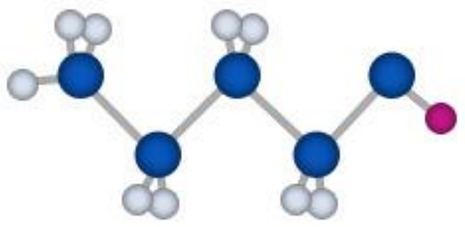

BIOBUTANOL AS AN ALTERNATIVE BIOFUEL

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Introduction

In order to meet the aims of Kyoto, several national as well as european initiatives were launched to replace fossil fuels by biofuels to a certain extent. Beside biodiesel and bioethanol, biobutanol is another type of biofuel, which can serve to reach these aims. In Austria several biodiesel plants are in operation with a total capacity of 240000 t biodiesel per year[1], as well as a large bioethanol plant with a capacity of 190000 t[1]. Biobutanol is not produced to this date.
Butanol (1-Butanol, n-Butanol, CH_3-CH_2-CH_2-CH_2OH), an aliphatic, saturated C4-alcohol (properties table 1) can be used as a fuel additive for transport. It is miscible with gasoline as well as with gasoil. At present time, butanol is used primarily as a solvent for industrial applications. The estimated world market for this product is 1,3 billion liters per year, and the U.S. share of this amount is 830 million liters per year.
Biobutanol requires no modification to gasoline-powered engines and can easily fuel today's standard vehicles in gasoline blends or added to ethanol to reduce evaporative emissions.
It is far less corrosive than ethanol and can be distributed through existing oil and gas pipelines more easily than ethanol. Biobutanol will not damage automobile components, such as valves and gaskets or any segment of fuel distribution systems.

Table 1: Properties butanol

Molecular weight	74.12 g/mol
Specific weight	810 kg/m³
Boiling point	117.7°C
Vapour pressure	5.6 hPa (at 20°C)
Flash point	35 – 37°C
Solubility in water	90 g/L (at 25°C)
Volumetric energy content	Ca. 27.0 MJ/liter
Research Octane number	94

Process

An especial sustainable pathway for its production is the biotechnological way, the so called ABE fermentation, a strict anaerobic process, which was well known as Weizmann-process in world war one. Therein different substrates are converted to acetone, butanol and ethanol, by different *Clostridia sp*. (Table 2), under participation of several metabolic pathways interacting in a complex manner. Butanol can be produced from many kinds of renewable organic material such as corn, wheat, wood pulp, sugar cane, sugar beets and even cheese whey.

Table 2: Microorganisms investigated for biobutanol production

Organism	**Product**
Clostridium beijerinckii	ABE
Clostridium acetobutylicum	ABE
Clostridium aurantibutyricum	Acetone, butanol and isopropanol
Clostridium tetanomorphum	Butanol and ethanol

During exponential growth of the cells the main products are different acids like lactate, acetate und butyrate as well as hydrogen and CO_2 (acidogenesis). Only at the stationary growth phase the production of solvents is taking place (solventogenesis). During the fermentation using *C. acetobutylicum* acetone, butanol und ethanol are produced in a ratio of 3:6:1 and up to a concentration of 12 g/L butanol. Usually, maximum total ABE concentration of 20 g/L is achieved.

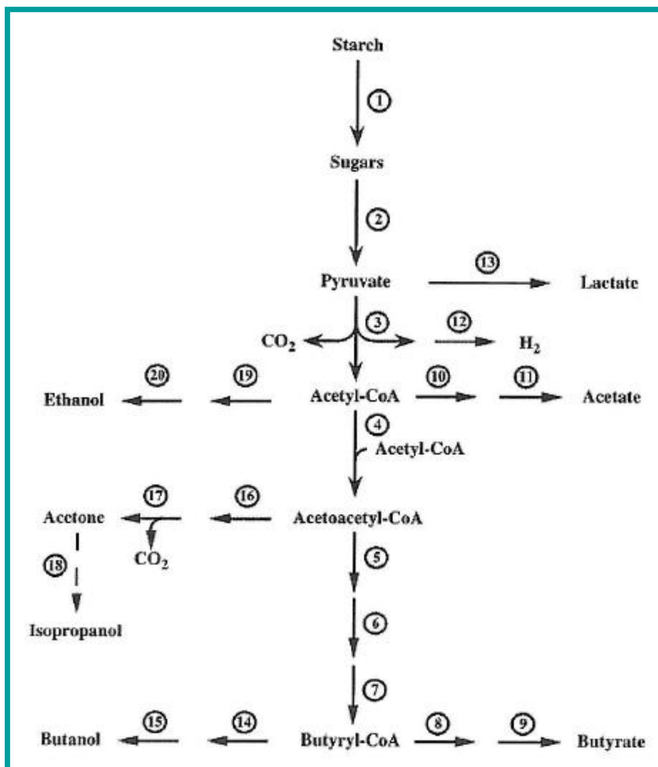


Figure 1: Metabolic pathways of solvent forming microorganisms with starch as initial substrate (numbers indicate enzyme catalysed steps and are not described here)[3]

Challenges

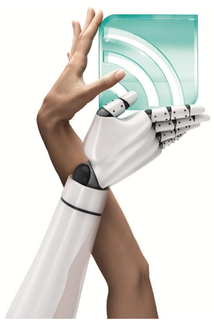
However, this process is hampered by end product inhibition, uneconomical product recovery, and the use of dilute substrate solutions, thereby resulting in large process stream volumes as well as process instabilities. Different bioreactors and different operation modes are in investigation. Using online product recovery the total ABE content could be increased to 230 g/L.[4]

Methods of product separation:[3,5]

- Adsorption using silicagel or ion exchange resins
- Gas stripping and subsequent condensation of solvent/water vapour
- Liquid/liquid extraction: Contact of non-water miscible solvents with fermentation liquid
- Membrane evaporation: Selective diffusion through porous membranes
- Perstraction: Separation of extraction liquid and fermentation broth by a membrane
- Pervaporation: Selective diffusion through a non-porous membrane, regeneration by vacuum or gas
- Reversed osmosis: High pressure separation of a diluted solution into a concentrate and water phase via a semipermeable membrane.

Outlook

Currently, several international initiatives are ongoing in order to make biobutanol production economically feasible (BP etc.).
A national project is planned with the aim to set up a competitive process for biobutanol production, by approaching the main scientific goals: Identifying the optimal microbiological system, application of an innovative substrate pretreatment and concept and test of an integrated fermentor and product upgrading system.



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