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Leibniz-Institut für Agrartechnik und Bioökonomie

Bioconversion of municipal solid waste into lactic acid

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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

SDG‘s statt Ressourcenknappheit, Kostenzwänge…

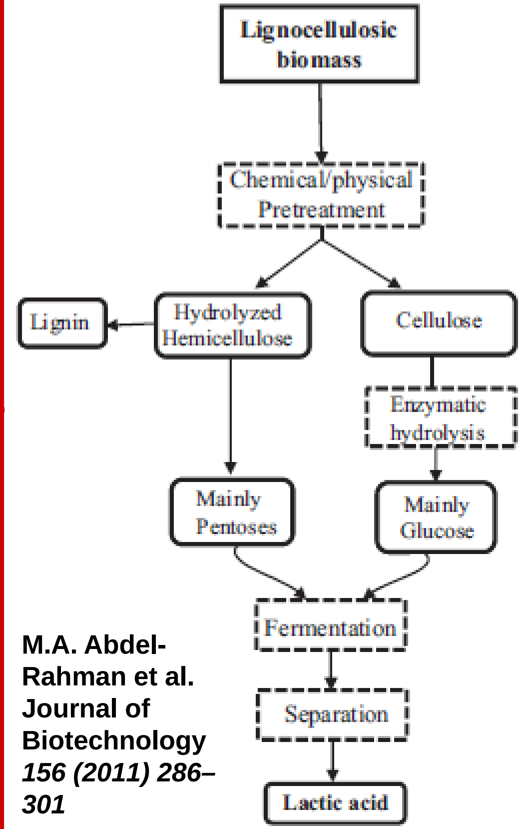
Renewable Resources
Angew. Chem. Int. Ed. 2011, 50, 10502–10509
DOI: 10.1002/anie.201102117

Beyond Petrochemicals: The Renewable Chemicals Industry**

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

Chemical	Market type	Market size (Mty^{-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*

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.

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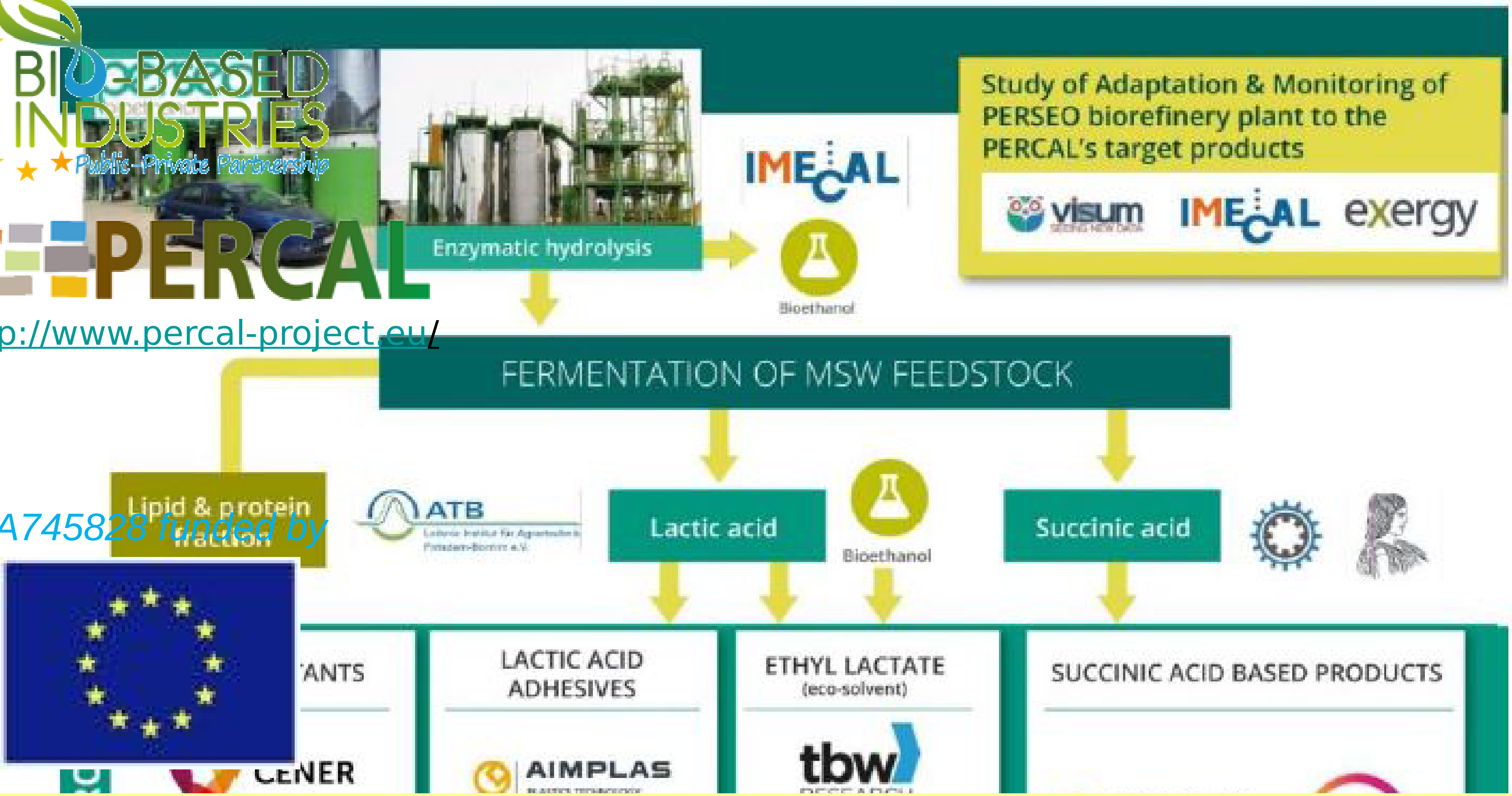
CHEMICAL BUILDING BLOCKS FROM VERSATILE MSW BIOREFINERY



