ATB
Leibniz-Institut für
Agrartechnik und Bioökonomie

Lignocellulosic Biomass and Residues as Potential Substrates for the Industrial Biotechnology

J. Venus

5th Latin American Congress on
Biorefineries
From laboratory to industrial practice
January 7-9, 2019 - Concepción, Chile

Leibniz-Gemeinschaft

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

Leibniz-Gemeinschaft

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.

Leibniz-Gemeinschaft

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

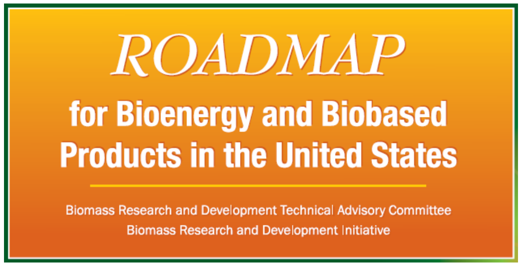
Energetic use

(Biogas, wood pellets, biochar)

Valorization of residues, sidestreams etc.

Biotechnological

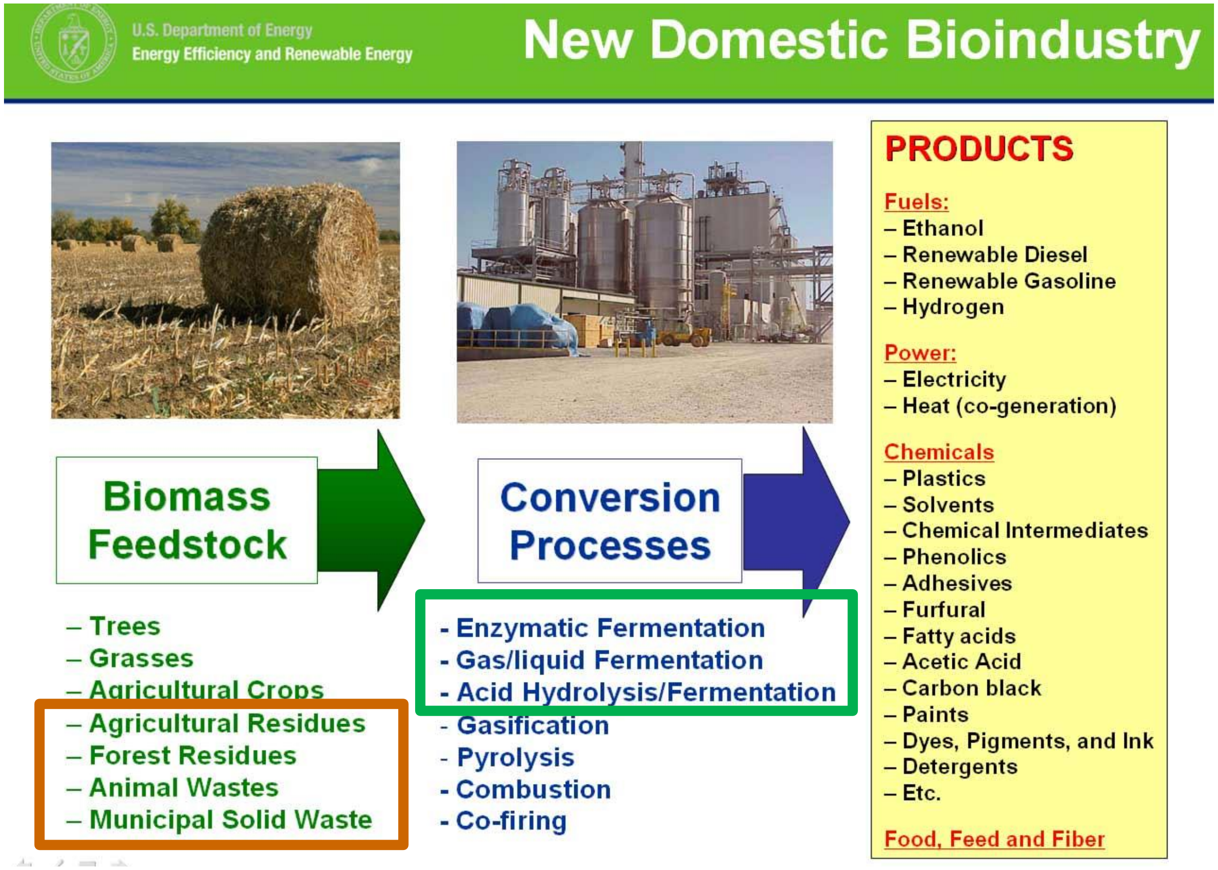
Biomass conversion into high-value chemical products and fuels



ROADMAP

for Bioenergy and Biobased Products in the United States

Biomass Research and Development Technical Advisory Committee
Biomass Research and Development Initiative



U.S. Department of Energy
Energy Efficiency and Renewable Energy

New Domestic Bioindustry

Biomass Feedstock

- Trees
- Grasses
- Agricultural Crops
- Agricultural Residues
- Forest Residues
- Animal Wastes
- Municipal Solid Waste

Conversion Processes

- Enzymatic Fermentation
- Gas/liquid Fermentation
- Acid Hydrolysis/Fermentation
- Gasification
- Pyrolysis
- Combustion
- Co-firing

PRODUCTS

Fuels:
- Ethanol
- Renewable Diesel
- Renewable Gasoline
- Hydrogen

Power:
- Electricity
- Heat (co-generation)

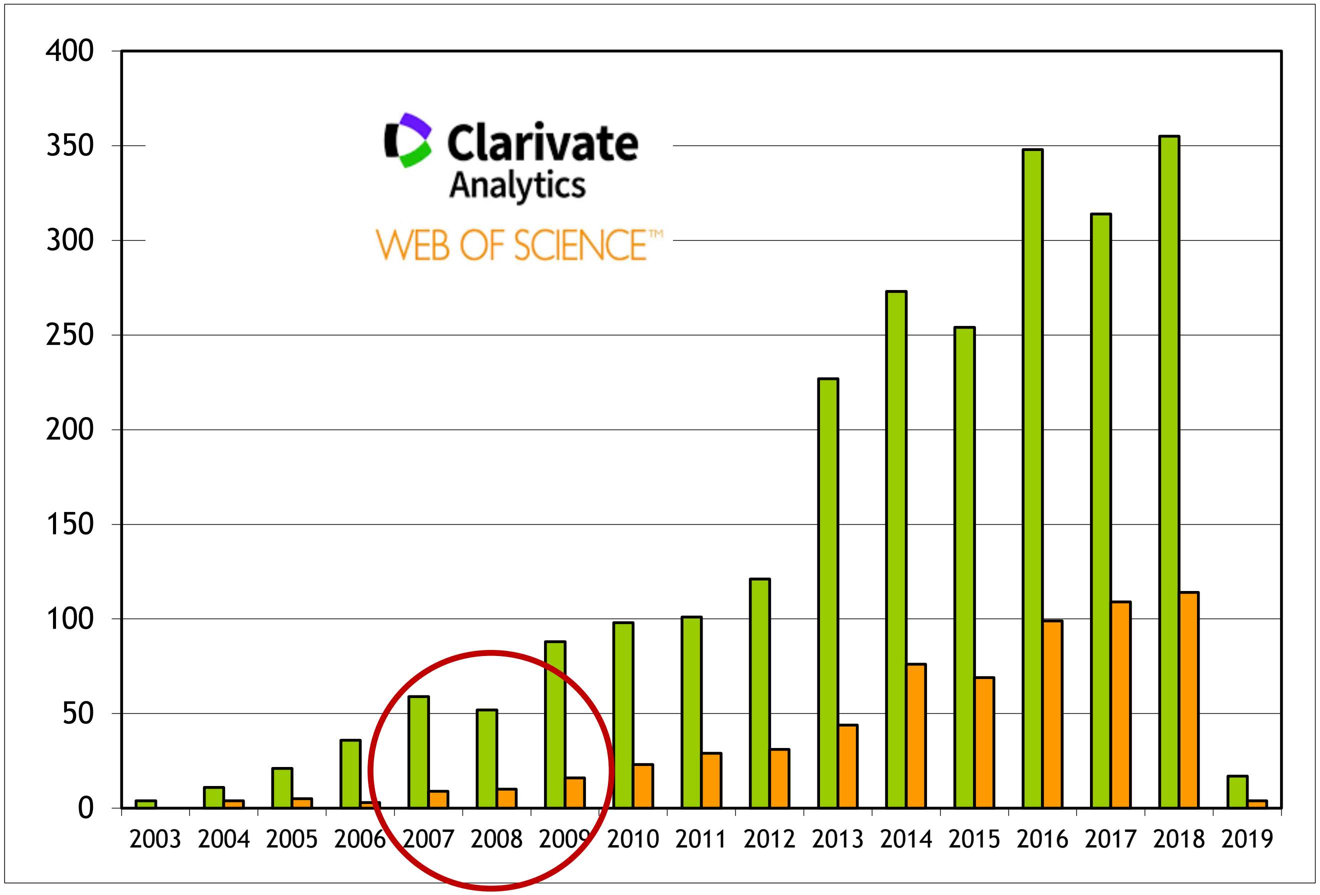
Chemicals
- Plastics
- Solvents
- Chemical Intermediates
- Phenolics
- Adhesives
- Furfural
- Fatty acids
- Acetic Acid
- Carbon black
- Paints
- Dyes, Pigments, and Ink
- Detergents
- Etc.

Food, Feed and Fiber

Biorefineries in theory would use multiple forms of biomass to produce a flexible mix of products, including fuels, power, heat, chemicals and materials. In a biorefinery, biomass would be converted into high-value chemical products and fuels (both gas and liquid). Byproducts and residues, as well as some portion of the fuels produced, would be used to fuel on-site power generation or cogeneration facilities producing heat and power.

(lignocellulosic) biorefineries in the scientific community[#]

Biorefineries are classified based on, technological (implementation) status, type of raw materials used or main type of conversion processes applied. A search of the literature revealed a variety of terms describing **Biorefineries**



[#] **08.01.19: 2.414 records Title=(bioref*) OR Title=(bio-ref*); 645 AND (lignocell*)**

Conventional Biorefineries	1st, 2nd, and 3rd Generation Biorefineries
Whole Crop Biorefineries	Thermochemical Biorefineries
Advanced Biorefineries	Lignocellulosic Feedstock Biorefineries
Marine Biorefineries	Two Platform Concept Biorefineries
Green Biorefineries	**[IEA Bioenergy:T42:2009:01]**

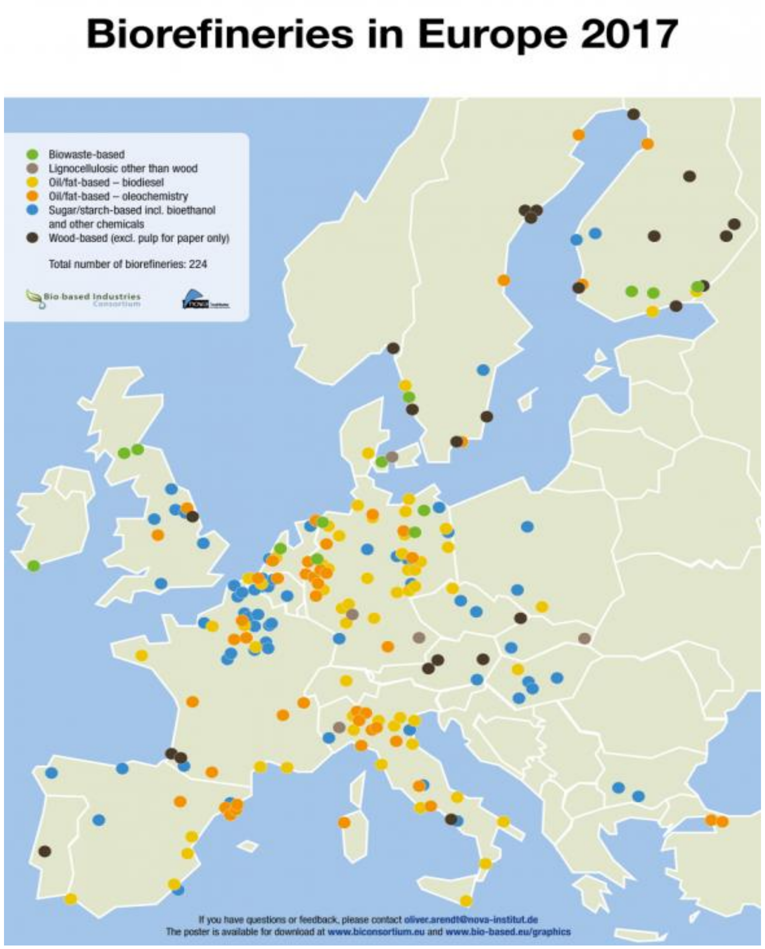
27 November 2017

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).

