

# Biotechnologische Verfahren zur stofflichen und energetischen Verwertung von Biomasse & Reststoffen



Fachforum Ressourcen 2019  
Bioökonomie und Rohstoffwandel – Nachwachsende  
Rohstoffe für nachhaltige Produkte, 12.11.2019

# History

- 1927 Experimental farm of the Agricultural University Berlin
- 1933 Independent research center on agricultural mechanization
- 1952 Central institute of agricultural engineering of East Germany
- 1992 Reestablished after the reunification of Germany

Today:

Leibniz Institute for Agricultural Engineering and Bioeconomy

- member of the Leibniz Association



# Our mission:

Our research is aimed at sustainable intensification. We analyze, model and evaluate **bio-economic production systems**. We develop and integrate new technologies and management strategies for a knowledge-based, **site-specific production of biomass**, and its **use for food, as bio-based materials and fuels** - from basic research to application.



# Research Program

## „Material and energetic use of biomass “

Coordination: Dr. Joachim Venus

Consideration of the entire value chain -  
System's approach

### Biomass provision

(Cultivation, harvest, storage... e.g. short rotation wood, hemp)

### Chemicals & Materials

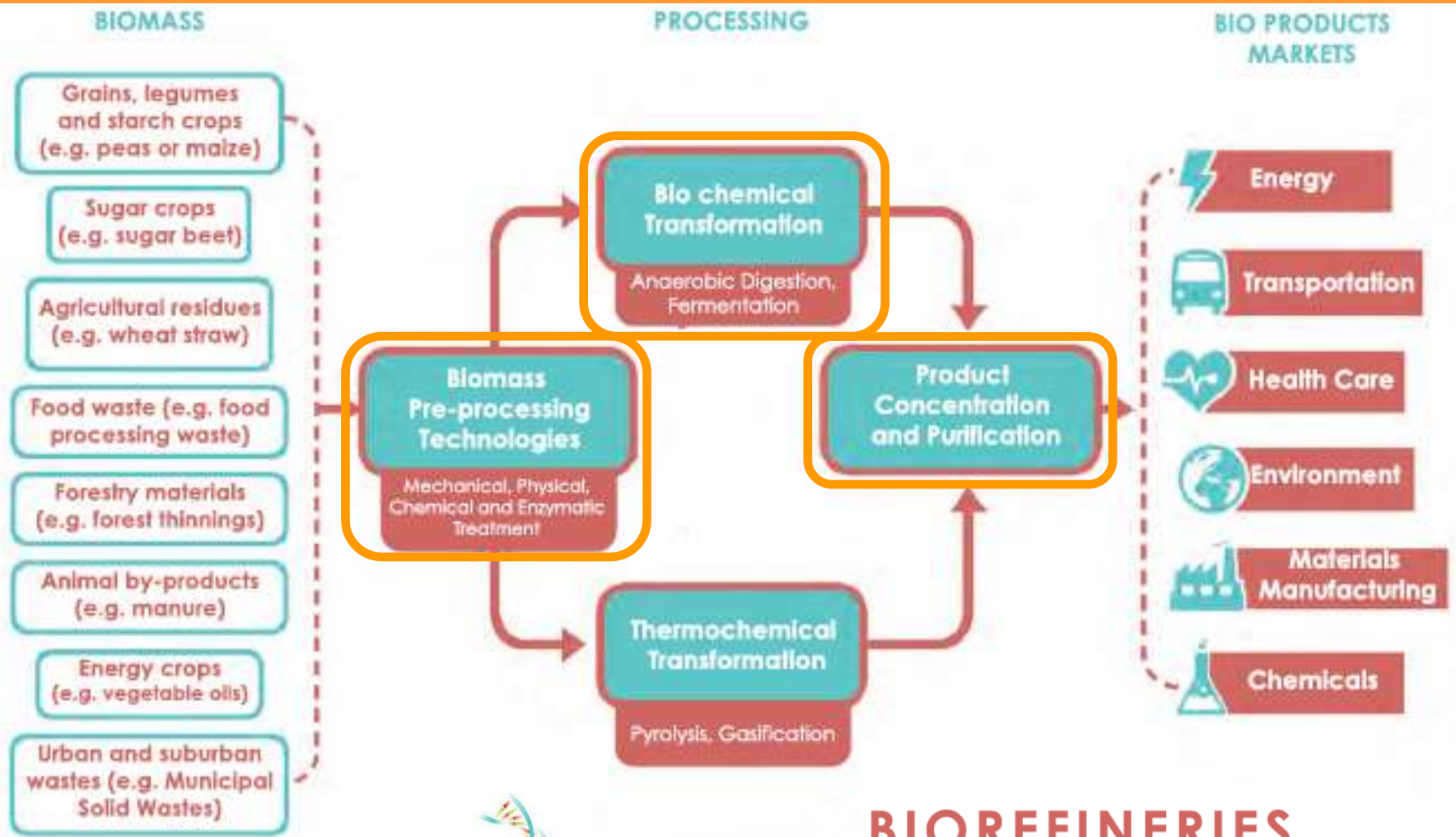
➔ biotechnological products

Energetic use  
(Biogas, wood pellets, biochar)

Valorization of residues, sidestreams etc.



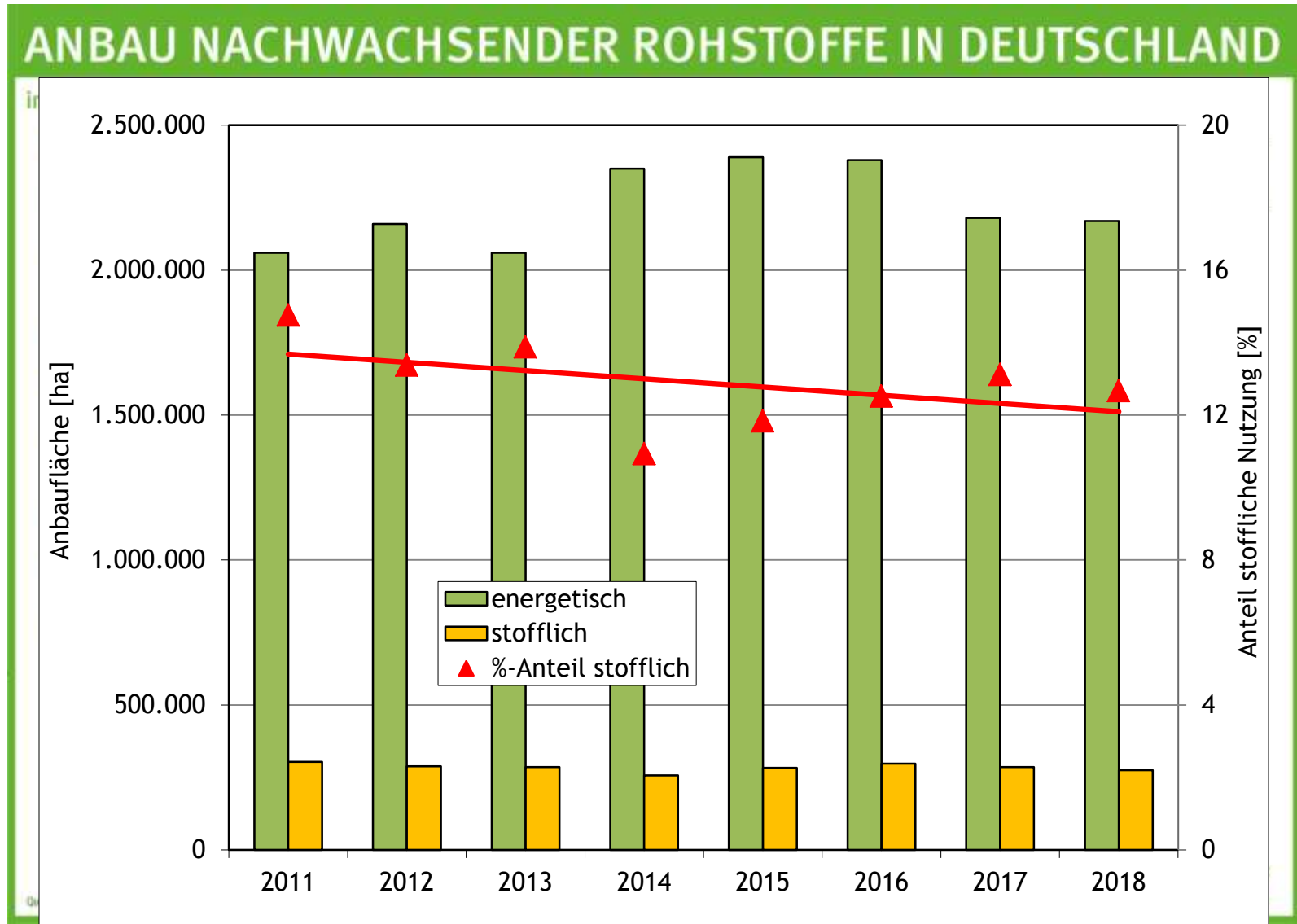
„Bioraffinerie ist ein integratives Gesamtkonzept für die **Konversion von nachwachsenden Rohstoffen zu Chemikalien, Werkstoffen**, Brenn- und Kraftstoffen sowie ggf. zur Erzeugung von Energie (zur Eigennutzung und/oder Auskopplung) als Beitrag zum Nachhaltigen Wirtschaften unter möglichst vollständiger Ausnutzung der Biomasse (BM)“  
 [Def. VDI-Richtlinie 6310, 2016]



# BIOREFINERIES

RESOURCE EFFICIENCY EXEMPLIFIED

# Anbau und Verwendung nachwachsender Rohstoffe



# Beim Übergang von petrochemischen zu nachwachsenden Rohstoffen gibt es eine Reihe von Herausforderungen

- Menge und Verfügbarkeit
- Rohstoff Komplexität
- Rohstoff Vorbehandlung
- Prozessentwicklung & Prozessskalierung
- Kaskaden & Mehrfachnutzung
- Integration der Stoffe in Wertschöpfungsketten
- Akzeptanz bei Kunden & Verbrauchern
- Kosten der Herstellung

[Wagemann/Hirth/Popp, 2010]

