

Biobased Chemistry and Technology Annual report 2018



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Introduction

It is my pleasure to present to you the annual report 2018 of the Biobased Chemistry and Technology (BCT) group.

In the last year fierce discussions were ongoing in the Dutch society with regard to the climate agreements. No matter the details of the outcome this will have an impact on our daily life. The research of BCT contributes to that discussion by performing research on the energy and resource efficient production of chemicals we all need every day.

The BCT group organized two important events last year, i.e. the first International conference on Oil Bodies/Oleosomes and the EFCATS (European Federation of Catalysis Societies) Young researcher contest. The oil body conference was organized by Costas Nikiforidis, one of our staff members and a world expert on oil bodies. The EFCATS young researcher contest, where the participants had to write a research proposal in 2.5 days, was organized by Harry Bitter. Both events were a great success.



In 2018 the on-campus master 'biobased sciences' started. The first courses, where BCT was involved as well, were a great success. The interdisciplinarity of this master, without losing in-depth scientific building of the students, is a great added value. I have great expectation for the future that we are able to educate students how to have a broad view on biobased sciences but also to have expert knowledge.

All this made 2018 again an interesting and exiting year and I'm sure you feel the same after reading this report.

With kind regards

Prof. J.H. (Harry) Bitter
Chair holder Biobased Chemistry and Technology

Collaborations

The strategy of the BCT group is to develop fundamental insights in processes relevant for biobased conversions and based thereon suggest improvements of process technology in the biobased economy. This not only requires the incorporation of several length and time scales, but also the knowledge and expertise of multiple disciplines. Therefore, we established collaborations with other groups within and outside Wageningen. Some of our collaborations are summarized in the table below.

At the end of 2016, the chemistry groups at Wageningen University started closer collaborations within WUR-Chemical Sciences in which BCT plays an important role by contributing one position to the board.

Collaborating group in Wageningen	Topic
Environmental Technology (ETE)	Combining chemo and bio-electro-catalysis Modelling of water-energy-material nexus in industrial and urban environments
Wetsus	Waste water treatment and modeling
Organic chemistry (ORC)	Teaching and research proposals
Bionanotechnology (BioNT)	Combining catalysis and NMR in microreactors. Use of natural constructs as carriers for nanoparticles
Physical Chemistry and Soft Matter (PCC)	Education on natural materials
Plant breeding (PBR)	Synergy between plant sciences and biorefinery
Food and Biobased research (FBR)	Different research projects and acquisitions

The BCT group participates within Wageningen in the research schools VLAG and WIMEK and is part of the Netherlands Institute for Catalysis Research (NIOK) and the Institute for sustainable process technology (ISPT). In addition, the group participates in the Working Group on Drying (NWGD), the Dutch Process Control Initiative, the Dutch Institute for Systems and Control (DISC) and WETSUS.

The group also collaborates intensively with other academic and industrial consortia both within WUR (FBR-Wageningen Research) and outside to address the multi-disciplinary character of the challenges (e.g., within EU projects, STW, TIFN, ISPT, Center for Biobased Economy (CBBE) and advisory boards such as the advisory board of the VNCI and the bioeconomy federation).

In 2018 Harry Bitter was appointed as adjunct (guest) professor in sustainable catalysis at the department of green chemistry of Monash University in Melbourne Australia. This collaboration will strengthen the biobased activities within Wageningen both at research and education level.

Conversion

Staff: Dr. Elinor Scott, Dr Piet Buwalda, Prof. Harry Bitter,
Dr Tomas van Haasterecht
PhD students and post-docs: Tim Hoogstad, Frits van der Klis,
Roxani Chatzipanagiotou, Xinhua Goerner-Hu, Nazila Masoud,
Carlos Cabrera Rodriguez, Marlene Führer, Cynthia Klostermann
Contact: Elinor.scott@wur.nl

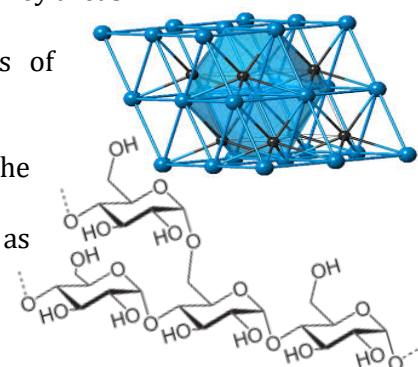


Background and goal

Today's society enjoys many comforts due to the development of chemicals, materials and fuels. However, many of these are derived from fossil resources. However environmental concerns and issues regarding security of supply are forcing society to investigate alternative renewable feedstocks to produce fuels and materials. Biobased molecules have a large variety of functionalities and have a rich chemistry. This will lead to opportunities to make existing and new materials with enhanced functionality.

However, the use of renewable resources requires new chemistry and technology in order to be implemented. In order to achieve this, we are developing several key areas:

- The development of catalysts for deoxygenation reactions of biobased molecules
- The development of robust catalysts for biomass conversion
- Catalytic conversions of biomacromolecules to modify the structure-function relationship
- These new materials can be used in various applications such as performance materials and in innovative foods
- Novel pre-treatment and fractionation technologies for lignocellulosic biomass
- Innovative chemical conversions using seaweed
- Processing of feathers to new products and materials
- New materials for CO₂ capture.



Student projects envisioned

Most activities within the Conversion group are based on experimental lab work. In a number of areas this may be combined with modeling.

If you are interested in a thesis in these general areas, please contact Elinor.Scott@wur.nl to discuss specific details and possibilities.



Direct CO₂ Capture from Air - Challenges and Opportunities of a Solid Sorbent

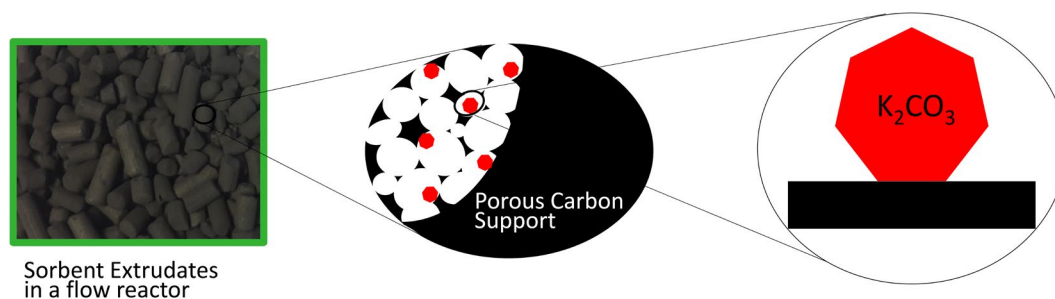
Name Postdoc: Dr. Nazila Masoud
Involved staff members: Prof.dr. Harry Bitter and Dr.ir. Tomas van Haasterecht
Project sponsor: European Regional Development Fund
Partners: Antecy and Bronswerk
Start/(expected) end date of project: October 2017-October 2019



Background and goal of project

Development of capture technologies that directly capture CO₂ from air is of prime importance to mitigate negative effects of global warming. A first step is to develop suitable sorbents that are able to capture CO₂ efficiently, to release it with little energy input, and to sustain its performance for a long time. Here we study the use of K₂CO₃ as a promising solid sorbent for the capture of CO₂ from air in a flow reactor. To make efficient use of K₂CO₃ it must be dispersed on a support (Figure). The question is that what sites on the sorbent, at microscopic level, are the most effective for the capture?

Therefore, the main part of this project is devoted to elucidating the relation between the sorbent chemical and structural properties and its performance. Another part of the project focuses on kinetics of CO₂ capture and release in a typical flow reactor. The project involves preparation and characterization of new sorbents, and the ultimate goal is to improve the performance of the carbon supported K₂CO₃ as a CO₂ sorbent.



Highlight of the past year

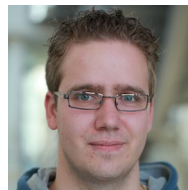
We focused on three different commercial carbon supports: CA1, SX ultra, and Ketjen Black. These carbons are different in their porosity and surface functionalities. CA1 and SX ultra are mainly microporous while Ketjen black is mesoporous. CA1 has polar surface functions with point of zero charge of 2 while SX ultra and Ketjen Black show more apolar surface properties with point of zero charge of 7. We found out that only Ketjen Black induced fast sorption kinetics and displayed a high CO₂ uptake capacity of the sorbent. Hence, the support affected the performance of K₂CO₃.

Type of student projects envisioned

The project includes wet chemical synthesis of inorganic materials and application of different characterisation techniques like X-ray diffraction, physisorption, chemisorption, and spectroscopy. The physical chemistry knowledge of the student will be challenged.

Selective catalytic transformations of non-edible carbohydrates

Name PhD: Frits van der Klis BSc.
Involved staff members: Prof. dr. J.H. Bitter; Dr. D. S. van Es;
Dr. J. van Haveren
Project sponsor: TKI-programs, CatchBio, EU SPLASH, EU
Pulp2Value
Start/(expected) end date of project: October 2013 – October 2019



Background and goal of project

The general goal is to selectively convert carbohydrates from residual agricultural waste streams, such as sugar beet pulp, into valuable products by means of catalysis.

Highlight of the past year

In the last year, we focussed on the reactor design for carbohydrate oxidations over supported Au-catalysts, with oxygen as the green oxidant. A batch reactor and a continuous plug flow reactor were both evaluated based on performance (productivity / selectivity), and their bottlenecks were identified.^[1]



Fig 1: Batch reactor set-up (left), and plug flow reactor setup (right)

For the batch process we achieved the highest selectivity (>99 mol%), at a maximum productivity of 60 kg product/m³/h. Bringing enough oxygen into solution was found to be the rate limiting factor, something that might be improved by working under pressure. For the continuous plug flow reactor, the selectivity was slightly lower (94 mol%), but a much higher productivity was achieved (>500 kg product/ m³/h). The lower selectivity can be explained by the more difficult pH control over this reactor.

Type of student projects envisioned

There are no available places this year.

[1] *React. Chem. Eng.* **2018**, 3, 540– 549.

Specific dietary fiber combinations for decreasing antibiotics use and faster recovery of gut microbiota

Name PhD: Cynthia Klostermann, MSc

Involved staff members: dr. Piet Buwalda, prof. dr. Harry Bitter

Involved members: prof. dr. Henk Schols (FCH), prof. dr. Paul de Vos (UMCG)

Project sponsor: NWO, CCC (CarboBiotics)

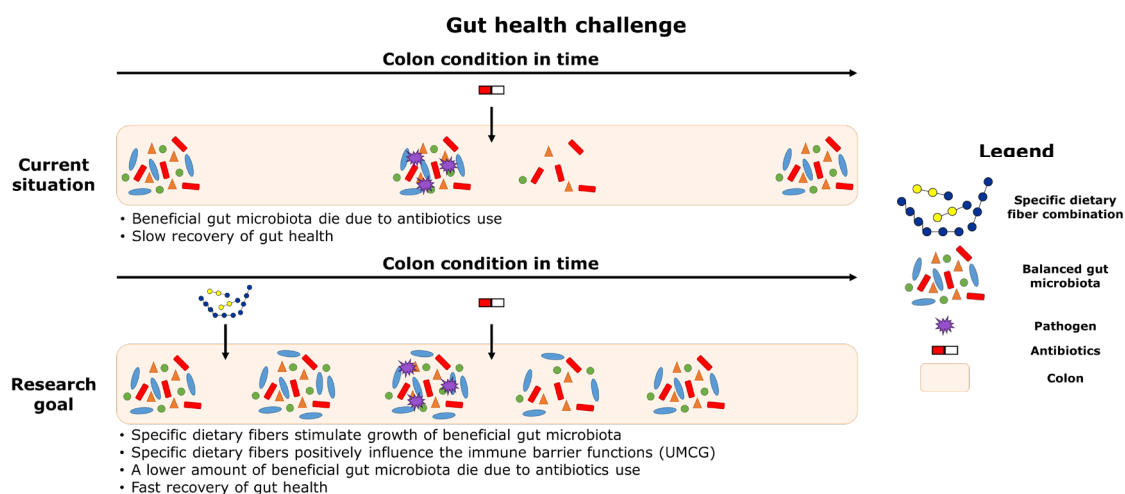
Start/(expected) end date of project: 15-11-2018 / 15-11-2022



Background and goal of project

Antibiotics have a negative effect on beneficial microbiota and gut barrier function. Because of these negative effects and the fact that bacteria become more and more resistant against antibiotics, there is a need for reduction of antibiotics use. Special developed fiber combinations might positively influence immune barrier functions, allowing a lower and less frequent antibiotics dosage. In addition, the gut microbiota might recover faster after antibiotic treatment, due to these special developed fibers.

The objective of this study is to develop specific combinations of soluble and insoluble dietary fibers, able to prevent or recover damage to microbiota and mucosa and enhancing gut barrier function before, during or after antibiotics use.



Highlight of the past year

The project just started. The main focus of the coming year will be on enzymatic synthesis of monodisperse amyloses and controlling their crystallization.

Student projects envisioned

Research topics involve lab work on chemical and physical characterization of the different carbohydrates (eg. HPAEC-PAD, HPSEC-RI, ¹H-NMR, XRD, DSC, Mastersizer). Also, the enzymatic digestion of the carbohydrates and their effect on gut microbiota might be studied.

