Symposium

Carbon and Nitrogen Valorization: Sustainability in Focus

Venue: ***Technical University of Munich (TUM) - Campus Straubing, Uferstraße 53 (Room U3, Ground floor), 94315 Straubing, Germany***

Date and time: **11 June 2024; 08:30 h - 11:50 h**

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5 invited speakers from Denmark, France, Germany and Belgium

DTU TUM cnrs Fraunhofer IGB European Innovation Council

Organized by: ***ECOMO, a European Innovation Council (EIC) funded project***

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CO_2 CO acetate diamines

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Agenda

Time (h)	Proceedings	Speaker
08:30 - 08:40	Welcome and Opening Remarks	
08:40 - 09:10	The role of thermodynamics, kinetics, and mass transfer in gas fermentations	Hariklia N. Gavala (DTU, Denmark)
09:10 - 09:40	Microbial upgrading of C1 feedstocks	Bastian Blombach (TUM, Germany)
09:40 - 10:10	**Coffee break**	
10:10 - 10:40	Bioinspired chemistry as entry to exclusive functional materials	Michael Richter (Fraunhofer IGB, Germany)
10:40 - 11:10	Electrochemical studies of CO_2-reducing enzymes	Vincent Fourmond (CNRS, France)
11:10 - 11:40	How to make a business out of research results through the hands-on portfolio approach	Francesco Matteucci (European Innovation Council)
11:40 - 11:50	Closing	

Each invited speaker will present for 20 minutes followed by 10 minutes discussion

The titles and abstracts of the invited speakers' presentations are summarised in the following pages, along with a concise biography of each invited speaker

Presentation 1

The role of thermodynamics, kinetics, and mass transfer in gas fermentations

by **Hariklia N. Gavala**

Associate Professor, Department of Chemical and Biochemical Engineering, Technical University of Denmark (DTU), Kgs. Lyngby 2800, Denmark

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Abstract: Over the last 8 years, at DTU Chemical Engineering we have developed a thermodynamics-assisted methodology for directing microbial enrichments specialized for gas fermentations, a thermodynamics-consistent modeling of the biochemical reactions as well as a Trickle Bed Reactor, TBR, for highly efficient gas biological conversions to bulk chemicals and biomethane. TBR offers the dual benefit of high surface area, thus facilitating mass transfer, as well as high density of microbes that results in enhanced production rates. Dynamic modeling of both biochemical reactions involved, and mass transfer is a powerful tool that can be used for optimal up scaling, and reliable predictions that can be tailored to specific cases in terms of scale and products.

Thermodynamics, kinetics, and mass transfer play a critical role in the efficiency of the process. The presentation will start with explaining how thermodynamics and kinetics can affect the viability and specificity of microbial conversions. Specific case-studies from in-house experience will be presented to highlight the necessity of considering both kinetics and thermodynamics for optimizing a gas fermentation process. The second part of the presentation will focus on the importance of mass transfer and how modeling of variable volumetric mass transfer coefficient allows for optimal up-scaling of a rather complex reactor system. Predicting and controlling the volumetric mass transfer

coefficient can be proved valuable, not only for maximizing the mass transfer rate, but equally importantly, to preventing inhibition and toxicity phenomena. Temperature, pressure, reactor geometry and gas and liquid flow rate can be adjusted to secure maximum efficiency of the gas fermentation process. As this approach and modeling tool can be adjusted to different reactors and microbial systems, it can be very useful for designing new and re-visiting established processes in the field. Finally, use of the accumulated experience and developed tools for optimal conversion of CO to acetate in ECOMO project will be discussed.

Short Biography: **Hariklia N. Gavala** is Chemist with a PhD in Biochemical Engineering and Environmental Technology (Departments of Chemistry and Chemical Engineering, respectively, University of Patras, Greece). She is currently Associate Professor at the Department of Chemical and Biochemical Engineering at the Technical University of Denmark. Her research focus is in Biorefinery Conversions with emphasis on production of biofuels, bulk chemicals and materials (bioplastics) from biomass including industrial effluents as well as in developing the syngas and CO_2 platform towards biotechnological applications. Dr. Gavala has expertise in anaerobic digestion and fermentation processes with axenic cultures and mixed microbial consortia, pre-treatment methods, kinetics and modeling as well as membrane application in biorefineries. Since 2012, Dr. Gavala has participated in more than 15 research projects funded by national and international funding agencies. Dr. Gavala has obtained two Marie Curie fellowships and in 2010, she was nominated for the "EliteForsk-priser" from the Department of Biotechnology, Chemistry and Environmental Engineering of Aalborg University in Denmark. She has published 90 publications in peer-reviewed scientific journals, 4 book chapters (h-index 35; All Databases, WoS) and she has made more than 100 contributions in international scientific conferences and workshops.

Presentation 2

Microbial upgrading of C1 feedstocks

by **Bastian Blombach**

Professor, Professorship Microbial Biotechnology, Technical University of Munich (TUM), Campus Straubing for Biotechnology and Sustainability, Uferstraße 53, 94315 Straubing, Germany.