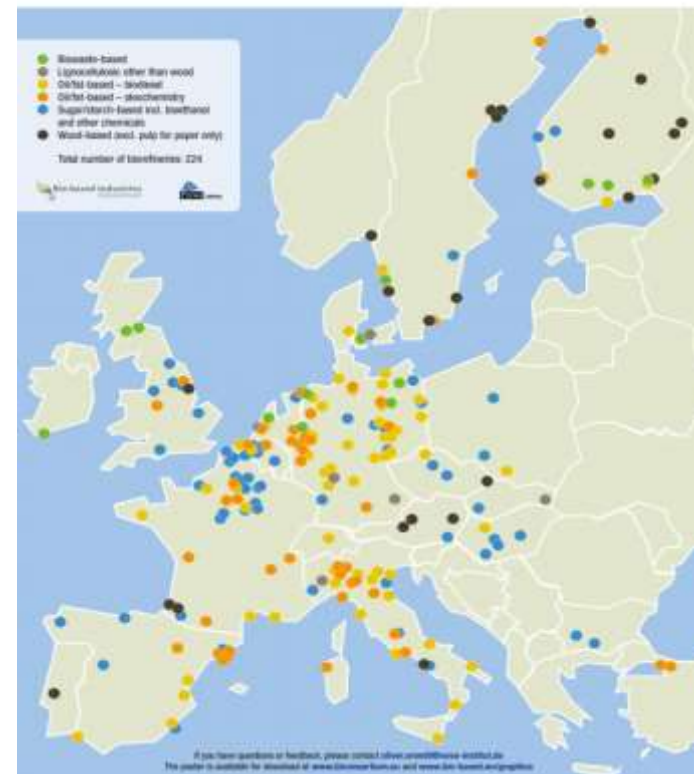
## Map of 224 European biorefineries published by BIC and nova-Institute

Biorefineries are the heart of the bioeconomy. Here, different types of biomass are fully utilised and transformed into a large variety of chemicals and materials.

The map distinguishes between “Sugar-/starch based biorefineries”, producing bioethanol and other chemicals (63), “Oil-/fat-based biorefineries - biodiesel” (64) and “Oil-/fat-based biorefineries - oleochemistry” (54), “Wood-based biorefineries” (25) excluding those that produce pulp for paper only, “Lignocellulose other than wood” (5) and finally “Biowaste-based biorefineries” (13).

The prevalence of biorefineries differs considerably between countries. The type of biorefinery is clearly dependent on the locally available biomass. Wood-based biorefineries can be found mainly in Northern Europe and “Sugar-/starch based biorefineries” mainly in France, Belgium, Germany and Hungary, where we see high yields in sugar and starch.

Biorefineries in Europe 2017



The map can be downloaded for free at [www.bio-based.eu/graphics](http://www.bio-based.eu/graphics) or [www.biconsortium.eu](http://www.biconsortium.eu)



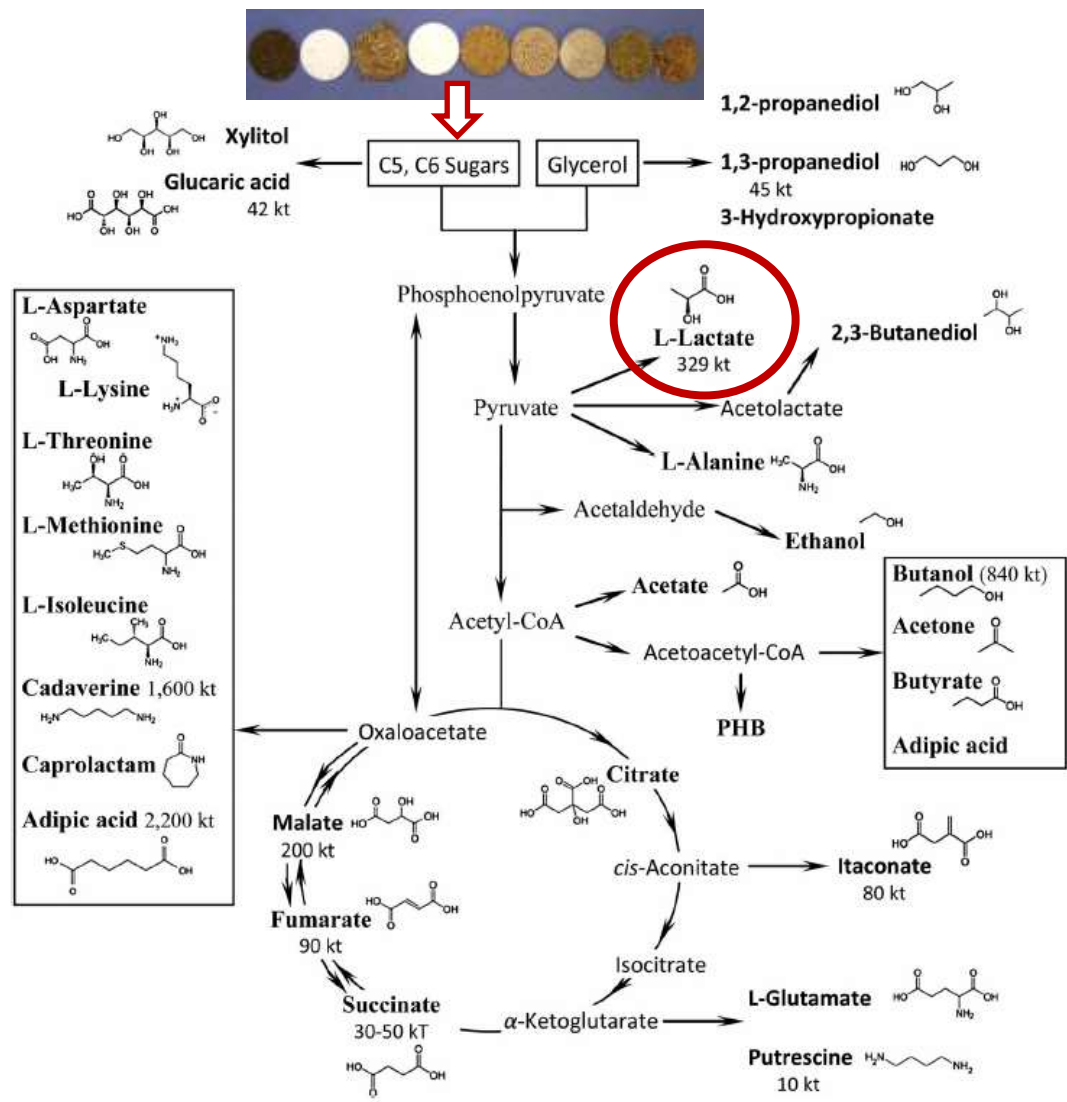
# Building blocks that could be produced via fermentation

## REVIEW ARTICLE

Valorization of industrial waste and by-product streams *via* fermentation for the production of chemicals and biopolymers

Apostolis A. Koutinas,<sup>1\*</sup> Anestis Vlysidis,<sup>2\*</sup> Daniel Pleissner,<sup>1</sup> Nikolaos Kopsahelis,<sup>3</sup> Isabel Lopez Garcia,<sup>1</sup> Ioannis K. Kookos,<sup>1</sup> Seraphim Papanikolaou,<sup>4</sup> Tsz Him Kwarl and Carol Sze Ki Lin<sup>2\*</sup>

➔ Numbers next to biochemicals designate the total annual production in thousands of t



**Berlin, 5 December 2018** – The results of the European Bioplastics' annual market data update, presented today at the 13<sup>th</sup> European Bioplastics Conference in Berlin:

**The global bioplastics production capacity is set to increase from around 2.1 Mio t in 2018 to 2.6 Mio t in 2023. Innovative biopolymers such as PLA and PHAs are driving this growth.**



# Chemicals from Biomass: A Market Assessment of Bioproducts with Near-Term Potential

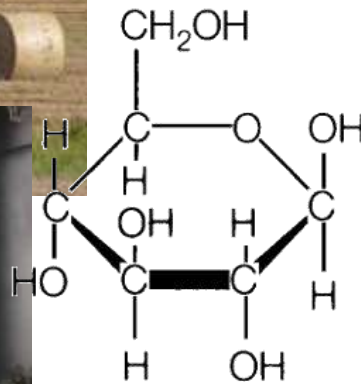
Mary J. Bidy, Christopher Scarlata, and Christopher Kinchin - *National Renewable Energy Laboratory*

## Data Gaps

Scale-up of lactic acid production would require **clean, cheap sugars from lignocellulosic biomass** to compete with commodity sugar and starch substrates. There is a **lack of data about lactic acid production and purification from biomass hydrolysates, including issues of C5 sugar** utilization, although it appears work has started to address some of these issues.

# Biorefinery-concept for (1<sup>st</sup>, 2<sup>nd</sup>, 3<sup>rd</sup>...?) biomass feedstocks

## - BIOCONVERSION -



Alexandri, M.; Venus, J.: Feedstock flexibility in sustainable chemistry: Bridging sectors still not sufficiently familiar with each other-Showcases of ongoing and emerging initiatives. *Current Opinion in Green and Sustainable Chemistry* 2017, 8:24–29

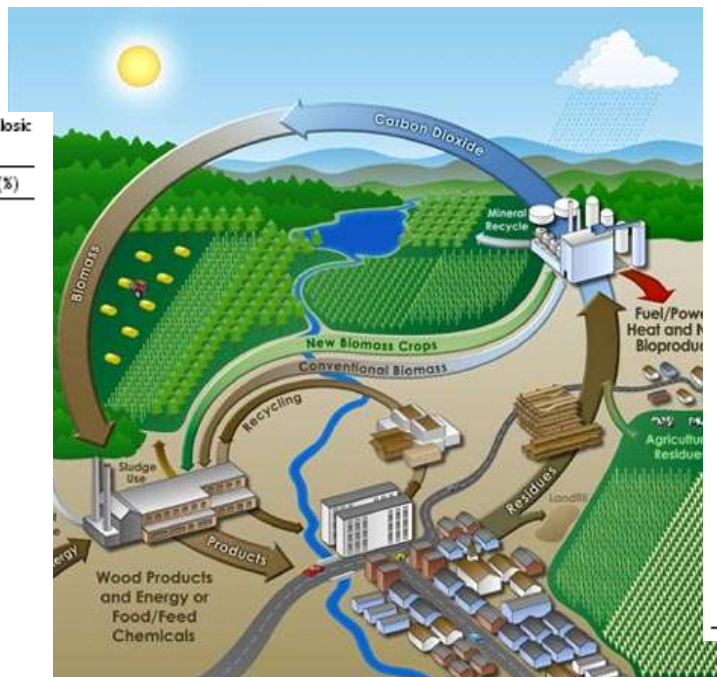
Venus, J.; Fiore, S.; Demichelis, F.; Pleissner, D.: Centralized and decentralized utilization of organic residues for lactic acid production. *Journal of Cleaner Production* 172 (2018) 778-785

