Commodity Chemicals from Forest Biomass (BioForest)

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Canada

TKK

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Tom Granström, TKK

History of ABE fermentation

- The production of butanol in a microbial fermentation was first reported by Pasteur in 1861
- Between 1912 and 1914 Chaim Weizmann isolated butanol producing strains named as *Clostridium acetobutylicum*
- The Weizmann process was issued a patent in 1915 to produce acetone for cordite production
- Butanol and butyl acetate were ideal solvents for quick drying lacquers and industrial solvent production started at the Terre Haute plant in 1920 (USA)

History of ABE fermentation

- In 1960 factory-scale process was brought into operation in Dokshukino (USSR)
- In China the total production capacity reached 210,000 tons (2006)
- The total solvent production is expected to reach 1,000,000 tons in China (based on 2008 data)
- ABE fermentation is studied in two different universities in Finland

Biofuel comparison

Property	Acetone	n-Butanol	Ethanol	Isopropanol	Gasoline
Heating value (MJ/m^3)	**26000**	**29000**	**21000**	**24000**	**32000-34700**
Oxygen content	**27.6**	**21.6**	**26.6**	**34.7**	**-**
RON	**-**	**96-113**	**106**	**121-129**	**91-99**
MON	**78-93**	**94**	**96-102**	**92**	**81-89**
Price (€/m^3)	**668**	**984**	**588**	**881**	**558**

Future Challenges

- Low yields of solvents
- Inhibitory products particularly butanol
- Cost effective downstream processing not yet developed
- Current fermentation processes optimised for starch, but lignocellulosics is the future feedstock
- Production strains should be adjusted to utilize local feedstocks

Feedstock comparison

Feed Stock	Price	$/Dry 1000 kg	NHV (GJ/dry 1000kg)	$/GJ
Fossil Feed Stocks				
Oil	$100/barrel	720	36	20
Natural Gas	$11/1000 scf	550	43	13
Coal		60	30	2
Renewable Feed Stocks				
Sugar		330	14	24
Corn kernels	$4/bushel	156	14	11
Pulp Wood		100	18	6
Recycled fibers		70	14	5
Wood Biomass		55	18	3

Material efficiency and LHV heat content for wood biomass

Type of Biomass	Domestic Softwood in Finland		Domestic Hardwood in Finland		
Species	Pine	Spruce	Black Alder	Aspen	Silver Birch
<u>Fischer-Tropsch synthesis</u>					
LVH MJ kg dry biomass	13.7	13.4	12.6	13.5	13.6
LVH % raw material	71.2	70.2	66.9	72.0	72.8
C utilization efficiency	42.6	41.4	41.8	47.2	46.4

Melin and Hurme, 2009

EtOH fermentation C6 sugars					
LHV Ethanol MJ/kg dry biomass	8.7	9.0	6.7	7.2	6.8
LVH % EtOH/Raw material	44.8	47.1	35.6	38.6	36.4
Carbon material efficiency %	82.8	82.2	83.2	82.7	82.0

ABE fermentation C6 and C5 sugars					
LHV Products MJ/kg dry biomass	10.5	10.5	9.6	10.0	10.3
LVH % of Fermentation products/Raw material	54.2	55.2	50.9	53.5	55.1
Carbon material efficiency %	80.7	80.9	80.7	80.1	78.7

Melin and Hurme, 2009

- **Gas routes enables the highest amount of heat content of the raw material to be transferred into the products**

- **The heat efficiency of fermentation route is improved, when lignocellulosics is used as a feedstock due to the high heating value of lignin**

Project objective

- **To create an economic process for production of commodity chemicals from forest biomass and recycled fibers**