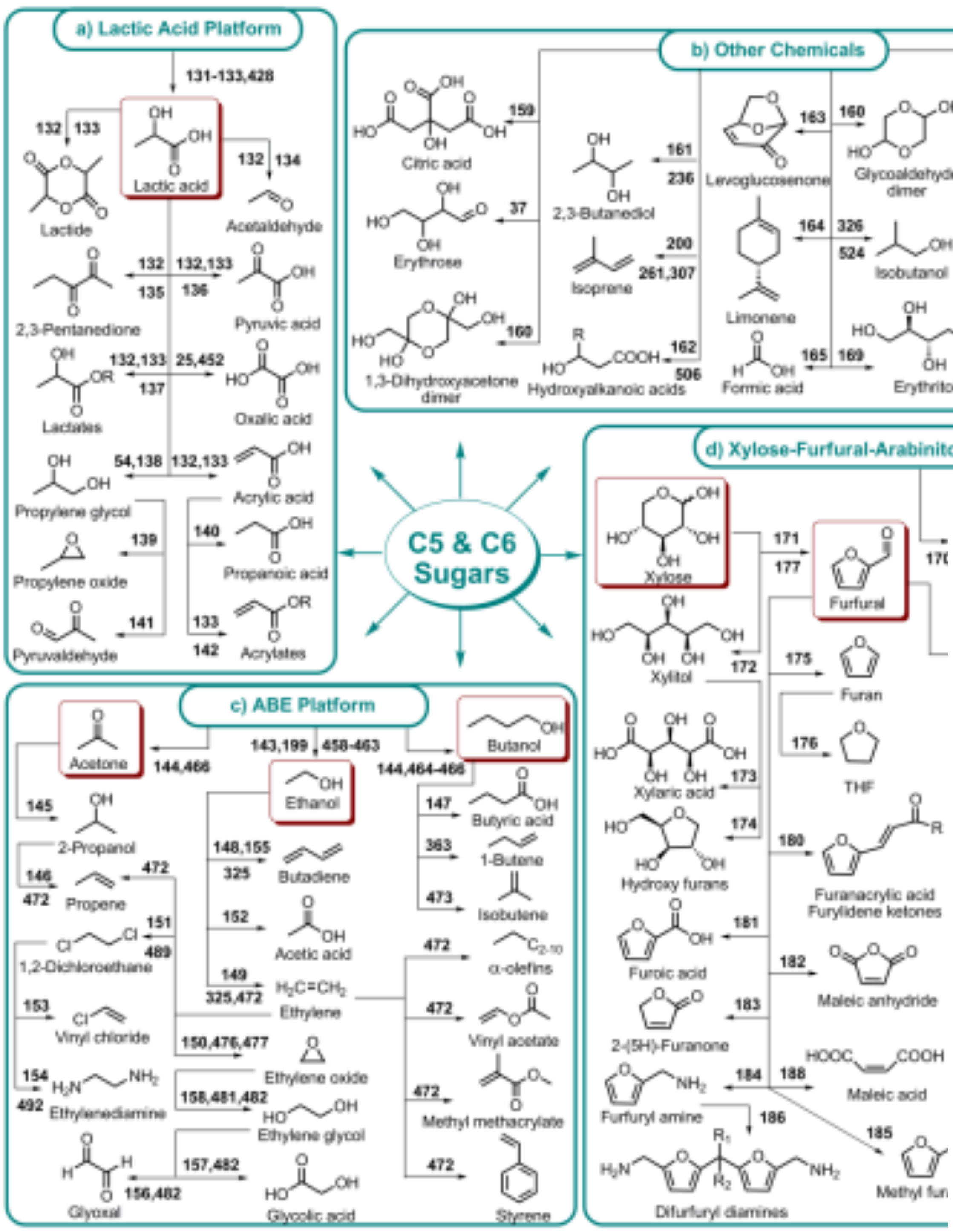
The prevalence of biorefineries differs considerably between countries. The type of biorefinery is clearly dependent on the locally available biomass. Wood-based biorefineries can be found mainly in Northern Europe and “Sugar-/starch based biorefineries” mainly in France, Belgium, Germany and Hungary,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



The map can be downloaded for free at www.bio-based.eu/graphics or www.biconsortium.eu

www.bio-based.eu

ATB

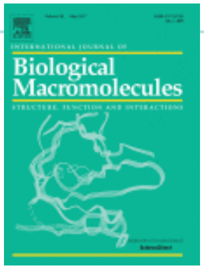


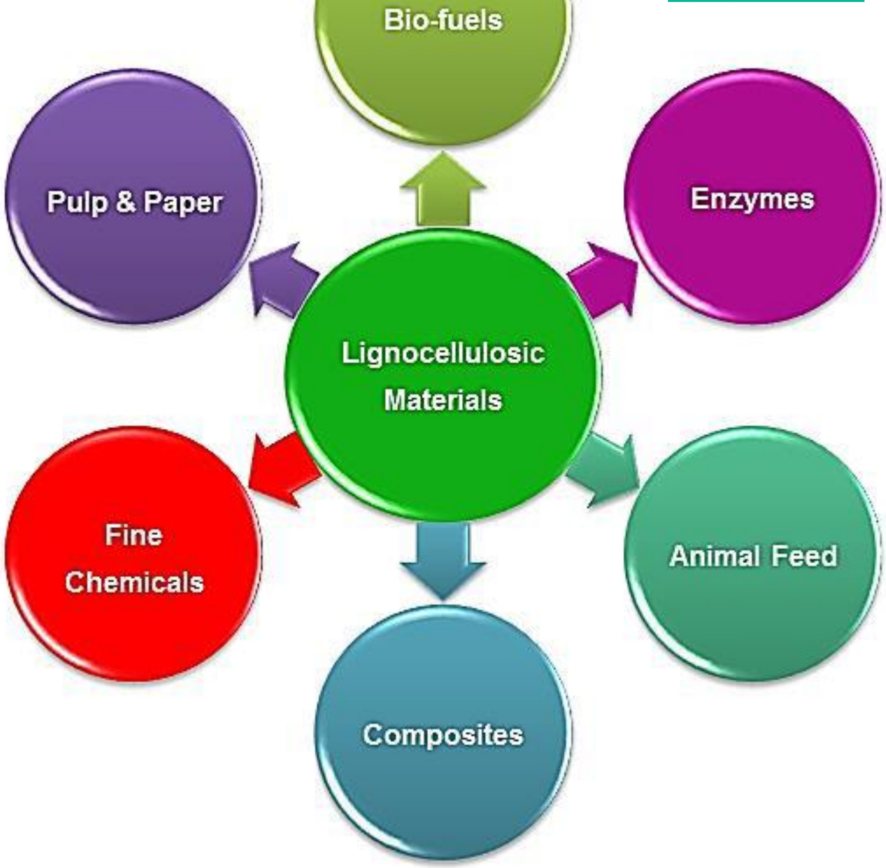
International Journal of Biological Macromolecules
Volume 98, May 2017, Pages 447–458

Review

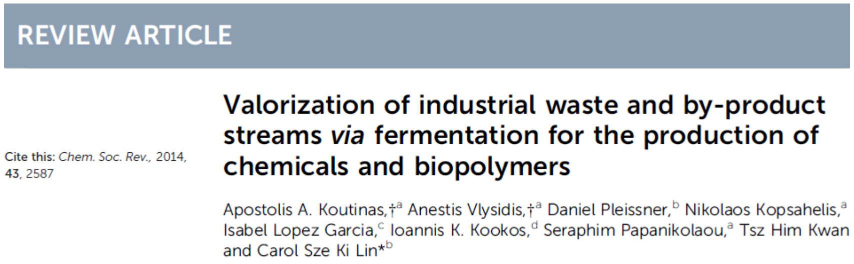
Biotransformation of lignocellulosic materials into value-added products—A review

M. Bilal, M. Asgher, H.M.N. Iqbal, H. Hu, X. Zhang





Building blocks that could be produced via fermentation



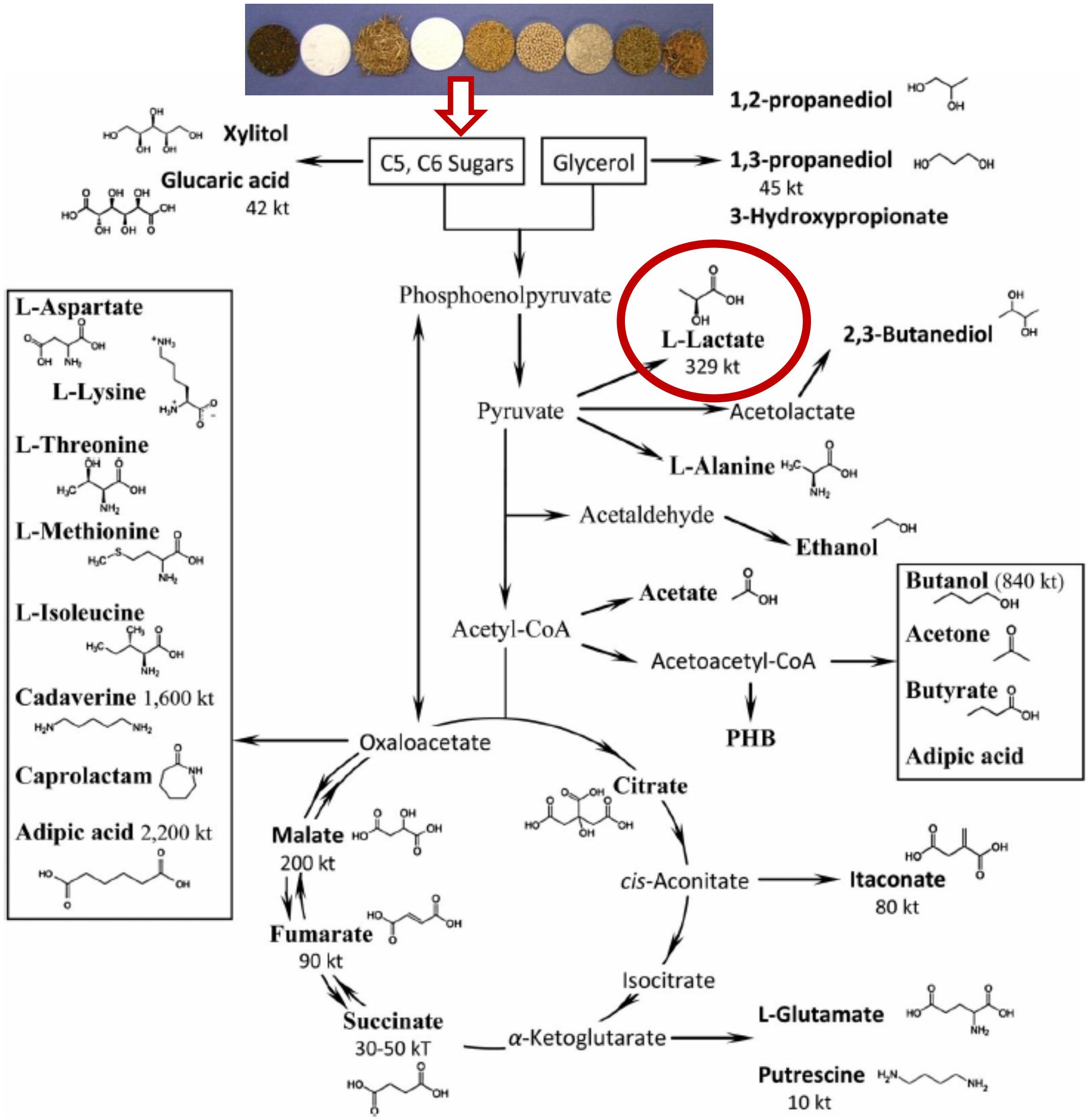
REVIEW ARTICLE

Cite this: *Chem. Soc. Rev.*, 2014, **43**, 2587

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

Apostolis A. Koutinas,†[a] Anestis Vlysidis,†[a] Daniel Pleissner,[b] Nikolaos Kopsahelis,[a] Isabel Lopez Garcia,[c] Ioannis K. Kookos,[d] Seraphim Papanikolaou,[a] Tsz Him Kwan and Carol Sze Ki Lin*[b]