On-flow NMR: monitoring a multi-phase reaction

Name PhD/Postdoc: Gerben Wierda
Involved staff members: Harry Bitter, Elinor Scott,
Aldrik Velders
Project sponsor: VLAG graduate school
Start/(expected) end date of project:
September 2015 – September 2019



Background and goal of project

We have developed an on-flow NMR monitoring technique. The chemical fingerprint of alternating gas bubbles and reactant plugs in a multi-phase reaction can be measured with this technique. We use the hydrogenation of mesityl oxide to mesityl isobutyl ketone with hydrogen gas over a platinum catalyst as a model reaction. This new multi-phase monitoring technique can help in the development of catalytic reactors and in better understanding of catalyst behavior.

Highlight of the past year

The NMR methods were optimised to obtain reliable spectra from a stable slug-flow. We now measure the slug composition three times per second. Additionally, home-built capillary reactors were prepared and the performance of a wall-coated platinum catalyst in could be studied. The technique was found to be sensitive to small flow rate fluctuations, such as caused by the slug-flow formation and the pump. Therefore, control of the slug-flow is essential when applying this technique.

Student projects envisioned

Use our newly developed technique to better understand the performance of catalytic microreactors. Interested? – send me an e-mail: gerben.wierda@wur.nl

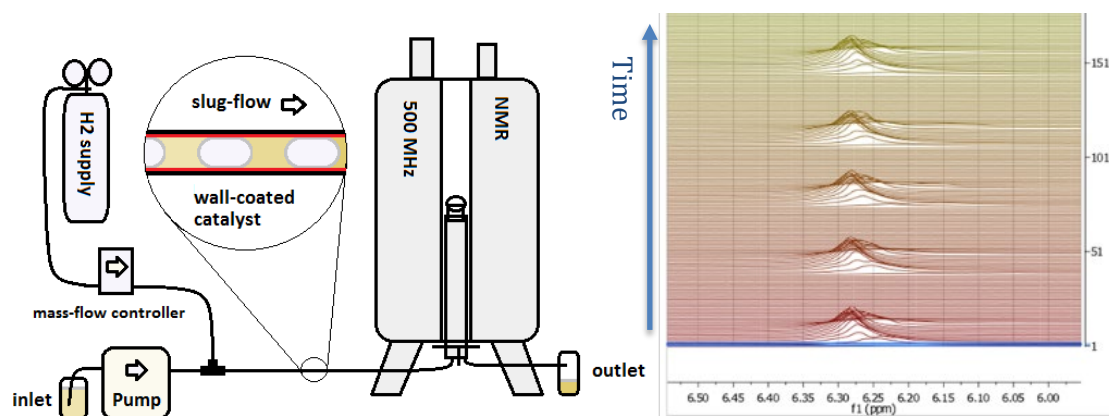


Figure 1, Left) the set-up: gas and liquid phases are combined at the T-junction and lead through the NMR. Before the NMR a catalytic reactor can be inserted. **Right)** stacked NMR spectra over time show the appearance and disappearance of individual slugs.

Combining Chemo- and Bio- electro-catalytic synthesis of chemicals

Name PhD/Postdoc: Konstantina Roxani Chatzipanagiotou, MSc

Involved staff members: prof. dr. Harry Bitter (BCT),
prof. dr. ir. Cees Buisman (ETE),
dr. ir. David Strik (ETE)

Start/(expected) end date of project: March 2015/March 2019



Background and goal of project

Carbon dioxide (CO₂) is the primary contributor to climate change. Using (renewable) electricity, CO₂ can be converted to valuable chemicals, both by metal catalysts, as well as bio-catalysts (bacteria) (Figure 1). This project aims to investigate whether and how the two types of catalytic CO₂ conversion can affect each other.

Highlight of the past year

We have previously shown that we can enhance CO₂ conversion of the bio-catalyst (bacteria), by adding metal catalysts on the cathode. Here, we investigate how this addition can affect a metal catalyst.

For bacteria to grow, the cathode compartment needs to contain growth nutrients, which can either positively [1] or negatively [2] affect the performance of a metal catalyst. We found that the catalytic activity of metal electrodes for CO₂ conversion increases in the presence of these nutrients (Figure 2). Thus, the medium needed for bacterial growth can also enhance the activity of metal electro-catalysts.

For the combination of metal and bacterial catalyst, the effect on both catalytic processes should be carefully considered. However, our results show that such a combination could be promising for improving the overall performance of electro-catalytic CO₂ conversion.

Student projects envisioned

The individual and combined catalytic processes can be investigated using laboratory methodology. Different catalysts and support materials can be compared, using chemical, electro-chemical, spectroscopic, and surface characterization techniques, in the presence and absence of bacteria.

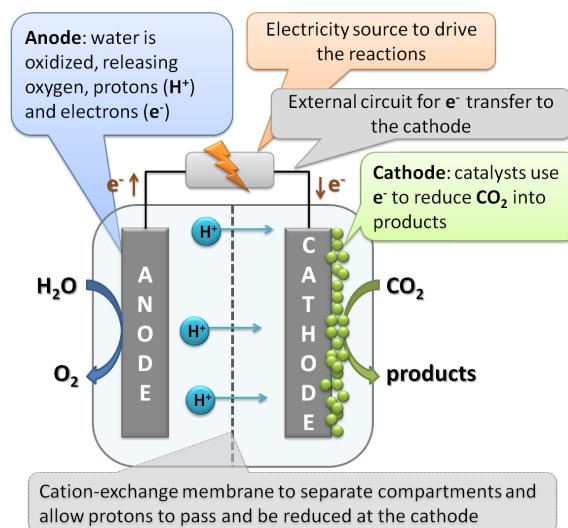


Figure 1: Electro-catalytic CO₂ conversion, with either metal catalysts or bacteria (bio-catalysts) at the cathode.

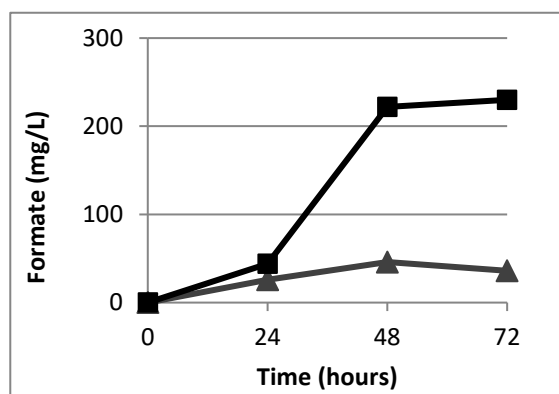


Figure 2: Formate production from CO₂ with metal catalyst over time, in the presence (■) and absence (▲) of growth nutrients. No bacteria are added in either experiment.

[1] R. Kortlever, K.H. Tan, Y. Kwon, M.T.M. Koper, J Solid State Electrochem 17 (2013) 1843.

[2] C. Gimkiewicz, R. Hegner, M.F. Gutensohn, C. Koch, F. Harnisch, ChemSusChem 10 (2017) 958.

Mixed metal carbides for biomass

Name PhD: Marlene Führer

Involved staff members: prof. dr. Harry Bitter, Tomas van Haasterecht

Project sponsor: NWO & FAPESP

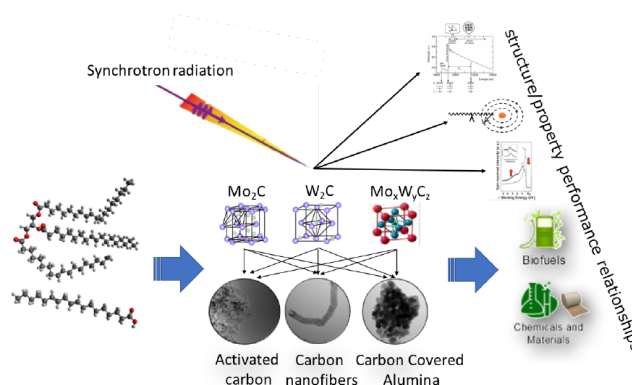
Start/end date of project: September 2018 – September 2022



Background and goal of project

Noble metals such as platinum and palladium are commonly used as catalysts for hydrogenation and hydrogenolysis. However, the high cost and the limited availability of these metals have promoted a search for new types of catalyst. Promising results have been obtained using tungsten and molybdenum (W & Mo) carbides which will be used during this study as a replacement for noble metal catalysts for the deoxygenation of fatty acids.

Supported nanoparticles of Mo-carbides and W-carbides can convert triglyceride-based feedstock to alkanes and alkenes. Interestingly, the W-carbides did show a high selectivity (>50%) towards the higher value substrate (alkenes), while the Mo-carbides were more active.¹ Therefore, the aim of this research is to investigate property-performance relationships for mixed (MoW-)carbides for the deoxygenation of triglyceride-based feedstocks.



Highlight of the past year

The main focus of this year was to control the carburisation method. Therefore, XANES and EXAFS measurements were taken to study the carburisation mechanism and the different phases of the mixed carbides. In Figure 1 a typical XANES spectra of the MoW supported on activated carbon (AC) catalyst can be seen. Further analysis of the XANES and EXAFS data needs to be done and is in progress.

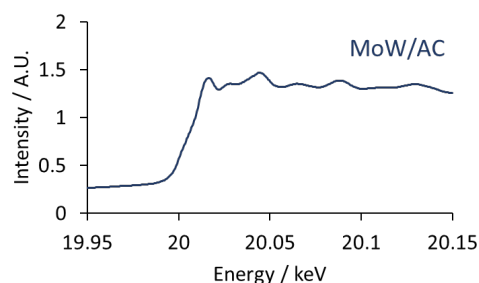


Figure 2. Preliminary XANES spectra at the Mo K edge under 20% CH₄/H₂ at 650 °C for the carburized MoW supported on AC

Student projects envisioned

This research project involves mostly lab work. Catalyst synthesis and characterization techniques like XRD, TEM, N₂ physisorption and chemisorption are applied. So far the deoxygenation reactions are evaluated in a batch system. However, we are aiming to set up a plug flow system in the following year.

1. D. R. Stellwagen and J. H. Bitter, Green Chem, 2015, 17, 582-593.

Processing of feathers to proteins – from fundamental insight to application

Name PhD: Xinhua Goerner-Hu
 Involved staff members: E. Scott; O. Schneider;
 T. van Haasterecht; H. Bitter
 Project sponsor: SARIA International GmbH
 Start(expected) end date of project: 2015/2019



Background and goal of project

More than one million tons of feathers are produced as by-product annually in Europe. Feathers have high protein content and various amino acids. Therefore, feathers have good potential as feed ingredient. However, feathers are not digestible and have no nutritional value at the native state. Therefore, feathers have to be processed into more digestible proteins, peptides and amino acids. The processing changes the molecular structure of feathers, in particular, cleavage of disulfide bond of cystine. Consequently, cystine content decreases during the processing which results in increase of digestibility and unfortunately, also formation of an unnatural amino acid lanthionine (Figure 3). On the other hand, it is essential to maintain the sulfur-containing amino acids, cysteine and cystine, because they play an important role in metabolic pathways and in building of protein structure.

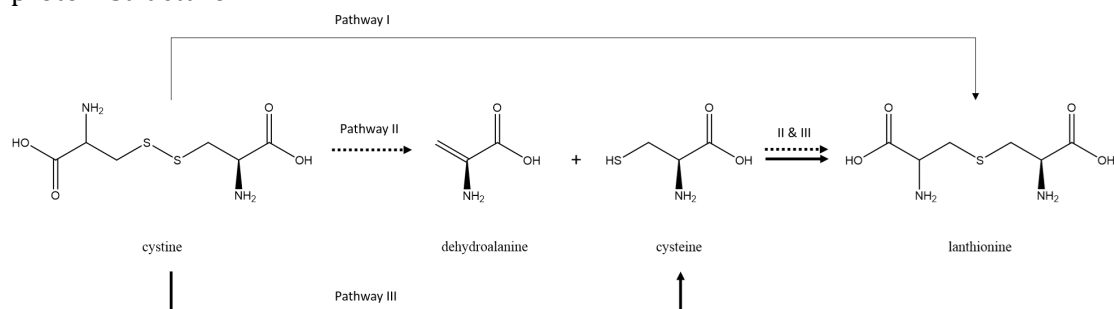


Figure 3: Reaction pathways of cystine conversion to lanthionine

Goal of our project is to understand the change of molecular structure of feathers during the processing, to investigate the effect of selected process parameters on structural change and to adapt and implement the knowledge into commercial feather production.

Highlight of the past year

Prolonged temperature and time are beneficial for the digestibility, however, are detrimental for maintaining of Cys content. Therefore, it is essential to balance the process.