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Abstract: Industrial waste gases emit large amounts of greenhouse gases into the atmosphere and may contain significant amounts of CO_2, CO, and H_2 but depending on the source also O_2 (e.g. from the cement industry). Such gas steams represent an abundant source for gas fermentation to produce chemicals with microbial catalysts. Anaerobic gas fermentation has become a technology of industrial maturity and first production plants have been successfully installed. However, due to the anaerobic lifestyle, the commonly applied acetogenic bacteria are energy limited and the production of ATP-demanding molecules might become challenging. To overcome this limitation, we recently proposed to utilize carboxydotrophic Knallgasbacteria as cell factories to convert O_2-containing waste gases into valuable chemicals. One representative is *Hydrogenophaga pseudoflava* which we engineered this bacterium for the aerobic production of the C_{15} sesquiterpene (E)-α-bisabolene from syngas.

Acetate is an alternative carbon source and can efficiently be generated from C1 gases by anaerobic fermentation using acetogenic bacteria. However, the valorization of acetate

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as sole carbon source by microbial fermentation has rarely been addressed so far. A promising host to upgrade acetate is *Corynebacterium glutamicum*, which is an established workhorse for the large-scale production of several amino acids such as l-lysine and l-glutamate in millions of tons per year from sugar-based carbon sources. As proof of concept, we tailored *C. glutamicum* for the efficient production of itaconic acid from acetate by rewiring the central carbon and nitrogen metabolism and optimizing the culture conditions.

Short Biography: Professor Bastian Blombach studied biotechnology at the University of Applied Sciences Weihenstephan and received his doctorate in 2009 from the Institute of Microbiology and Biotechnology at the University of Ulm. Beginning in 2012, he was a junior research group leader at the Institute of Biochemical Engineering at the University of Stuttgart. Prof. Blombach is heading the Professorship for Microbial Biotechnology (MIB) at TUM Campus Straubing for Biotechnology and Sustainability since October 2018. The research at MIB focuses on the development and optimization of microbial production processes for chemicals and fuels from renewable resources and systems-level physiological studies of microbes under industrial process conditions. To achieve this goal, the group applies the methodology of metabolic engineering, systems biology, and synthetic biology to exploit the potential of established and novel microbial systems for industrial biotechnology. The construction of tailor-made cell factories is carried out by modern methods of genetic engineering and is supported by metabolome analyses. The development of a quantitative and systemic understanding of the metabolic performance of microbial platforms such as *Vibrio natriegens*, *Hydrogenophaga pseudoflava*, and *Corynebacterium glutamicum* is essential in this context.

Presentation 3

Bioinspired chemistry as entry to exclusive functional materials

by **Michael Richter**

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Abstract: Today the use of renewable resources and the utilization of nature's chemistry is in the focus of multiple research and development approaches that follow the principles of sustainable chemistry. In this context, many fields such as organic chemistry, bioorganic chemistry, biosynthesis and biocatalysis are relevant for the interdisciplinary tasks. The talk will cover representative research highlights carried out at Fraunhofer IGB by using bioinspired and biomimetic chemistry strategies involving **i)** the synthesis of terpene-based polyamides, **ii)** the exploitation of biosynthetic modules for diversity-oriented synthesis **iii)** the development of biohybrid systems for electrobiocatalytic CO_2 conversion. According to this, bioinspired chemistry is a complementary response to the technical requirements of modern sustainable chemistry. Solutions can be identified and be developed through an adaptive matrix approach. The talk shall stimulate discussion of how to use nature's toolbox, in order to combine biobased chemistry with established technologies for future markets.

Short Biography: **Dr. Michael Richter** is a chemist and has been conducting research at the Straubing branch of the Fraunhofer IGB (Germany) since June 2015. Here he initially worked on developments in the fields of applied biocatalysis and biobased materials. In 2019, he took over as head of the Bioinspired Chemistry department, a highly interdisciplinary research group dedicated to innovative developments in the field of sustainable chemistry in a holistic manner, using nature as a source of ideas.

Presentation 4

Electrochemical studies of CO_2-reducing enzymes

by **Vincent Fourmond**

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Abstract: Only two metalloenzymes are able to reduce directly CO_2 : the NiFe CO dehydrogenase, which reduces CO_2 to CO, and the Mo/W formate dehydrogenase, which produces formate. These enzymes are fast, energy efficient and highly specific in terms of product, hence the interest to understand their catalytic mechanism and the origin of their catalytic performances. They can readily be connected to electrodes, so we have used Protein Film Electrochemistry[1] to learn about various aspects of their reactivity. We have demonstrated that the form of "CO_2" being reduced is really CO_2 (as opposed to HCO_3^-) both for formate dehydrogenases and CO dehydrogenases[2], and that CO dehydrogenases, although they have high sequence similarities, have very different properties in the reaction with their substrates and inhibitors[3,4].

