New Analytical Technology at PFI

Focus on the Cell: High Resolution Natural Product Analysis at a Cellular Level

Optimum supply of nutrients to microorganisms is a crucial requirement for ensuring that fermentation processes for the production of biobased materials and sustainable energy proceed efficiently and economically. The design of growth media and trace element solutions plays an important role in the control and optimisation of these processes. This is particularly challenging in complex fermentations and whenever residue-based growth media are used instead of synthetic ones. PFI will in future be using an innovative measuring technique for the targeted optimisation of fermentation processes: So-called Single Cell ICP-MS permits determination of concentrations of process-relevant nutrients and trace elements in the bacterial cell. This will lead to considerable advances in medium optimisation and medium recycling in the Power2Gas process as well as in the use of trace elements in biogas plants.

In an investment project funded by the German Federal Ministry for Economic Affairs and Energy (BMWi) PFI will acquire an ICP-MS with a Single Cell (SC) module. ICP-MS stands for inductively coupled plasma mass spectrometry.

SC-ICP-MS is a newly developed technique which permits determination of the concentrations of elements in individual undamaged cells. It is based on methods for the study of nanoparticles (single particle ICP-MS or SP ICP-MS for short). The special feature of SC as compared to the SP technique is that the living cells are transported non-destructively into the plasma and the natural product contents in the cells can be determined.

Using the new technique, we plan to further enhance our research and development competence in the research fields of biogas and power-to-gas.

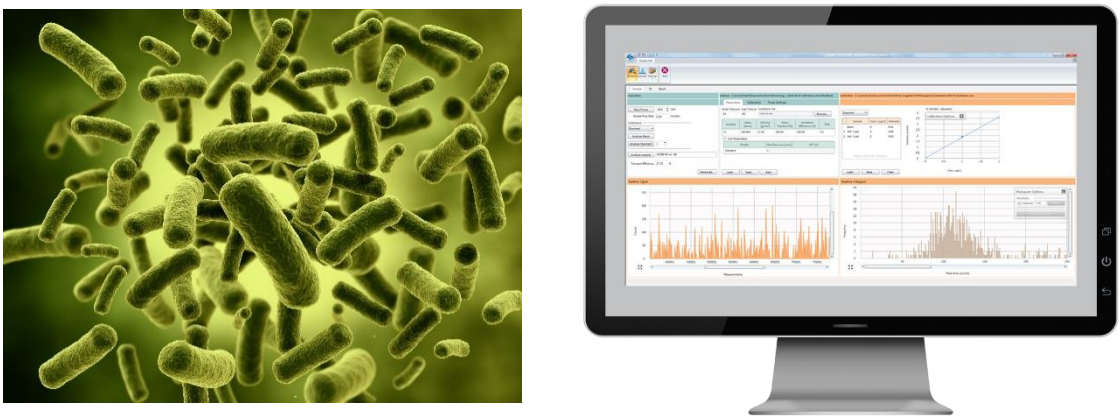

Fig. 1: Determination of nutrient and trace element concentrations on a cellular level by SC-ICP-MS.

In the biogas sector numerous innovative approaches for improvement of the process biology and for substrate treatment have already been developed in the course of various research projects and industrial cooperation programmes. The availability of certain micronutrients is of crucial importance for the stability of fermentation. Among others, these include the elements cobalt, nickel, molybdenum, and selenium, which are important for the activity of methanogenic archaea. Meanwhile, many agricultural biogas plants make use of trace element solutions to stabilise the fermentation process. Determination of the overall concentrations of these elements in biogas fermenters is state-of-the-art technology and is offered both by PFI and by many other laboratories.

Reliable Information about Process-relevant Nutrient Status in Biogas Fermenters

Typically, however, only small proportions of the micronutrients present in a biogas fermenter are biologically available. This is due to the continuous formation of hydrogen sulphide during the fermentation process, which leads to precipitation of certain micronutrients. In the form of insoluble metal sulphides (e.g., NiS) the micronutrients are no longer bioavailable. The overall contents of the elements mentioned above only permit very limited conclusions about the process-relevant nutrient status. Much R&D work is needed on the topic of the bioavailability of micronutrients in biogas fermenters.

First of all, reproducible measurements of dissolved fractions of certain metals require highly sensitive measuring methods. In a second step, these data can be compared with SC-ICP-MS analyses of enrichment cultures obtained directly from the fermenter. Comparison of different fermenter types (with regard to feed and process engineering) permits categorisation in order to provide a basis for development of an optimum plant-specific assessment of trace-element demand. A corresponding research project focusing particularly on plants using predominantly fibre-rich and/or nitrogen-rich feed substrates is currently in preparation. This is because of changes in the German Renewable Energies Act (Erneuerbare-Energien-Gesetz, EEG), according to which plants operated with maize feed will become less important. Instead, there will be a medium-term increase in the use of alternative substrates and residues such as manure, grass, straw, and poultry dung. Because our present knowledge about the significance of trace elements for the biogas process is based mainly on plant operation with a high proportion of maize in the feed substrate there is an enhanced need for R&D particularly in this area.

Improvement of Biological Methanation in P2G

Another important field of application of SC-ICP-MS is seen in biological methanation, a key process step in power-to-gas technologies. PFI is one of the leading research institutes in the field of biological methanation and operates Germany's largest demonstration plant at the Pirmasens-Winzeln Energy Park. The R&D activities of PFI and other research establishments and companies are currently strongly focussed on process optimisation to improve the economic efficiency of P2G plants. There is considerable potential for improvement here, particularly by increasing the productivity of the microorganisms used in the bioreactors. As in the biogas process, particular importance attaches to an optimum nutrient supply to the methanogenic bacteria. Since sulphur-containing compounds act as reducing agents in the bioreactors, precipitation reactions and the bioavailability of relevant nutrients play a key role here. Another factor is the process-related water production in the reactors, which leads to dilution of the growth medium and thus strongly affects the nutrient status. High-resolution elemental analysis will therefore make an important contribution to optimisation of growth media and the development

of medium recovery methods. Moreover, thanks to SC-ICP-MS methods new possibilities open up in relation to nutrient uptake and trace element availability in an ongoing process.

Conclusion: The introduction of SC-ICP-MS-based analytical techniques harbours considerable potential for increasing innovative competence in several of the key research areas of PFI Biotechnology.

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