NOVEL BIOREFINERY PILOT

The ABOWE project aimed to provide 'proof of concept' on how biomass-based waste materials could be used as raw materials for biorefinery

Future biorefineries will work according to the principles of Nature, using microbes and enzymes for upgrading wastes and other biomass into biofuels, other energy substances, platform chemicals, and organic fertilisers. The concept of 'waste' will become unnecessary in industries, communities, agriculture and forestry since all materials are now being refined and recycled. The ABOWE (Implementing Advanced Concepts for Biological Utilization of Waste, 12/2012-11/2014) project and pilots, of the EU Baltic Sea Region Programme, have paved the way for this industrial revolution, as introduced in this article.

Purpose of the work

The novel biorefinery concept (Pilot A), innovated and developed by Adjunct Professor Elias Hakalehto, Finnoflag Oy and the University of Eastern Finland, was one of the two platforms of ABOWE. The second platform was biogas dry digestion technology (Pilot B) piloted under the supervision of Ostfalia University of Applied Sciences, Germany.

The ABOWE strategy aimed to test:

- Effective pretreatments and hydrolysis of various industrial and municipal wastes;
- Enhanced natural microbial bioprocesses for the upstream production of fuels and chemicals; and
- Preliminary planning of the simultaneous product collection.

The goal of the ABOWE project and pilots A and B was to provide 'proof of concept' on the ways that biomass-based waste materials could be used as raw materials. The production was directed to biofuels, organic platform chemicals, renewable energy, fertilisers and nutrients in an economically feasible way, with the help of micro-organisms.

The process room of ABOWE Biorefinery Pilot A

Future biorefineries will be industrial fields where side-streams from industries and municipalities are treated and refined into useful products in successive process solutions. The ABOWE project has paved the way for the complete exploitation of organic wastes in future societies.

One bioprocess alternative tested in Pilot A is based on the accelerated bacterial metabolism of 2,3-butanediol fermentation, but the concept has been useful for various bioproducts (Hakalehto *et al.* 2008). This substance is a useful raw material for producing synthetic rubber, plastic monomers, anti-icing chemicals, textiles, cosmetics and many other commodities. Semi-industrial implementation of novel production principles was tested in three countries on various different wastes, with several other biochemical products. Downstream processing techniques were developed in co-operation with Ostfalia UAS. Ethanol and hydrogen are valuable byproducts of this fermentation. For complete biowaste treatment, technologies of pilots A and B plus a downstream unit are to be combined.

The biorefinery process' novelty is in improved productivity, low initial investment costs and versatile product repertoire. The production exploits results from basic research on the physiology and regulation of bacterial metabolism. This research has been accomplished at laboratory scale, and in the field, by the enhanced cultivation unit (Portable Microbe Enrichment Unit) developed by Finnoflag Oy in 1997.

When products can be produced faster, the minimum facility size reduces, enabling lower investment. Moreover, downstream processing of the products is more affordable when end product concentrations can be increased and the total duration of the process shortened. Biogas technology (Pilot B) helps to establish innovative biorefinery systems via the supply of renewable energy to the biorefinery from corresponding co-products and residues.

The semi-industrial mobile Pilot A was designed, realised and tested in Finland, Poland and Sweden with selected waste materials. The desired outcome was implementer/investor-driven continuation projects targeting full scale plant investments.

The Pilot A team consisted of Finnoflag Oy experts, Savonia University of Applied Sciences' engineers and engineering students, personnel from subcontracting companies and students from Savo Vocational College. Versatile engineering knowledge was therefore combined in Pilot A during 2013.

Results

The first testing period took place in Kuopio, Finland, at Savon Sellu cartonboard factory's wastewater treatment plant during February and March 2014.

Products from these test runs were:

- Ethanol;
- Butanol;
- 2,3-butanediol;
- Organic acids;
- Hydrogen;
- Fertiliser biomass;
- Biogas;
- Purified water;
- Decreased waste treatment expenses; and
- Lesser environmental and climate load.

