ETIP Bioenergy
European Technology and Innovation Platform

Alcohol fuels from sugars

LAB SCALE → BENCH SCALE → PILOT PLANT → DEMONSTRATION → PRODUCTION

DEFINITION

Two main processing pathways are established to produce ethanol and higher alcohols from sugars.

(1) Ethanol from lignocellulose-derived sugars: Cellulosic ethanol is chemically identical to first generation ethanol (i.e. CH_3CH_2OH). However, it is produced from different raw materials via a more complex process (cellulose hydrolysis). While first generation bioethanol is derived from sugar or starch produced by food crops (e.g. wheat, corn, sugar beet, sugar cane, etc.), cellulosic ethanol may be produced from agricultural residues (e.g. straw, corn stover), other lignocellulosic raw materials (e.g. wood chips) or energy crops (miscanthus, switchgrass, etc.).

(2) Higher alcohols from isolated sugars: Isolated sugars, today from crop or starch sources but in the future possibly also from lignocellulosic sources, are the starting point for a number of pathways to biofuels.

PROCESSING TECHNOLOGY

Cellulosic Ethanol

The first step in the processing of lignocellulosic feedstocks to ethanol is a pre-treatment consisting of a physico-chemical step and an enzymatic liquefaction step, which fractionates the feedstock into its three main components (cellulose, hemicellulose and lignin). The most common method is steam explosion with or without an acid catalyst, but also acid and base treatment and organosolv processes can be used. Afterwards, hydrolysis and saccharification of the cellulose and hemicelluloses oligomers take place. This step uses specifically developed enzyme cocktails, but also acid hydrolysis has been used. The enzyme treatment results in

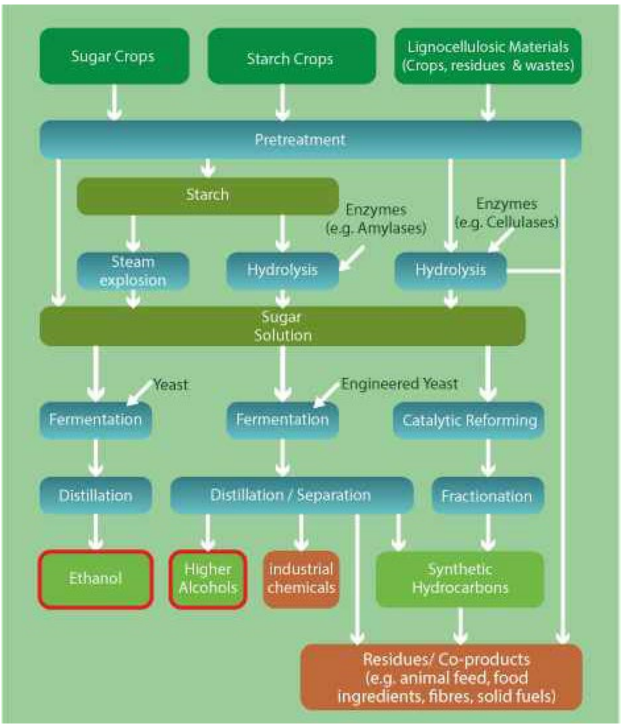

Figure 1: Alcohol fuels from sugars value chain

unhydrolysed solids and a pumpable slurry. The slurry is either fermented in the same vessel (Simultaneous Saccharification and Fermentation) or in a downstream fermenter (Separate Hydrolysis and Fermentation), while lignin is separated before or after fermentation. The cellulose- and hemicellulose- derived C6 sugars are fermented by yeast strains derived from traditional yeasts (commonly used for wine, beer or bread) while genetically modified yeasts have been developed in the recent years to ferment C5 sugars. Finally, ethanol is recovered by distillation and dehydration.

The main end-product of the process is ethanol, with a concentration of 98.7% m/m, suitable for the application as biofuel. At present, the technology can give up to 300 liters of ethanol per tonne of agricultural waste of which a significant part is derived from the C5 sugars, i.e. an efficiency to biofuels in the order of 30%. Lignocellulosic ethanol is considered an advanced biofuel under EU regulation.

Higher Alcohols

Butanol can be obtained by applying bacteria that naturally produce butanol, or by engineered yeasts in the fermentation step (see Figure 1). Although production costs are higher than for ethanol, there is a significant interest in butanol as biofuel, due to its attractive properties. For instance, heating value, vapor pressure, water tolerance, corrosiveness, and polarity of butanol are more adequate to a gasoline blend (e.g. vapor pressure, water entrainment). Butanol may also serve as an alternative fuel, as e.g. 85% Butanol/gasoline blends can be used in unmodified petrol engines. This fermentation pathway can also be used to produce both n-butanol and iso-butanol, the latter having a high value as a chemical building block.

Fermentation with engineered microorganisms can also be applied to produce iso-butene that can be the basis for chemicals or be oligomerized and hydrogenated to e.g. gasoline. Since iso-butene is a gas that separates from the broth, this facilitates the product separation and upgrading, as well as limiting any product inhibition issues.

A by-product of the overall sugar-to-alcohols process is lignin, which is usually dried and later combusted to produce process heat and/or for power generation. Lignin also serves as feedstock for a variety of chemical products or materials.

EXAMPLES OF DEMOPLANTS

https://www.etipbioenergy.eu/databases/production-facilities

Location: Kajaani , Finland

Plant: **Cellulonix Kajaani** of St1 Biofuels, started operation in 2017 (TRL 6-7)

Process units: pre-treatment, enzymatic hydrolysis, fermentation and ethanol distillation

Feedstock: sawdust from forest residues (80,000 t/y)

Products: cellulosic ethanol (8,000 t/y)

By-products: terpentine, wood vinasse, lignin, furfural, biogas and CO_2

Link: https://www.st1.com/cellunolix-ethanol-plant-to-be-built-in-finland, https://www.st1.com/

Location: Podari,Romania

Plant: Sunliquid® plant of Clariant, expected to become operational in late 2021 (TRL 8)

Process units: "sunliquid" process-integrated production with raw material-specific biocatalysts

Feedstock: wheat and other cereal straw as agriculture residues (250,000 t/y)

Products: cellulosic ethanol (50,000 t/y)

By-products: lignin, used to provide energy to the process

Link: https://www.clariant.com/en/Company/Contacts-and-Locations/Key-Sites/Romania

More information on www.etipbioenergy.eu.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825179