# (Different) Composition & Behaviour of (lignocellulosic) Biomass

The contents of cellulose, hemicellulose, and lignin in various types of lignocellulosic biomass (% dry weight)<sup>a</sup>

Lignocellulosic materials	Cellulose (%)	Hemicellulose (%)	Lignin (%)
Algae (green)	20-40	20-50	NA <sup>b</sup>
Aspen hardwood	51	29	16
Birch Hardwood	40	39	21
Chemical pulps	60-80	20-30	2-10
Coastal Bermuda grass	25	35.7	6.4
Corn cobs	45	35	15
Cornstalks	39-47	26-31	3-5
Cotton seed hairs	80-95	5-20	0
Cotton, flax, etc.	80-95	5-20	NA <sup>b</sup>
Grasses	25-40	25-50	10-30
Hardwood	45 ± 2	30 ± 5	20 ± 4
Hardwood barks	22-40	20-38	30-55
Hardwood stems	40-55	24-40	18-25
Leaves	15-20	80-85	0
Newspaper	40-55	25-40	18-30
Nut shells	25-30	25-30	30-40
Paper	85-99	0	0-15
Pine softwood	44	26	29
Primary wastewater solids	8-15	NA <sup>b</sup>	24-29
Softwood	42 ± 2	27 ± 2	28 ± 3
Softwood barks	18-38	15-33	30-60
Softwood stems	45-50	25-35	25-35
Solid cattle manure	1.6-4.7	1.4-3.3	2.7-5.7
Sorted refuse	60	20	20
Spruce softwood	43	26	29
Swine waste	6.0	28	NA <sup>b</sup>
Switch grass	45	31.4	12.0
Waste papers from chemical pulps	60-70	10-20	5-10
Wheat straw	37-41	27-32	13-15
Willow Hardwood	37	23	21

M.A. Abdel-Rahman et al.  
Journal of Biotechnology 156 (2011) 286-301



Composition of representative lignocellulosic feedstocks.

Feedstocks	Carbohydrate composition (% dry wt)			References
	Cellulose	Hemicellulose	Lignin	
Barley hull	34	36	19	[12]
Barley straw	36-43	24-33	6.3-9.8	[13,14]
Bamboo	49-50	18-20	23	[15,16]
Banana waste	13	15	14	[17]
Corn cob	32.3-45.6	39.8	6.7-13.9	[18,19]
Corn stover	35.1-39.5	20.7-24.6	11.0-19.1	[20]
Cotton	85-95	5-15	0	[21]
Cotton stalk	31	11	30	[22]
Coffee pulp	33.7-36.9	44.2-47.5	15.6-19.1	[23]
Douglas fir	35-48	20-22	15-21	[24]
Eucalyptus	45-51	11-18	29	[16,25]
Hardwood stems	40-55	24-40	18-25	[26,27]
Rice straw	29.2-34.7	23-25.9	17-19	[28,29]
Rice husk	28.7-35.6	11.96-29.3	15.4-20	[30,31]
Wheat straw	35-39	22-30	12-16	[29,32]
Wheat bran	10.5-14.8	35.5-39.2	8.3-12.5	[33]
Grasses	25-40	25-50	10-30	[34,35]
Newspaper	40-55	24-39	18-30	[26]
Sugarcane bagasse	25-45	28-32	15-25	[16,36]
Sugarcane tops	35	32	14	[37]
Pine	42-49	13-25	23-29	[25]
Poplar wood	45-51	25-28	10-21	[38]
Olive tree biomass	25.2	15.8	19.1	[39]
Jute fibres	45-53	18-21	21-26	[40]
Switchgrass	35-40	25-30	15-20	[26]
Grasses	25-40	25-50	10-30	[26,27]
Winter rye	29-30	22-26	16.1	[41]
Oilseed rape	27.3	20.5	14.2	[41]
Softwood stem	45-50	24-40	18-25	[26,27]
Oat straw	31-35	20-26	10-15	[14]
Nut shells	25-30	22-28	30-40	[42]
Sorghum straw	32-35	24-27	15-21	[43,44]
Tamarind kernel powder	10-15	55-65	-	[45]
Water hyacinth	18.2-22.1	48.7-50.1	3.5-5.4	[46,47]

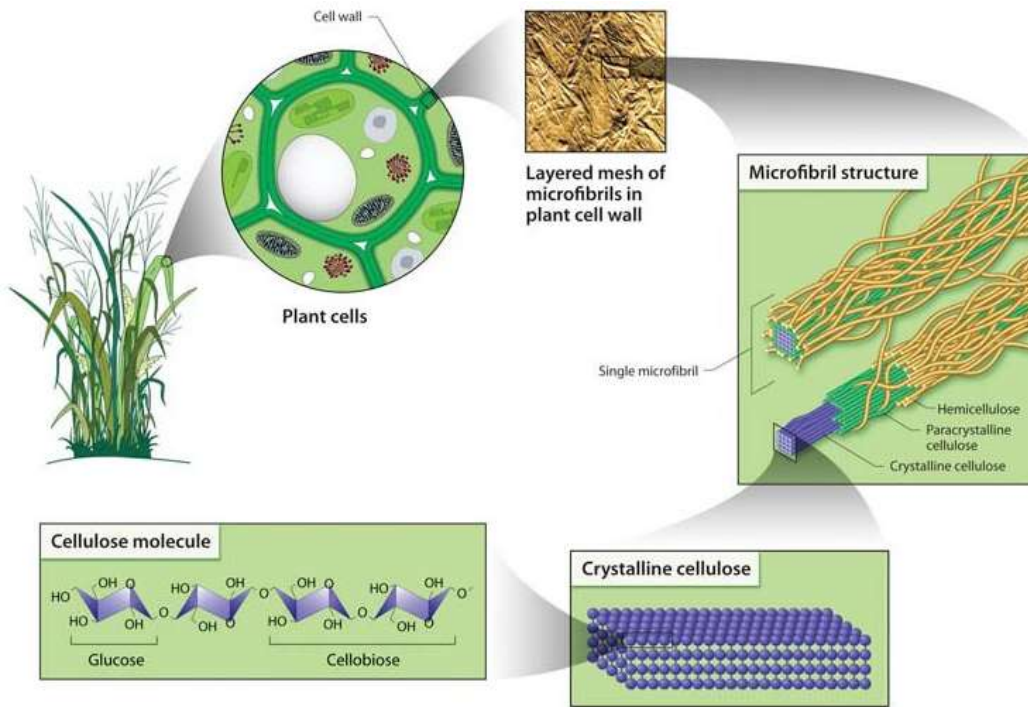
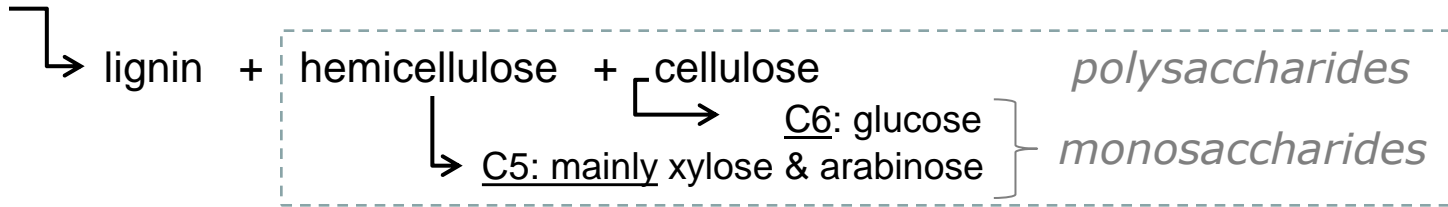
V. Menon, M. Rao  
Progress in Energy and Combustion  
Science 38 (2012) 522-550

Percent dry weight composition of lignocellulosic feedstocks

Feedstock	Glucan (cellulose)	Xylan (hemicellulose)	Lignin
Corn stover <sup>a</sup>	37.5	22.4	17.6
Corn fiber <sup>b,c</sup>	14.28	16.8	8.4
Pine wood <sup>d</sup>	46.4	8.8	29.4
Poplar <sup>d</sup>	49.9	17.4	18.1
Wheat straw <sup>d</sup>	38.2	21.2	23.4
Switch grass <sup>d</sup>	31.0	20.4	17.6
Office paper <sup>d</sup>	68.6	12.4	11.3

N. Mosier et al. / Bioresource Technology 96 (2005) 673-686

# Lignocellulose (LC)



- Complex structure, therefore highly robust
- Cellulose bound as crystalline microfibrils
- Plant cell is protected against mechanical, chemical and microbial stresses
- Problems to tackle:
  - opening up the robust structure
  - dealing with C5-sugars

## Beyond Petrochemicals: The Renewable Chemicals Industry\*\*

P. N. R. Vennestrøm, C. M. Osmundsen, C. H. Christensen, and Esben Taarning\*

Chemical	Market type	Market size (Mty <sup>-1</sup> ) <sup>[a]</sup>	Major player(s)	Feedstock
acetic acid	existing	9.0	–	ethanol
acrylic acid	existing	4.2	Arkema, Cargill/Novozymes	glycerol or glucose
C <sub>4</sub> diacids	emerging	(0.1–0.5)	BASF/Purac/CSM, Myriant	glucose
epichlorohydrin	existing	1.0	Solvay, DOW	glycerol
ethanol	existing	60	Cosan, Abengoa Bioenergy, ADM	glucose
ethylene	existing	110	Braskem, DOW/Crystalsev, Borealis	ethanol
ethylene glycol	existing	20	India Glycols, Dacheng Industrial	glucose or xylitol
glycerol	existing	1.5	ADM, P&G, Cargill	vegetable oil
5-hydroxymethylfurfural	emerging	–	–	glucose/fructose
3-hydroxypropionic acid	emerging	(≥0.5)	Novozymes/Cargill	glucose
isoprene	existing/emerging	0.1 (0.1–0.5)	Danisco/Goodyear	glucose
<b>lactic acid</b>	existing/emerging	0.3 (0.3–0.5)	Cargill, Purac/Arkema, ADM, Galactic	glucose
levulinic acid	emerging	(≥0.5)	Segetis, Maine Bioproducts, Le Calorie	glucose
oleochemicals	existing	10–15	Emery, Croda, BASF, Vantage Oleochemicals	vegetable oil/fat
1,3-propanediol	emerging	(0.1–0.5)	Dupont/Tate & Lyle	glucose
propylene	existing	80	Braskem/Novozymes	glucose
propylene glycol	existing/emerging	1.4 (≥2.0)	ADM, Cargill/Ashland, Senergy, Dacheng Industrial	glycerol or sorbitol
polyhydroxyalkanoate	emerging	(0.1–0.5)	Metabolix/ADM	glucose

[a] Market size of an existing market is given as its current size including production from fossil resources; for emerging markets the expected market size is reported in parenthesis.