Regarding formate dehydrogenases, according to the current consensus, the metal ion of the catalytic center in its active form is coordinated by 6 S (or 5 S and 1 Se, see figure) atoms, leaving no free coordination site to which formate could bind to the metal[5]. Some

authors have proposed that one of the active site ligands decoordinates during turnover to allow formate binding, while another proposal is that the oxidation of formate takes place in the second coordination sphere of the metal. The analysis of our electrochemical data, obtained on two different formate dehydrogenases, strongly support the "second coordination sphere" hypothesis[6], showing that formate likely does not bind to the metal of the active site.

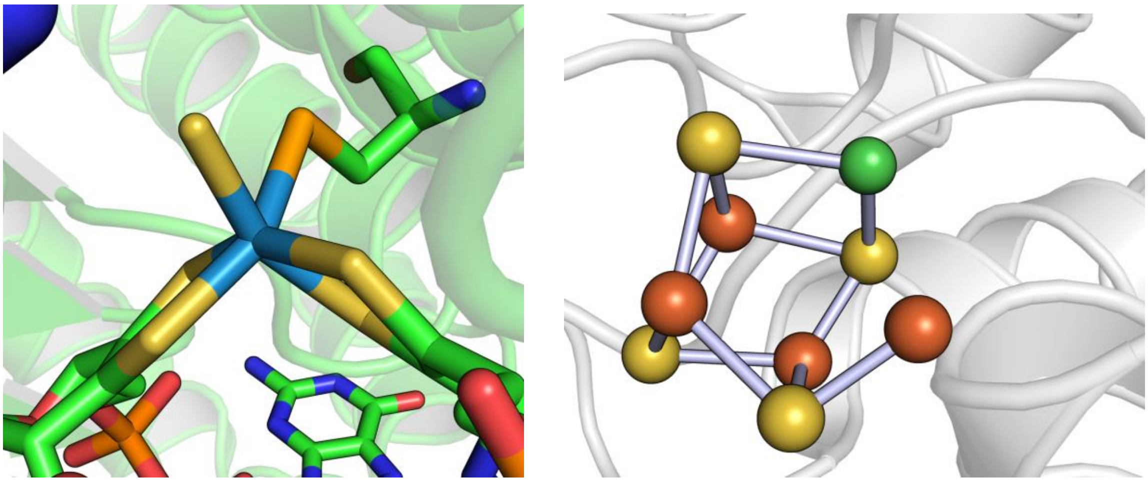

***Figure**: Active sites of the formate dehydrogenase (left) and CO dehydrogenase (right)*

References: [1] Butt et al, Nature Reviews Methods Primers, 2023, 3, 77; [2] Meneghello et al, Angew. Chem. Int. Ed. Engl., 2021, 60, 9964-9967; [3] Domnik et al, Angew. Chem. Int. Ed. Engl., 2017, 56, 15466-15469; [4] Benvenuti et al Biochim. Biophys. Acta Bioenerg., 2020, 1861, 148188; [5] Oliveira et al, ACS Catal. 2020, 10, 3844–3856; [6] M. Meneghello et al, Angew. Chem. Int. Ed. Engl., 2023, 62, e202212224.

Short Biography: **Vincent Fourmond** studied physics at the École Normale Supérieure (Paris), and turned to the interface between Physics, Biology and Chemistry during his PhD on the reconstitution of photosynthetic electron-transfer chains in electrochemical cells, under the supervision of Winfried Leibl (CEA Saclay). He worked as post-doctoral fellow on the electrochemistry of metalloenzymes (Marseille, team leader Christophe Léger) and of biomimetic complexes (Grenoble, team leader Vincent Artero). He works as research fellow in the CNRS (Marseille) with Christophe Léger since 2011. His activities include the study of redox metalloenzymes using electrochemistry and other kinetic techniques, the modelling of complex reaction/diffusion, and the development of the data analysis software QSoas.

Presentation 5

How to make a business out of research results through the hands-on portfolio approach

by **Francesco Matteucci**

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Abstract: Europe produces world-class fundamental research, but this too rarely translates into innovative products for the market. To overcome this in 2021 the European Commission set up the European Innovation Council (EIC), Europe's flagship innovation programme to identify, develop and scale up breakthrough technologies and game changing innovations. One particularity of the EIC is its hands-on portfolio approach. Portfolios are groups of projects that share common topics/themes, know-how/technology, or stakeholders or belong to the same value chain. The hands-on approach is a content-wise way of streamlining innovation. It goes beyond funding breakthrough research as it is facilitating the innovation journey of beneficiaries by providing them the necessary innovation tools (both scientific-, regulatory- and business-wise) identified and needed to successfully position themselves in the market. One key element of the hands-on approach is to promote an entrepreneurial mindset in the

scientific context. The talk will present how EIC operates and present some of the innovation journeys to make a business out of a research result.

Short Biography: **Dr. Francesco Matteucci** is an innovation manager with more than 20 years of experience spent as a researcher in materials science, as a Corporate R&D Manager and a start-up cofounder within the field of technologies for renewable energy production and storage, and as an intermediary of knowledge trying to exploit the research results coming out of Cleantech scientific labs. Since 2020 he is the European Innovation Council (EIC) Programme Manager for Advanced Materials and Environmental sustainability.