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

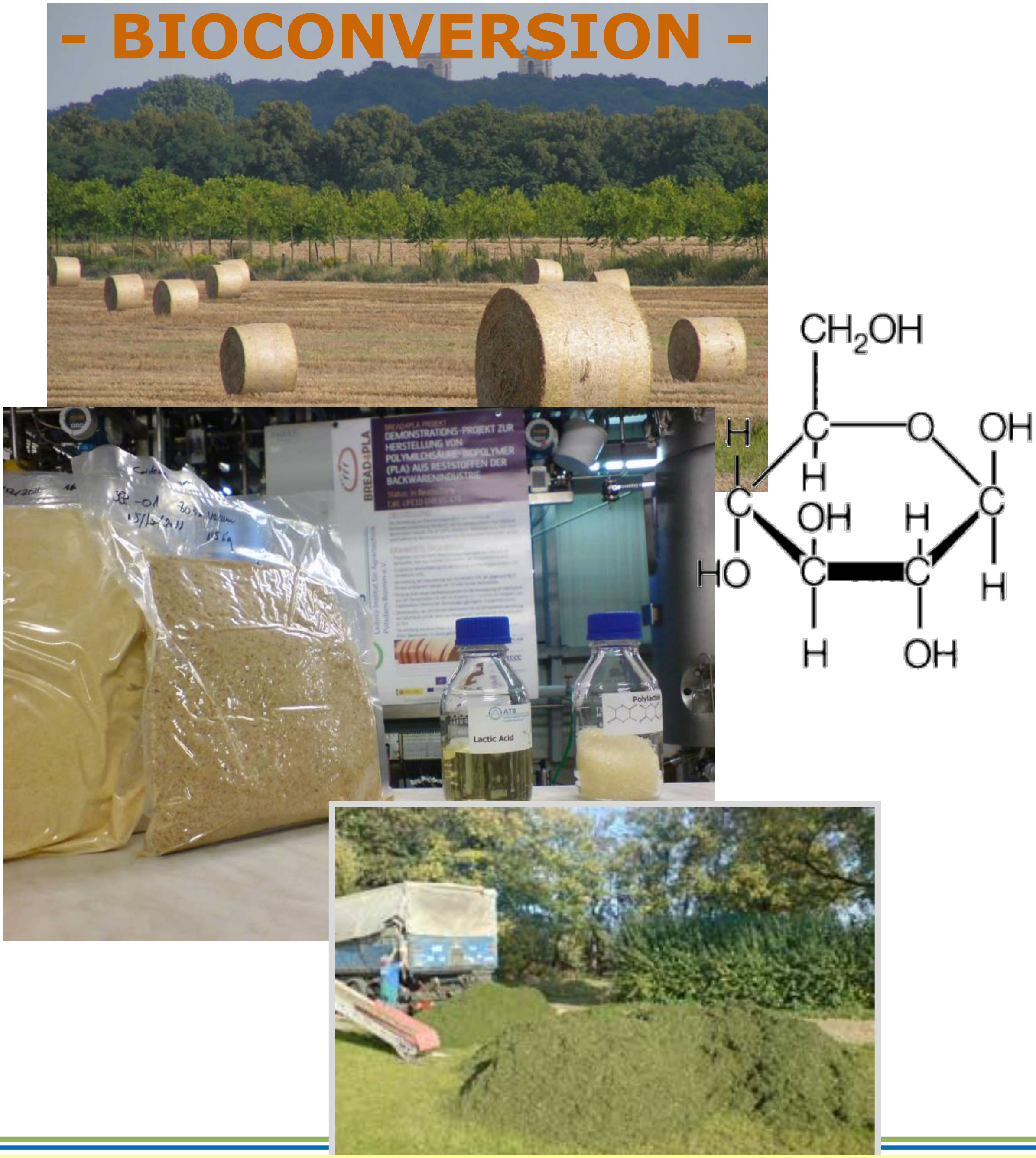


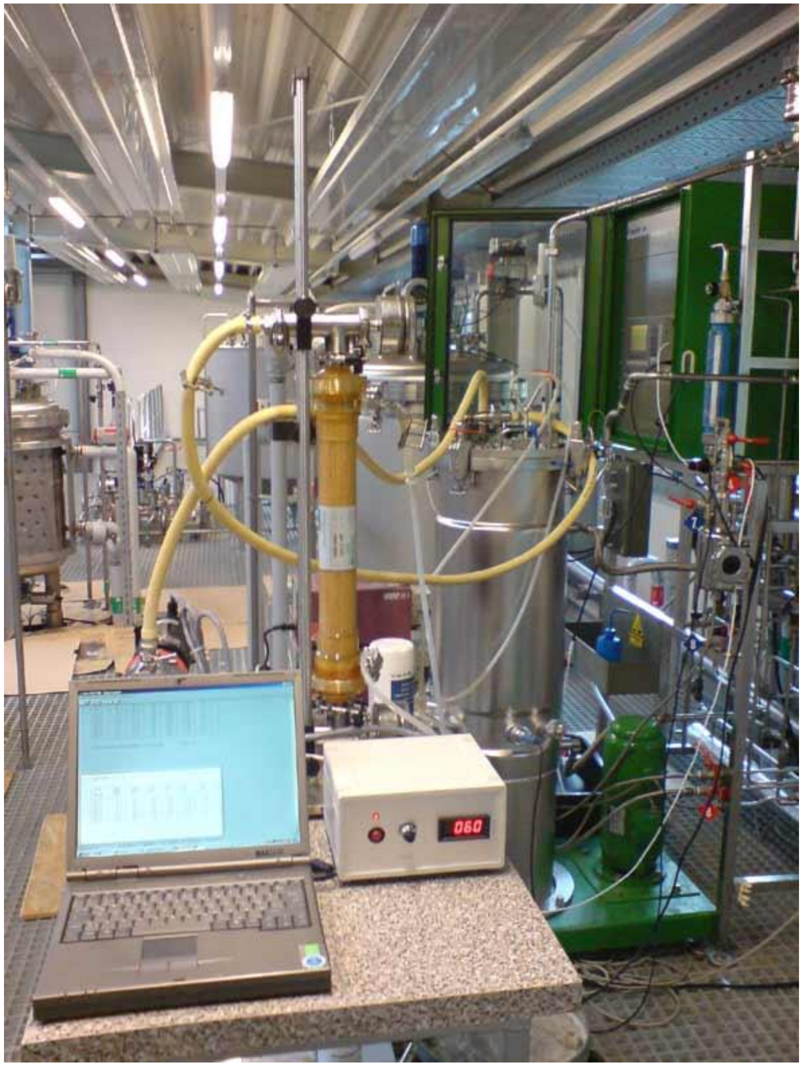
Berlin, 5 December 2018 – The results of the European Bioplastics' annual market data update, presented today at the 13th European Bioplastics Conference in Berlin:

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.

Biorefinery-concept for (1st, 2nd, 3rd…?) biomass feedstocks

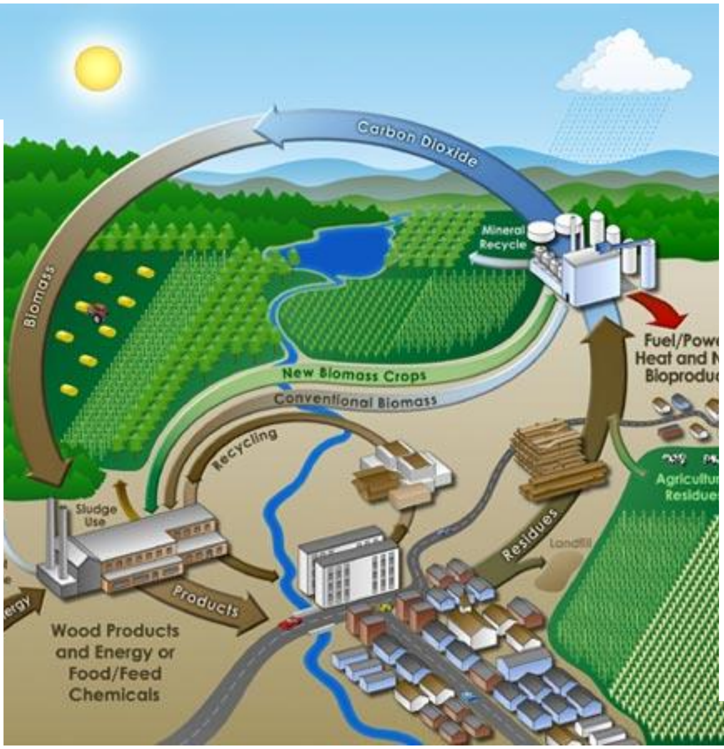
- BIOCONVERSION -

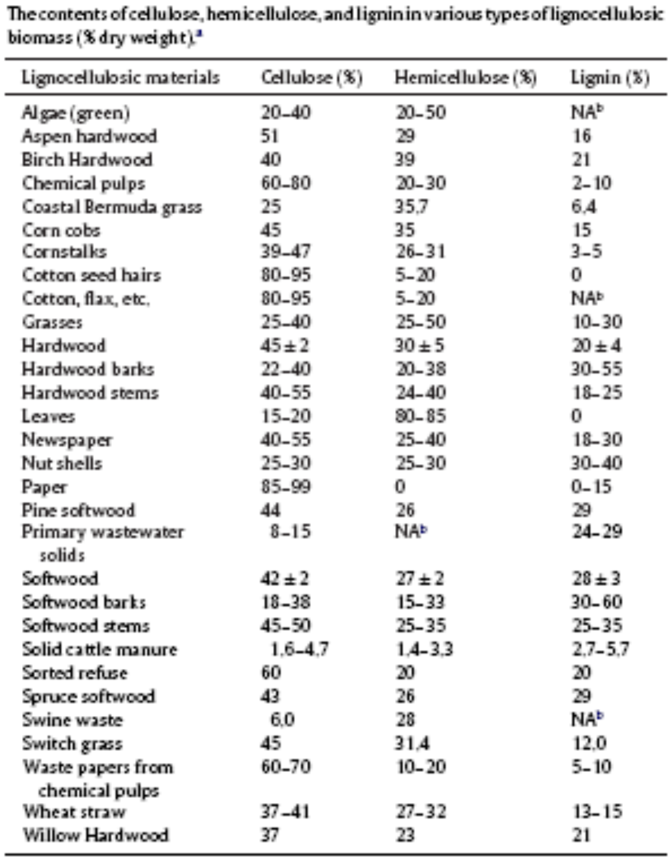




Pleissner, D.; Qi, Q.; Gao, C.; Perez Rivero, C.; Webb, C.; Lin, C.S.K.; Venus, J.: Valorization of organic residues for the production of added value chemicals: A contribution to the bio-based economy. Biochemical Engineering Journal 116 (2016) 3-16

(Different) Composition & Behaviour of (lignocellulosic) Biomass

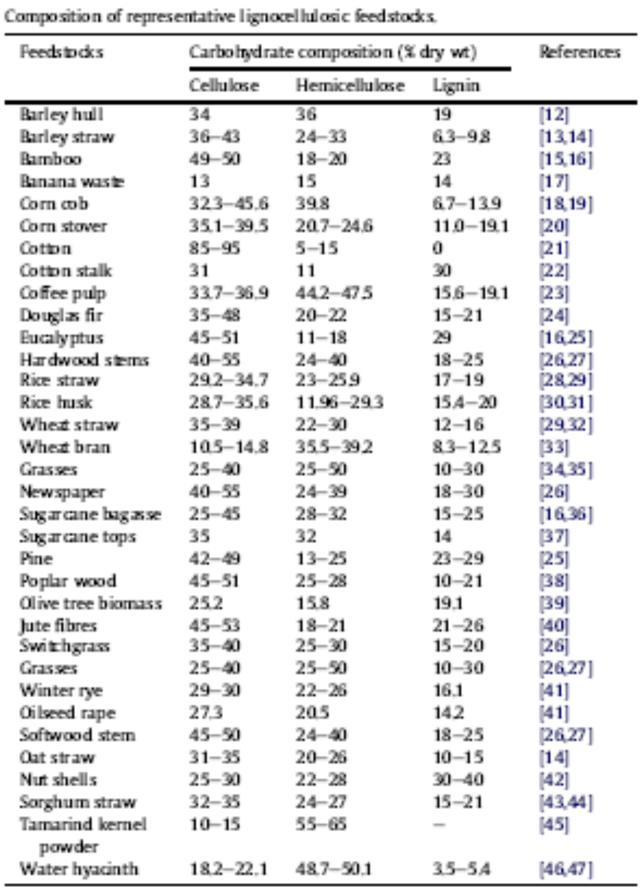




The contents of cellulose, hemicellulose, and lignin in various types of lignocellulosic biomass (% dry weight).[a]

Lignocellulosic materials	Cellulose (%)	Hemicellulose (%)	Lignin (%)
Algae (green)	20–40	20–50	NA[b]
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[b]
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[b]	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[b]
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

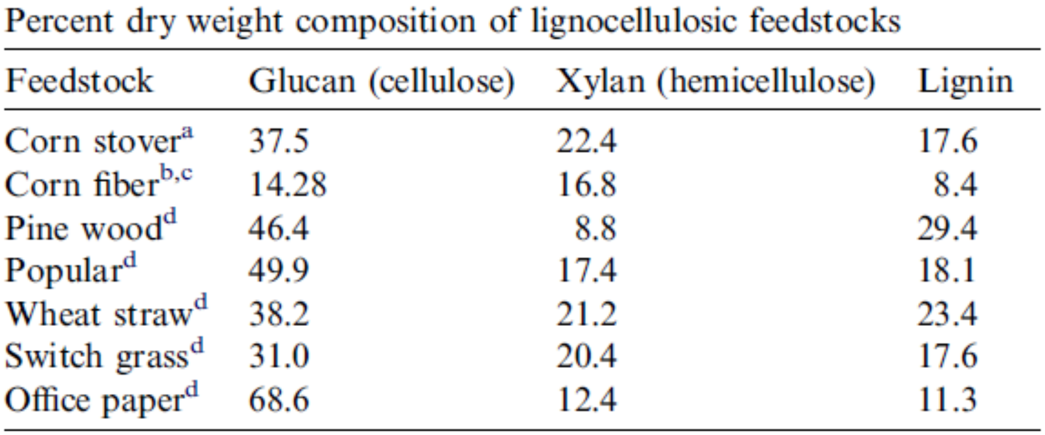
M.A. Abdel-Rahman et al.
Journal of Biotechnology 156 (2011) 286– 301



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]

