hydraulic load, bran separation technology reduces dryer energy consumption by about 10%.

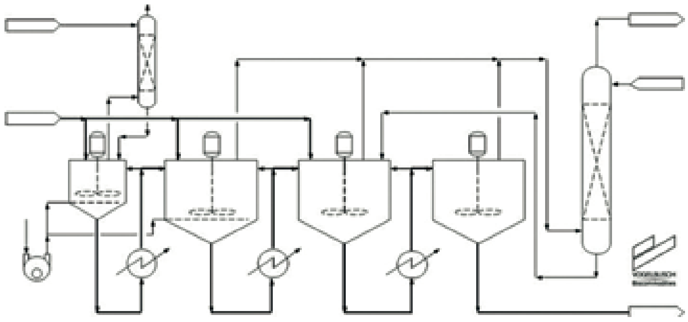
Furthermore, fibrous brans can be sold separately if high-protein DDGS is produced.

Starch hydrolysis is another key step in the upstream processing of bioethanol production, whereas the optimal liquefaction strategy depends on the grain variety.

Wheat starch liquefaction can be performed in a stirred vessel by a conventional liquefaction process at 85°C without incurring yield losses. Corn processing plants achieve higher yields by application of a jet cooker. This technique generates high temperatures (105-120°C) in combination with shear forces and creates destructive conditions to the starch granules. The destruction facilitates better enzymatic digestion in the subsequent liquefaction process and reduces the residual starch in the fermented mash significantly.

High temperature liquefaction causes an increased steam consumption compared to conventional hydrolysis, but the thermal energy can be recovered by, for example, preheating the alcoholic mash before entering the distillation.

Jet cooker application is also recommended for by-products of starch processing plants. According to our experience, B and C starch streams often reveal high microbial loads triggering unstable fermentation processes.



Flowsheet of continuous fermentation. The number of main fermenters depends on production

Heating up to 105-120°C followed by a heat holding section decrease the contamination risk significantly.

Another strategy is low temperature liquefaction at 50-60°C. This process is energy efficient, but only appropriate for raw materials with low microbial loads.

The performance of grain-based fermentation processes has been improved within the last decades.

The development of liquefaction and saccharification enzymes in combination with selected industrial yeast strains allows yields of 94%. Depending on the raw material, fine tuning of the fermentation by adding proteases and optimisation of nutrient dosage drops the fermentation time below 50 hours when achieving an alcohol content up to 14 % v/v.

Enzyme development also facilitates conversion processes and plant designs. Aditionally starch saccharification during the fermentation process provides several advantages.

Equipment cost savings can be realised and contamination risks can also be significantly reduced due to the absence of a saccharification vessel, which offers bacteria a growth promoting environment.

Our experience shows contemporaneous saccharification and fermentation does not provoke prolonged fermentation time and is suitable for continuous yeast propagation in the aerated fermentation tanks.

Cascade of 7 main fermenters for the continuous production of 625 m³ per day of bioethanol

Sugar-based fermentation

Molasses and sugar syrups seldom require special treatment; they are diluted, acidified, and fed straight to the fermentation unit. For substrates containing large amounts of inhibiting substances, pasteurisation or stripping may be necessary. Occasionally, a sludge removal process may be required. The average alcohol content in molasses based fermented mash is about 11-13% v/v.

Moreover, up to 16.5% v/v with beet molasses is possible, depending on the quality and inhibitor content of the raw material. When fermentation is finished, sugar based mash provides the opportunity to recycle the yeast in order to reduce sugar consumption for yeast growth.

In brief, yeast will be separated from the alcoholic mash by a disc centrifuge, washed and is reused in the fermentation process. Alternatively, the separated yeast can generate extra income when sold as high protein fodder.

Fermentation strategies

With regard to customer requirements and available raw materials, VOGELBUSCH offers different options for ethanol fermentation: continuous, batch, or a combination of both.

Continuous fermentation starts in an aerated prefermenter under adjusted conditions that promote yeast growth. The fermenting mash flows steadily through a series of fermenters, while the alcohol concentration increases.

Final alcohol concentration in the mash of 13 to 15% v/v is regularly achieved in grain-based fermentation.

Compared to batch processes, continuous fermentation requires less investment.

Due to reduced cleaning frequencies and the set-up time of the fermenter (once per several months), vessel volumes can be reduced by about 20%. Equipment subjected to an increased contamination risk (e.g. heat exchanger or air sparger) can be cleaned independently of the operating status of the fermenter.

Investment and operating costs can be reduced. On the one hand, less cleaning effort means less quantities of spent CIP solution, which must be evaporated in an energy consuming process.

On the other hand, yeast consumption is significantly reduced as the continuous fermentation cascade starts in an aerated and yeast growth promoting prefermenter.

The annual yeast consumption of a continuous fermentation process with a production capacity of 100,000 litres of biofuel per day is less than 100 kg.

Another advantage of the continuous fermentation is a reduced contamination risk due to alcohol protection. Even the prefermenter where yeast propagation and ethanol fermentation start has a permanent alcohol content of minimum 6.5% v/v.

The batch process is the method of choice for substrates with high inhibitor concentrations like low-quality molasses.

Low alcohol contents in the fermented mash and, as a consequence, high steam consumption of the distillation are expected for such substrates.

Higher alcohol contents and reduced energy costs will be achieved when low quality molasses are processed by batch instead of continuous fermentation.

For example, the VOGELBUSCH high pressure distillation unit saves about 200 kg steam per 1,000 litres of product if the alcohol concentration in the mash is increased from 8 to 10% v/v.

The energy saving aspect of an increased alcohol concentration achieved by a batch process takes even more effect in distillation units operated at low steam pressure.

Advantages of both strategies are brought together when continuous and batch strategies are combined.

Continuous processing at the beginning of the fermentation line limits the yeast consumption and provides alcohol protection at the stage which is most exposed to contamination whereas batch processing at the end of the fermentation provides higher alcohol contents, and in consequence lower energy consumption of the distillation unit.

However, this option limits some advantages of the continuous process. Larger volumes of spent CIP solution have to be evaporated and, therefore, savings of equipment costs are smaller.

Conclusion

The optimal conversion process in biofuel production depends on the type and quality of the raw material. Customised design of pretreatment and fermentation units paves the way to an efficient and competitive production process. Appropriate upstream operation does not only ensure high fermentation yields and demanded product quality, but also saves energy in downstream processing. ●

For more information:
This article was written by Sven Gross-Selbeck, technologist at VOGELBUSCH Biocommodities.
Visit: vogelbusch-biocommodities.com

“Analysis work and fermentation tests are carried out if the raw material quality plays a major role in plant performance. This is essential for molasses or side products of the starch industry like B and C starch”