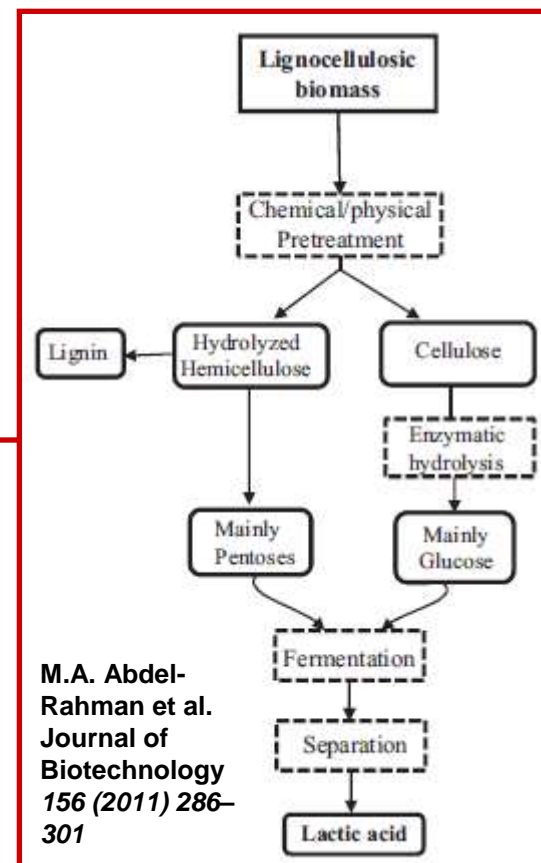
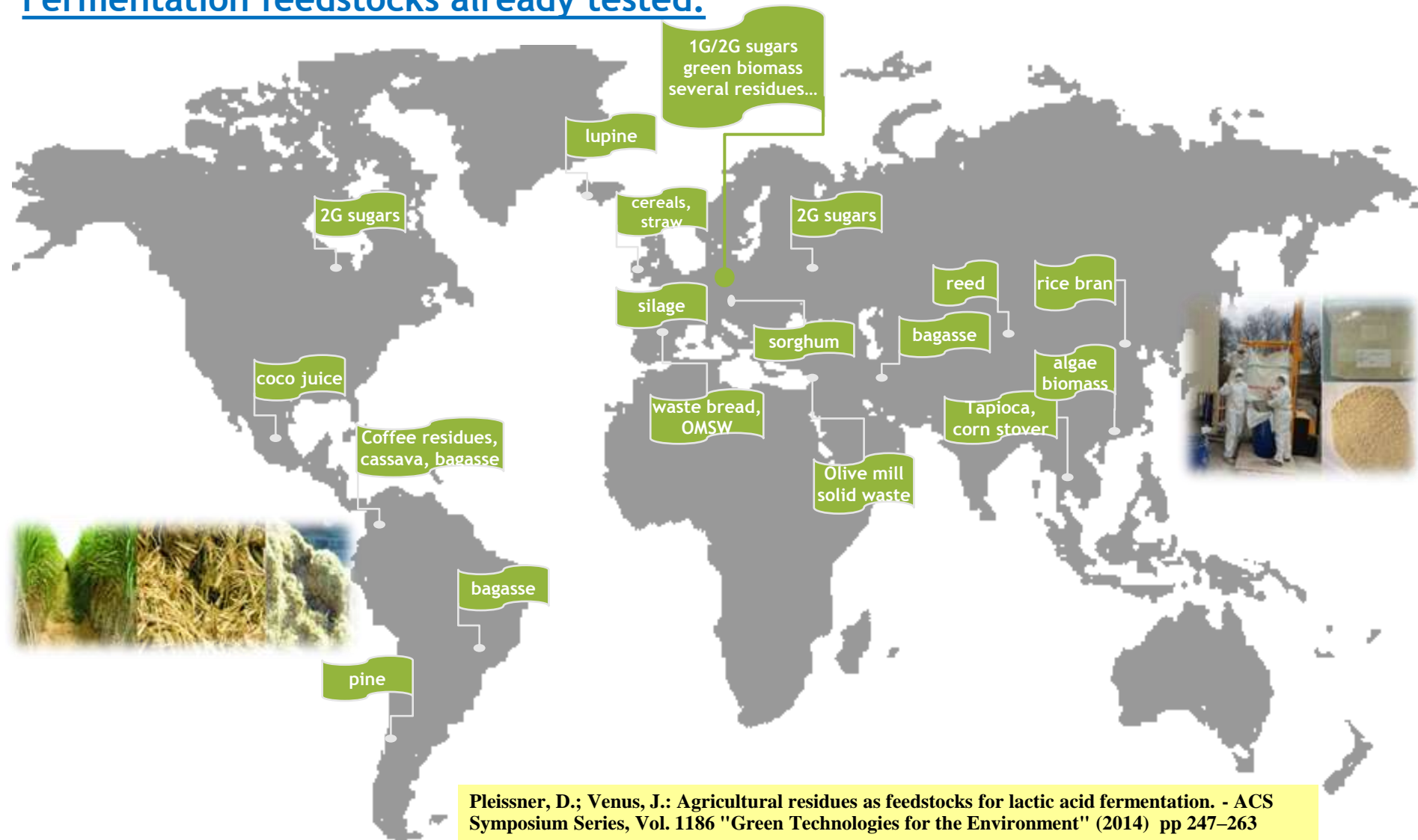


Table 1: Overview of chemicals that are currently produced, or could be produced, from biomass together with their respective market type, size of the market, and potential biomass feedstock. Major players involved are also given.

## Fermentation feedstocks already tested:



Pleissner, D.; Venus, J.: Agricultural residues as feedstocks for lactic acid fermentation. - ACS Symposium Series, Vol. 1186 "Green Technologies for the Environment" (2014) pp 247–263

- Starchy materials (cereals, industrial grade corn/potatoe starch, tapioca)
- Green biomass (alfalfa, grass juice, lupine, sweet sorghum, forage rye, silage, coco juice)
- Lignocellulosics (wood/straw hydrolysates, 2<sup>nd</sup>G sugars, bagasse, reed)
- Residues & By-products (oilseed cake/meal, thick juice, molasses, whey, coffee residues, waste bread, waffle residues, algae biomass, fruit residues, rice bran, meat & bone meal, OMSW, AD digestates, corn stover...)

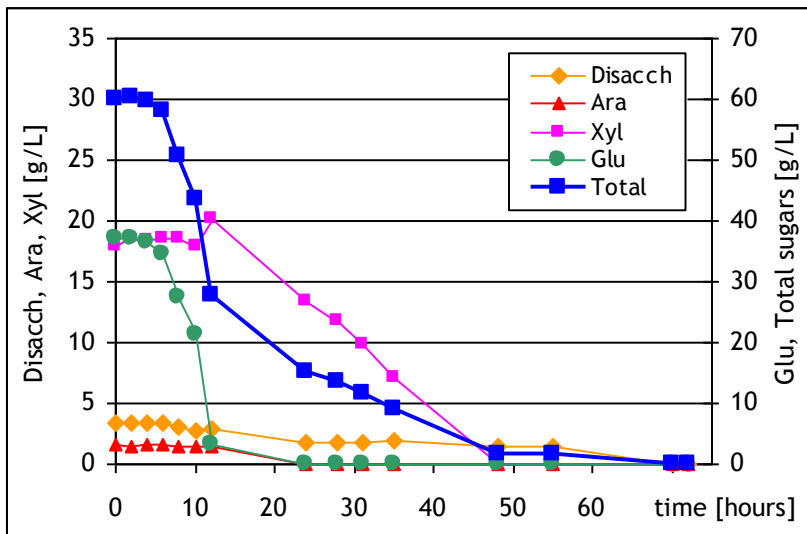
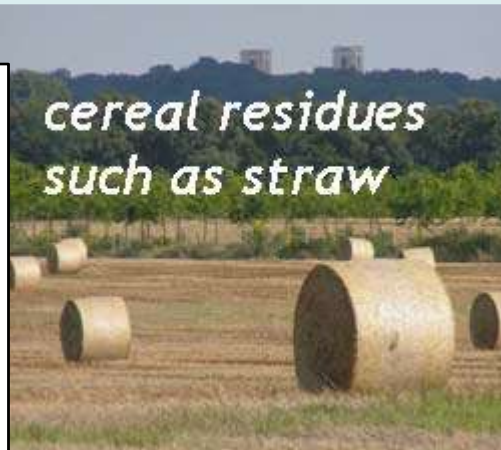
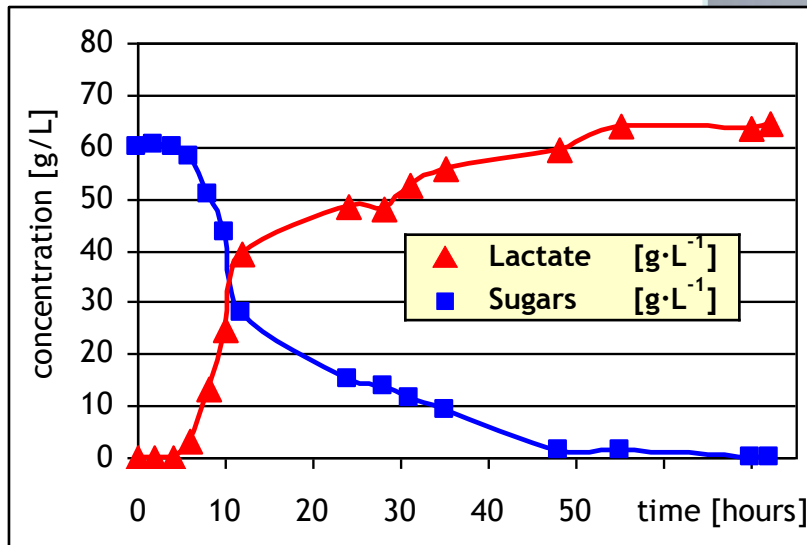
# The processes for producing lactic acid from biomass/residues include the following 4 main steps:

- (1) **Pretreatment - breaking down the structure of the feedstock matrix**
- (2) Enzymatic hydrolysis - depolymerizing biopolymers like starch, cellulose etc. to fermentative sugars, such as glucose (C6) and xylose (C5), by means of hydrolytic enzymes
- (3) Fermentation - metabolizing the sugars to lactic acid, generally by LAB
- (4) **Separation and purification of lactic acid - purification of lactic acid to meet the standards of commercial applications**



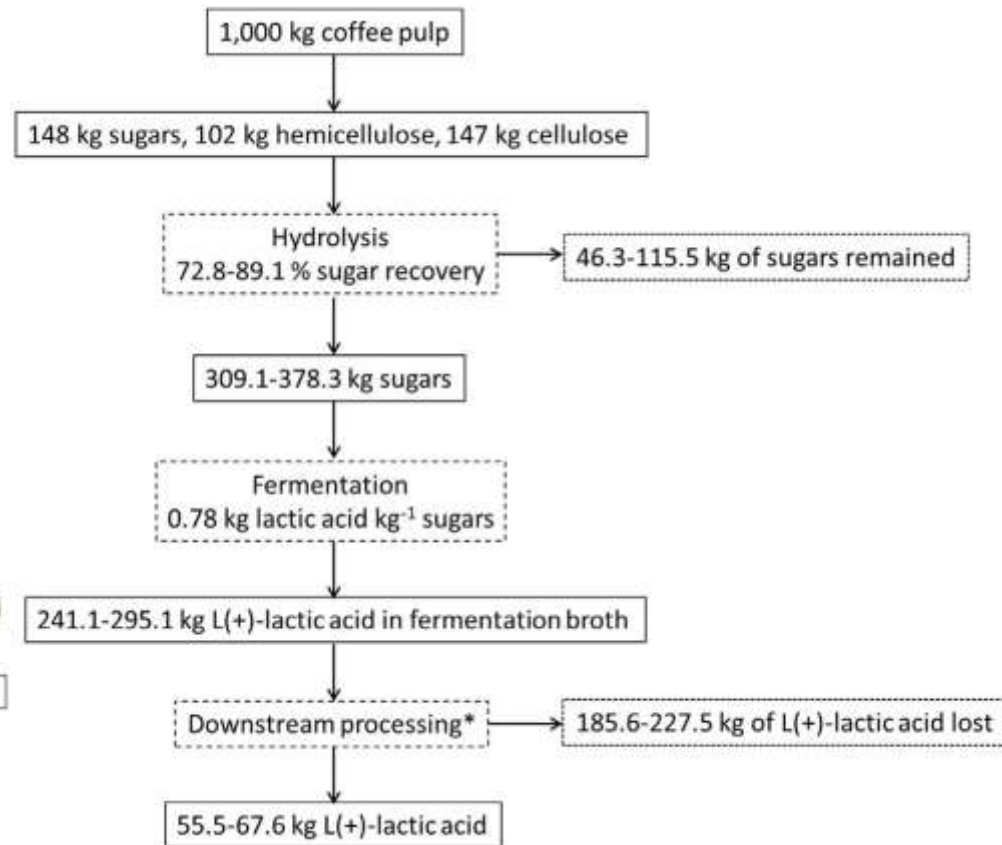
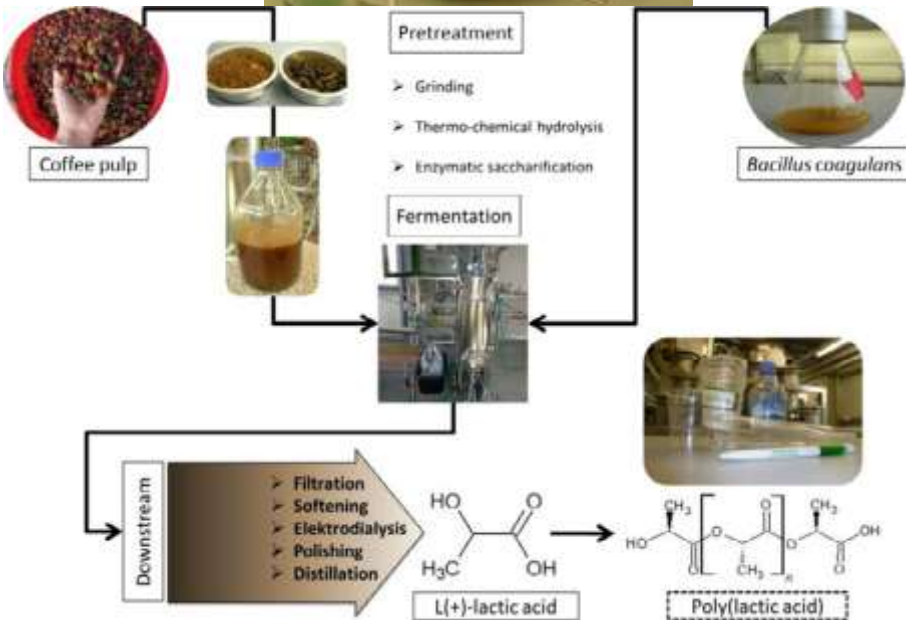
Pilot plant facility for lactic acid fermentation at Leibniz Institute for Agricultural Engineering and Bioeconomy (ATB Potsdam)

# Example wheat straw: Sugar uptake & product formation



- Fermentation ended after 50-60 hours with a yield of nearly 100% and 64 g/L (top left)
- (Total) Sugars (firstly Glucose followed by Arabinose/Xylose with residues of Disaccharides) have been used completely in the same time (bottom left)
- (Max) Lactate productivity ( $>5 \text{ g}\cdot\text{L}^{-1}\cdot\text{h}^{-1}$ ) is much higher than comparable published results [Li/Cui: Microbial Lactic Acid Production from Renewable Resources, pp. 211-228. In O.V. Singh and S.P. Harvey (Eds.), Sustainable Biotechnology - Sources of Renewable Energy. Springer, 2010]

# Example coffee residues: residues from the coffee production



Mass balance from coffee pulp to lactic acid (\*downstream processing was not optimized). All figures are based on dry weight.

Pleissner, D.; Neu, A.-K.; Mehlmann, K.; Schneider, R.; Puerta-Quintero, G.I.; Venus, J.: Fermentative lactic acid production from coffee pulp hydrolysate using *Bacillus coagulans* at laboratory and pilot scales. *Bioresource Technology* 218 (2016) 167–173

# BranLact



## ● Thermophilic lactic acid production utilizing defatted rice bran in continuous cultivation

- *Funded by PtJ/BMBF (2016 - 2019)*
- *Partner: Beijing University of Chemical Technology*

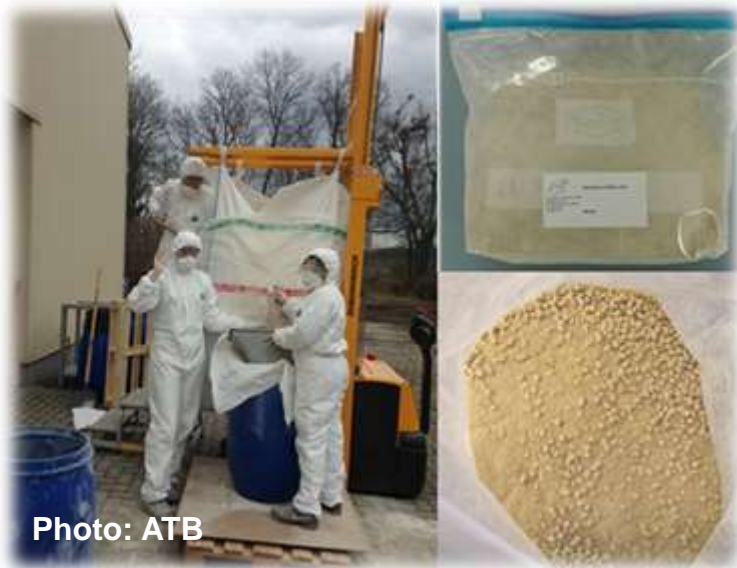
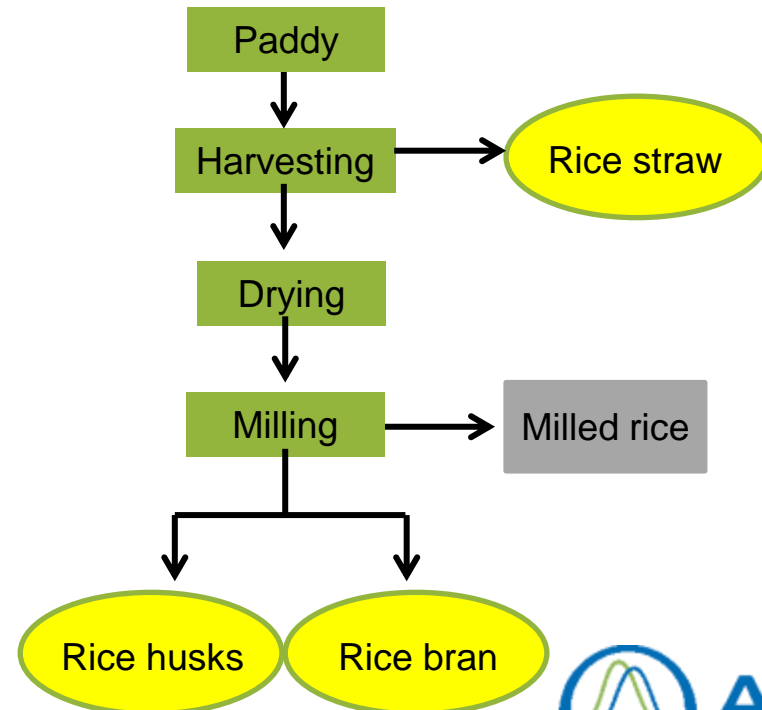