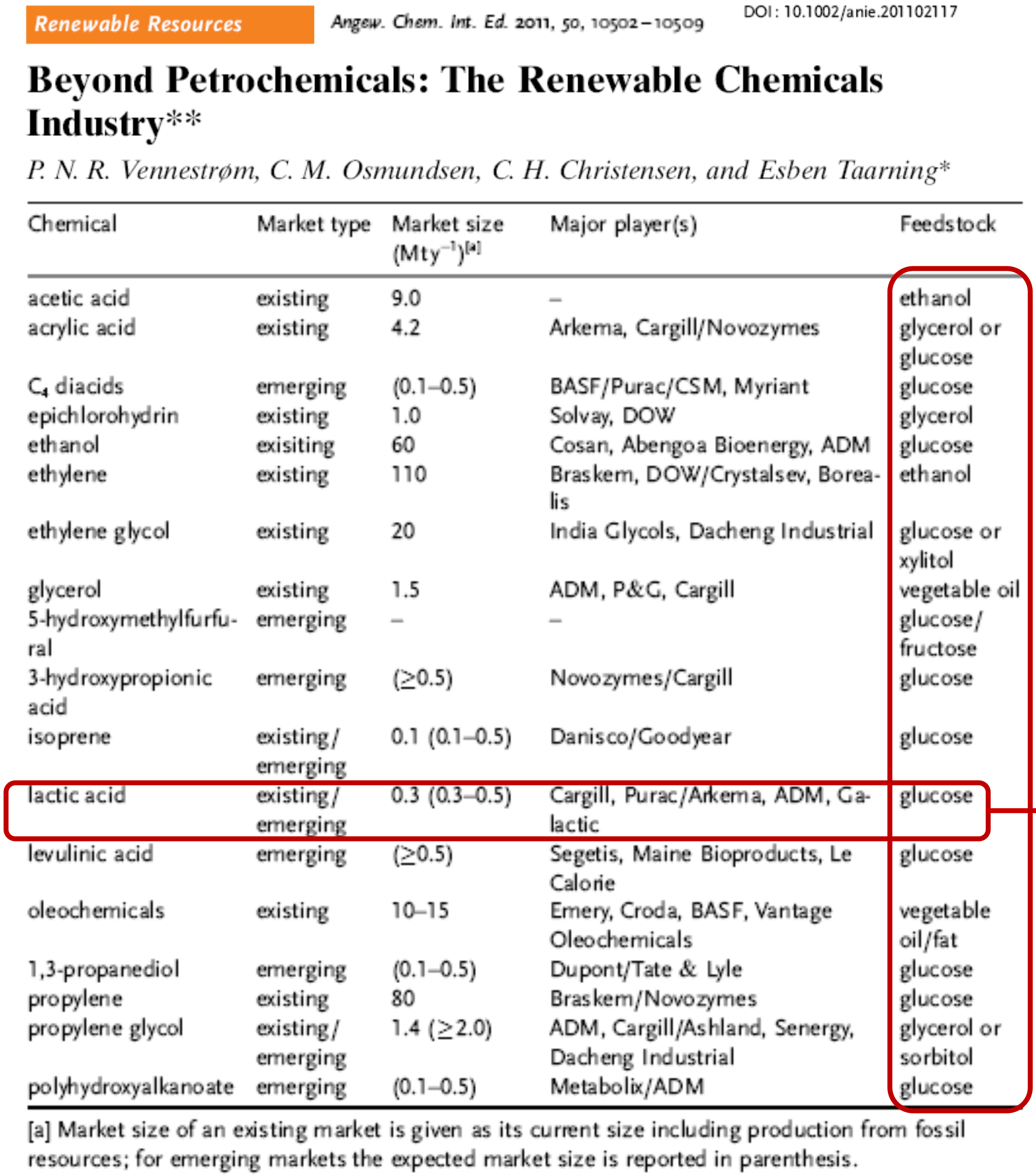
V. Menon, M. Rao
Progress in Energy and Combustion Science 38 (2012) 522-550



Percent dry weight composition of lignocellulosic feedstocks

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

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



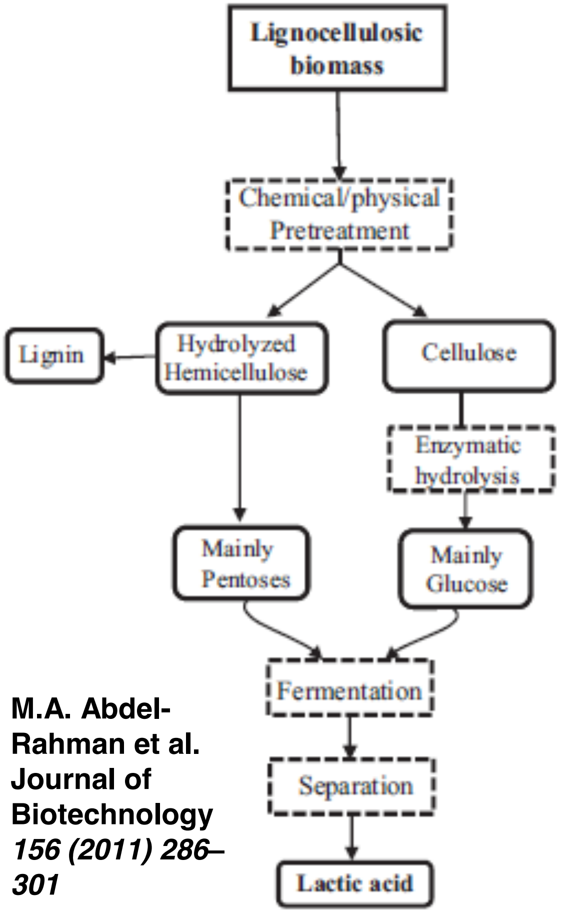
Renewable Resources Angew. Chem. Int. Ed. 2011, 50, 10502–10509 DOI: 10.1002/anie.201102117

Beyond Petrochemicals: The Renewable Chemicals Industry**

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

Chemical	Market type	Market size (Mt y^{-1})[a]	Major player(s)	Feedstock
acetic acid	existing	9.0	–	ethanol
acrylic acid	existing	4.2	Arkema, Cargill/Novozymes	glycerol or glucose
C_4 diacids	emerging	(0.1–0.5)	BASF/Purac/CSM, Myriant	glucose
epichlorohydrin	existing	1.0	Solvay, DOW	glycerol
ethanol	exisiting	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
lactic acid	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.



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

<u>Table 1:</u> 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.

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)

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

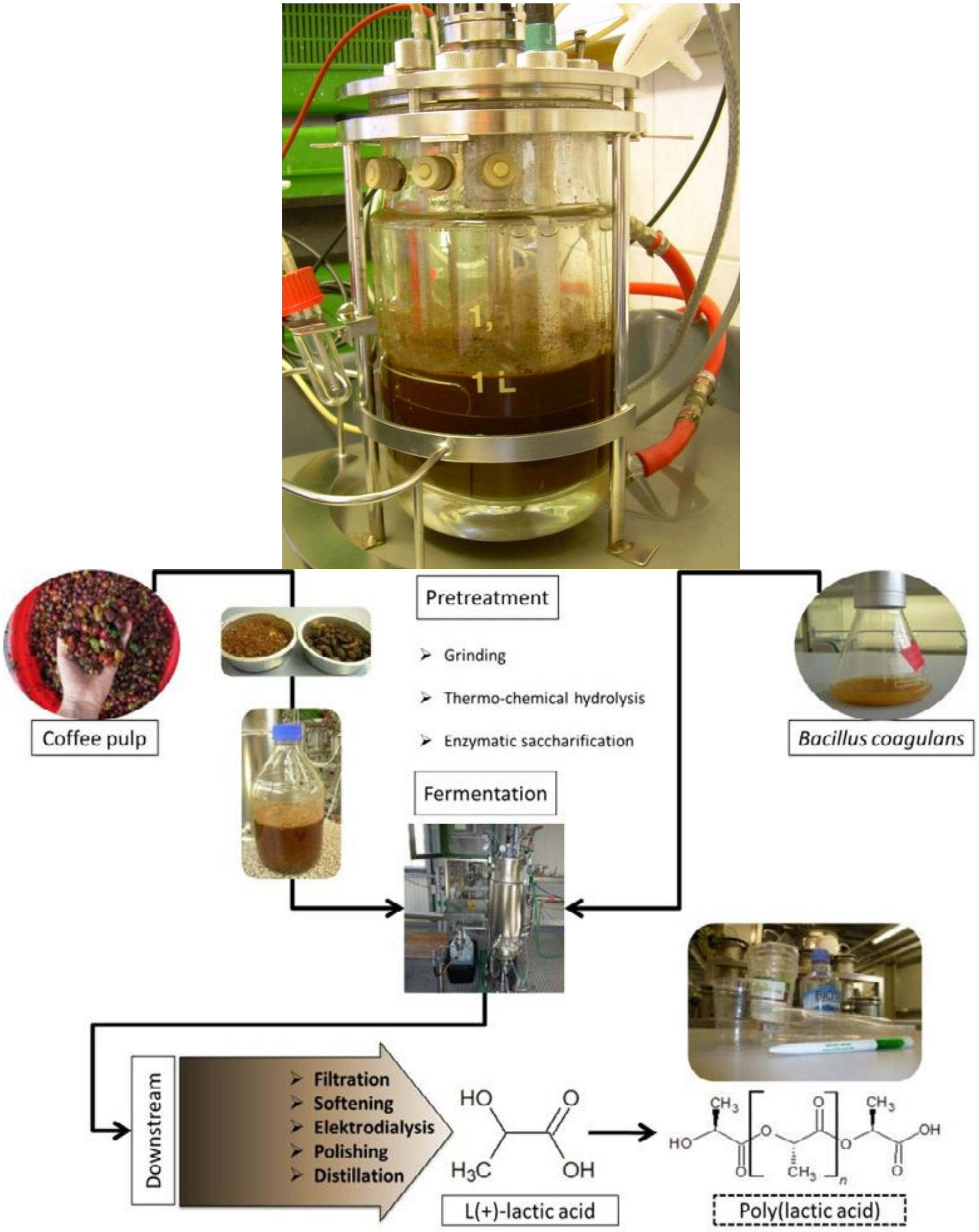
Mary J. Biddy, Christopher Scarlata, and Christopher Kinchin - *National Renewable Energy Laboratory*

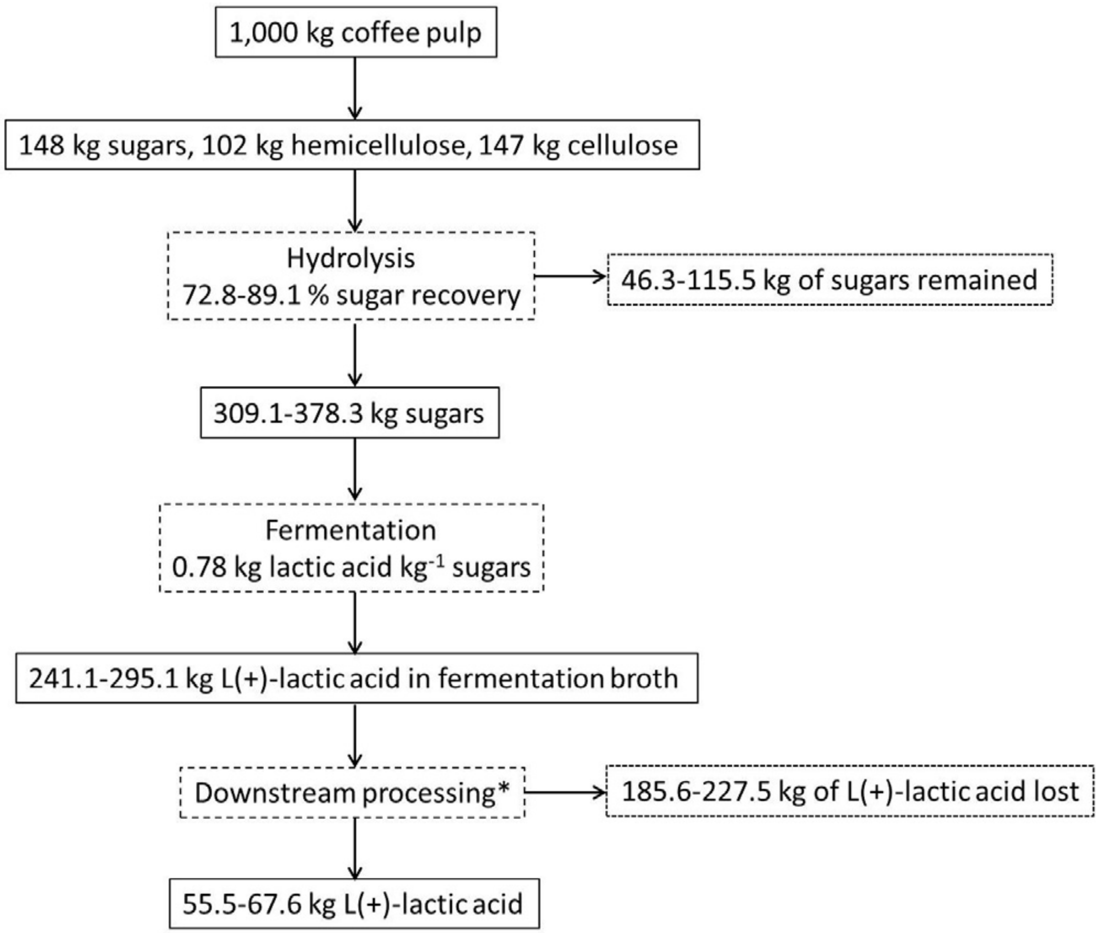
Data Gaps

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.

This report is available at no cost from the National Renewable Energy Laboratory (NREL) at www.nrel.gov/publications
Technical Report NREL/TP-5100-65509 - March 2016/Contract No. DE-AC36-08GO28308

Example coffee residues: residues from the coffee production





1,000 kg coffee pulp

148 kg sugars, 102 kg hemicellulose, 147 kg cellulose

Hydrolysis
72.8-89.1 % sugar recovery

46.3-115.5 kg of sugars remained

309.1-378.3 kg sugars

Fermentation
0.78 kg lactic acid kg^{-1} sugars

241.1-295.1 kg L(+)-lactic acid in fermentation broth

Downstream processing*

185.6-227.5 kg of L(+)-lactic acid lost

55.5-67.6 kg L(+)-lactic acid

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

Example agro-residues: Sugarcane bagasse

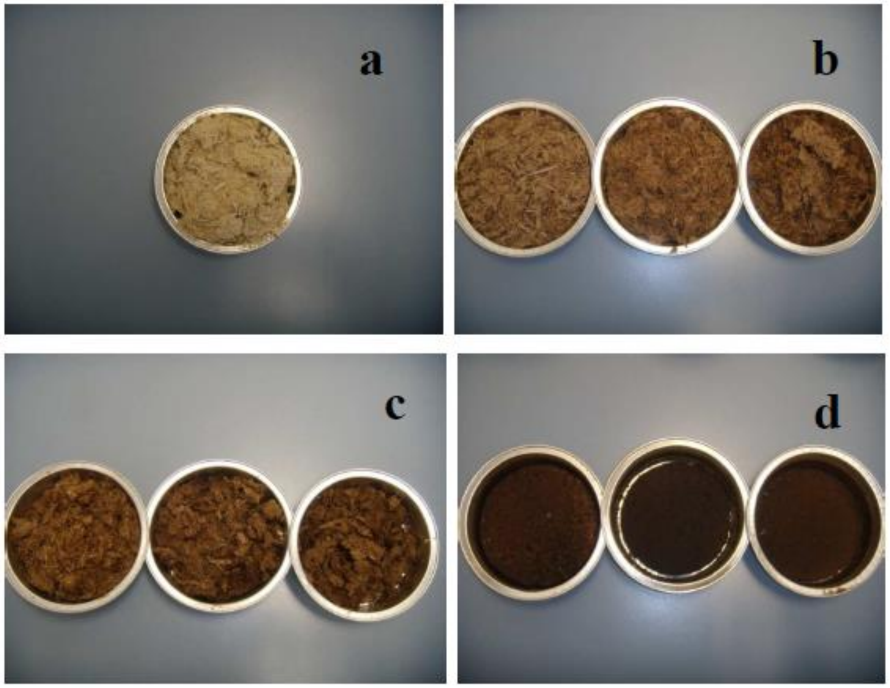


Figura 1 – Fotos de bagaço da cana de açúcar: **(a)** sem tratamento térmico; **(b)** 180°C; **(c)** 200°C e **(d)** 220°C por 5, 10 e 15 minutos (da esq. para dir.).

