HUMAN & BIOTECHNOLOGY

Fields of Expertise TU Graz

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Gernot Müller-Putz, Human & Biotechnology
Source: Lunghammer – TU Graz

After a "hot autumn" with the deadlines for FWF START, ERC Starting, ERC Consolidator and ERC Synergy Grants, we would like to point out that there is an ERC Club at TU Graz that aims to provide applicants with the best possible support for their applications and interviews. In a relaxed atmosphere, ERC grantees talk about their experiences and applicants can ask questions on all topics related to the ERC, such as When should you start? What does high risk/high gain mean? How does the review process work? How should one write the different parts of the proposal? What are the panels? These and many more questions will be addressed at the next ERC Club meeting in spring 2023. Interested parties can contact Gerald Pichler at the Research & Technology House.

However, it is also again possible to get a large grant at TU Graz. Currently, the LEAD projects are being advertised again and there is the possibility to apply with a consortium. We call on our FoE members to participate in this TU Graz-internal funding opportunity.

We have good news to report from our FoE. The Stefan Schuy Prize of the ÖGBMT (Austrian Society for Biomedical Engineering) has been awarded to Sonja Langthaler (Institute of Health Care Engineering). The prize was presented at the three-country meeting of the German, Swiss and Austrian societies in Innsbruck at the end of September.

Helmut Schwab has written an interesting article on a highly topical subject of industrial biotechnology for this issue. It is about the use of carbon dioxide and hydrogen for the microbial production of valuable substances, in his case protein as animal feed.

Helmut Schwab

Protein from Carbon Dioxide: A Sustainable Perspective

The extreme release of CO_2 into the atmosphere by using fossil carbon resources is drastically influencing the climate of our planet. Technology to recycle CO_2 and turning it into valuable compounds not only provides important solutions to reduce negative impacts on the climate, but also opens up a sustainable raw material source.

Helmut Schwab researches at the Institute for Molecular Biotechnology.

Source: Foto Fischer

With our research for developing a bioprocess for producing protein based on CO_2, novel routes for food and feed production are enabled. The company Econutri GmbH, a spin-off from research work performed at TU Graz and the Austrian Centre of Industrial Biotechnology (acib GmbH), is now transferring basic research into industrial application by research at pilot scale.

WHY PROTEIN?

The supply of protein in sufficient quantities for human nutrition is increasingly becoming a challenge due to the rising population growth. In particular people in developing countries are already severely suffering from lack of protein, thus generating hunger and problems in the development of body and brain in children.

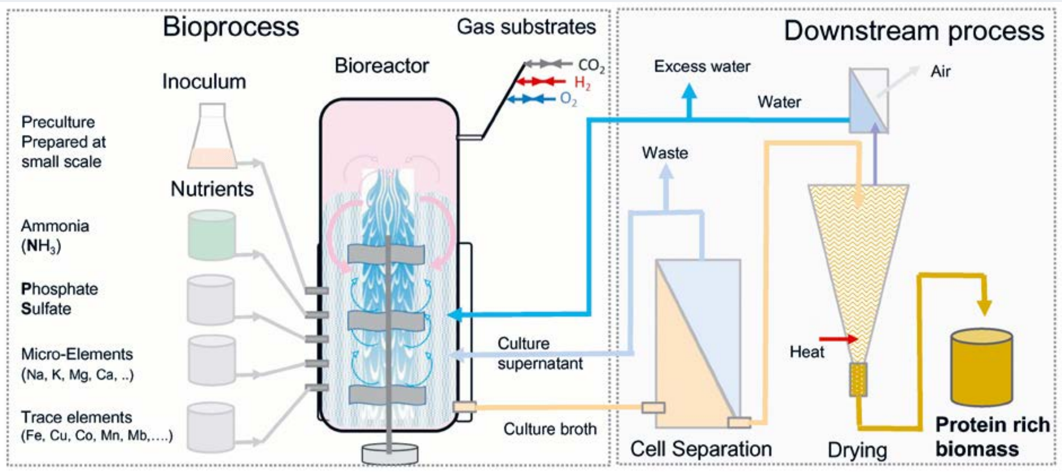

Figure 1: Scheme of the bioprocess for SCP from CO_2.
Source: H.Schwab / Econutri

The current sources of protein for human nutrition, plants and animals have already come up against strong barriers. The cultivation of protein-rich plants, such as for example soy bean, needs large areas of cultivable land, high amounts of water and the application of herbicides and pesticides. As the available cultivable land is already totally limited, large areas of virgin forest are being burned down thus triggering additional CO_2 release into the atmosphere. Fisheries are a major source of protein from animals. Extreme overfishing of our oceans is already strongly endangering fish populations, and fish farming again needs other protein sources. As a consequence, novel solutions for protein supply not needing large land or fish resources are indispensable in order to guarantee sufficient protein.