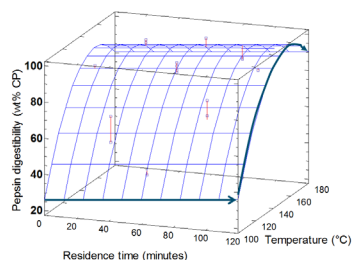


Figure 4: Effect of temperature and time on digestibility

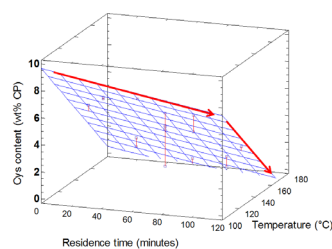


Figure 5: Effect of temperature and time on Cys content

Type of student projects envisioned

MSc student: lab work, e.g. experiment performance and analysis

Selective polysaccharide oxidation – new catalysts and new chains

Name PhD: Marlene Fuhrer, Luana Macedo (from May 2019),
Involved staff members: Prof. Harry Bitter, Dr. Piet Buwalda
Project sponsor: NWO, Avebe
Start/(expected) end date of project: 01.01.2016 – 01.05.2021



Background and goal of project

Anionic starches, i.e. starches functionalized with negatively charged groups hold great potential as replacements for polyacrylates. As such they offer a biobased and renewable alternative for applications such as adhesives, superabsorbents in nappies or as coating agent in the paper- and textile industry. Here we want to develop heterogeneous catalysts which can oxidize starch efficiently and sustainably. Therefore, the use of a heterogeneous catalysts and oxygen or air is the goal of this project. Since starch is a large polymeric molecule it is expected that adsorption of the reactants and products are of crucial importance of the performance of the catalyst. The role of catalyst preparation, with the aim of investigating Pt-particle size effects and investigating the role of surface oxygen groups was further investigated. For the moment the oxidation of glucose was used as model reaction.

Highlight of the past year

Different activated carbon supported Pt catalysts have been prepared. The figure (left) shows the role of support oxidation (AC vs AC-ox) and Pt-precursor oxidation (calcined Pt vs Pt) impact on the activity of Pt/carbon for the oxidation of glucose. To explain this different characterization techniques (chemisorption, TEM, XRD, N₂-physorption, XPS, XAFS) have been applied. The figure on the right shows the XANES spectra of the different catalysts. Since the edge is different for the different catalysts electronic effects might explain the different behavior of the catalysts though the exact explanation is currently under study.

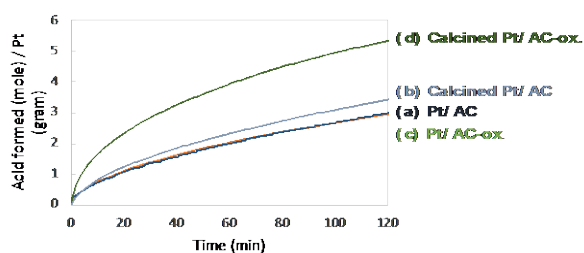


Figure 1: activity of Pt/AC for glucose oxidation

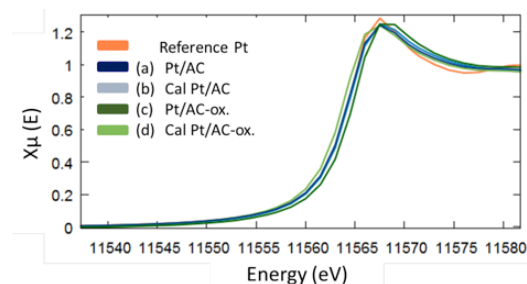


Figure 2: XANES of Pt/AC

Type of student projects envisioned

Research projects involve mostly lab work during which many different techniques are applied: catalyst synthesis and characterization (e.g. XRD, TEM, ICP-OES), the oxidations themselves, product analysis (HPLC, HPAEC, colorimetric assays,...).

Bioelectrochemical chain elongation of CO₂ to caproate: Electrification of biotechnology

Name PhD/Postdoc: ir. Sanne de Smit

Involved staff members: prof. dr. Harry Bitter (BCT), prof. dr. ir. Cees Buisman (ETE), dr. ir. David Strik (ETE)

Project sponsor: WIMEK, ChainCraft

Start/(expected) end date of project: Sep 2018 – Sep 2022



Background and goal of project

With the growing world population, arable land becomes scarce and innovative new solutions are required to make efficient use of the available land and energy sources. Capturing CO₂ and utilization of waste streams to (re)produce chemicals in electricity driven microbial electrosynthesis represents an effective solution to circularly utilize waste-resources from our society.

Bioelectrochemical chain elongation (BCE, Figure 1) is a promising technique to produce caproate from CO₂ or evenly organic waste streams (Jourdin et al., 2018). Caproate is a platform chemical that can be used as animal feed additive, plant growth promotor or for the production of biodegradable plastics or fuels.

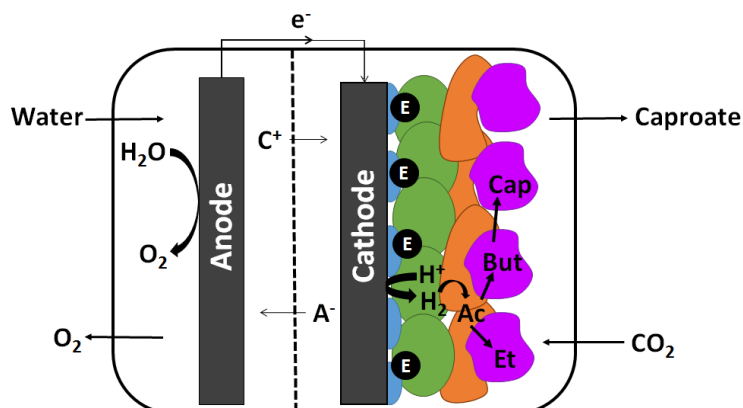


Fig 1. Schematic overview of a bioelectrochemical chain elongation system.

In BCE, water is oxidized to release electrons which are supplied to the biofilm where a CO₂ elongating biofilm grows. The current process yields can be further improved for practical application of the process. Also the working mechanisms of this process remain to be further revealed.

Student projects envisioned

A student on this project would work in the laboratory, maintaining and analysing the bioelectrochemical systems. The experimental conditions can be varied to study different parts of the bioelectrochemical chain elongation processes occurring at the cathode. Analysis of the system is done using chromatography, microscopy, sequencing of the microbial community and spectrometry.

Jourdin, L., Raes, S. M. T., Buisman, C. J. N., & Strik, D. P. B. T. B. (2018). Critical Biofilm Growth throughout Unmodified Carbon Felts Allows Continuous Bioelectrochemical Chain Elongation from CO₂ up to Caproate at High Current Density. *Frontiers in Energy Research*, 6. doi: 10.3389/fenrg.2018.00007

Biobased Functional Materials (BFM)

Staff/Theme Leader: Dr. Costas Nikiforidis

Post-doc: Dr. Christos Fryganas

PhD students: Laura Schijven, Eleni Ntone, Lakshminarasimh Sridharan, Juliana Romero Guzman (FPE), Dimitris Karefyllakis (FPE)

Contact: costas.nikiforidis@wur.nl

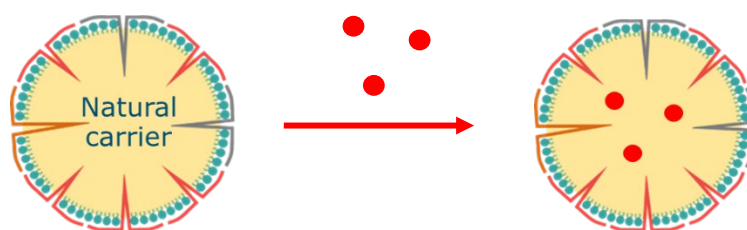


Background and goal

Advances in technology resulted in developing synthetic materials for multiple applications. However, there are several limitations when using these materials, mostly linked to their functionality and biodegradability, especially for applications in food and pharma. A solution could be the focus on molecules and molecular complexes derived by nature. Nature offers sophisticated architectures made with a limited selection of components, like proteins, polysaccharides and lipids forming highly functional materials. For example, the safe storage of lipids and their arduous mixing with hydrophilic systems has been resolved by nature with organelles called oleosomes (or oil bodies). The noteworthy properties of the oleosome membrane that grants them extreme physical and chemical stability could be exploited to carry sensitive hydrophobic molecules in natural oil dispersion systems. Another example is the High Density Lipoprotein (HDL) from egg yolk that is a suitable agent for the delivery of diagnostic and therapeutic compounds and could replace synthetic nanocarriers.

In other words, the **Biobased Functional Materials** theme, aims to overcome three challenges:

- (1) understand the function of natural complexes
- (2) translate the natural architectures into a wider range of molecular combinations and
- (3) design practical methods to construct biobased materials



Natural carriers (oleosomes) for functional molecules

Main topics

- Plant protein/starch complexes to stabilize oil-in-water emulsions
- Protein/oleosome mixtures to stabilize oil-in-water emulsions
- Behaviour of oleosomes on interfaces
- Molecular interactions in oleosome membranes
- Oleosomes as carriers of hydrophobic molecules
- Food-grade lipoproteins as nanocarriers of therapeutic agents and diagnostics

Thesis subjects are related to the research work of PhD students and postdoctoral researchers in the Biobased Functional Materials theme.

Conversion of natural oil body based emulsions to stable powders

Name Postdoc: Dr. Christos Fryganas
 Involved staff members: Dr. C. V. Nikiforidis
 Project sponsor: Givaudan Flavors Corp.
 Start/(expected) end date of project: 21/09/2017 – 21/03/2019



Background and goal of project

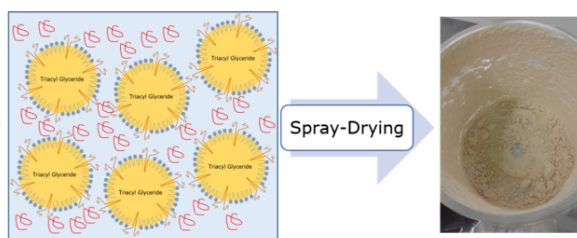
Oleosomes or oil bodies (OBs) are small ($d \sim 0.5\text{--}2 \mu\text{m}$), spherical organelles that protect oil in plant seeds with a membrane consisting of phospholipids and proteins. Aqueous extraction of OBs results in natural oil-in-water emulsions, which could be used for food, pharma and cosmetic applications. Drying of emulsions reduces bulk storage and delays microbial spoilage. However, conventional drying methods rely on the use of additives for the increase of powder yield. When OBs are the dispersed phase in natural oil-in-water emulsions, co-extracted oilseed components (proteins, fibre) could protect them during drying and stabilise the dried emulsions.

The aim of this project is to develop dry oil-body based delivery systems from oilseeds. Investigations on the physical properties and the surface morphology of OBs pre-and post-drying will shed light on the key interactions with innate seed components.

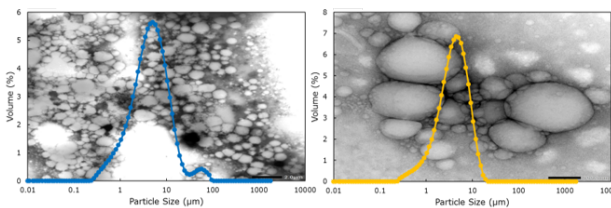
Highlight of the past year

📍: phospholipid 📍: protein 📍: extrinsic component

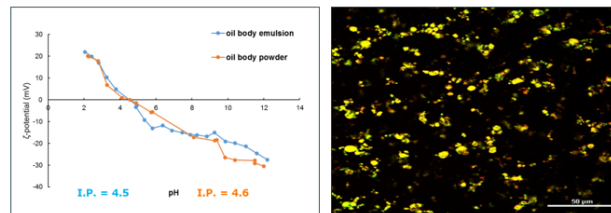
Co-extracted fibres and seed proteins protect OBs during drying procedures



Laser Diffraction and Transmission Electron Microscopy showed that drying had no impact on the OB size and the aggregation levels



Dynamic Light Scattering and Confocal Laser Scanning Microscopy proved that OB related and extraneous seed proteins contribute to the emulsion stability in a similar manner



Stains:
 Coumarin 6 → lipids
 Rodhamine B → proteins

Student projects envisioned

Students interested in biobased functional ingredients will work in the lab for the development of new effective extraction methods of OBs and their further use in novel industrial applications.

Egg yolk lipoproteins as nanocarriers: from lipid to nanoparticle carrier

Name PhD:

Laura Schijven

Involved staff members:

dr. Costas Nikiforidis (BCT)

dr. Vittorio Saggiomo (BNT)

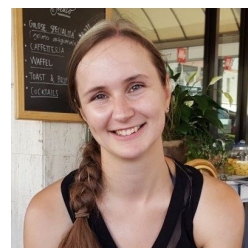
prof. dr. Aldrik Velders (BNT)

prof. dr. Harry Bitter (BCT)

Project sponsor:

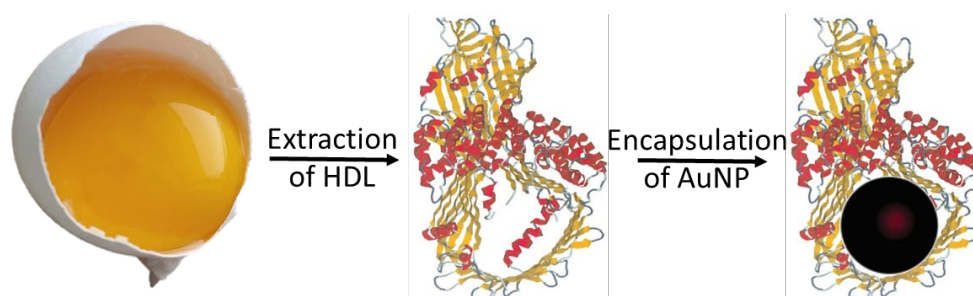
VLAG Graduate School

Start/(expected) end date of project: September 2017 – September 2021



Background and goal of project

Nearly 40% of approved drugs are poorly water-soluble, making their transportation throughout the body and reaching their targets more difficult. The mechanism that organisms have developed to transport water-insoluble molecules, like lipids, is the encapsulation in carriers, called lipoproteins. The structures of lipoproteins are built up of a monolayer of phospholipids, cholesterol and embedded apo-lipoproteins, the lipid molecules are enclosed in the hydrophobic core. Besides lipids, lipoproteins could potentially also host other type of water insoluble molecules, like contrast agents for medical imaging. An example of a lipoprotein is the high-density lipoprotein (HDL), in egg yolk. Therefore, the focus of this project is to assess the biomedical purposes of egg yolk HDL by encapsulating hydrophobic molecules and/or nanoparticles.



