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ABE from lignocellulosic biomass
Bacterial solvent production in the former Soviet Union

Introduction

During the first half of the 20th century a major part of the world´s demand of the technically important acetone, butanol and ethanol (ABE) was produced by bacteria from sucrose or starch. Unfortunately, most of the information on the production process and most of the industrial strains (*Clostridium acetobutylicum*, *C. beijerinckii* and others) were lost. Unlike in the Western countries, in Russia this production, the Weizmann process, was run up to the 80ths. After the Perestroika the archives in the Soviet Union became accessible and the details on the Russian industrial ABE process can now be investigated. The situation in Russia promises to have conserved more of the previously confidential material than the West, because the production plants were state-owned and the information and the bacterial strains were preserved in state owned institutes.
A preliminary summary of the study undergone so far is presented, including data on the scale of the process and the fermentation technology and microbiology used. More archival and experimental studies have to be done in Russia, especially on the strains and the technical processes used. There is a good chance to revive the strains and to investigate their production potential in the light of the present-day needs for modern biotechnological processes. Most interestingly, hydrolysates from lignocellulosic biomass were used for bacterial fermentations.
The first industrially run process for the production of ABE from agricultural waste material (not starch or sucrose!) in a bacterial fermentation to solvents is described.

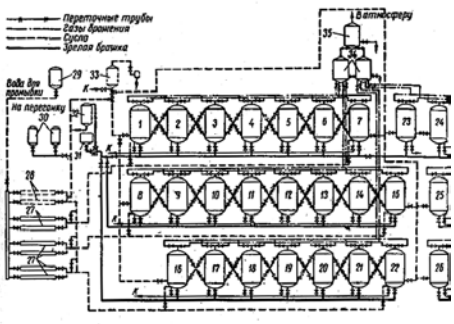
A list of production plants for ABE fermentation in the former Soviet Union

9 different industrial-size plants for the production of **acetone** and **butanol** from agricultural material have been reported to have run in Russia:

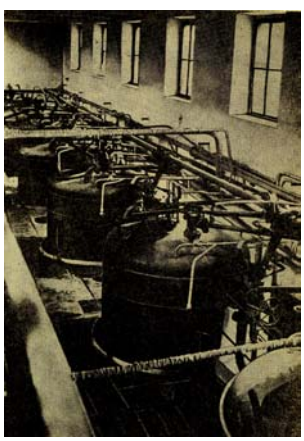
Name of plant	Data available from	Comment
Dokshukinski	1961, 1969	flour / molasses (30:70); acid hydrolysates from corn stubs, sun flower shells, hemp waste etc.
Evremowski	1982	
Grosnyinski	1962	Demonstration plant for continuous process since 1939
Nartkalinski	1962, 1975, 2003	molasses
Petrovski	1975	
Metrofanovski	1975	
Michurinski	1975	
Bulchovski	1975	potatoe starch

An example plant

Schematical presentation of the acetone-butanol production line: the substrate passes 3 parallel lines of 7or more fermenters each (#1-26). The preculture fermenter is #33, the feeding fermenters are #30. #27/28 are substrate coolers. CO_2 is collected in #34/35. At the time of description in 1975 this plant has been run successfully for 10 years.

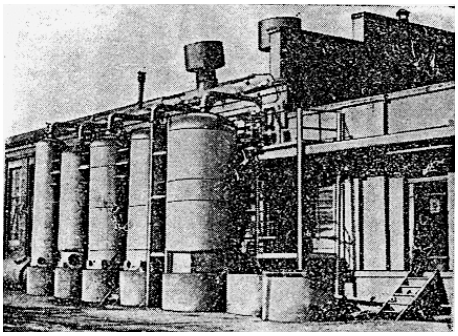


Schematical drawing of the Dokshukinski fermentation plant

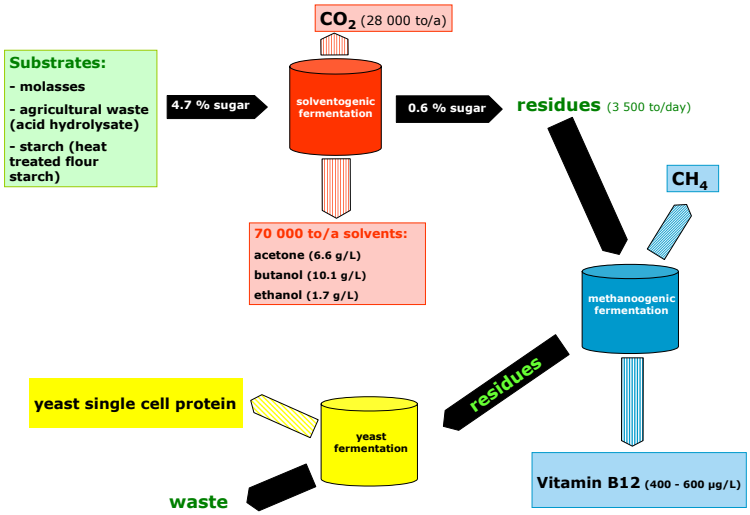


Fermentation vessels for Clostridia (upper part, in 1963)

The Dokshukino plant in 1969: fermentation



Flow chart of the *Dokshukinski* process:



It was reported that at the ***Dokshukinski*** plant the solvent production was transferred to a continuous process in 1960. But the plant was working much earlier, probably since the 2nd World War. In 1961 the substrate was modified from pure flour hydrolysate (wheat and/or rye) to a mixture of flour (heat treated) and molasses (30:70). Additionally, an acid hydrolysate from corn stubbers and other agricultural waste was also used (sulfuric and phosphoric acid 3:1 or 4:1).

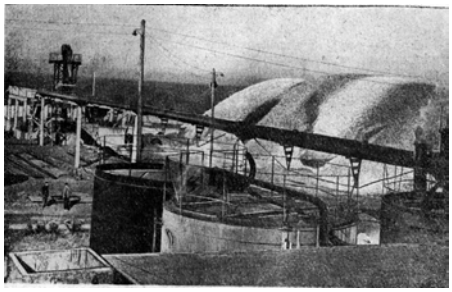
Efficiency: 50 % of the substrate sugars were converted to CO_2, and 33-39 % to solvents (60 % of that was butanol), leading to a yield of 9 tons solvents per 100 tons grain. By-products were CO_2, vitamin B_{12} and yeast protein for feed. The production of methane gas provided the energy for running the process.

Summary

The results from this literature survey show that the bacterial acetone-butanol production process was extensively used in the Soviet Union up to the 80s and surprisingly may be running even now as a large scale continuous process where favorable local circumstances allow (e.g. the ***Nartkalinski*** plant). The long-time experience with this obligatory sterile process at a large scale and with well adapted bacterial strains may be used for establishing a similar process at a local basis in Western Europe, if modern process technology (esp. for product recovery) were combined with the use of cheaper substrates such as waste material from agriculture or food industry.

More archival studies have to be done in Russia, especially on the strains and the technical processes used. The production strains should be obtained and their production potential investigated in the light of the present-day needs for modern biotechnological processes.

Substrate storage and hydrolysis at Dokshukino plant (1963): corn stubs



Acid hydrolysis at Dokshukino plant (1963)