Photo: ATB



# Flow diagram of the followed process

**Defatted Rice Bran**

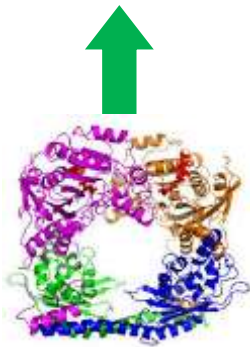


Starch: 35.3%,  
Fat: 3.0%,  
Protein: 17.3%,  
Cellulose: 9.8%,  
Hemicell: 20.6%,  
Lignin: 3.9%

**Upstream Processing**

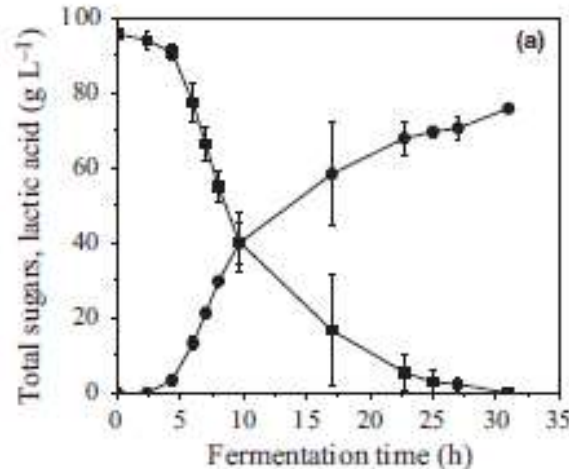


**Enzymatic Hydrolysis**



**Addition of amylases, glucoamylase and protease**

**Fermentation**



**Downstream processing**

Microfiltration  
Softening  
Mono-, Bipolar-  
Electrodialysis  
Ion-exchange  
chromatography  
Decolorisation  
Evaporation

**Lactic acid production**



**Screening of different thermophilic strains**



**Selection of the suitable strain**



# Biosurfactant production by Yeasts using sugarcane bagasse for solid state fermentation



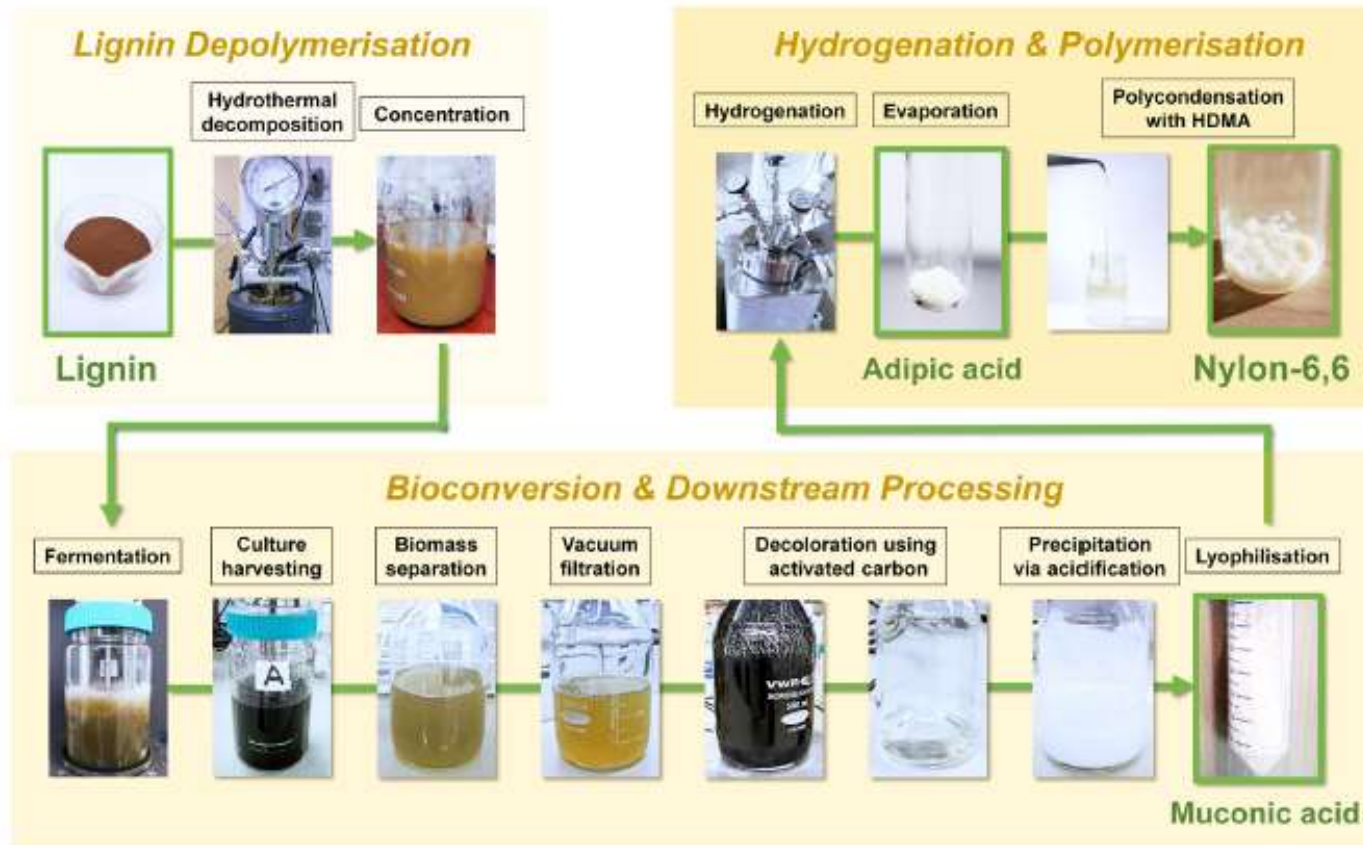
UNIVERSITY OF SÃO PAULO;  
DEPARTMENT OF BIOTECHNOLOGY  
SCHOOL OF ENGINEERING OF LORENA

Brumano, L.P.; Antunes, F.A.F.; Galeno Souto S.; dos Santos, J.C.; Venus, J.; Schneider, R.; da Silva, S.S.: Biosurfactant production by *Aureobasidium pullulans* in stirred tank bioreactor: new approach to understand the influence of important variables in the process. *Bioresource Technology* (2017) 243: 264–272



## From lignin to nylon: Cascaded chemical and biochemical conversion using metabolically engineered *Pseudomonas putida*

Michael Kohlstedt<sup>a</sup>, Sören Starck<sup>a</sup>, Nadja Barton<sup>a</sup>, Jessica Stolzenberger<sup>a</sup>, Mirjam Selzer<sup>a</sup>, Kerstin Mehlmann<sup>c</sup>, Roland Schneider<sup>c</sup>, Daniel Pleissner<sup>c,d</sup>, Jan Rinkel<sup>b</sup>, Jeroen S. Dickschat<sup>b</sup>, Joachim Venus<sup>c</sup>, Jozef B.J.H. van Duuren<sup>a</sup>, Christoph Wittmann<sup>a,\*</sup>



### Demonstration of the value chain from lignin to nylon.

The cascaded process comprised hydrothermal depolymerization of lignin to a mixture of aromatics, containing mainly catechol, phenol and small amounts of cresols; biochemical conversion of the aromatics to cis,cis-muonic acid by the advanced producer *Pseudomonas putida* KT2440 MA-9; purification of cis,cis-muonic acid; hydrogenation to adipic acid; and final polymerization to nylon 6,6.

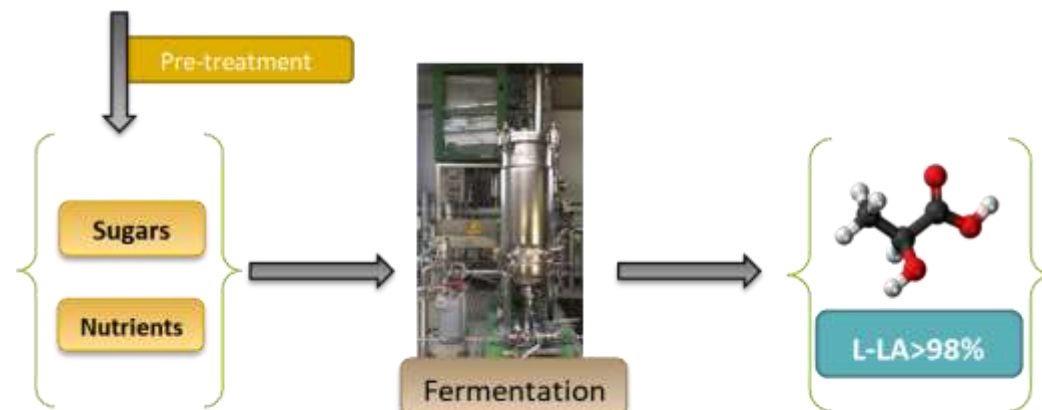
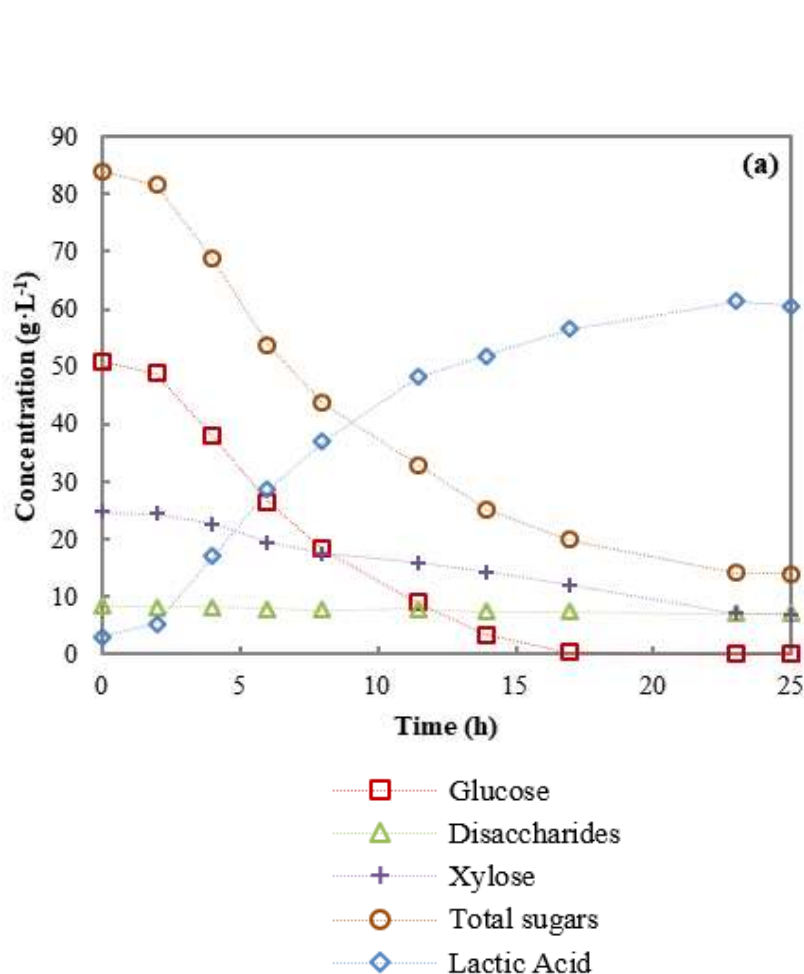
# CHEMICAL BUILDING BLOCKS FROM VERSATILE MSW BIOREFINERY