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

GA745828 funded by

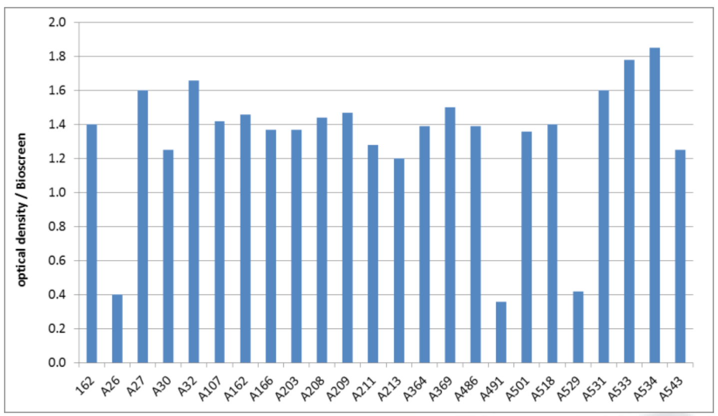
PERCAL will exploit Municipal Solid Waste (MSW) as feedstock to develop intermediate chemical products at high yield and low impurity level with huge industrial interest. These will be complementary to the bioethanol, to achieve a cascade valorisation of the MSW components, i.e.:

- **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**

WP 2 Tasks

- Task 2.1. Screening and selection of new/alternative bacterial strains

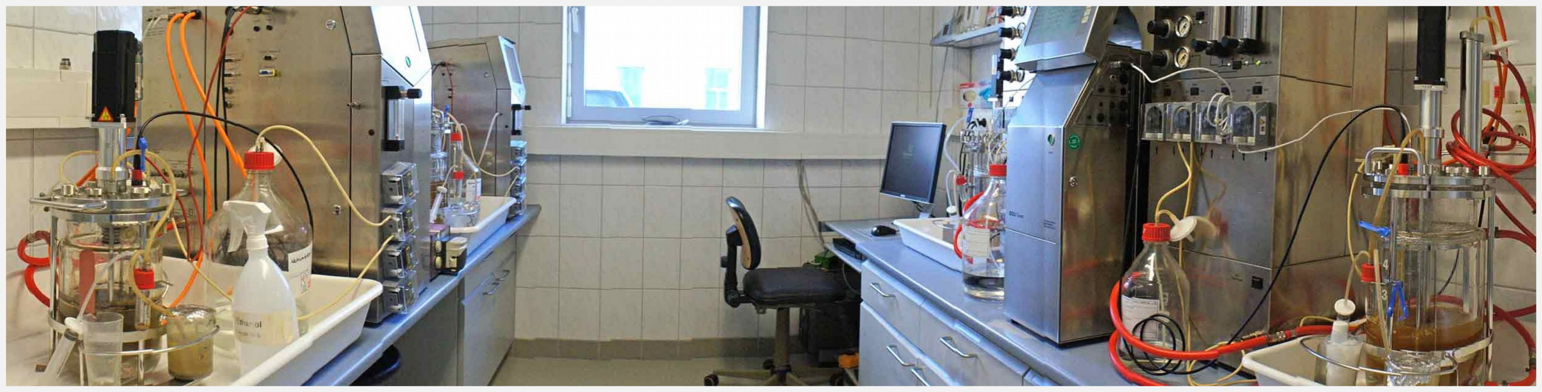
Screening and selection of new/alternative bacterial strains … the most promising microorganisms in first simple fermentations in tubes, bottles, shake flasks and lab-scale



WP 2 Tasks

- Task 2.2. Fermentation processes for converting biogenic fraction MSW into lactic acid

Develop efficient fermentation processes for converting bio waste into lactic acid (L(+) isomer). Mixtures and/or single fractions of the (C6/C5) sugar solution from pre-treated fractions will be converted to lactic acid in order to provide compounds for further processing steps.