Concept of the project: extraction of HDL from egg yolk and encapsulating nanoparticles^[1]

Highlight of the past year

We applied an easy and straightforward method to extract high amounts of HDL from egg yolk and studied its properties. Furthermore, we have developed a strategy to obtain water-soluble gold nanoparticles (AuNPs) of different sizes and narrow size distributions.^[2] This strategy can be applied to create a library of AuNPs of different sizes and ligands to investigate the interactions with HDL.

Type of student projects envisioned

The typical work within this project involves lab experiments, which include protein extraction, physicochemical characterization of proteins (e.g. SDS PAGE, ³¹P NMR) and synthesis and characterization of nanoparticles (e.g. TEM, UV-Vis, DLS, ¹H NMR).

^[1] Segrest, J.P. *et al.* (2001). *Journal of Lipid Research*. 42, 1346-1367

^[2] Ten Hove, J.B. and Schijven, L.M.I. *et al.* (2018). *Chem. Commun.* 54, 13355-13358.

Interfacial active protein/oil body mixtures from rapeseed valorisation by applying minimal processing steps

Name PhD: Eleni Ntone

Involved staff members: BCT: Costas Nikiforidis, Harry Bitter

Project sponsor: NWO-TIFN

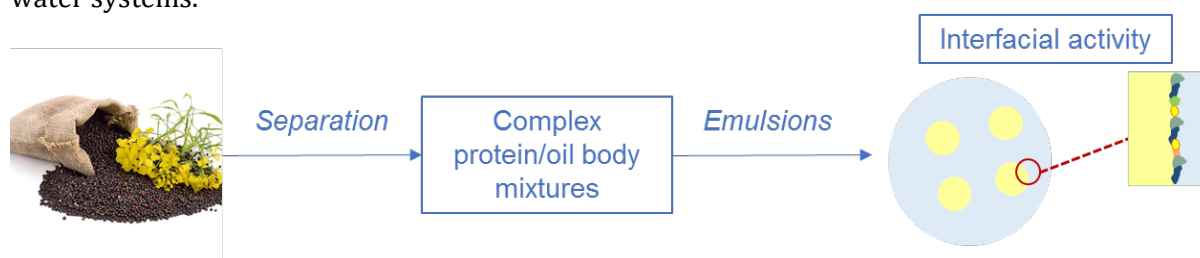
Start/(expected) end date of project: September 2017/September 2021



Background and goal of the project

The environmental impact of food production is in the spotlight, in principal the impact of animal derived products versus those of plant origin¹. The compounds that are mainly derived from animal sources are the proteins, which are broadly used by industry for many applications, such as interface stabilization in emulsions. Therefore, efforts have been made to replace them with plant derived proteins. However, intensive extraction conditions are needed in order to obtain them in relatively pure form² which can impact their functional properties.

In this study we propose to apply minimal process steps that lead to simultaneous extraction of native protein-oil body mixtures for rapeseed valorisation. This will lead towards the application of simple extraction steps to obtain multicomponent systems whose composition can be tailored based on the desired application. The resulted mixtures are studied for their emulsifying properties and interfacial activity on oil-in-water systems.



Highlights of the past year

Rapeseed protein and oil body (OB) mixtures were co-extracted in high yields under mild extraction conditions and their physicochemical properties were investigated.

Both storage proteins were extracted in the protein-rich mixture and their nativity was maintained through the process.

Protein-phenol interactions were restrained due to the applied mild conditions. Phenolic compounds were efficiently removed resulting to a protein concentrate.

Rapeseed OB were co-extracted in their natural structure in the oil body-rich mixture.

Type of student projects envisioned

Available projects for students include lab work, focusing on separation of rapeseed protein/ oil body mixtures and investigation of the molecular interactions and their effect on emulsifying properties and interfacial activity under various conditions (pH, ionic strength).

1. Poore J, Nemecek T. Reducing food ' s environmental impacts through producers and consumers. *Science* (80-). 2018;360(June):987-992.

2. Fetzer A, Herfellner T, Stabler A, Menner M, Eisner P. Influence of process conditions during aqueous protein extraction upon yield from pre-pressed and cold-pressed rapeseed press cake. *Ind Crops Prod*. 2018;112(December 2017):236-246. doi:10.1016/j.indcrop.2017.12.011.

3. Aiking H. Future protein supply. *Trends Food Sci Technol*. 2011;22(2-3):112-120. doi:10.1016/j.tifs.2010.04.005.

Interfacial and emulsifying properties of protein-starch mixtures obtained from yellow peas

Name: Simha Sridharan

Staff members: BCT: Costas Nikiforidis, Harry Bitter; FBR: Marcel Meinders

Project Sponsor: TiFN

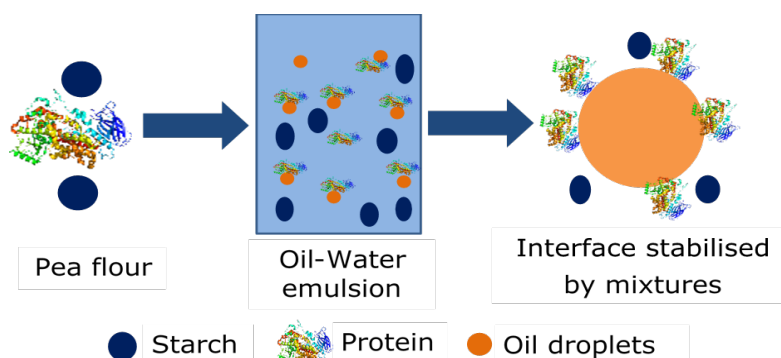
Start date/ End date(expected): October, 2017/October,2021



Background and Aim of the project:

Industrial food products are fabricated by mixing pure components such as proteins, starch, fibres and lipids. However, these components already co-exist in the same plant matrices. Therefore, instead of extracting these components and separating them, it would be more efficient if we could use them when they are still embedded in their native matrices. Following this approach, the challenge is to understand how the native mixtures behave in a food system as opposed to purified components.

Therefore in this research, the aim is to apply as little process steps as possible to a plant protein source (yellow peas - *Pisum sativum L.* -), obtain a native protein mixture and investigate the effect of the co-present components on the emulsifying ability of the plant proteins.



As a start the focus is on the finely milled yellow pea flour, which can actually be used to stabilize oil-in-water emulsions. The interfacial and emulsifying properties of the flour will be further investigated and its properties will be linked to the effect of each component and their interactions with the proteins. ².

Highlights of the past year

- Stable oil-in-water emulsions were produced by using yellow pea flour as stabilizer
- Native pea flour proteins were identified as primary emulsifying component
- Starch granules were found to be inert fillers that do not contribute or hinder the emulsifying ability of native pea proteins
- Pea flour was able to stabilize emulsions at both acidic (3.0 – 3.8) and neutral pH values and at varying oil concentrations (10-50 wt%)

Types of student projects envisioned

Student projects would include lab work focussed on investigating emulsifying and interfacial properties of pea flour at various conditions. Also to investigate possible interactions occurring between various components in pea flour mixtures that could affect their emulsifying properties.

References

1. Poore J, Nemecek T. Reducing food 's environmental impacts through producers and consumers. 2018;992(June):987-992.
2. Nikolopoulou D, Grigorakis K, Stasini M, Alexis MN, Iliadis K. Differences in chemical composition of field pea (*Pisum sativum*) cultivars: Effects of cultivation area and year. *Food Chem.* 2007. doi:10.1016/j.foodchem.2006.09.035

Tailoring the interactions of oleosomes (oil bodies) and co-extracted proteins for developing model food systems

Name PhD: Juliana Romero Guzmán (employed at FPE)
Involved staff members: Costas Nikiforidis (BCT) and Remko Boom (FPE)
Start/(expected) end date of project: October 2015 - October 2019



Background and goal of project

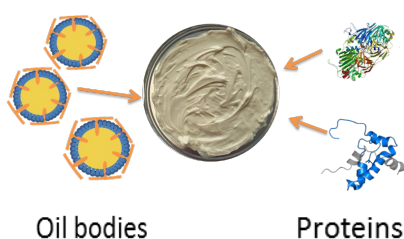
Currently, oil extraction from oleaginous seeds, like soybean, rapeseeds and sunflower seeds, is taking place by a pressing step followed by organic solvent extraction. This process can cause irreversible damage to the extracted oil and the remain proteins. A promising alternative for lipid extraction is to retain their native structure, called oleosomes (oil bodies) and extract them aqueously. Oleosomes are spherical droplets that contain the plant oils protected in a polar phospholipid/protein membrane. Oleosome structure is very similar to those of engineered oil droplets, however they exhibit remarkable high stability against physical and chemical stresses.

The aim of this project is to:

1. Investigate the interactions of oleosome membrane with metals and co-extracted biopolymers in order to understand the extraction mechanism and oleosome membrane stability
2. Simplify the oleosome extraction process by reducing the process steps and the amount of extraction solvent used.

Highlight of the past year

We understood the effect of monovalent (Na^+ , K^+) and divalent (Mg^{2+} , Ca^{2+}) metals on oleosome membrane and how this affects their extraction and their physical stability. All metals enhanced oleosome solubility and their subsequent extraction. However, K^+ had the most significant impact, since the highest oleosome solubility achieved. interactions. However, all added metals destabilized oleosomes against coalescence. The added metals can break the inter- and intra-protein bridges and apparently metal coordination in oleosome membrane proteins is important for their structural role.



Contact:

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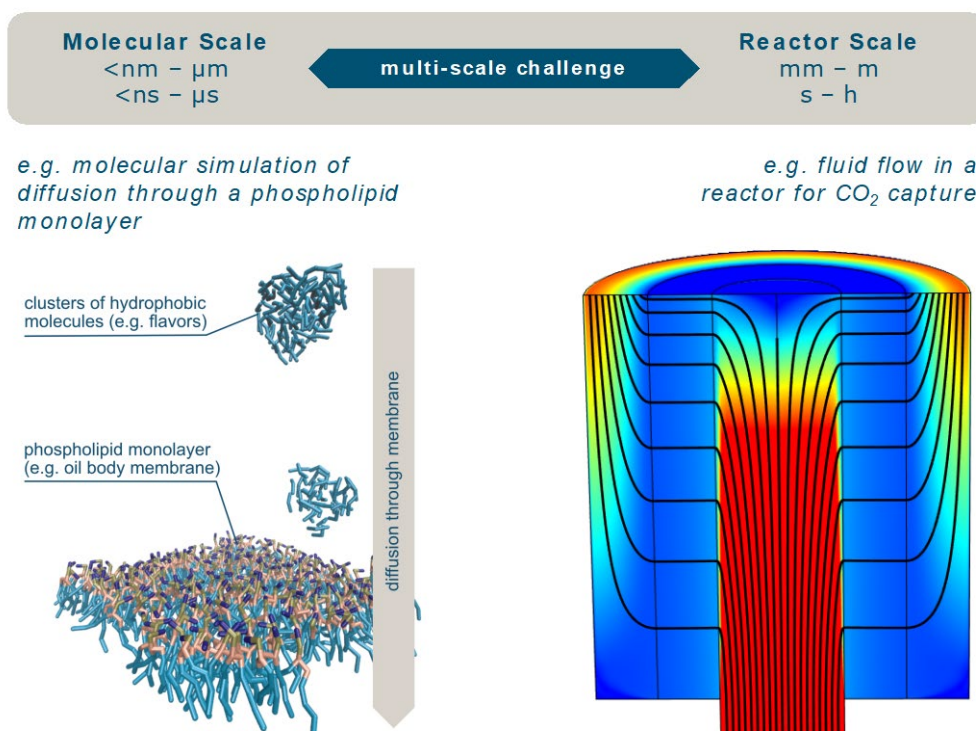
Technology

Theme leaders: Lars Kiewidt (lars.kiewidt@wur.nl)



Background and goal of this theme

How do molecules travel through narrow pores? How do chemical reactions change the temperature in their environment? And what effect does this have on the conversion and yield of a chemical process? These questions drive the research of the BCT technology team. Our goal is to understand and model the coupled flow, heat and mass transfer, and reaction processes during biomass conversion to improve existing and design new technologies for a sustainable circular economy. We therefore apply and develop multi-scale computer models from the molecular to the reactor scale.



Main topics

- solid catalysts for biomass conversion (e.g. starch oxidation)
 - development of kinetic models
 - coupling reaction and diffusion models
- capture of CO₂ from air (Direct Air Capture, DAC)
 - development of kinetic models
 - modelling condensation in micro- and mesopores
 - process design and heat integration
- stability of metal catalysts in aqueous environments
 - development of models for leaching and nanoparticle growth

Thesis subjects are related to the research work of PhD-students and Post Docs in the Technology theme or in cooperation to the other BCT themes.