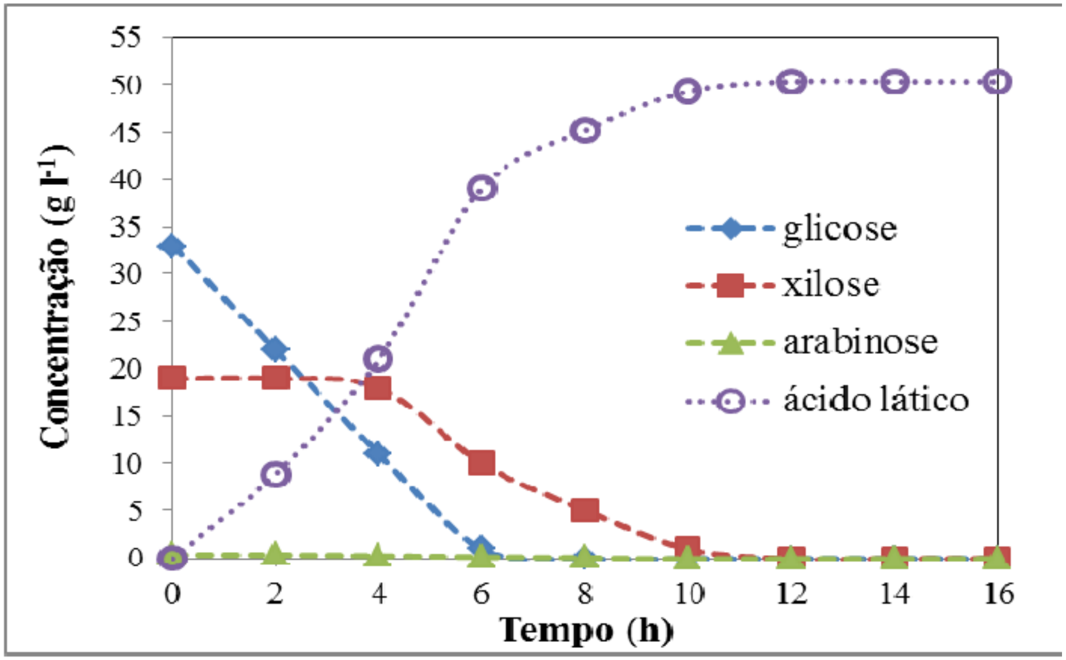


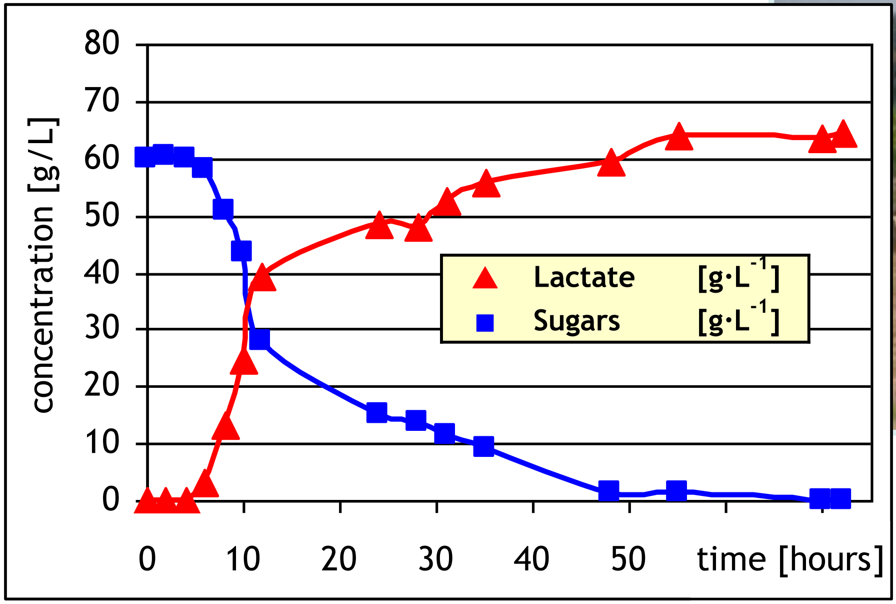
Figura 4 – Produção de ácido lático e consumo de açúcares presentes no meio MRS modificado contendo hidrolisado de bagaço (glicose 33 g l^{-1}, xilose 19 g l^{-1}, arabinose 0,4 g l^{-1}, extrato de levedura 15 g l^{-1}, K_2HPO_4 2 g l^{-1}, $MgSO_4$ 0,1 g l^{-1} e $MnSO_4$ 0,04 g l^{-1}).

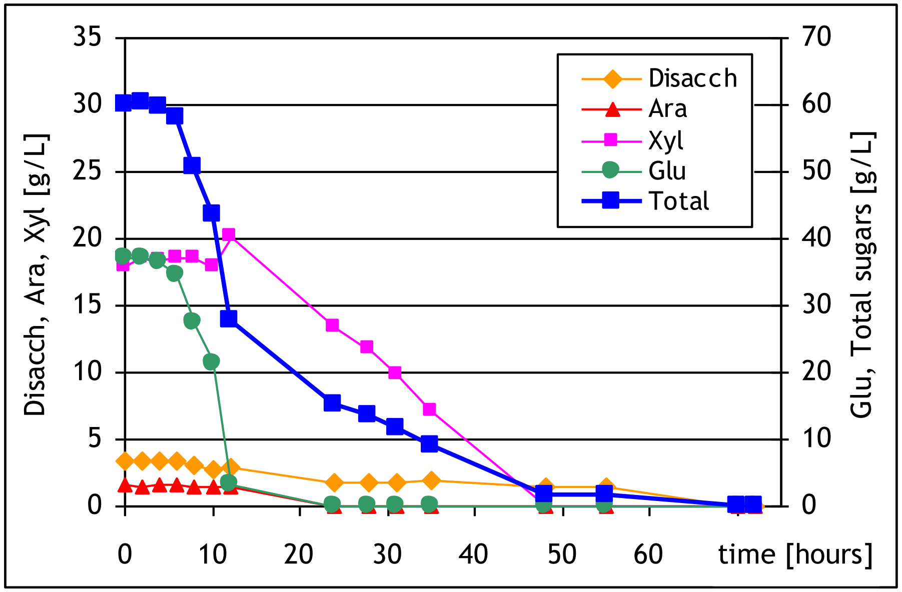
XVIII Simpósio Nacional de Bioprocessos
Caxias do Sul/RS - 24 a 27 de julho de 2011
SINAFERM 2011

Hidrólise Térmica de Bagaço da Cana-de-açúcar para Produção Homofermentativa de L-Ácido Lático

Giselle de Arruda Rodrigues[1], Joachim Venus[2] e Telma Teixeira Franco[1]

Example wheat straw: Sugar uptake & product formation





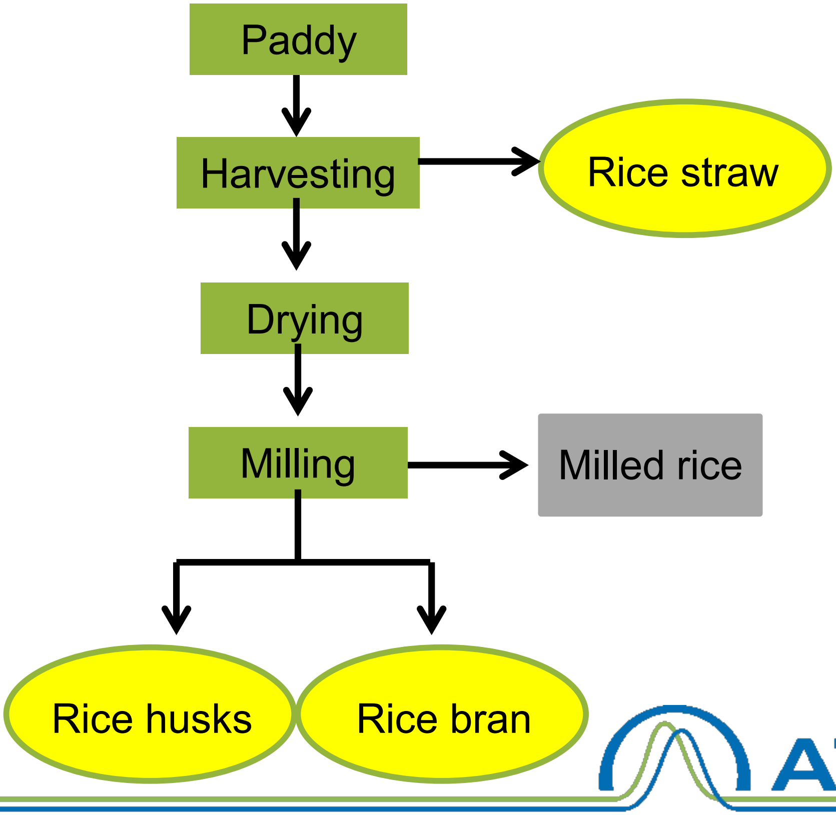
- Fermentation ended after 50-60 hours with a yield of nearly 100% and 64 g/L (top left)
- (Total) Sugars (firstly Glucose followed by Arabinose/Xylose with residues of Disaccharides) have been used completely in the same time (bottom left)
- (Max) Lactate productivity (>5 $g \cdot L^{-1} \cdot h^{-1}$) 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]

WO 2013164423 A1; WO 2013164425 A1
Pleissner, D.; Venus, J.: Agricultural residues as feedstocks for lactic acid fermentation. - ACS Books "Green Technologies for the Environment" (2014) Chapter 13, pp 247–263

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


Paddy
Harvesting
Rice straw
Drying
Milling
Milled rice
Rice husks
Rice bran

China produced 7,015,000 t of rice in 2014 (FAOSTAT)

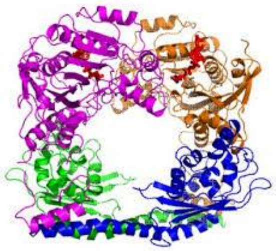
Flow diagram of the followed process

Defatted Rice Bran

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

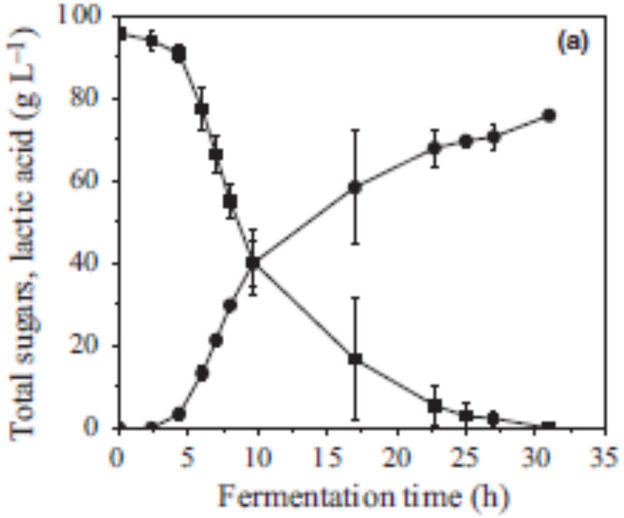
Upstream Processing

Enzymatic Hydrolysis

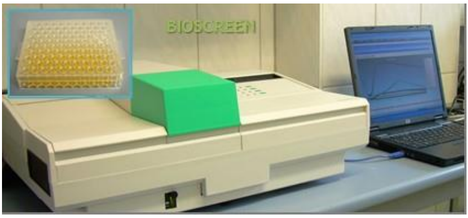


Addition of amylases, glucoamylase and protease

Fermentation



Screening of different thermophilic strains



Selection of the suitable strain

Downstream processing

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

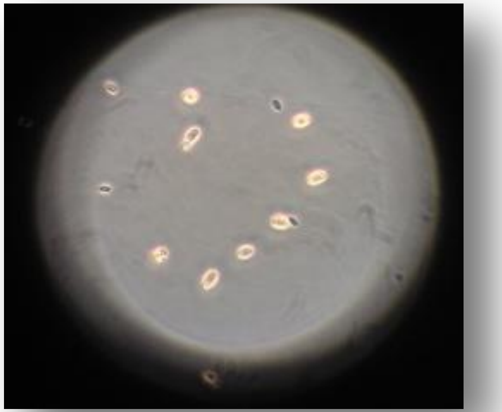
Lactic acid production

IBF
Industrial Biotechnology Forum 2018
A scientific conference by IBB Netzwerk GmbH and Technical University of Munich
March 13/14 2018
— Venue —
TUM Garching