WP 2 Tasks

- Task 2.3. Downstream processing (DSP) for recovery of lactic acid

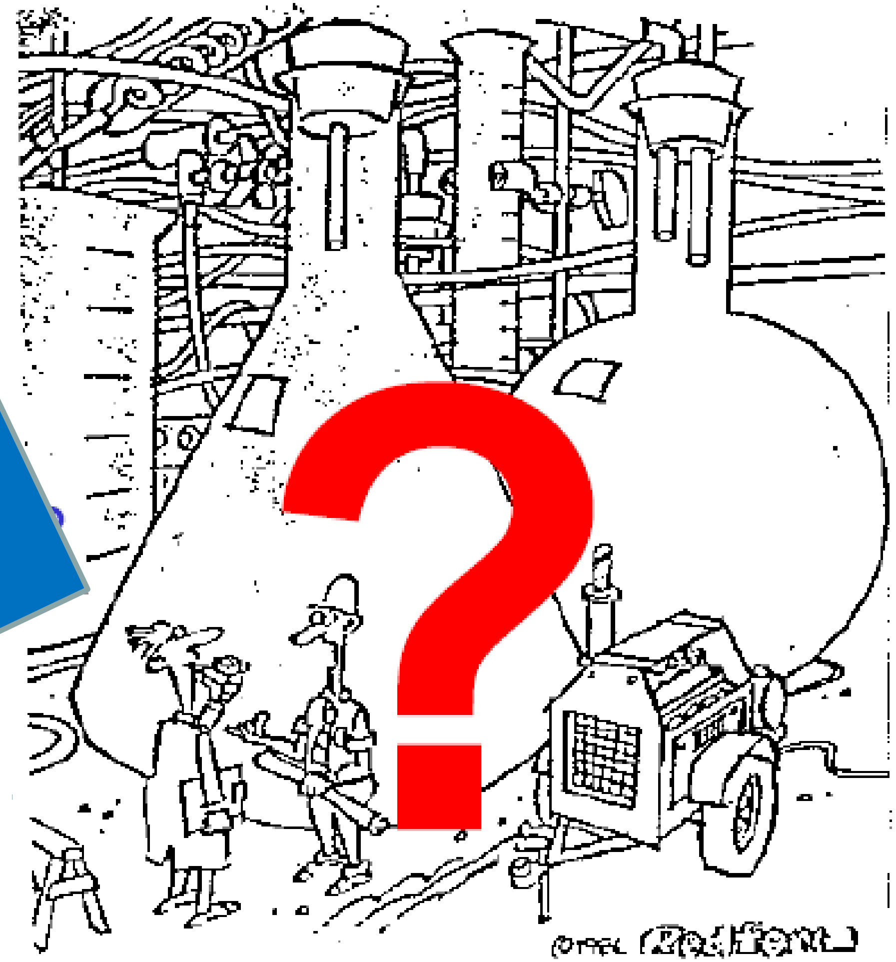
Downstream processing of raw lactates & lactic acid

Fermentation with cell retention	Pilot fermentor Type P, 450 L (Bioengineering AG) MOLSEP®Hollow fibre PES membrane (FS10-FC-FUS50E2, MICRODYN-NADIR GmbH/Daicen Membrane Systems Ltd.)
Softening	2 x 135 L PUROLITE, 1,5 m^3/h (UIT GmbH Dresden)
Monopolar/Bipolar Electrodialysis	FT-EDR/ ED4-15; 7,68 m^2 monopolar/3,2 m^2 bipolar (FuMA-Tech GmbH Vaihingen)
Ion exchange	Cationic resin, 50 L; Anionic resin, 2 x 90 L (UIT GmbH Dresden)
Decolorization	Activated carbon, several specific resins
Evaporation	«chemReactor» CR15 (Büchi AG Uster/Switzerland); Rotary Evaporator LABOROTA 20 S (Heidolph Instruments)

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."

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** w... **specific product requirements** in various applica...