Selective polysaccharide oxidation – new catalysts and new chains

Name PhD: Tim Hoogstad

Involved staff members: Lars Kiewidt, Ton van Boxtel, Piet Buwalda, Harry Bitter

Project sponsor: Avebe, NWO

Start/(expected) end date of project: 01-2016 till 06-2020



Background and goal of project

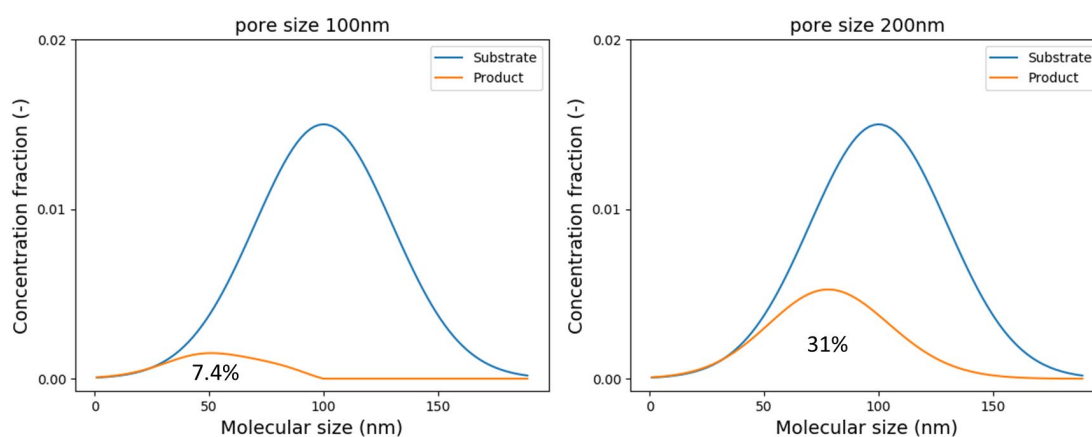
Oxidised (negatively charged) starches are used as a biobased and renewable replacement of polyacrylates and polyacrylamides, which are applied in paper/textile coating and food additives. However, the current chemical process to produce oxidised starches requires the use of strong chemical oxidants like NaOCl (bleach) and results in stoichiometric amounts salt as a by-product. The use of NaOCl and production of salt cause a high environmental impact. Using molecular oxygen for the oxidation of starch would remove the need for using NaOCl, reduce salt production, and consequently reduce the environmental impact.

Using molecular oxygen for the oxidation of starch requires the design of a selective catalyst that provides enough accessibility for the large starch molecules.

In my project I create models that describe the kinetics of the oxidation and depolymerisation of starch and the diffusion of large starch molecules in the porous catalyst.

Highlight of the past year

A reaction-diffusion model has been developed that estimates diffusion rates of starch molecules based on their size. This model, in combination with previously developed models that describe the oxidation and depolymerisation processes as a function of starch molecular size, can predict product size distributions. This allows to explore the influence of catalyst design parameters, such as the pore size, on product size distributions and yield. For example, when increasing the catalyst pore size from 100 nm to 200 nm, the product yield increases by a factor 4 and the average molecular size of the product is increased from 50 nm to 80 nm (figure).



Student projects envisioned

Student projects involve further development of reaction-diffusion models, conducting validation experiments, and kinetic measurements.

Modelling and process design of CO₂ capture from air

Name Postdoc: Carlos I. Cabrera-Rodriguez

Involved staff members: Harry Bitter, Lars Kiewidt

Project sponsor: European Regional Development Fund

Partners: Antecy and Bronswerk

Start/(expected) end date of project: November 2017/November 2019



Background and goal of project

The increase of global temperatures causes worldwide awareness regarding the carbon dioxide (CO₂) being released to the atmosphere. Carbon dioxide is an important gas that contributes to the greenhouse effect. The concentration of CO₂ has risen rapidly in the last years and reaches amounts of 400 ppmv. A promising option to reduce the CO₂ concentration is to capture it directly from air using CO₂ negative technologies. The aim of this project is to design a CO₂ negative technology for CO₂ capture from air and subsequent utilization of the CO₂.

Highlight of the past year

A fundamental thermodynamic model has been created to determine the main bottlenecks of the process and the type of materials that should be developed. The energy requirement for adsorption and desorption for different materials (represented by ΔG and ΔH of reaction) and capacities are shown in Figure 1. Reactions with low ΔG (<-15 kJ/mol) require less energy during adsorption. On the other hand, highly endothermic reactions of desorption increase the energy required during regeneration. The thermodynamic minimum energy needed for desorption is ~50x larger than for adsorption. With this analysis, efforts can be dedicated to improving the critical points for a feasible CO₂ capture technology. Additionally, a heat integration system (heat pump) has been designed in Aspen Plus to reduce the energy requirement during desorption.

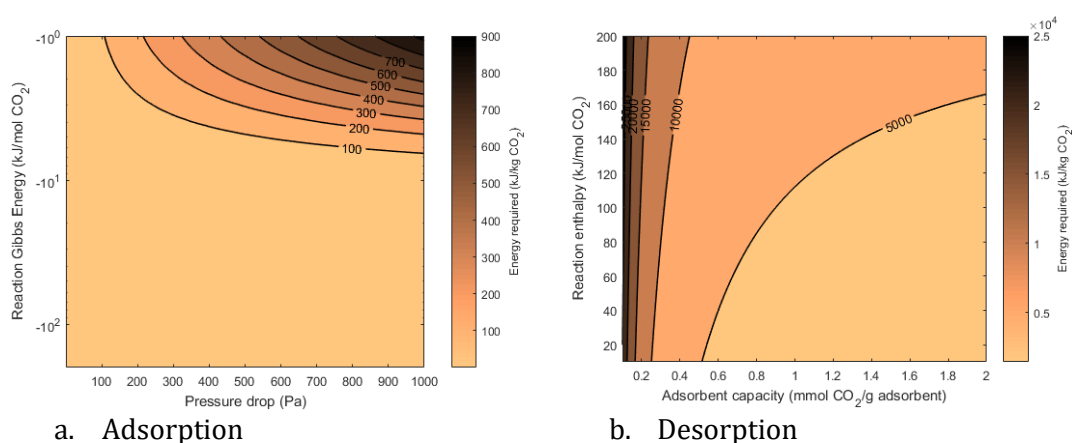


Figure 1. Minimum thermodynamic energy requirements for the adsorption of CO₂ from air for different reactions (a) and desorption with steam at 160 °C (b).

Type of student projects envisioned

To test the boundaries of the system, projects are available which involve modelling of the CO₂ capture and utilization, with main emphasis on investigating the reaction mechanism, kinetics, and potential diffusion limitations in the process. The models are created in COMSOL, Matlab and Aspen Plus and validated by experimental and pilot plant studies.

Contact: carlos.cabrerarodriguez@wur.nl

Value added amino acid supplements and chemicals intermediates from industrial side streams

Project Leader: Carlos I. Cabrera-Rodriguez
Involved staff members: Elinor Scott
Project sponsor: NWO- Take off
Partners: Greencoverly B.V., TU Delft
Start/(expected) end date of project: March 2019/September 2019



Background and goal of project

In a circular economy, no waste streams are produced and components are recovered from industrial side streams which creates zero emissions companies. One of the main bottlenecks to recover compounds from the side streams are the resource intensive separation and purification technologies. This limitation is caused by the heterogeneity and diluted nature of these streams. For this reason, new separation and upgrading technologies has to be developed.

In this project, the technology developed by the startup Greencoverly (at TU Delft) is coupled with the upgrading technology developed at BCT. The technology is based on mild conditions and a green solvent such as a CO₂-expanded alcohol. In this project it is used for the recovery and purification of amino acids.

Amino acids are present in several side streams. However, their utilization is limited by their recovery and purification. We combine the advantages from the CO₂-expanded alcohol technology with specific modifications of the amino acids to purify them for the production of supplements and chemicals intermediates (Figure 1).

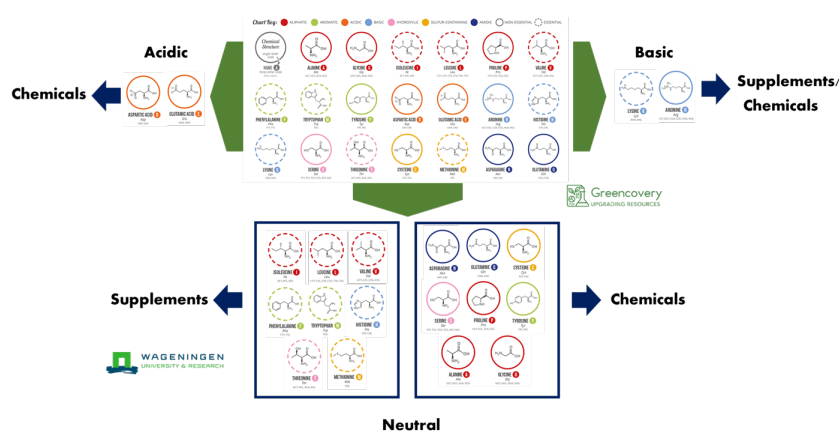


Figure 1. Application of the combined technology from Greencoverly B.V. and the Biobased Chemistry and Technology group for amino acids purification.

Highlight of the past year

The project will start this year, and is based on previous research done on both technical universities (TU Delft and WUR). The process will be implemented by the startup company Greencoverly B.V. which is incubated at StartLife.

Type of student projects envisioned

Projects are available for testing different conditions and parameters for the separation and purification, as well to elaborate a techno-economic analysis of the new developed process. Additional projects (internships) are available at the startup in technical fields (e.g. process development, prototype design) and business oriented (e.g. market analysis, supply chain).

Contact: carlos.cabrerarodriguez@wur.nl

Systems Group

Staff: Prof. Karel Keesman

PhD students and post-docs: Nik Grubben, Daniel Reyes Lastiri, Yu Jiang, Delaram Azari, Hakan Kandemir, Caspar Geelen, Ze Zhu, Hans Cappon, Simon Goddek

Contact: karel.keesman@wur.nl



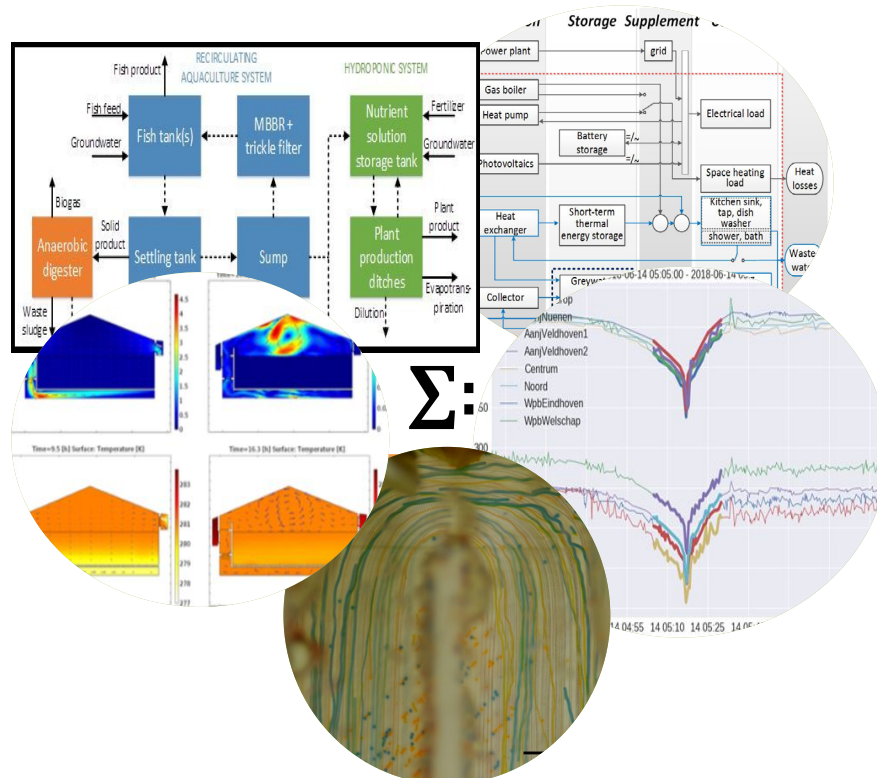
Background and goal

In the past decade, there have been strong developments in communication (internet, e-mail, smart phones, wireless), computation (Moore's exponential law - processors, memory, storage capacity), sensor networks (data warehouses) and cyber science (integration of knowledge). These developments allow the implementation of smart, high-tech, cost-effective solutions to water/energy/material related problems in a bio-based/circular economy.

The objective of the systems group is to support new and innovative technological solutions to complex, dynamic, and possibly constrained, systems (Σ ; see Figure) in a bio-based/circular economy, such as water-energy-material cycles in urban systems, S/N/P cycles in natural and industrial environments, food storage and aquaponic systems, through **network modelling** and **(big/fast) data-model integration**.

Main topics

- Efficient use and recovery of water, energy and nutrients in urban, industrial and agricultural environments
- Aquaponics as a novel/renewed resource-efficient fish-plant production system
- Smart food storage strategies for preserving quality of agricultural produce
- Ultrasound standing/travelling waves for fluid-particle or particle-particle separation
- Big data and water/energy/materials networks



Bioenergy policies for achieving liveable and sustainable cities of the future: An integrated game-model-data approach (E-game)

Name PhD: Yu Jiang

Involved staff members: Karel Keesman

Project sponsor: Climate KIC

Start/(expected) end date of project: Sep 2014/Sep 2018



Background and goal of project

Nowadays many cities aim at developing zero-carbon and self-sufficient energy systems. More intermittent renewable energy is expected to be included in the urban electricity system. Carbon-neutral options for balancing the electricity system are needed to keep the urban electricity system reliable and sustainable. Bioenergy has the potential to be both dispatchable and carbon-neutral, therefore can play an important role in balancing the future urban electricity system.