ALTERNATIVE PROTEIN BY PRODUCTION IN INDUSTRIAL PLANTS

Several concepts for producing protein in industrial plants have been established. One line is cultivation of insects, mainly as protein-rich larvae. Such processes can be performed in rather simple production facilities and usually use waste products from agriculture or food production. A more sophisticated strategy is cultivation of animal cells in tissue culture systems. This strategy is expected to directly serve as a substitute for meat. However, very complex and extremely expensive cultivation media are needed which again are dependent on agricultural resources. The most promising route is the cultivation of microbial cells in bioreactors (Single Cell Protein, SCP). Many microbes can efficiently synthesize protein and their biomass can contain up to 80% protein (SCP). Processes employing – for example – yeast have been run for many decades and are mostly based on sugar-containing substrates such as molasses, thus also creating a dependence on materials from agriculture.

CARBON DIOXIDE IS A CARBON SOURCE FOR BIOPROCESSES INDEPENDENT FROM AGRICULTURE

In living nature, carbon dioxide serves as the central carbon compound and is constantly consumed and produced in an equilibrated cycle system. Fixation of carbon dioxide in order to build organic compounds and biomolecules takes place in the domain of plants. Organisms which gain their nutrition directly or indirectly from plant products produce CO_2 acting as a sink in energy production. Besides plants, a variety of microbes also can utilize CO_2. Algae and microalgae (cyanobacteria), like plants, use solar energy via photosynthesis as an energy source. However, the establishment of industrial photobioprocesses is restricted by the demand of large surface areas for transmission of light to the cells. Alternatively, chemolithoautotrophic bacteria use chemical energy for CO_2 fixation. The most interesting group of such organisms are bacteria which can utilize molecular hydrogen as an energy source.

THE BACTERIUM CUPRIAVIDUS NECATOR – A WORK HORSE FOR CO_2-BASED BIOPROCESSES

The bacterium C. necator is a facultative chemolithoautotrophic bacterium which can either grow heterotrophically on organic compounds or autotrophically using CO_2 and hydrogen as sole sources of energy and carbon. It has been well-studied over decades and has a long history of safe use. Large bioprocesses based on heterotrophic nutrient supply are already well established, e.g. for the production of the biopolymer polyhydroxybutyrate (PHB). Autotrophic growth is well established at small scale and several companies are already considering this organism as a platform for the production of various compounds based on CO_2.

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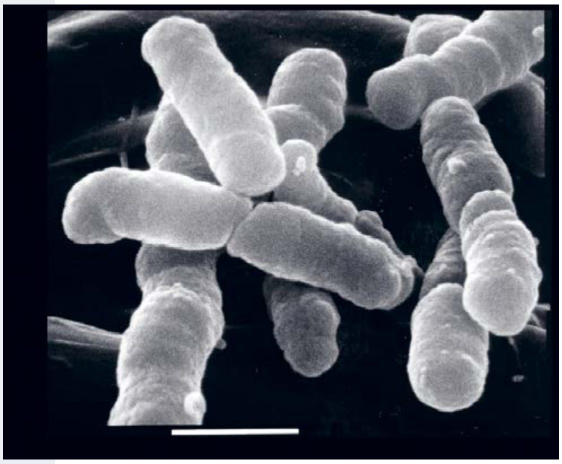

Figure 2:
Electron micrograph of cells of Cupriavidus necator.
The white bar represents 1 µm.
Source: H.Schwab / FELMI-ZFE

Figure 3:
Pilot gas bioreactor at 300 L volume capacity.
Source: H.Schwab / Econutri

GAS FERMENTATION AT LARGE SCALE IS A CHALLENGE

The bioprocess for protein production from CO_2 needs a bioreactor which provides a highly efficient gas-to-liquid transfer capacity. This is especially driven by the fact that molecular hydrogen is poorly soluble in aqueous systems and it represents the major molecule and cost-driving factor of the entire process. This becomes quite evident from the summarizing mass balance of the autotrophic protein production process.

$$21.36\ H_2 + 6.21\ O_2 + 4.09\ CO_2 + 0.76\ NH_3 \rightarrow ([\ C_{4.09}\ H_{7.13} O_{1.89} N_{0.76}\ ] = \text{biomass}) + 18.7\ H_2O$$

Most of the hydrogen is used for energy production by an electron transfer process from hydrogen to oxygen, thus creating water as an end product (biological "burning" of hydrogen). We have developed a novel reactor design for efficient gas fermentation to meet the demand for efficient gas-to-liquid transfer. The reactor operates under pressure up to 6 bar in order to raise the partial pressure of the gases and it has a specifically designed mixing system for creating high-contact surfaces between gas and liquid phases. In addition, the reactor design also includes a safety management system in order to prevent explosion. It is installed at the Institute of Thermal Engineering, where the proper infrastructure for operating processes using hydrogen has been established.

UPSCALING TO INDUSTRIAL LARGE SCALE

In our current research work performed in collaboration with acib GmbH, the operation parameters for the bioprocess are optimized and suitable fermentation protocols for high biomass production, high protein content and rapid growth are worked out. In the next year, the downstream process will also be included in the pilot plant. It is also planned to extend the research work by including the needed supply elements, such as hydrogen and oxygen production by electrolysis, and using real off-gas from CO_2 emitting industries. The first product of our process will be dried protein-rich biomass, which is intended to be used as an ingredient for animal feed. In the context of developing the downstream process, we will also perform research on extraction of pure protein fractions out of the biomass. Such a pure protein product could then also go directly into human nutrition.