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

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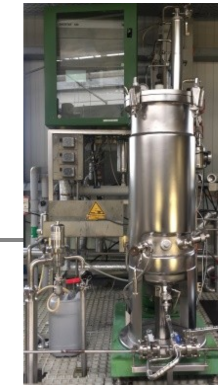
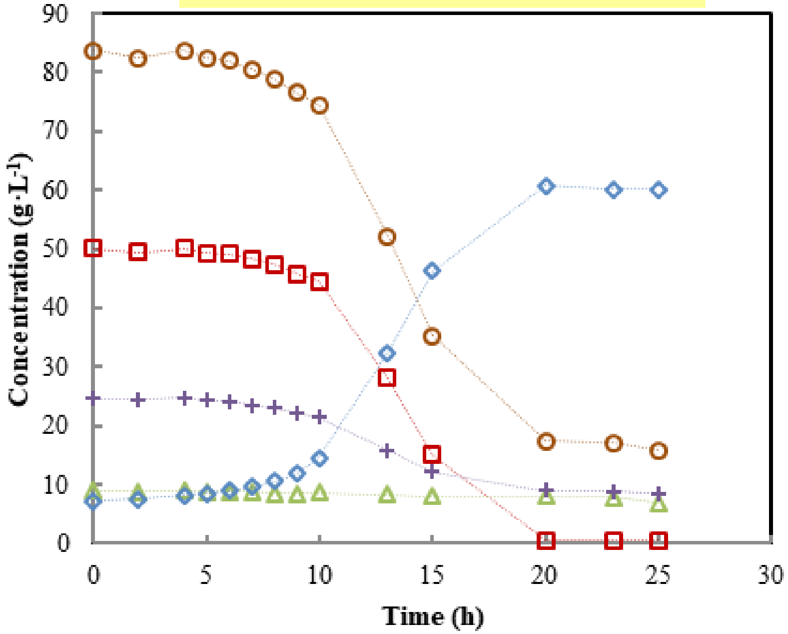
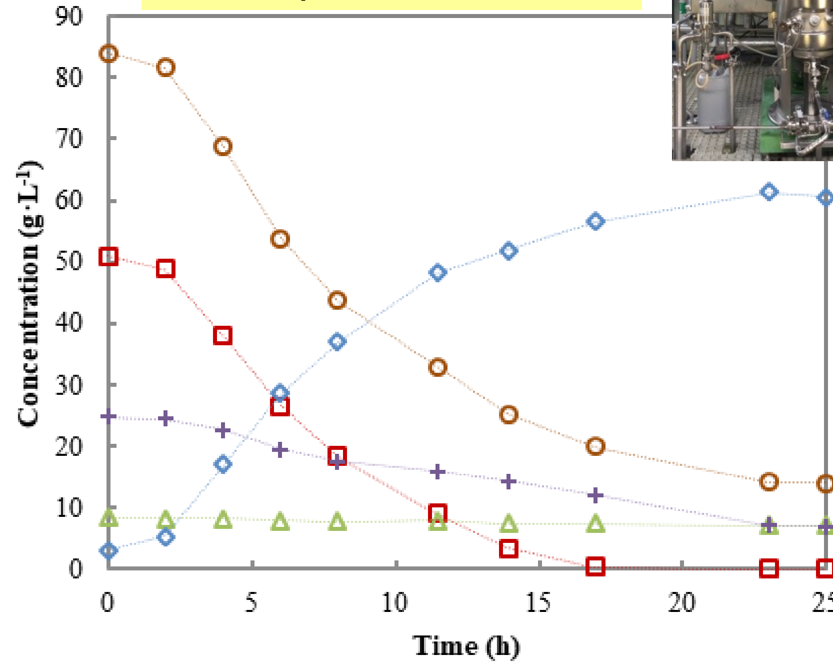
Pilot scale experiments...



Without pre-treatment



With pre-treatment



Yield of **0.94 g/g**

Final LA concentration of **60.7 g/L**

Complete consumption of glucose...
Residual sugars approx. 10 g/L

Max optical purity of **93%** L-LA

Yield of **0.94 g/g**

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

Max optical purity of **98,5%** L-LA

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Conclusions

- **OFMSW** hdrolysate is a **good substrate**. Total sugars concentration in the hydrolysate exceeding 70 g/L in some cases.
- Screening showed that many ***B. coagulans*** are able to grow and produce **LA** with **high yields**. The strain A166 has been selected for further work.
- The initial concentration of LA (racemic mixture) in the hydrolysate means that **a pre-treatment is necessary** if high optical purities are required.
- Pre-treated hydrolysate can reach a **L-LA of above 98%.**
- Experiments at the technical scale (30L) showed a **conversion over 90%** of sugars into LA.

Thank you for your attention!

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

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* (2019), https://doi.org/10.1016/j.bej.2019.107251