Alexandri, M.; Neu, A.; Schneider, R.; López-Gómez, J.P.; Venus, J.: Evaluation of various B. coagulans isolates for the production of high purity L-lactic acid using defatted rice bran hydrolysates. International Journal of Food Science & Technology, In Press, https://doi.org/10.1111/ijfs.14086

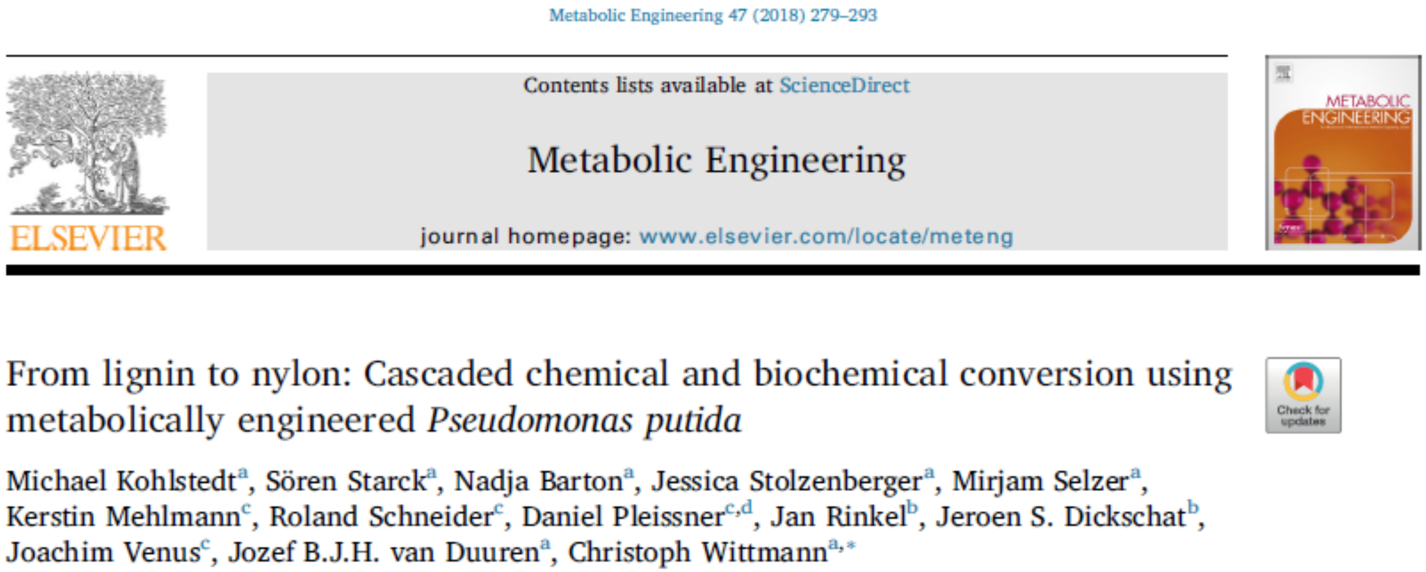
Biosurfactant production by Yeasts using sugarcane bagasse for solid state fermentation

Green Chemistry



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



Metabolic Engineering 47 (2018) 279–293

Contents lists available at ScienceDirect

Metabolic Engineering

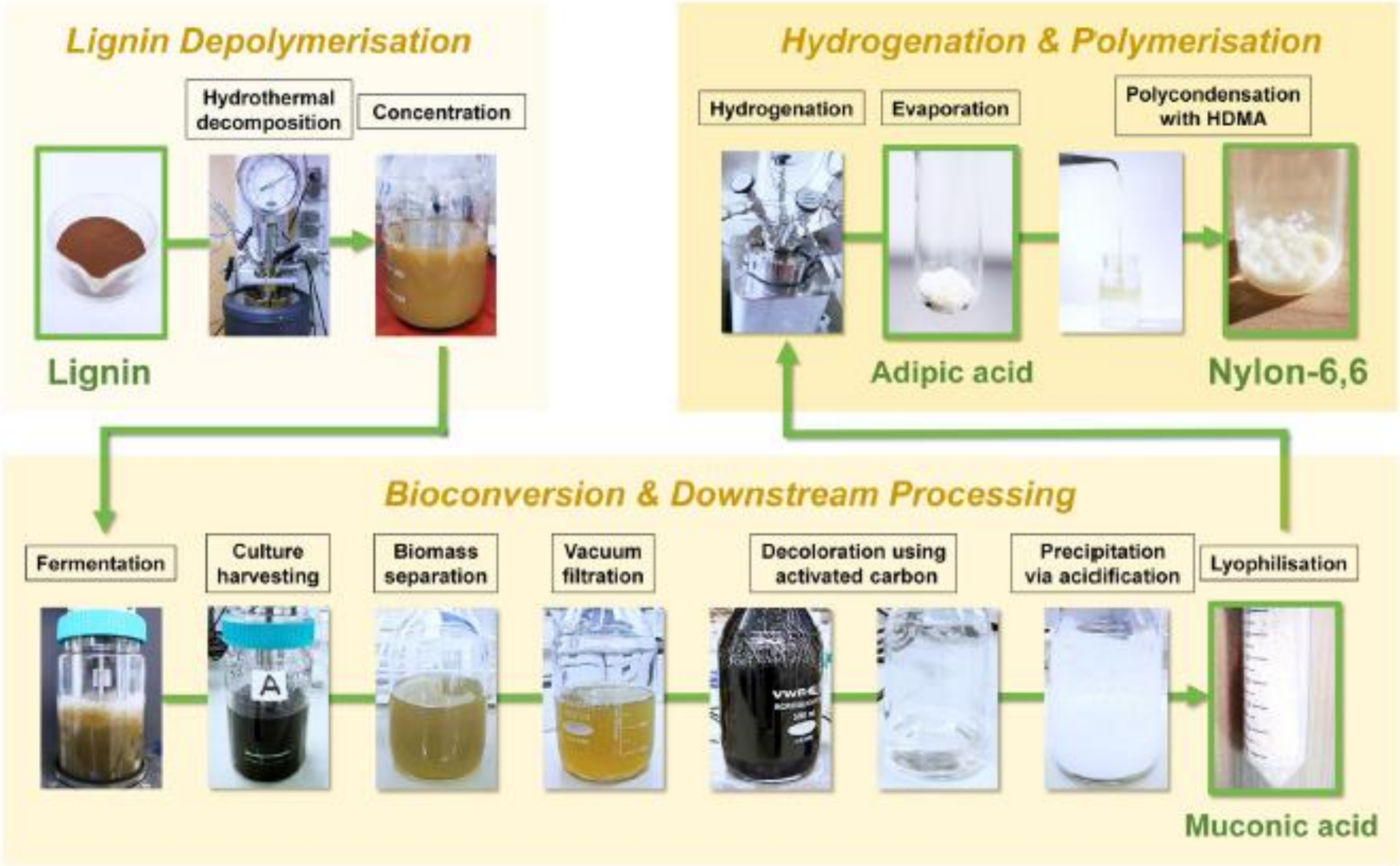
journal homepage: www.elsevier.com/locate/meteng

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

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

UNIVERSITÄT DES SAARLANDES

iSBio Institut für Systembiotechnologie



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-muconic acid by the advanced producer Pseudomonas putida KT2440 MA-9; purification of cis,cis-muconic acid; hydrogenation to adipic acid; and final polymerization to nylon 6,6.

ATB

CHEMICAL BUILDING BLOCKS FROM VERSATILE MSW BIOREFINERY

BIO-BASED INDUSTRIES
Public-Private Partnership

PERCAL

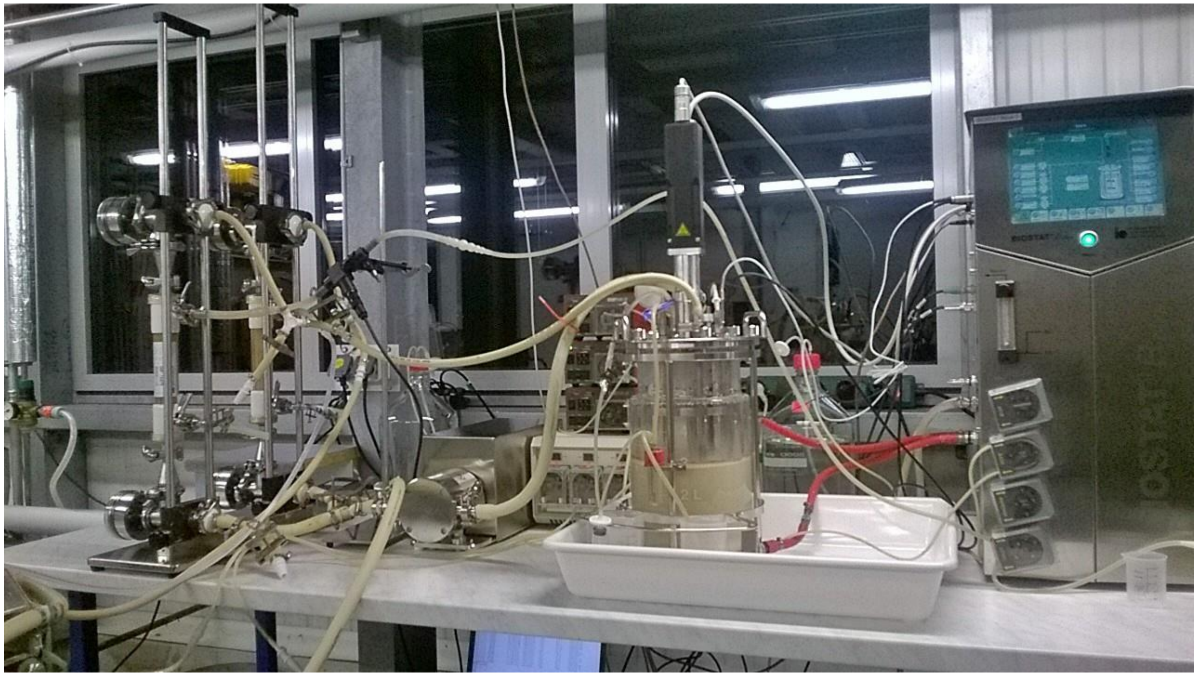
http://www.percal-project.eu/

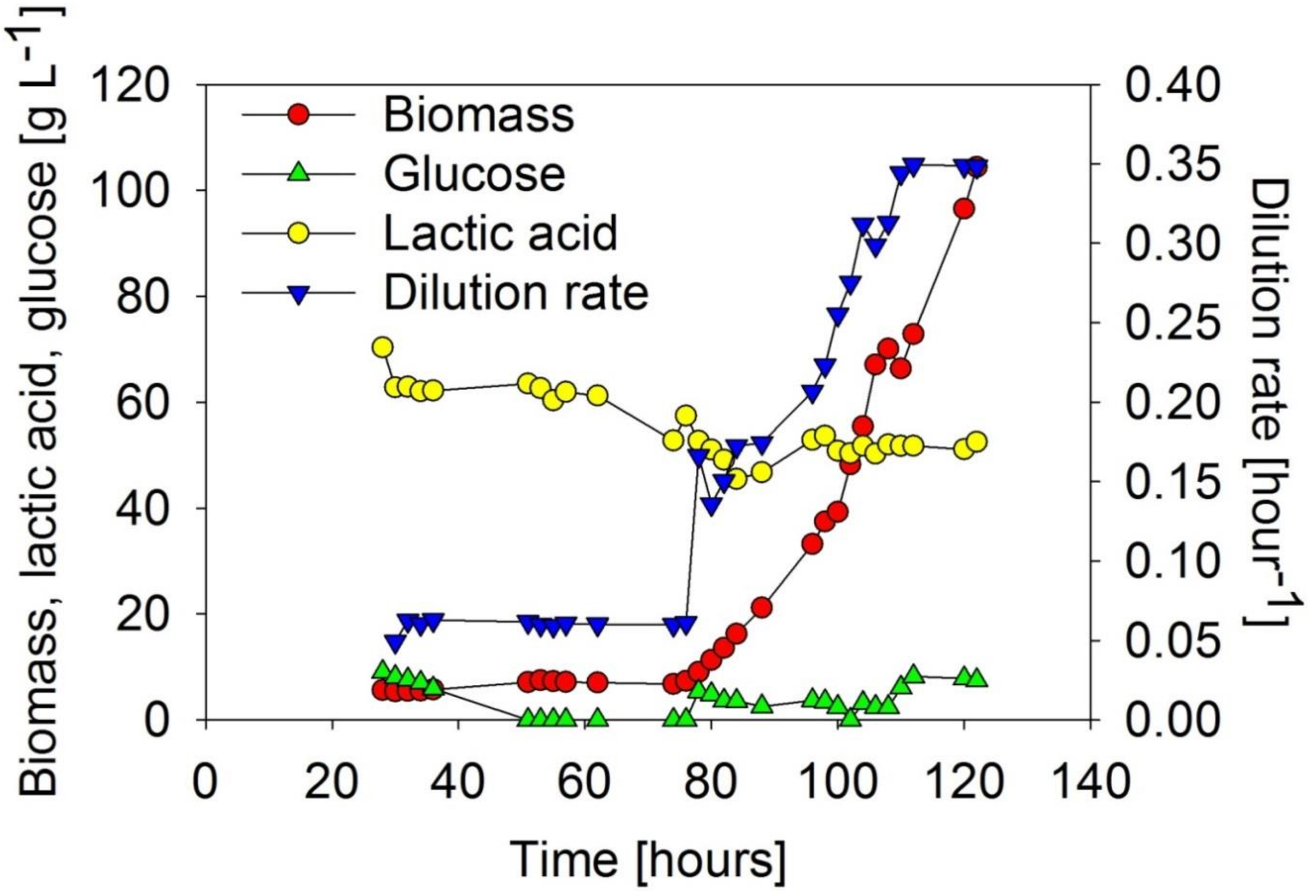
GA745828 funded by

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.:

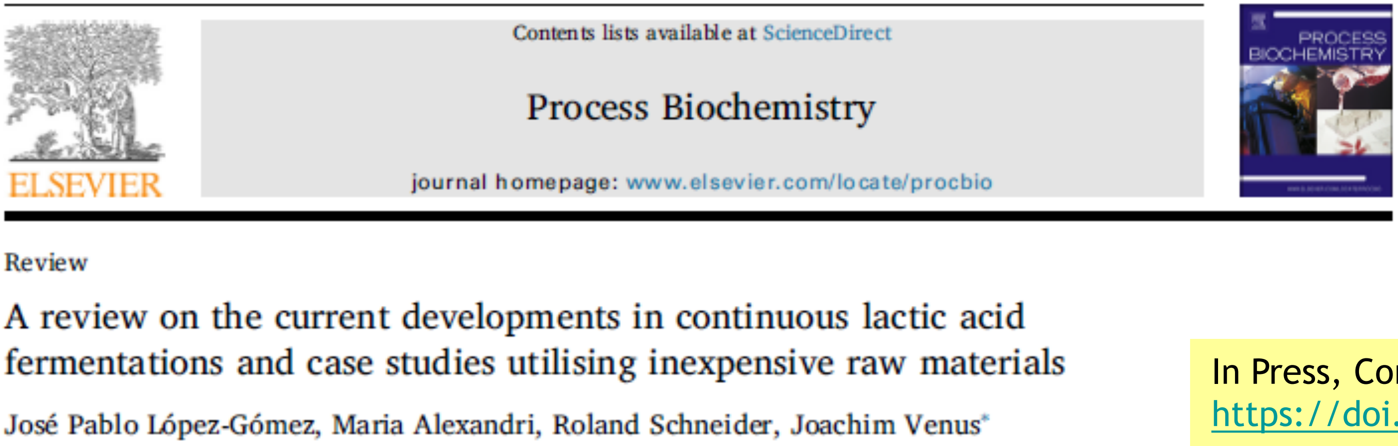
- **Lactic acid (LA) to produce:** 1) Eco-friendly ethyl lactate solvents by reactive distillation from lactic acid & bio-ethanol to be used in cleaning products and inks and 2) hot-melt adhesives for cardboard and other non-food applications in combination with maleic anhydride by reactive extrusion.
- **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.

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



Contents lists available at ScienceDirect

Process Biochemistry

journal homepage: www.elsevier.com/locate/procbio

Review

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

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

In Press, Corrected Proof,
https://doi.org/10.1016/j.procbio.2018.12.012

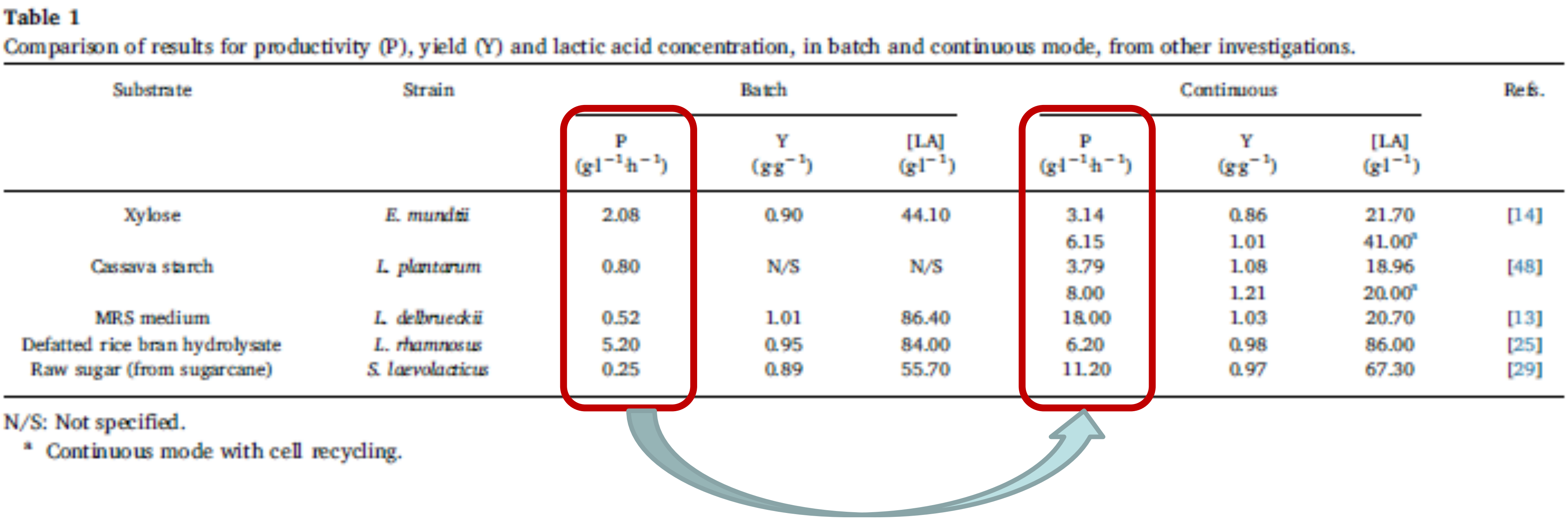


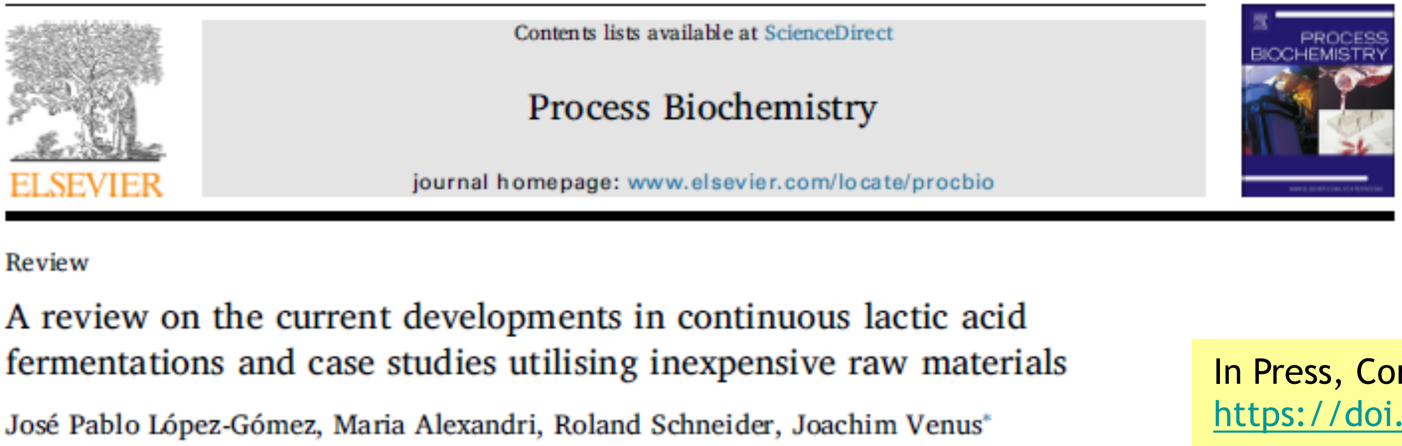
Table 1

Comparison of results for productivity (P), yield (Y) and lactic acid concentration, in batch and continuous mode, from other investigations.

Substrate	Strain	Batch			Continuous			Refs.
		P $(g\,l^{-1}\,h^{-1})$	Y $(g\,g^{-1})$	[LA] $(g\,l^{-1})$	P $(g\,l^{-1}\,h^{-1})$	Y $(g\,g^{-1})$	[LA] $(g\,l^{-1})$	
Xylose	*E. mundtii*	2.08	0.90	44.10	3.14	0.86	21.70	[14]
					6.15	1.01	41.00[a]	
Cassava starch	*L. plantarum*	0.80	N/S	N/S	3.79	1.08	18.96	[48]
					8.00	1.21	20.00[a]	
MRS medium	*L. delbrueckii*	0.52	1.01	86.40	18.00	1.03	20.70	[13]
Defatted rice bran hydrolysate	*L. rhamnosus*	5.20	0.95	84.00	6.20	0.98	86.00	[25]
Raw sugar (from sugarcane)	*S. laevolacticus*	0.25	0.89	55.70	11.20	0.97	67.30	[29]

N/S: Not specified.

[a] Continuous mode with cell recycling.



Contents lists available at ScienceDirect

Process Biochemistry

journal homepage: www.elsevier.com/locate/procbio

Review

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

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

In Press, Corrected Proof,
https://doi.org/10.1016/j.procbio.2018.12.012

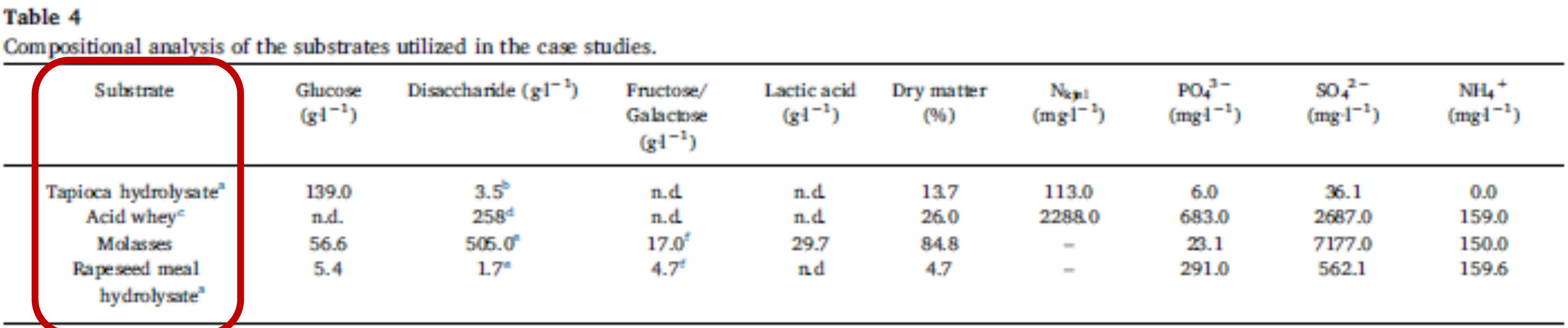


Table 4
Compositional analysis of the substrates utilized in the case studies.

Substrate	Glucose ($g\,l^{-1}$)	Disaccharide ($g\,l^{-1}$)	Fructose/ Galactose ($g\,l^{-1}$)	Lactic acid ($g\,l^{-1}$)	Dry matter (%)	N_{kjel} ($mg\,l^{-1}$)	PO_4^{3-} ($mg\,l^{-1}$)	SO_4^{2-} ($mg\,l^{-1}$)	NH_4^+ ($mg\,l^{-1}$)
Tapioca hydrolysate[a]	139.0	3.5[b]	n.d.	n.d.	13.7	113.0	6.0	36.1	0.0
Acid whey[c]	n.d.	258[d]	n.d.	n.d.	26.0	2288.0	683.0	2687.0	159.0
Molasses	56.6	505.0[e]	17.0[f]	29.7	84.8	–	23.1	7177.0	150.0
Rapeseed meal hydrolysate[a]	5.4	1.7[e]	4.7[f]	n.d	4.7	–	291.0	562.1	159.6

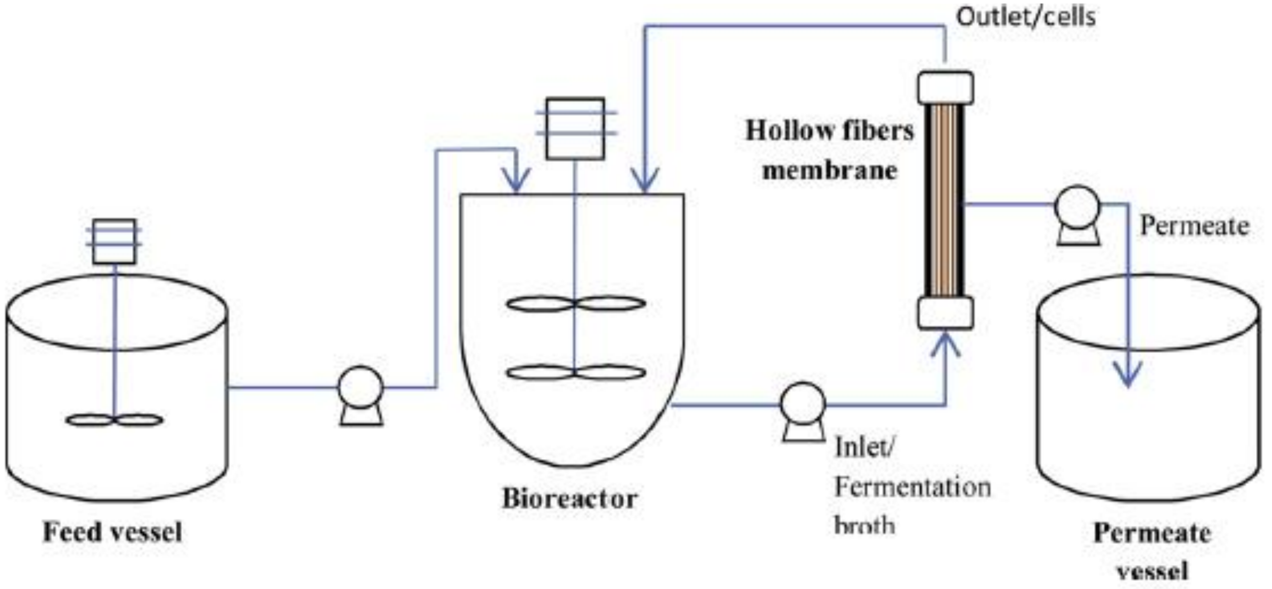


Fig. 1. Schematic representation of hollow fibers membrane-integrated bioreactor system for cell-recycle continuous production of lactic acid.