The objective of this project is to investigate the potential role of bioenergy in the transition to a sustainable and smart urban electricity system. Methodologies including energy system modelling, agent-based modelling, and model predictive control are used to provide scientific insights with respect to dynamics and interactions within the system and management strategies to support the ongoing urban energy system transition.

Highlight of the past year

We developed an agent-based model for an electricity system on an urban community scale. We aimed at exploring the effect of a biogas plant, using community waste as the feedstock, on the performance of the community electricity system, and we also evaluated the economic feasibility of this biogas plant. We introduced a double-sided auction mechanism and different pricing mechanisms, including uniform pricing scheme and pay-as-bid pricing scheme. In our modelling framework, we also integrated several metrics for the evaluation of the community electricity system. This work has been presented at the 41st IAEE conference, Groningen.

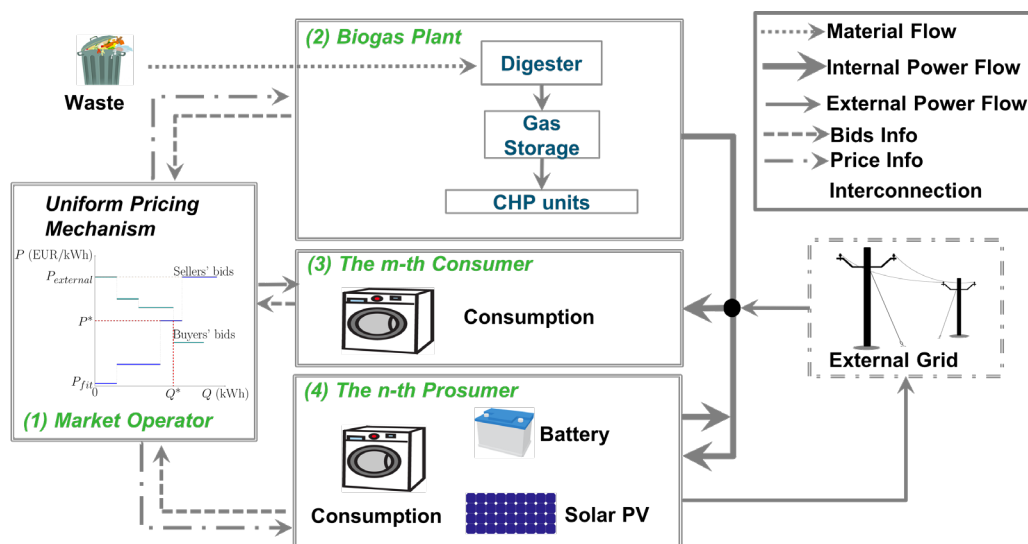


Figure 6 Illustration of the agents in a community electricity system

Type of student projects envisioned

This project has ended by the end of 2018.

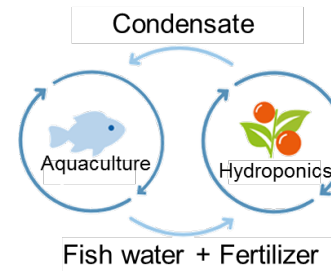
Modelling aquaponic systems

Name PhD: Daniel Reyes Lastiri
Involved staff members: Hans J. Cappon, Karel J. Keesman
Project sponsor: INAPRO (EU)
Start/End date of project: 15/06/2014-15/06/2018



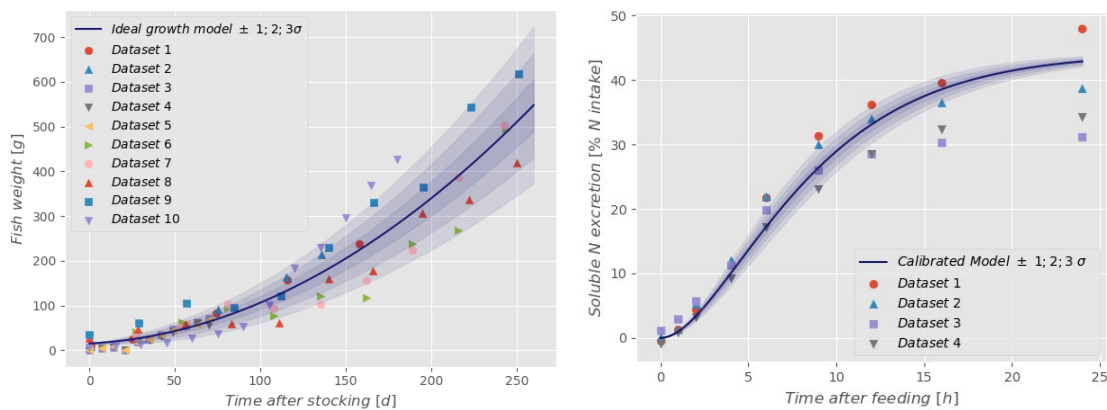
Background and goal of project

Aquaponics combines the production of aquatic species (*aquaculture*) with soilless horticulture (*hydroponics*), reusing waste from the aquatic animals to fertilize plants in a single water cycle. Understanding the nutrient balances in fish and plants is crucial for the development of commercial-scale aquaponics.



Our research is part of the EU project INAPRO. The project combines two decoupled loops: a recirculating aquaculture system (RAS) and a greenhouse hydroponic system.

Highlight of the past year



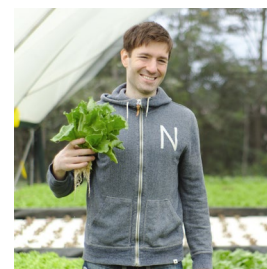
Model for fish growth (left) and nitrogen excretion (right).
Results from model calibration against multiple literature data.

We developed a model for fish growth based on nutrient dynamics. This model helps to predict and follow the flow of nutrients during fish growth.

The model also accounts for uncertainties. This information provides researchers and producers with tools for decision-making and system management, with better understanding of risks and opportunities.

Smart integrated multitrophic city food production systems – a water and energy saving approach for global urbanisation

Name Postdoc: Simon Goddek
Involved staff members: Karel Keesman
Project sponsor: NWO / JPI Urban Europe / Belmont Forum
Start/(expected) end date of project: March 2018 – March 2021



Background and goal of project

Far too much energy and water are used to produce and deliver the food cities need and that is one core issue in the Food-Water-Energy (FWE) Nexus regarding rapid worldwide urbanisation. The project CITYFOOD, therefore, focuses on sustainable urban infrastructure development in the form of aqua-agriculture (aquaponics) systems that are capable of managing flows of food, water, energy and waste through innovative strategies and conceptual designs. Multidisciplinary approaches will be applied for modelling and FWE optimisation involving urban planning, social aspects, and competitive interests.

Highlight of the past year

Within the scope of this project and my involvement in the aquaponics COST network, I have managed the writing of a book as the 1st editor in collaboration with scientists from 27 countries all over the world. The book *Aquaponics Food Production Systems* has been submitted to Springer Ltd. and is expected to be available under Open Access license in the second quarter of 2019. In addition, we submitted a paper on sizing greenhouse-based aquaponics systems in different environments (Figure 1).

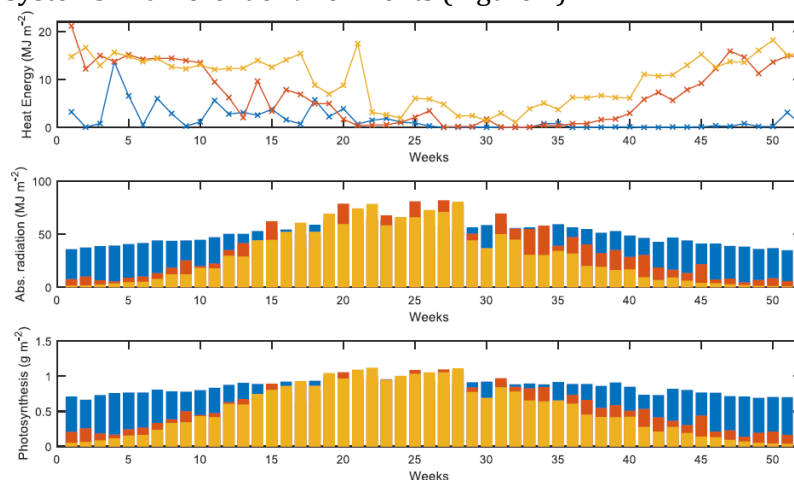


Figure 1. Example of weekly sums of heat energy (a), absorbed solar radiation by the crop (b) and net photosynthesis in lettuce over a period of 1 year for Namibia (blue), The Netherlands (red) and Faroe Islands (orange).

Student projects envisioned

MSc and BSc students working on modelling of aquaponics systems in terms of food production, water and energy consumption and waste treatment

Smart Detection and Real-time Learning in Water Distribution: an Integrated Data-Model Approach

Name PhD: Caspar Geelen

Involved staff members: Prof. Dr. Ir. Karel Keesman, Prof. Dr. Jaap Molenaar

Project sponsor: Wetsus

Start/(expected) end date of project: 09/2017 – 09/2021



Background and goal of project

The Dutch drinking water infrastructure belong to the best in the world, having water losses of less than 5% per year. Management of the grid is also done in an excellent way, employing real-time water pressure and flow sensors to timely detect pipe bursts. Although this reactive approach to leakage control is of a high quality, less effort is spent to predict and prevent pipe bursts. However, the big & fast data sets saved by the sensors placed in the water grid also allow for proactive leakage control, where the focus is placed on timely detecting suboptimal management of the grid and other disrupting events, which in turn allow asset management to prevent future bursts.

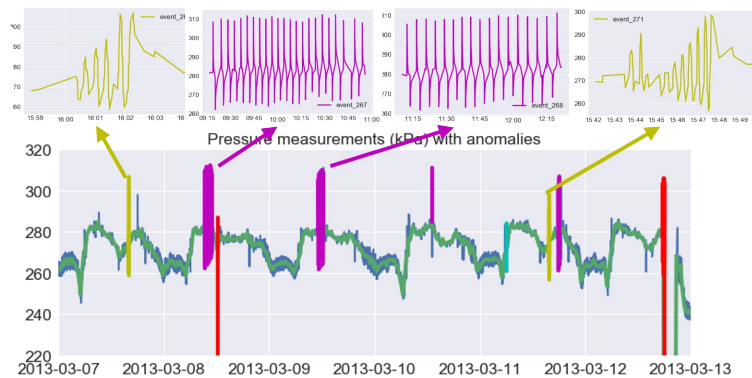


Figure 7 – Anomaly detection

Highlight of the past year

A combination of anomaly detection (see Figure 1) and clustering (see Figure 2) was successfully used to detect recurring irregularities present in water pressure measurements, which are indicative of suboptimal management of the grid. Early detection of these recurring patterns allows construction of an early warning system and decision support tool for preventing pipe bursts.

Student projects envisioned

The wealth of available (sensor) data allows for answering many interesting research questions, which all revolve around trying to optimize grid management and prevent bursts. For every student that has some programming experience (python/R/MatLab/...) and is interested in working with machine learning models and other state-of-the-art automatic data mining techniques is welcome to contact me.

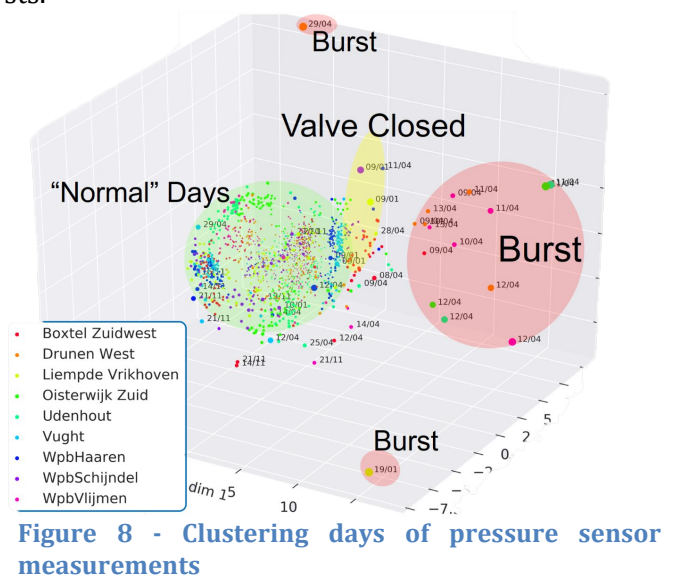


Figure 8 - Clustering days of pressure sensor measurements

Selective Particle Control in Suspensions Using Acoustics

Name PhD: M. Hakan Kandemir

Involved staff members: Prof. Karel Keesman

Project sponsor: Wetsus

Start/(expected) end date of project: 01-12-2017/01-09-2020



Background and goal of project

Acoustic separation is a method to separate particulate matter from suspensions. The advantage of this method is that such a separator does not contain any internal parts. Particles can be separated based on size, density or compressibility. Hence, such a separator has the potential to be a tuneable for different settings.