PERCAL will exploit Municipal Solid Waste (MSW) as feedstock to develop intermediate chemical products at high yield and low impurity level with huge industrial interest. These will be complementary to the bioethanol, to achieve a cascade valorisation of the MSW components, i.e.:

- **Lactic acid (LA)** to produce: 1) Eco-friendly ethyl lactate solvents by reactive distillation from lactic acid & bio-ethanol to be used in cleaning products and inks and 2) hot-melt adhesives for cardboard and other non-food applications in combination with maleic anhydride by reactive extrusion.
- **Succinic acid (SA)** as an intermediate building blocks to production of polyols for the polyurethane industry.
- **Biosurfactants** by chemical and/or microbiological modification of protein and lipid fraction from remaining fraction of MSW fermentation.

# Pilot scale experiments...



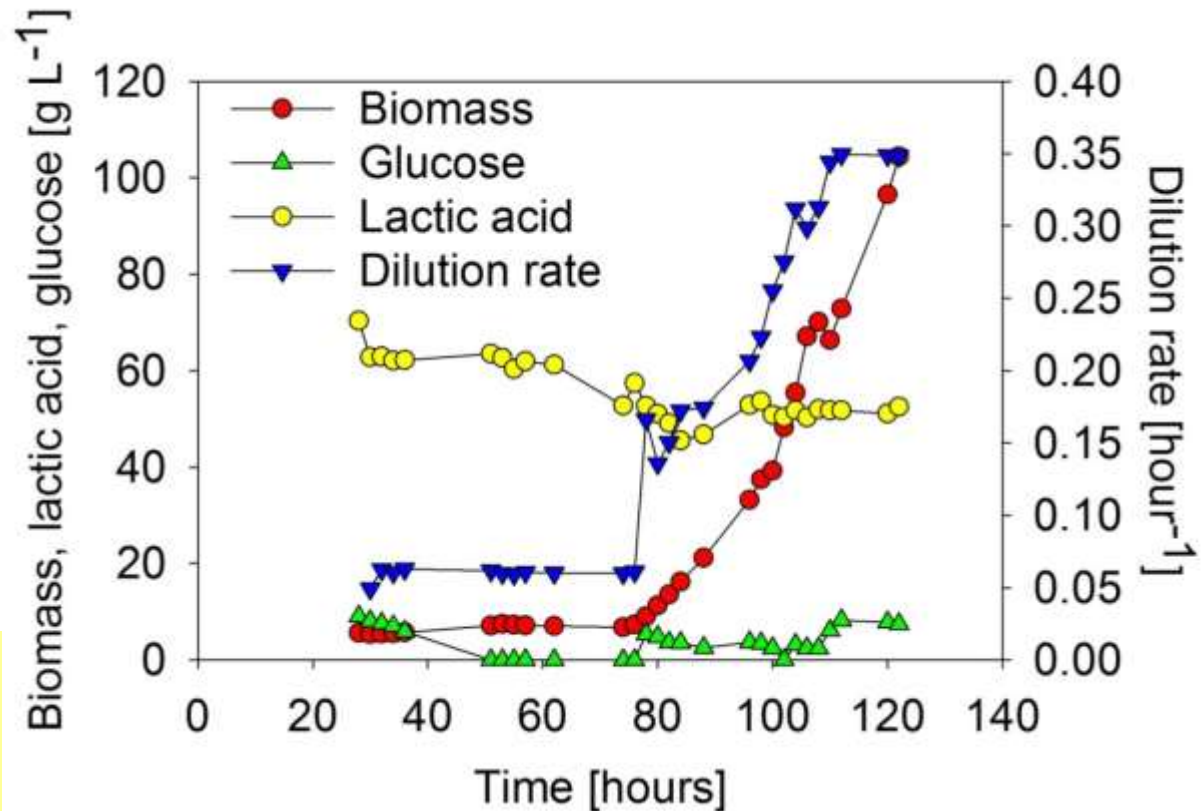
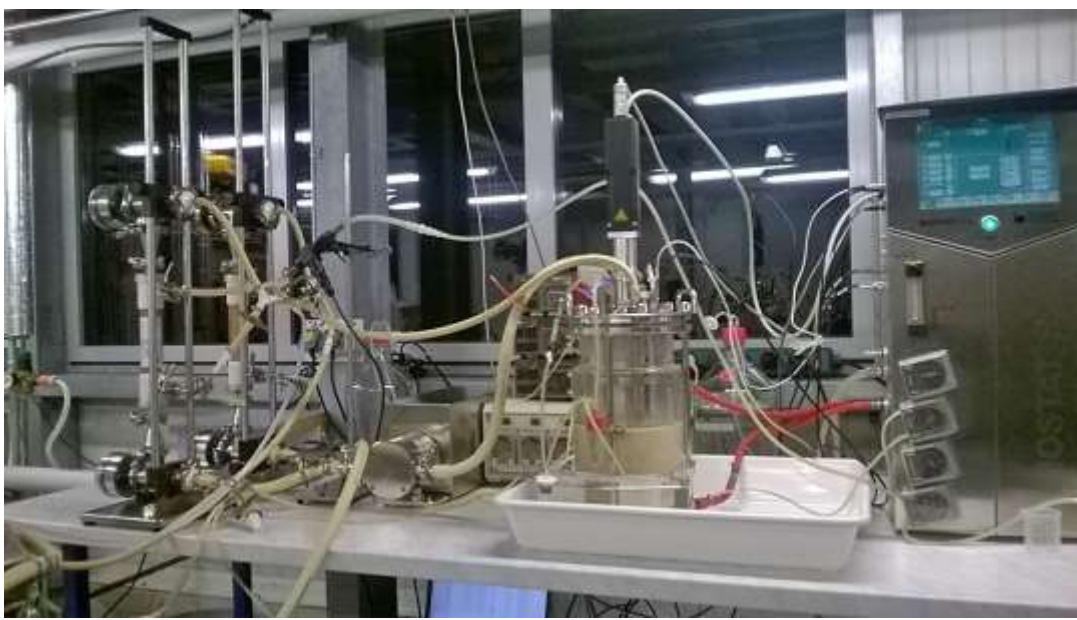
✓ Yield of **0.94 g/g**

✓ Final LA concentration of **61.1 g/L**

✓ Max optical purity of **98.5%** L-LA

López Gómez, J.P.; Latorre-Sánchez, M.; Unger, P.; Schneider, R.; Lozano, C.C.; Venus, J.: Assessing the organic fraction of municipal solid wastes for the production of lactic acid, *Biochemical Engineering Journal* 150 (2019), 107251, <https://doi.org/10.1016/j.bej.2019.107251>

# Continuous mode fermentation with cell retention by hollow fibre membranes



Pleissner, D.; Qi, Q.; Gao, C.; Perez Rivero, C.; Webb, C.; Lin, C.S.K.; Venus, J.: Valorization of organic residues for the production of added value chemicals: A contribution to the bio-based economy. *Biochemical Engineering Journal* 116 (2016) 3-16

## Review

## A review on the current developments in continuous lactic acid fermentations and case studies utilising inexpensive raw materials

José Pablo López-Gómez, María Alexandri, Roland Schneider, Joachim Venus\*

 Process Biochemistry 79 (2019) 1-10,  
<https://doi.org/10.1016/j.procbio.2018.12.012>
**Table 4**

Compositional analysis of the substrates utilized in the case studies.