Downstream processing of raw lactates & lactic acid

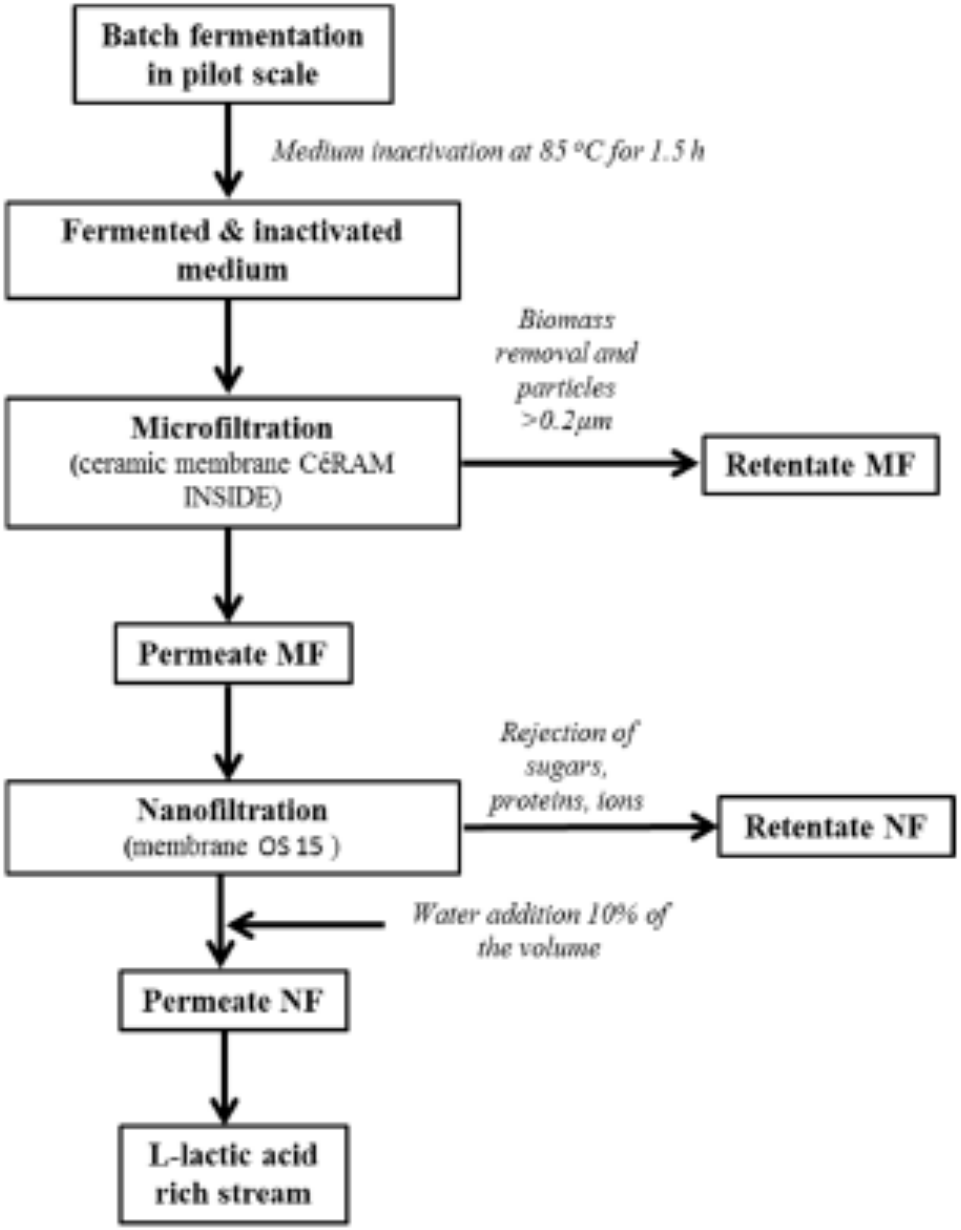


Figure 1. Schematic diagram of the studied process.

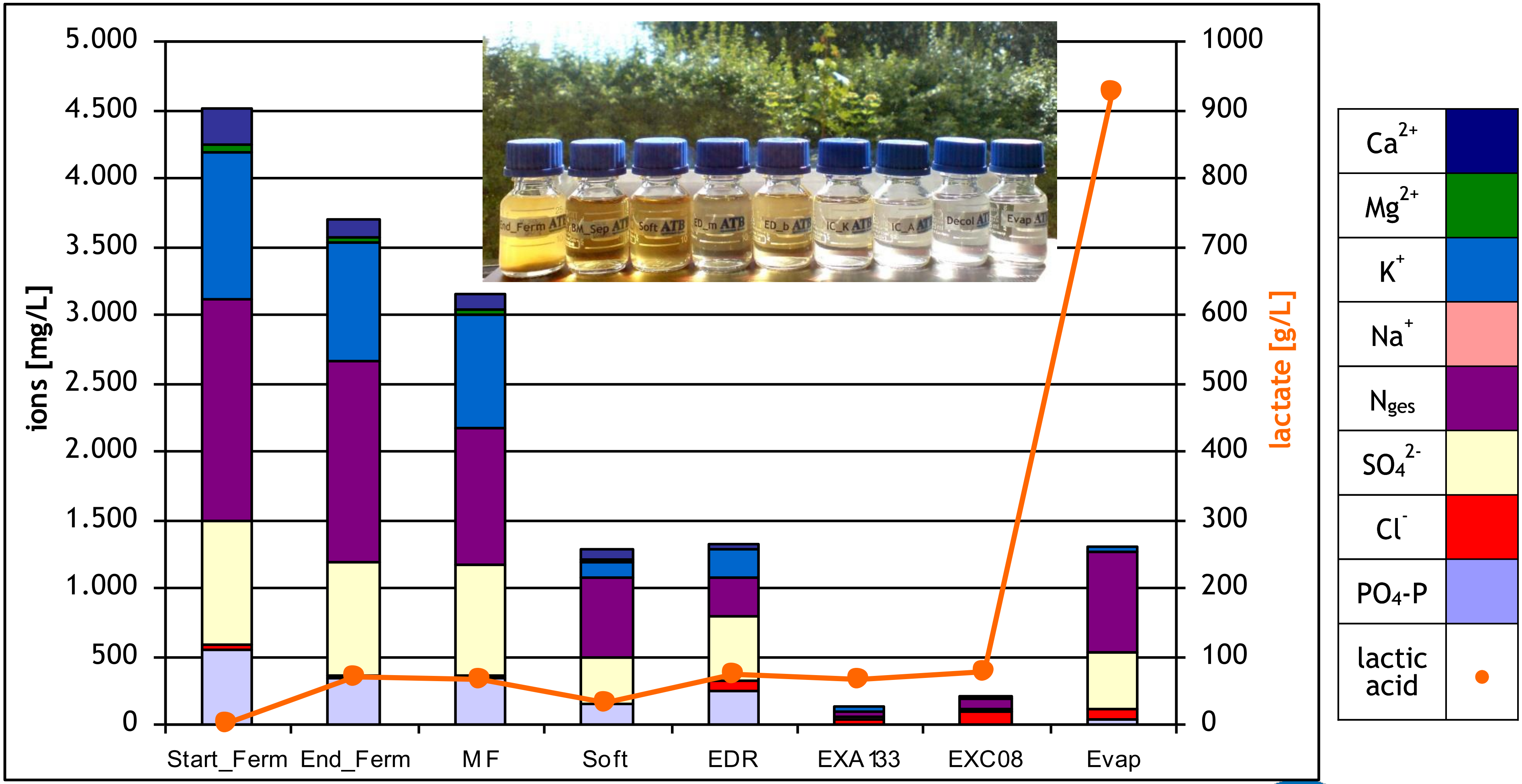
Alexandri, M.; Schneider, R.; Venus, J.: Membrane Technologies for Lactic Acid Separation from Fermentation Broths Derived from Renewable Resources. Membranes 2018, 8(4), 94, https://doi.org/10.3390/membranes8040094

Effect of several down-streaming steps on the purity of lactic acid

Na-Lactate
(Fermentation)

→

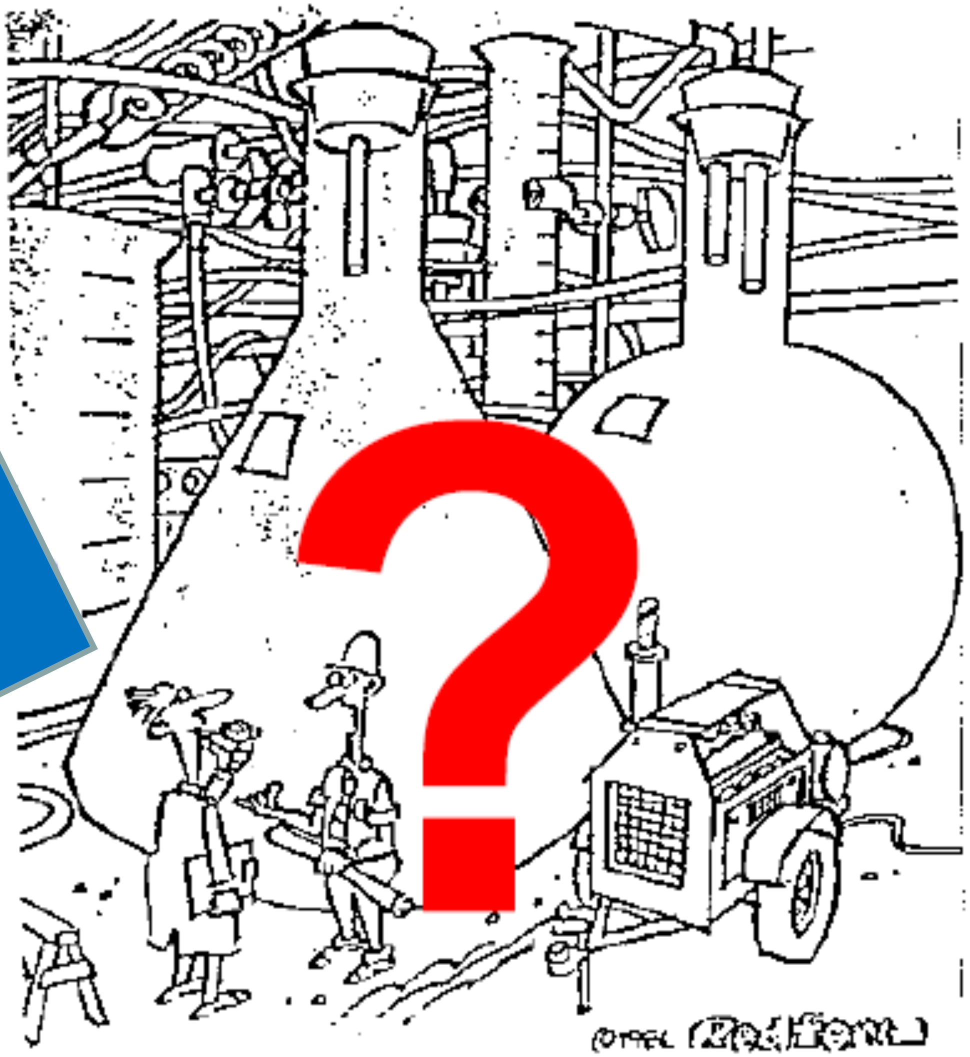
down-stream processing
(Filtration, Softening, Electrodialysis, Ion exchange, Evaporation)



Pleissner, D., Schneider, R., Venus, J., Koch, T.: Separation of lactic acid and recovery of salt-ions from fermentation broth. J. Chem. Technol. Biotechnol. (2017) 92: 504–511

Scale-up of bioprocesses

Process development up to xx 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

ATB
Agrartechnik Bornim

23. August
2006

Einweihung

Pilotanlage
„Milchsäure aus Biomasse“

Leibniz-Institut für Agrartechnik
Potsdam-Bornim e.V.

Förderung:

Carus/Carrez/Kaeb/Ravenstijn/Venus: Level Playing Field for Bio-based Chemistry and Materials. – bioplastics MAGAZINE [03/11] Vol. 6, 52-55

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

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

scale up

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 Engineer-ing/Biotechnology 166 (2019) pp. 373-410

Microbe of the year 2018

WITH LACTOBACILLUS FROM YOGHURT TO BIOFILM

Press release on the microbe of the year is online
Poster to the microbe of the year for self-printing

Press release from the Association for General and Applied Microbiology (VAAM) - 12/2017

Microbe of the year 2018

Lactobacillus - delicious and healthy

Mulching film made of poly-lactic acid is biologically building land.
© F. Kesselring, FKuR Willich

Bio-plastic and medical technology

Biotechnologically, lactobacilli are used to produce lactic acid on an industrial scale - about 500,000 tons per year in Germany. As a food additive (E 270), lactic acid increases the shelf life of baked goods, sweets and lemonades. Soaps, creams and detergents also contain the disinfecting lactic acid.

Linking several lactic acid molecules produces lactic acid chains called polylactides. The resulting materials are stable but biodegradable, making them bio-films and packaging. Medical technicians use polylactides for sutures and implants that eventually disintegrate in the body.

With the support of:

Thank you for your attention!

Pilotanlage Milchsäure

DIESES PROJEKT WIRD VOM
EUROPÄISCHEN FONDS FÜR REGIONALE
ENTWICKLUNG KOFINANZIERT

More information: www.atb-potsdam.de

ATB 2016 - To scroll through the latest research report 2016 click here ...

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