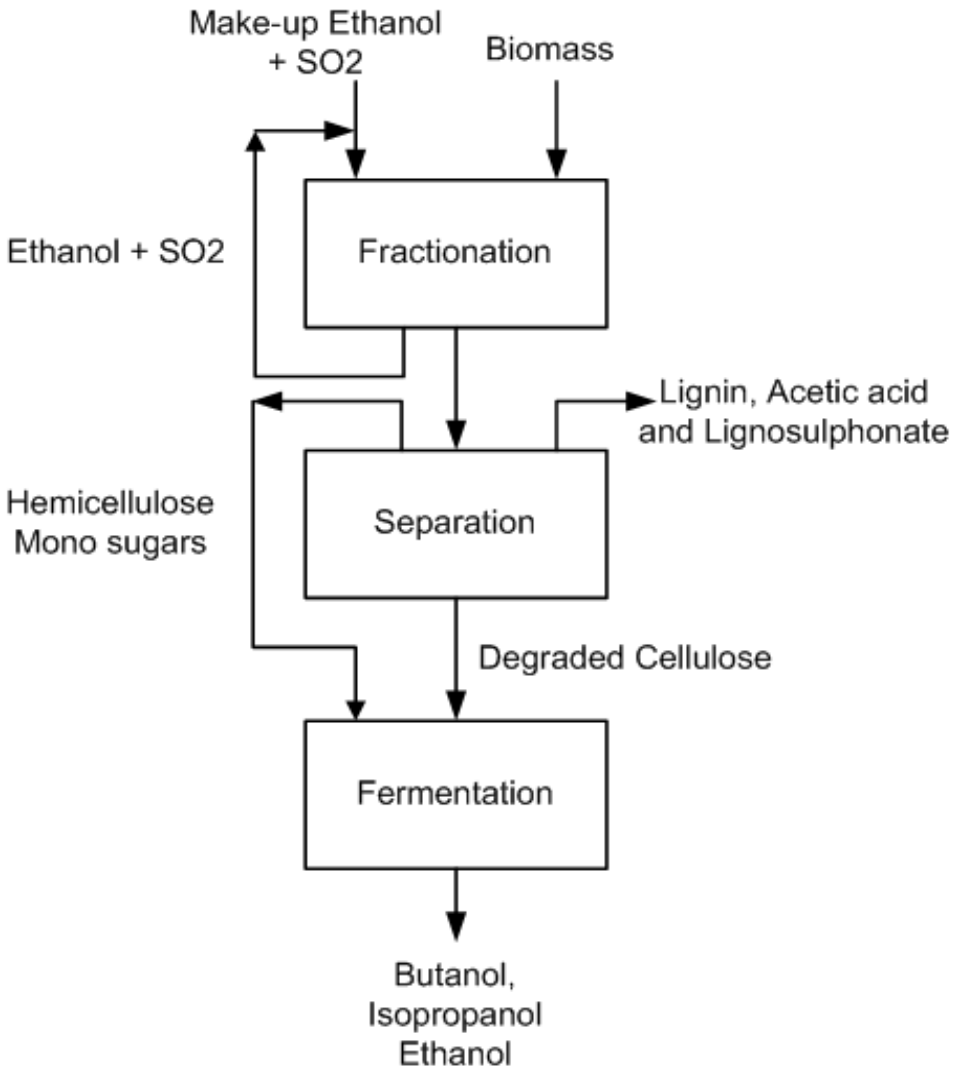
TREE TOPS, LIMBS, TWIGS, STUMPS, RECYCLED FIBERS…

→ Butanol, isopropanol, ethanol

↓

A MIXTURE TO REPLACE GASOLINE!

BioForest Process



Chemical composition of spruce chips

CHEMICAL COMPOSITION		
Component	**Average (%)**	**STDEV**
Extractives	2,5	-
Lignin	27,7	0,10
Acid insoluble	27,3	0,10
Acid soluble	0,3	0,00
Ash	0,4	0,01
Acetyl groups	1,2	0,06
Carbohydrates	71,9	0,1
Glucan	47,3	0,5
Mannan	14,2	0,2
Xylan	6,5	1,9
Galactan	2,9	2,3
Arabinan	1,0	1,8
TOTAL	**103,6**	

Chemical composition of the spent liquor of SEW process after pulping.

Component	Concentration (g/L)
Arabinose	1,8
Xylose	6,7
Rhamnose	0,3
Galacturonic acid	2,1
4-O-Me-glucuronic acid	1,4
Mannose	14,3
Galactose	3,9
Glucose	3,8
Total Carbohydrates	**34,4**

