European Biofuels TECHNOLOGY PLATFORM

Biofuel Fact Sheet

Bioenergy value chain 5: sugar to alcohols

Lab scale | Bench scale | Pilot Plant | Demonstration | Production

Feedstock

Sugars can be fermented into alcohols. Sugars are obtained from sugar crops, starch crops and lignocellulose.

Sugar crops

Among sugar crops, the most extended are sugarcane and sugar beet, and to a lesser extent, sweet sorghum. The sugar is extracted via milling (sugarcane, sweet sorghum) or via heat extraction and vaporisation (sugar beet).

Starch crops

Starch crops are mainly maize, wheat, other cereals and potatoes. Starch is a polysaccharide and needs to be hydrolized into monosaccharides (sugars) for fermentation. For this saccharification the technique commonly applied is enzymatic hydrolysis, generally associated to ”jet cooking”.

In the enzymatic hydrolysis, the starch crops are crushed and mashed; then enzymes (e.g. amylases) are added to the mash which dissolve the starch into sugar.

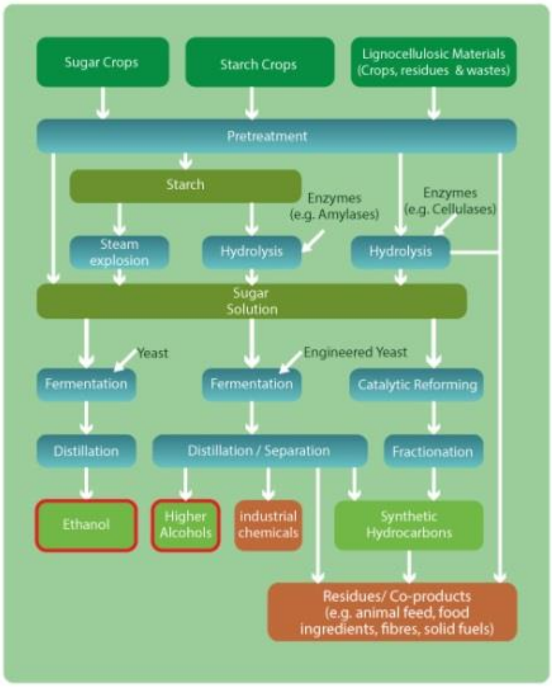
Lignocellulosics

Lignocellulose is the structural material of biomass. It consists of cellulose (mainly C6 sugar polymers like the sugar extracted from sugar and starch crops), hemicellulose (mainly C5 sugar polymers) and lignin (aromatic alcohol-polymers). The term lignocellulosics includes agricultural and wood residues, wood from forestry, short rotation coppices (SRC), and lignocellulosic energy crops, such as energy grasses and reeds.

A pretreatment is generally first applied on the raw material before saccharification to separate the different elements. The most common one is the steam explosion associated or not with an acid catalyst.

Once the cellulose and the hemi-cellulose are separated from the lignin, saccharification of these polysaccharides can take place, generally speaking through enzymatic hydrolysis (use of cellulases and hemi cellulases). The C6 sugars can be fermented by common yeasts while C5 sugars need specific microorganisms to get fermented. Lignin is for now usually separated and dried to be used as a fuel for the process or for power generation.

Figure 1: Biochemical value chains



End products

Bioethanol

Biobutanol

Properties of butanol are closer to gasoline than properties of ethanol as concerns e.g. heating value, vapor pressure, water tolerance, corrosiveness, and polarity.

By-products

Lignin

Often combusted to produce process heat; also serves as feedstock for a variety of chemical products or materials.

Yeast fermentation to ethanol

C6 sugars are fermented by traditional yeasts that are also used for the production of wine, beer or bread. The process is:

$C_6H_{12}O_6 \leftrightarrow 2\ C_2H_5OH + 2\ CO_2$.

For the fermentation of C5 sugars genetically modified yeasts have been developed in the recent years.

As ethanol is a toxin, there is a limit to the maximum concentration in the brew produced by the yeasts. The upgrading of ethanol from lower concentrations to the required 98.7%m/m for the application as biofuel is performed employing the following known and widely applied technological steps:

- Evaporation of ethanol from beer: in this step the first evaporation of ethanol is performed in order to obtain 'crude' ethanol with concentration ~45%V/V.
- Rectification: in rectification the ethanol concentration is increased to ~96%V/V

Dehydration: by dehydration the remaining azeotropic water is removed in order to obtain the fuel bioethanol with concentration 98.7%m/m and water content below 0.3% m/m.

Yeast fermentation to butanol

There is significant interest in the production of butanol as a biofuel because its properties are more adequate to a gasoline blend (e.g. vapor pressure, water entrainment) but the production cost is still more expensive than for ethanol. Some bacterias naturally produce butanol and yeast can be engineered to produce butanol instead of ethanol. Butanol may serve as an alternative fuel, as e.g. 85% Butanol/gasoline blends can be used in unmodified petrol engines.

Microbial Fermentation via Acetic Acid

Microbial fermentation of sugars can also use an acetogenic pathway to produce acetic acid without CO_2 as a by-product. This increases the carbon utilization of the process. The acetic acid is converted to an ester which can then be reacted with hydrogen to make ethanol.

The hydrogen required to convert the ester to ethanol could be produced through gasification of the lignin residue. This requires fractionation of the feedstock into a sugar stream and a lignin residue at the beginning of the process.

Example projects on sugar-to-alcohols production

Pilot

Butamax Advanced Biofuels LLC	British facility producing butanol from sugar and starch crops; joint venture of BP and DuPont; currently idle
Gevo	US-company producing iso-butanol via a biocatalysis/ fermentation; operational since 2012

Demo

Inbicon	producing ethanol and lignin by products from mainly wheat straw; run by DONG Energy (Denmark); operational since 2009
Booregaard	Norwegian facility producing ethanol, lignin and chemicals from various lignocellulosic crops and residues; operational since 2012
Abengoa	Spanish facility producing ethanol from organic waste; currently idle

First-of-a-kind commercial

Beta Renewables	Italian facility producing ethanol from lignocellulosic crops and residues; joint venture of Mossi & Ghisolfi, Chemtex and TPG; operational since 2012

Further information

Read up-to-date information about the biochemical conversion technology on www.biofuelstp.eu.