Goal of this project is to achieve acoustic separation in a selective way. Selectivity in acoustic separation is possible thanks to the interplay between acoustic force and drag force on the particles. Proposed selective methods will be modelled and tested with model particles under lab conditions and on real-life applications, such as wine and wheat beer filtration.

Highlight of the past year

Standing acoustic wave fields are most commonly used in the acoustic separation systems. A prototype has been developed in the lab and was tested with respect to its selective particle separation possibilities. This prototype consists of a sound source to generate the sound, and internal structures to regulate the flow and create the standing wave field. The flow inside the channel has a serpentine shape and with this method it is possible to selectively trap the particles (see Figure 1). Furthermore, filtration of wheat beer was achieved in this system. In addition to the standing wave methods, dynamic acoustic fields have also been investigated and experimented. Theories for particle selectivity in dynamic systems are currently being tested for experimental verification.

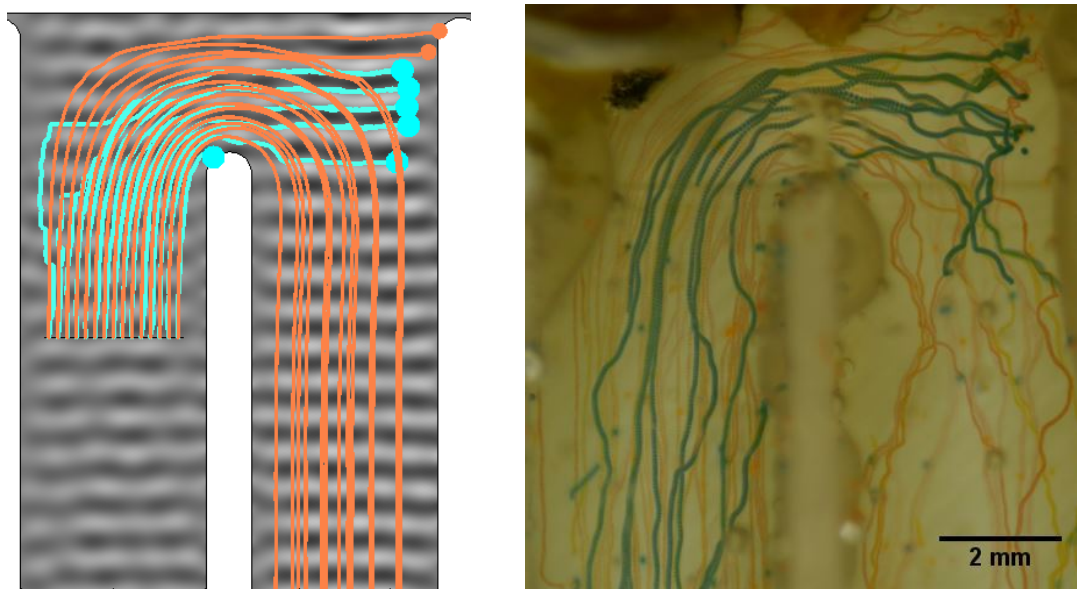


Figure 9 – Computer simulations of particle trajectories (left) and particle trajectories recorded in the experiments (right)

Type of student projects envisioned

The application area of this project includes any particle suspensions with particles in the micrometer-range. Development and testing of acoustic separator prototypes are possible student projects. Application of existing prototypes in real-life cases is also a possibility. Students (preferably) with a background in acoustics/vibrations or biotechnology and wish to learn and investigate different scenarios for separation are welcome.

A novel aquaponic system: bioenergy recovery and carbon dynamics

Name PhD: Ze Zhu

Involved staff members: Prof. dr. Karel Keesman (WUR, NL),

Prof. dr. Amit Gross (BGU, Israel)

Project sponsor: ICA, CSC and others

Start/(expected) end date of project: 30/10/18-30/10/22



Background and goal of project

In recent years, there is a renewed interest in aquaponics due to its efficient water utilization and conservation of nutrients and energy in the production of plants and aquatic products. A novel model of a near-zero water discharge aquaponic system that can efficiently recycle its nutrients for enhanced plant production as well as generate energy for off-grid operation via anaerobic digestion of its carbonaceous waste was recently proposed (see Fig 1). The aim of the current study is to test the model in pilot and full scale desert aquaponics systems, focusing on the carbon cycle and bioenergy production.

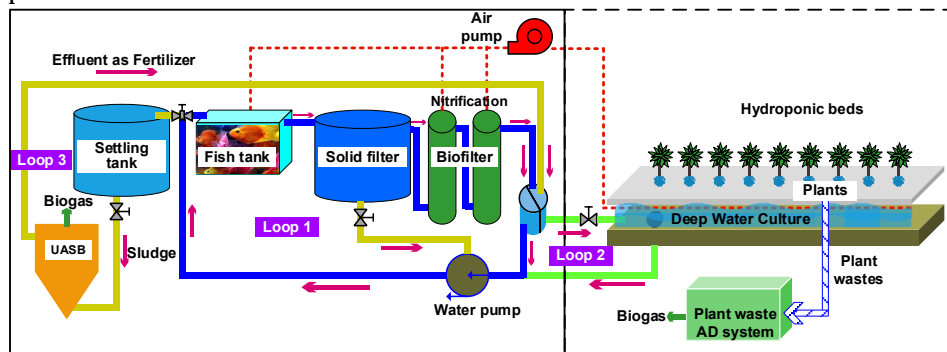


Fig. 1 Schematic representation of the aquaponics research system.

Highlight of the past year

Results suggest that about 27% C was utilized for fish biomass growth. The solid fish-waste (15% C) was transferred to the anaerobic digester (UASB) and converted to bio-methane, a green energy source. The high-quality liquid fertilizer from the UASB was used in the hydroponics beds. Moreover, unusable parts of the plants, such as roots and inedible shoots, were anaerobically digested and accounted for about 75% of the system's energy demand. Interestingly, net CO₂ sequestration was observed (about 1.4 kg plants-C for 1 kg feed-C), which dramatically reduces the aquaponic system environmental footprint and improves its sustainability.

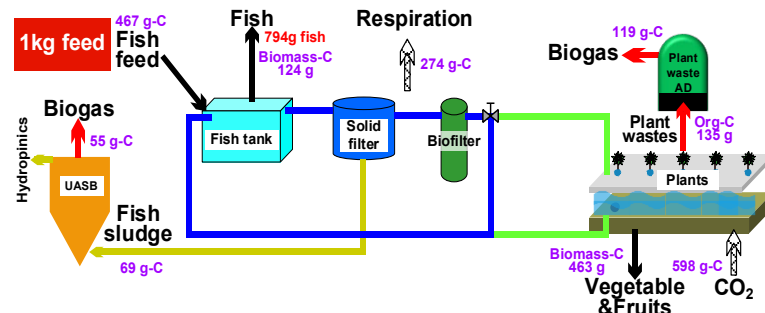


Fig. 210 Carbon mass balance for the different units of the aquaponic system.

Student projects envisioned

The project includes the development of a dynamic system model of nutrient and water streams, determination of the energy balance of the desert multi-loop aquaponic system, performing uncertainty analyses and finding optimal system design parameters.

Education

Bachelor and Master courses BCT and contribution to other courses

Code	Course title
BCT-20306	Modelling Dynamic Systems
BCT-21306	Control Engineering
BCT-22803	Physical Transport Phenomena
BCT-23306	Biorefinery
BCT-23806	Principles of Biobased Economy
BCT-30806	Physical Modelling
BCT-31306	Systems and Control Theory
BCT-31806	Parameter Estimation and Model Structure Identification
BCT-32306	Advanced Biorefinery
BCT-33806	Conversions in Biobased Sciences
BCT-50306	Renewable Resources and the (Bio)Chemical Production of Industrial Chemicals
BCT-51306	Biobased Economy

Code	Course title
BPE-10305	Process Engineering Basics
BPE-12806	Bioprocess Engineering Basics BT
BPE-60312	Bioprocess Design
FTE-12803	Introduction Biosystems Engineering part 2
FTE-34806	Modelling of Biobased Production Systems
ORC-12803	Organic Chemistry 1
ORC-12903	Organic Chemistry 2
ORC-13803	Bio-organic Chemistry for Life Sciences
PCC-33309	From Molecule to Designer Materials
XWT-21305	Process Dynamics (Wetsus)
YEI-60312	Research Master Cluster: Proposal Writing

BCT: Biobased Chemistry and Technology
FTE: Farm Technology
XWT: Wetsus Academy
PCC: Physical Chemistry and Soft Matter

BPE: Bioprocess Engineering
ORC: Organic Chemistry
YEI: Educational Institute

BSc Theses

- Stelt, Gideon van der; Optimizing the aqueous extraction and spray drying of oleosomes derived from Brassica napus into stable powders
- Wacker, Jan-David; Modelling the Effects of Excretion Variations on Nutrient Dynamics in a Recirculating Aquaculture System
- Hertsig, Karlijn; Catalytic hydrogenation of seaweed for sugar alcohol production
- Heer, Floris de; The making of a basic mathematical model for the optimization with respect to the energy use of a direct air capture system
- Beersum, Ellen van; Modelling the influence of particle design on CO₂ capture from ambient air using solid adsorbents
- Fikke, Tamara; Egg yolk lipoprotein-based nanocarriers of gold nanoparticles
- Lucas, Tess; Optimizing oil body extraction to facilitate drying of natural emulsions from sunflower seeds
- Dekkers, Kirsten; Process design for sustainable extraction of rapeseed protein mixtures
- Graas, Silvester; On the stability of the MIL-101(Al)-NH₂ framework during mechanochemical immobilization of a metathesis catalyst
- Oladosu, Aji; The effect of homogenization on the reproducibility of feather hydrolysis and boisen analysis
- Zijlma, Jelte; Modelling potato growing conditions for initial storage quality
- Verhagen, Simone; Improving the Value of Spent Coffee Grounds by Converting Carbohydrates into Fermentable Sugars

MSc Theses

- Ham, Matthijs van der; Characterisation of lignin and cellulose obtained by zinc chloride hydrate pretreatment and valorisation of cellulose by fermentation
- Torres Ruano, Timon; Effect of partial CO pressure on the acetate metabolism of *C. hydrogenoformans* and the effect of biological condition on Ru/C activity
- Hendricks, Guido; Mathematical model of the artificial pancreas; a Utopia?
- Dijkgraaf, Klaas Hielke; Modelling innovative aquaponics farming in Kenya
- Theobald, Sophie; Influence of H₂ partial pressure on the acetate production by extremophiles and in situ conversion to ethanol using a heterogeneous ruthenium catalyst
- Zwietering, Jeroen; Evaluating the incorporation of a new biorefinery concept in the Dutch sugar supply chain
- Bordanaba Florit, Guillermo; CO₂ capture from air by carbon supported potassium carbonate
- Esbroeck, Elianne van; Temperature control of microalgae cultivation under variable conditions
- Scharf, Mirka; Aqueous extraction of oil bodies and proteins from tomato processing residues
- Goedhart, Joost; The potential role of urban waste biomass in the biobased economy – a case study for Amsterdam
- Vollenbroek, Nick; Protein recovery from duckweed species
- Roos, Charlotte; Exploring processes for energy efficient preparation of cold water soluble potato starch
- Vanwinsen, Bert; Exploring the Potential of the Radial Flow Packed Bed Reactor for the Capture of CO₂ from Ambient Air
- Verboom, Steven; The design of micro-fluidic multi-phase reaction devices for on-flow NMR measurements

- Yonsel, Sema; Extraction of protein mixture from rapeseed for food applications
- Kerssemakers, Bram; A novel approach for the production and isolation of tulipalin-A from bulbous tulip biomass
- Fuhrer, Marlene; Carbohydrate oxidation by platinum on activated carbon: Altering the catalytic performance by changing the surface chemistry of the support
- Hol, Stefan; Modelling the physiological changes of the potato skin regarding water loss during long term storage
- Raedts, Roy; Application of RID to farm located conversion systems for agricultural on-farm products and residues

PhD Theses

- Bowden, Nathan; Modelling the Solubility of the 20 Proteinogenic Amino Acids with Experimentally Derived Saturation Data
- But, Andrada; Nitrogen containing biobased chemicals produced using enzymes
- Grubben, Nik; Modelling ventilated potato bulk storage facilities
- Meussen, Bas; Developing a role for *Rhizopus oryzae* in the biobased economy by aiming at ethanol and cyanophycin coproduction
- Zaal, Piet van der; Isomalto/malto-polysaccharides from starch - Reaction pathways and new characterization strategies