25 g dry wood / 150 ml fractionation liquer

***Clostridia*-bacteria:**

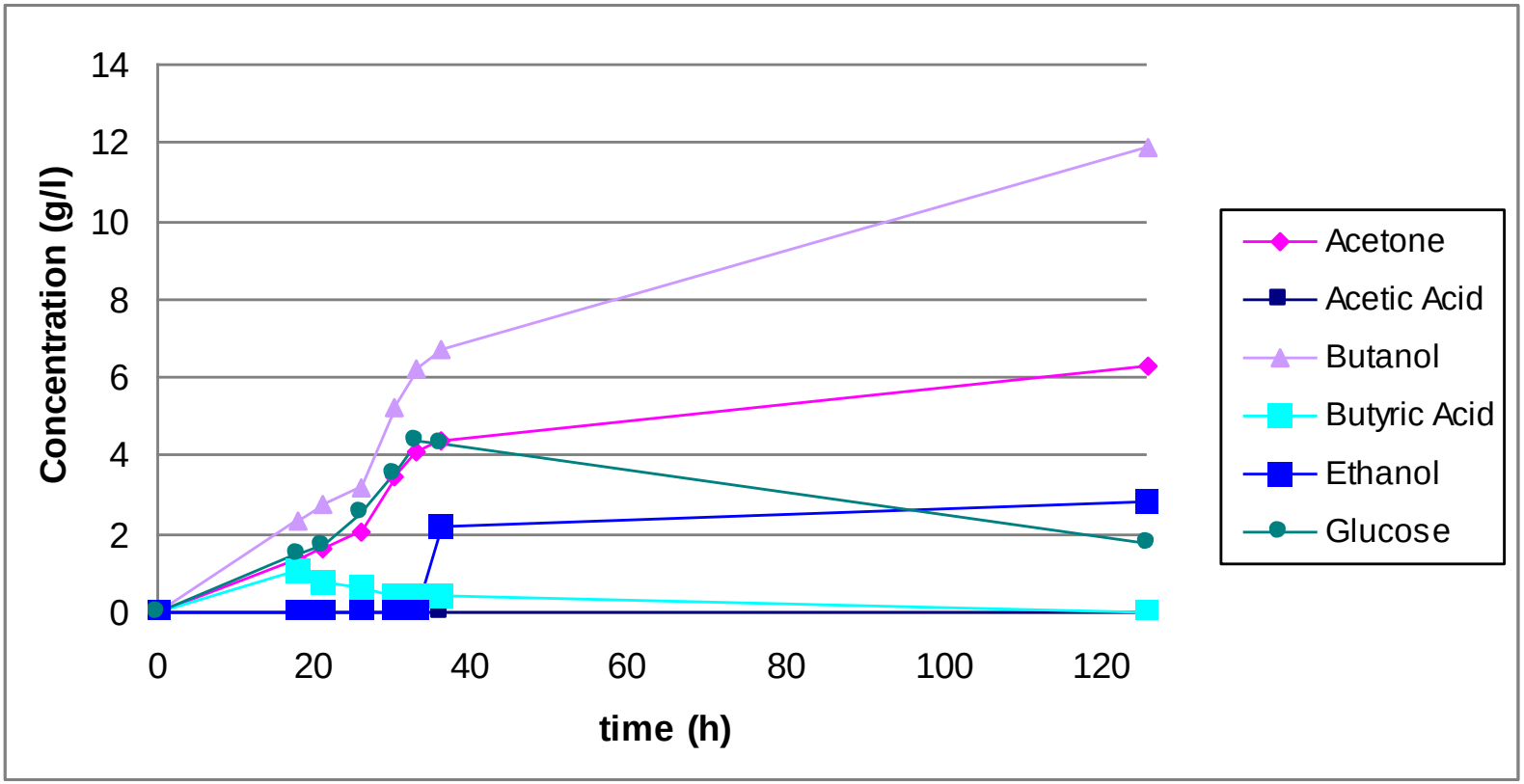
- **wide substrate spectrum**
- **activity against crystalline cellulose**
- **hemicellulose utilizer**

Feedstocks:

- **Lignocellulose biomass**
- **Agricultural sidestreams**
- **Wood biomass**
- **Starch**
- **Hemicellulose**

Photo: Germen Jurgens

Clostridia acetobutylicum growing on corn starch



Total ABE product 20.98 g/l and yield 40% from corn starch

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Summary

- Lignocellulosic biomass hydrolysis without significant formation of inhibitors
- Lignocellulosic biomass hydrolysis without enzyme treatment
- Five carbon sugars (pentoses) bacterial fermentation
- Wood liquer upgrading for fermentation studies is in process

Bioforest Research Group
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Professor Adriaan van Heiningen

Feedstock	Fermentation	Downstream
Adriaan van Heiningen	Tom Granström	Herbert Sixta
Minna Rakkolainen	German Jurgens	Adriaan van Heiningen
Mikhail Iakovlev	Svetlana Zakharova	Evangelos Sklavounos
	Anna-Lydia Teräsvuori	

Tekes