Implementing Bioeconomy with Electrobiorefinery

Food, chemical and industrial sectors are challenged with the growing population, increasing longevity and quality of life. In consequence, the demand for fossils energy sources, agricultural land and drinking water what will lead to irreversible changes in climate with unpredictable consequences. A recent declaration of G7 leaders that in 2100 all major economies are intended to operate free of fossil fuels requires new solutions. A possible direction to sustainably address this challenge is increasing the efficiency of current processes and to replace fossil energy sources by renewable biomass resources.

The substitution of fossil-resource-derived chemicals and fuels with biomass for the production of food, platform chemicals and fuels is known as bioeconomy. A basic productive unit in the bioeconomy is *biorefinery*. Bringing biorefineres to practice is expected to contribute to low carbon economies, by production of chemicals, energy and jobs without using fossil fuels. The design and implementation of a biorefinery depends on a large number of factors, including availability of feedstocks, advances in biomass production and processing technologies, environmental impacts and socio-economic conditions.

Energy efficiency is a key factor for bioeconomy and decarbonisation success

Despite the long history of biomass use by humans, biomass processing and converting technologies are mostly traditional and not efficient in terms of outputs and energy consumption. Therefore, fossil sources are often preferred for synthetic chemicals and energy production. During last centuries, fossil fuels based technologies for electricity generation achieved high efficiency, e.g. ~ 35% for oil and coal power stations and ~ 60% for combined heat-electricity processes. However, biomass based processes are fundamentally less efficient than fossil fuel based sources, as the efficiency of the solar energy conversion to chemical energy by photosynthesis is 5% at most. However, given the advantages of biomass in terms of product versatility and local and global availability, there is a strong motivation to develop new processes and technologies that will boost the energy efficiency of biorefineries.

One type of these new technologies is based on pulsed electric fields (PEF). First developed in the USSR in the 40ies and 50ies and then in Europe in the 60ies of last century for oil, juice and phytochemicals extraction and microorganisms inactivation, tremendous progress in fundamental understanding on PEF impact on cells, development of new processes and technologies suggests that PEF can become an essential tool for energy efficient biorefineries, i.e. *electrobirefineries* (Figure 1).

How pulsed electric field processes work on biomass?

In 1972, Neumann and Rosenheck reported first observations of transient permeability changes in the vesicle membranes as a consequence of external electric field impact. In recent decades this observation led to understanding of cell membrane electroporation phenomena. Electroporation is already used in medicine for tumor treatment, in basic molecular biology for gene introduction into cells and in food industries for disinfection and phytochemicals extraction. The unique property of electroporation technology, to affect cell membranes selectively and non-thermally. This selective targeting of cell membrane opens applications of this technology for sustainable biorefinery.

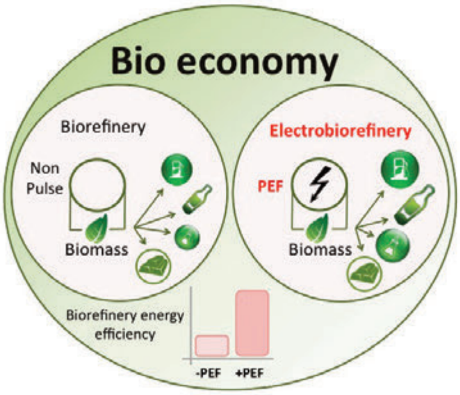

Figure 1: Electrobirefiney improves the energy efficiency of biomass processing

Biorefinery processes that already benefit from electroporation based technologies

Electroporation technologies are already used in biorefinery applications such as feedstock development, biomass dehydration and extraction of high value and energetic products. Genetic modifications of microalgae and plants have been done by transferring the genes inside the cells using electroporation. In dehydration, one of the most energy intensive processes in biomass processing, electroporation

Figure 2: Industrial test of PEF (10t/hour) in sugar beet factory

pretreatment increases diffusion of water and vapor, thus reducing the energy and processing time required for biomass drying. For example, the time required for drying energy crops in an oven could be reduced by a factor of 2-3 compared to material not electroporated, i.e. not treated by PEF.

PEF provides a new and scalable technology for extraction of phytochemicals from biomass for energetic use. Lignocellulosic biomass from terrestrial plants, energy crops, and crop residues and macroalgae exhibit strong potential for biofuel or biogas production. Energy-efficient PEF-assisted recovery of value-added compounds, e.g. proteins. lipids and phenolic compounds will boost the economic efficiency of these biorefineries. Due to its fractionating abilities, PEF enables energy efficient subsequent recovery of minerals, lipids and proteins from microalgae. For instance, after PEF treatment and separation of the water-soluble fraction, the lipid yield from the residual fraction was 3-4 times higher, compared to untreated samples, recovering more than 80% of stored lipids on average. Moreover, electroporation can accelerate hydrolysis steps and digestion during biogas production from dedicated biomass and waste.

How electroporation technologies can transform the biorefineries?
Electroporation based technologies have been very successful in the medical applications, transforming the fields such as gene therapy, DNA vaccination and cancer treatment. They are a part of every biology lab where they are used for genetic modifications of organisms. On lab scale, electroporation technology shows promising results for multiple biorefineries applications. Next step will be the industrial implementation. Biorefineries today are complex systems that integrate multiple technologies for agriculture, aquaculture and biomass processing. Integrating PEF system into existing facilities is a technological and economic challenge. However, as it has been demonstrated in the sugar industry, where up to 10 tons/hour PEF systems exist (Figure 2), this integration is possible when justified. Future research on pilot scale biorefinery PEF units will provide detailed answers about the energetic, water and resource benefits of the processes that use electroporation technologies in biorefinery applications.

The concept electrobiorefineries was developed within the European Cooperation in Science and Technology framework – COST Action TD1104. COST Action TD1104 is now in its 4th – final year and has organised in September the 1st World Congress on Electroporation in Portorož, Slovenia attended by 400 participants from 42 countries. The 2nd World Congress is already announced for September 24 to 28, 2017 in Norfolk, Virginia, USA.

Prepared by:

Alexander Golberg, PhD. Porter School of Environmental Studies, Tel Aviv University, Israel.

Eugene Vorobiev, PhD Departement de Genie Chimique, Universite de Technologie de Compiegne, Centre de Recherche de Royallieu, France.

Wolfgang Frey, PhD. Karlsruhe Institute of Technology, Institute for Pulsed Power and Microwave Technology, Germany.

Illustations: by Mark Polikovsky. Porter School of Environmental Studies, Tel Aviv University, Israel.

Professor Damijan Miklavčič
Chair
COST Action TD1104
Tel: +386 1476 8456
damijan.miklavcic@fe.uni-lj.si
www.electroporation.net