Substrate	Glucose (g l <sup>-1</sup> )	Disaccharide (g l <sup>-1</sup> )	Fructose/ Galactose (g l <sup>-1</sup> )	Lactic acid (g l <sup>-1</sup> )	Dry matter (%)	N <sub>org</sub> (mg l <sup>-1</sup> )	PO <sub>4</sub> <sup>3-</sup> (mg l <sup>-1</sup> )	SO <sub>4</sub> <sup>2-</sup> (mg l <sup>-1</sup> )	NH <sub>4</sub> <sup>+</sup> (mg l <sup>-1</sup> )
Tapioca hydrolysate <sup>a</sup>	139.0	3.5 <sup>b</sup>	n.d.	n.d.	13.7	113.0	6.0	36.1	0.0
Acid whey <sup>c</sup>	n.d.	258 <sup>d</sup>	n.d.	n.d.	26.0	2288.0	683.0	2687.0	159.0
Molasses	56.6	505.0 <sup>e</sup>	17.0 <sup>f</sup>	29.7	84.8	-	23.1	7177.0	150.0
Rapeseed meal hydrolysate <sup>g</sup>	5.4	1.7 <sup>h</sup>	4.7 <sup>i</sup>	n.d.	4.7	-	291.0	562.1	159.6

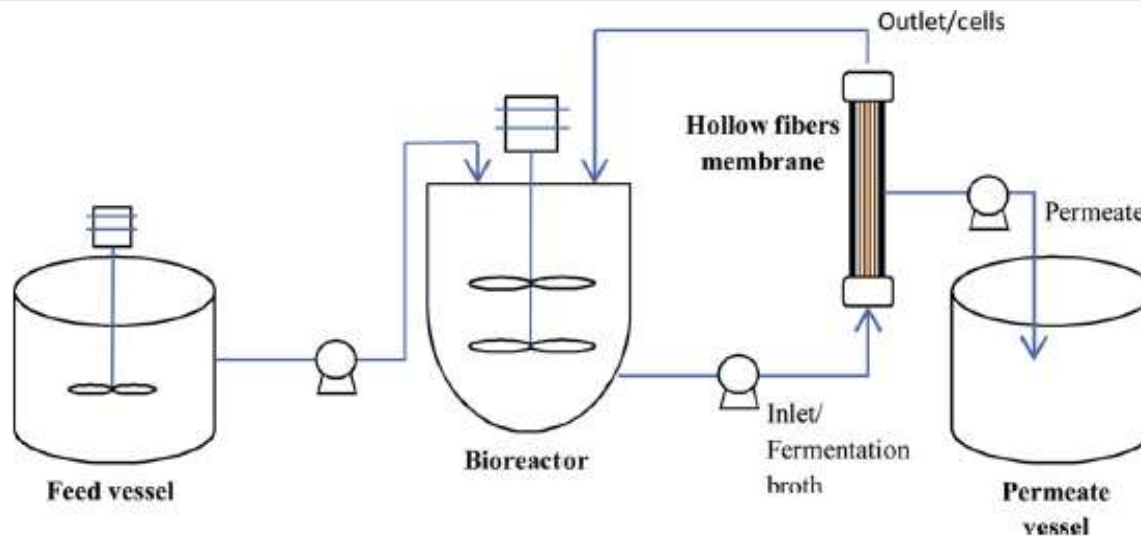


Fig. 1. Schematic representation of hollow fibers membrane-integrated bioreactor system for cell-recycle continuous production of lactic acid.

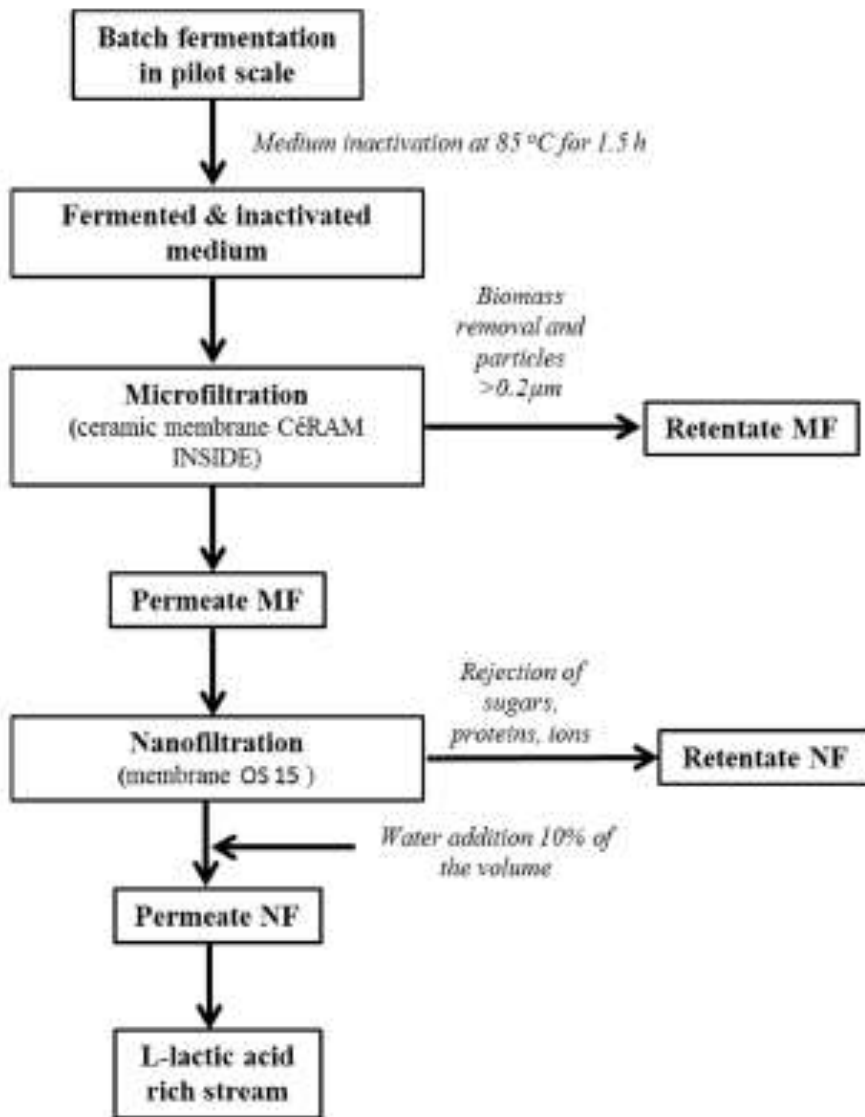


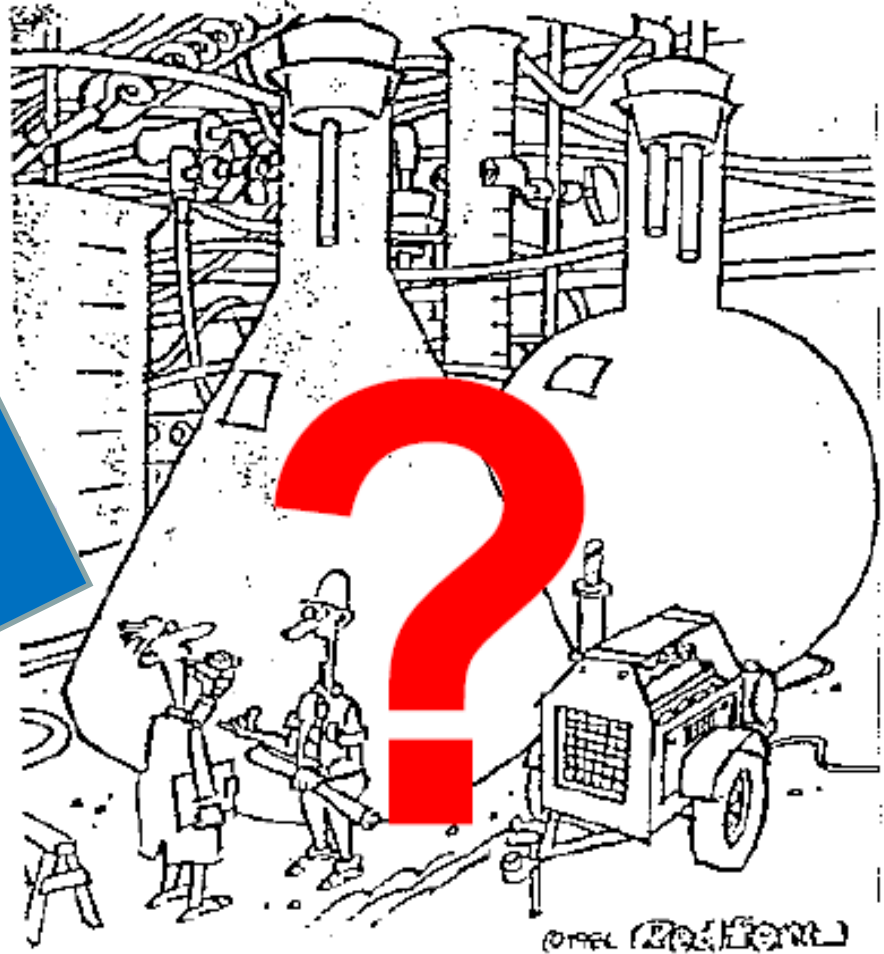
Figure 1. Schematic diagram of the studied process.



# Scale-up of bioprocesses



Process development  
up to  
 $xx \text{ m}^3$  ??



*"Got a few problems going from lab scale up to full-scale commercial."*

## The Copenhagen Declaration for a Bioeconomy in Action

...

9. The conference also underlined the **need for new pilot and demonstration plants and scaling up facilities, in particularly biorefineries**. It was stressed, that the development of these facilities requires smart integration of various funding sources, including the Common Agricultural Policy, the Common Fisheries Policy, the Cohesion Policy, the Renewable Energy Policy, Horizon 2020, and private investments.

...

*Copenhagen conference "Bioeconomy in Action"  
on 26 March - 28 March 2012*

**Universities, Research**

**Institutes, SMEs**

Applied &  
basic research

„Valley of death“

**Industry**

Industrial application  
Large-scale production



# Pilot plant facility

- **pilot facility for production of lactic acid** at the ATB consequently fills a gap in the various phases of bioprocess engineering
- **provision of product samples** is intended to open up the possibility of interesting **partners in industry with specific product requirements** in various applications



scale up

BIostat® Bplus (Sartorius BBI Systems GmbH, Germany) equipped with a digital control unit DCU for the continuous fermentation with cell recycling



Pilot fermentor Type P, 450 L (Bioengineering AG)

Venus, J.; Richter, K.: Development of a Pilot Plant Facility for the Conversion of Renewables in Bio-technological Processes. Eng. Life Sci. 2007, 7, No. 4, 395-402  
Pleissner, D.; Dietz, D.; van Duuren, J.B.J.H.; Wittmann, C.; Yang, X.; Lin, C.S.K.; Venus, J.: Biotechnological production of organic acids from renewable resources. Advances in Biochemical Engineering/Biotechnology 166 (2019) pp. 373-410

# Pilot plant facility for bioprocess development & scale-up at ATB Potsdam



# Pilot fermentor Type P, 450 L (Bioengineering AG)



**BIOSCREEN**

**Bioprocess Scale-up**



**BIOSTAT® Bplus (1-10 L)**



**Biostat® UD (50 L)**



**6-fold parallel lab scale fermentor system ELOFORM**



# Thank you for your attention!



More information: [www.atb-potsdam.de](http://www.atb-potsdam.de)

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<http://www2.atb-potsdam.de/atb-jab-2016-flipbook/atb-jab-2016.html>