In the case of food industry wastes, maximum productivities of 8-10g/l/h of 2,3-butanediol were achieved by Finnoflag Oy in laboratory tests before ABOWE (Hakalehto *et al.* 2013). The principles of the production concept on the basis of the cellular metabolism of *Klebsiella* sp. bacteria were demonstrated.

During ABOWE, the national and international teams learned to co-operate well in this milieu, where biological components (biomass, microbes and enzymes) met with metal hardware, sensors and computerised control. Industrial levels of various organic acids, alcohols and energy gases were produced. In the Polish test runs, high levels of organic acids and alcohols were produced from potato industry waste and sorted municipal biowastes. In Sweden, tedious protein and lipid wastes from a chicken slaughterhouse and farm were converted into aliphatic energy and chemical compounds. The experimental period lasted two months in each of the three testing sites. All byproducts from production cycles seemed to be suitable for combining with biogas production.

Conclusions

Due to the decreasing supply of cheap fossil fuels worldwide, increasing interest has been directed towards the effective use of biomasses, including the organic wastes. The price of the utilised waste materials can even be negative, which improves the overall economies of these industrial applications. Tightening regulation upon discarding organic masses will boost future need for novel solutions. ABOWE utilised biocatalysis to achieve these goals instead of extensive outside energy sources.

An important aspect for the future success of biorefinery is the cascading principle with alternative energy supply from byproducts and wastes as demonstrated in ABOWE.

In 2014, the ABOWE project was chosen as the winner out of all Finnish universities of applied sciences' projects in the series Applied Research Knowledge and Innovations in the national Kärjet (SPEARHEADS) competition.

Videos from the ABOWE Biorefinery Concluding Seminar in Helsinki on 30 October 2014 can be seen at www.abowe.eu.

International training of the ABOWE Biorefinery operation took place in February 2014 at Savon Sellu cartonboard factory's wastewater treatment plant

All ABOWE publications are available for download from the same website.

References on the background of Pilot A

Hakalehto E, Humppi T, Paakkanen H (2008). Dualistic acidic and neutral glucose fermentation balance in small intestine: Simulation *in vitro*. *Pathophysiology* 15, 211-220
http://www.pathophysiologyjournal.com/article/S0928-4680(08)00028-X/abstract

Hakalehto E, Jääskeläinen A, Humppi T, Heitto L (2013): Biorefineries using waste – production of energy and chemicals from biomasses by micro-organisms. In Dahlqvist E (Ed.): *Biomass as Energy Source: Resources, Systems and Applications*. CRC Press, Taylor & Francis, London, UK

Thorin E, Ahrens T, Hakalehto E, Jääskeläinen A (2013): Organic waste as biomass resource. In Dahlqvist E (Ed.): *Biomass as Energy Source: Resources, Systems and Applications*. CRC Press, Taylor & Francis, London, UK

Dahlqvist E, Hakalehto E, Silveira S (2013): Concluding remarks and perspectives on the future of energy systems using biomass. In Dahlqvist E (Ed.): *Biomass as Energy Source: Resources, Systems and Applications*. CRC Press, Taylor & Francis, London, UK
All: http://www.crcpress.com/product/isbn/9780415620871

Hakalehto E (2015): Bacteriological indications of human activities in the ecosystems. In Armon R & Hänninen O (Eds.): *Environmental Indicators*. Springer, Dordrecht, Germany
http://www.springer.com/environment/pollution+and+remediation/book/978-94-017-9498-5

Hakalehto E (2015): Enhanced microbial process in the sustainable fuel production. In Jinyue Y (Ed.): *Handbook of Clean Energy Systems*, part 1/6. Wiley-Blackwell, J R Wiley, New York, USA. Print due May 2015
http://eu.wiley.com/WileyCDA/WileyTitle/productCd-1118388585.html

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