Scientific Publications 2018

Refereed article in a journal

- [Moisture Dependent Diffusion and Shrinkage in Yam during Drying](#)
Amankwah, Emmanuel A. ; Dzisi, Komla Agbeko ; Straten, Gerrit van; Boxtel, Anton J.B. van (2018)
International Journal of Food Engineering 14 (7-8). - 15 p.
- [Modeling the equilibrium moisture content of desorption and adsorption of yam \(Dente\)](#)
Amankwah, E.A. ; Dsizi, K.A. ; Straten, G. van; Boxtel, A.J.B. van (2018)
Agricultural Engineering International 20 (1). - p. 184 - 192.
- [Solubility of the Proteinogenic \$\alpha\$ -Amino Acids in Water, Ethanol, and Ethanol-Water Mixtures](#)
Bowden, Nathan A. ; Sanders, Johan P.M. ; Bruins, Marieke E. (2018)
Journal of Chemical and Engineering Data 63 (3). - p. 488 - 497.
- [Modelling the effects of ethanol on the solubility of the proteinogenic amino acids with the NRTL, Gude and Jouyban-Acree models](#)
Bowden, Nathan A. ; Sevillano, David Mendez ; Sanders, Johan P.M. ; Bruins, Marieke E. (2018)
Fluid Phase Equilibria 459. - p. 158 - 169.
- [How to analyse urban resource cycles : a dynamic systems approach to facilitate decision-making](#)
Bozileva, Elvira ; Leusbrock, Ingo ; Cappon, Hans J. ; Rijnaarts, Huub H. ; Keesman, Karel J. (2018)
IFAC-PapersOnLine 51 (2). - p. 541 - 546.
- [In vitro lipid digestion in raw and roasted hazelnut particles and oil bodies](#)
Capuano, Edoardo ; Pellegrini, Nicoletta ; Ntone, Eleni ; Nikiforidis, Constantinos V. (2018)
Food & Function 9 (4). - p. 2508 - 2516.
- [A methodology to quantify the aerobic and anaerobic sludge digestion performance for nutrient recycling in aquaponics : Une méthodologie pour quantifier les performances de digestion aérobie et anaérobie des boues, pour le recyclage des nutriments en Aquaponie](#)
Delaide, Boris ; Goddek, Simon ; Keesman, Karel J. ; Jijakli, M.H.M. (2018)
Biotechnology, Agronomy, Society and Environment 22 (2). - p. 106 - 112.
- [High Rate Biomethanation of Carbon Monoxide-Rich Gases via a Thermophilic Synthetic Coculture](#)
Diender, Martijn ; Uhl, Philipp S. ; Bitter, Johannes H. ; Stams, Alfons J.M. ; Sousa, Diana Z. (2018)
ACS sustainable chemistry & engineering 6 (2). - p. 2169 - 2176.
- [Modelling smart energy systems in tropical regions](#)
Dominković, D.F. ; Dobravec, V. ; Jiang, Y. ; Nielsen, P.S. ; Krajačić, G. (2018)
Energy 155. - p. 592 - 609.
- [Techno-economic evaluation of microalgae harvesting and dewatering systems](#)
Fasaei, F. ; Bitter, J.H. ; Slegers, P.M. ; Boxtel, A.J.B. van (2018)
Algal Research 31. - p. 347 - 362.
- [Comparison of Lactuca sativa growth performance in conventional and RAS-based hydroponic systems](#)
Goddek, Simon ; Vermeulen, Tycho (2018)
Aquaculture International 26 (6). - p. 1377 - 1386.
- [Nutrient mineralization and organic matter reduction performance of RAS-based sludge in sequential UASB-EGSB reactors](#)
Goddek, Simon ; Delaide, Boris P.L. ; Joyce, Alyssa ; Wuertz, Sven ; Jijakli, M.H. ; Gross, Amit ; Eding, Ep H. ; Bläser, Ingo ; Reuter, Michael ; Keizer, L.C.P. ; Morgenstern, Rolf ; Körner, Oliver ; Verreth, Johan ; Keesman, Karel J. (2018)
Aquacultural Engineering 83. - p. 10 - 19.

- [The necessity of desalination technology for designing and sizing multi-loop aquaponics systems](#)
Goddek, Simon ; Keesman, Karel J. (2018)
Desalination 428 . - p. 76 - 85.
- [Controllability and observability of 2D thermal flow in bulk storage facilities using sensitivity fields](#)
Grubben, Nik L.M. ; Keesman, Karel J. (2018)
International Journal of Control 91 (7). - p. 1554 - 1566.
- [In Vitro Fermentation Behavior of Isomalto/Malto-Polysaccharides Using Human Fecal Inoculum Indicates Prebiotic Potential](#)
Gu, Fangjie ; Borewicz, Klaudyna ; Richter, Bernadette ; Zaal, Pieter H. van der; Smidt, Hauke ; Buwalda, Pieter L. ; Schols, Henk A. (2018)
Molecular Nutrition & Food Research 62 (12).
- [Size-controlled and water-soluble gold nanoparticles using UV-induced ligand exchange and phase transfer](#)
Hove, Jan Bart ten; Schijven, Laura M.I. ; Wang, Junyou ; Velders, Aldrik H. (2018)
Chemical Communications 54 (95). - p. 13355 - 13358.
- [Economics of social trade-off : Balancing wastewater treatment cost and ecosystem damage](#)
Jiang, Yu ; Dinar, Ariel ; Hellegers, Petra (2018)
Journal of Environmental Management 211 . - p. 42 - 52.
- [Covalent Bonding of Chlorogenic Acid Induces Structural Modifications on Sunflower Proteins](#)
Karefyllakis, D. ; Salakou, Stavroula ; Bitter, J.H. ; Goot, A.J. van der; Nikiforidis, K. (2018)
ChemPhysChem 19 (4). - p. 459 - 468.
- [Optimal input design for minimum-variance estimation of parameters in nonlinear state-space models](#)
Keesman, Karel J. (2018)
IFAC-PapersOnLine 51 (15). - p. 365 - 370.
- [Nitrogen dynamics in flooded soil systems: An overview on concepts and performance of models : Model concepts of nitrogen dynamics in flooded soils](#)
Khairudin, Nurul ; Gaydon, Donald S. ; Jing, Qi ; Zakaria, Mohamad P. ; Struik, Paul C. ; Keesman, Karel J. (2018)
Journal of the Science of Food and Agriculture 98 (3). - p. 865 - 871.
- [Glocal assessment of integrated wastewater treatment and recovery concepts using partial nitrification/Anammox and microalgae for environmental impacts](#)
Khiewwijit, Rungnapha ; Rijnaarts, Huub ; Temmink, Hardy ; Keesman, Karel J. (2018)
Science of the Total Environment 628-629 . - p. 74 - 84.
- [The effect of me-substituents of 1,4-butanediol analogues on the thermal properties of biobased polyesters](#)
Klis, Frits van der; Knoop, Rutger J.I. ; Bitter, Johannes H. ; Broek, Lambertus A.M. van den (2018)
Journal of Polymer Science. Part A, Polymer Chemistry 56 (17). - p. 1903 - 1906.
- [From batch to continuous : Au-catalysed oxidation of d-galacturonic acid in a packed bed plug flow reactor under alkaline conditions](#)
Klis, F. van der; Gootjes, L. ; Haveren, J. van; Es, D.S. van; Bitter, J.H. (2018)
Reaction Chemistry & Engineering 3 (4). - p. 540 - 549.
- [Closed-loop spray drying solutions for energy efficient powder production](#)
Moejes, S.N. ; Visser, Q. ; Bitter, J.H. ; Boxtel, A.J.B. van (2018)
Innovative Food Science and Emerging Technologies 47 . - p. 24 - 37.
- [Towards commercial aquaponics : a review of systems, designs, scales and nomenclature](#)
Palm, Harry W. ; Knaus, Ulrich ; Appelbaum, Samuel ; Goddek, Simon ; Strauch, Sebastian M. ; Vermeulen, Tycho ; Haïssam Jijakli, M. ; Kotzen, Benz (2018)
Aquaculture International 26 (3). - p. 813 - 842.

- [Model-based management strategy for resource efficient design and operation of an aquaponic system](#)
Reyes Lastiri, Daniel ; Geelen, Caspar ; Cappon, Hans J. ; Rijnaarts, Huub H.M. ; Baganz, Daniela ; Kloas, Werner ; Karimanzira, Divas ; Keesman, Karel J. (2018)
Aquacultural Engineering 83 . - p. 27 - 39.
- [Controlling Ethanol Use in Chain Elongation by CO2 Loading Rate](#)
Roghair, M. ; Hoogstad, Tim ; Strik, D.P.B.T.B. ; Plugge, C.M. ; Timmers, P.H.A. ; Weusthuis, R.A. ; Bruins, M.E. ; Buisman, C.J.N. (2018)
Environmental Science and Technology 52 (3). - p. 1496 - 1505.
- [Day-to-night heat storage in greenhouses : 3 Co-generation of heat and electricity \(CHP\)](#)
Seginer, Ido ; Beveren, Peter J.M. van; Straten, Gerrit van (2018)
Biosystems Engineering 172 . - p. 1 - 18.
- [Isomalto/malto-polysaccharide structure in relation to the structural properties of starch substrates](#)
Zaal, P.H. van der; Schols, H.A. ; Bitter, J.H. ; Buwalda, P.L. (2018)
Carbohydrate Polymers 185 . - p. 179 - 186.

PhD Theses

- [Modelling the solubility of the 20 proteinogenic amino acids with experimentally derived saturation data](#)
Bowden, Nathan A. (2018)
Wageningen University. Promotor(en): Johan Sanders, co-promotor(en): Marieke Bruins. - Wageningen : Wageningen University, - 261
- [Modelling ventilated potato bulk storage facilities](#)
Grubben, Nik L.M. (2018)
Wageningen University. Promotor(en): Karel Keesman. - Wageningen : Wageningen University, - 173
- [Developing a role for Rhizopus oryzae in the biobased economy by aiming at ethanol and cyanophycin coproduction](#)
Meussen, Bas Johannes (2018)
Wageningen University. Promotor(en): Johan Sanders, co-promotor(en): Ruud Weusthuis. - Wageningen : Wageningen University, - 169
- [Isomalto/malto-polysaccharides from starch : Reaction pathways and new characterization strategies](#)
Zaal, Pieter H. van der (2018)
Wageningen University. Promotor(en): Harry Bitter, co-promotor(en): Piet Buwalda. - Wageningen : Wageningen University, - 132

Refereed book chapters

- [Dynamic optimization in drying](#)
Boxtel, A.J.B. van (2018)
In: Intelligent drying in control / Martynenko, Alex, Bück, Andreas, Boca Raton, Florida, USA : CRC Press / Taylor & Francis, (Advances in Drying Science and Technology) - p. 75 - 102.
- [Potato Starch](#)
Semeijn, Cindy ; Buwalda, Pieter L. (2018)
In: Starch in Food / Sjö, Malin, Nilsson, Lars, Elsevier Inc. Academic Press, - p. 353 - 372.

Other output

Orals invited

Bioderived and bioinspired functional material;
K. Nikiforidis, Agrotechnology & Food Sciences Group, Wageningen University and Research, Wageningen, The Netherlands, 13 Feb 2018

Catalytic decarboxylation: challenges in heterogeneous, homogenous and biocatalysis;
J.H. Bitter, Biomass Conversion, Delft University, The Netherlands, 26 Mar 2018

Predicting Pipe Bursts using Data Science;
Caspar Geelen, Brabant Water, The Netherlands, 3 Apr 2018

Processing of Big & Fast Sensor Data for Failure Prediction, the benefits and downsides of machine learning;
Caspar Geelen, Wetsus annual workshop day, Leeuwarden, The Netherlands, 19 Apr 2018

Data-Driven Burst Prediction, a Brabant Water Case Study;
Caspar Geelen, Brabant Water, The Netherlands, 9 May 2018

Bioderived and bioinspired functional material
K. Nikiforidis, Soft Matter Group of the Faculty of Mechanical, Maritime and Materials Engineering in TU Delft, The Netherlands, 11 May 2018

Strategies to stabilize supported Ni-nanoparticles in aqueous reaction mixtures
J.H. Bitter, Norwegian University of Science and Technology (NTNU), Trondheim, Norway, 18 May 2018

Natural oil droplets for food and pharma applications
K. Nikiforidis, Botaneco, Calgary, Canada, 11 Jun 2018

Biobased Chemistry and Technology, assisting the transition to a biobased economy
J.H. Bitter, CSIRO Food Innovation Centre, Melbourne, Australia, 17 Jul 2018

Heterogeneous non-noble metal catalysts for biobased conversions
J.H. Bitter, Monash University, Melbourne, Australia, 17 Jul 2018

Some challenges for a biobased economy
J.H. Bitter, Monash University, Melbourne, Australia, 17 Jul 2018

Biobased Chemistry and Technology, assisting the transition to a biobased economy
J.H. Bitter, Food Waste, Melbourne, Australia, 19 Jul 2018

Orals contributed

Carbon supported metal-carbides and metal phosphide for biomass-based conversions. / Bitter, J.H.; Souza Macêdo, L.; Oliveira Jr, R.R.; van Haasterecht, T.; Auxiliadora, M.; Baldanza, S.; Teixeira da Silva, V.
8th International symposium on Carbon for Catalysis, Porto, Portugal, 26-29 June 2018

On the Stability of Supported Carbides for Deoxygenation Reactions. / Bitter, J.H.; Gosselink, R.W.; Stellwagen, Daniel; Souza Macêdo, L.; Wiegersma, Tijmen; van Haasterecht, T.; Teixeira da Silva, V.

American Chemical Society fall 2018, Boston, United States, 19-23 August 2018

Towards combining heterogeneous electro-catalysis and microbial electro-synthesis. / Chatzipanagiotou, K.R.; Jourdin, Ludovic; van Haasterecht, T.; Buisman, C.J.N.; Strik, D.P.B.T.B.; Bitter, J.H.

XIXth NCCC The Netherlands' Catalysis and Chemistry Conference, Noordwijkerhout, Netherlands, 5-7 March 2018.

Characterisation of rapeseed oil bodies in natural dispersions and dried powders. / Fryganas, Christos; di Bari, V.; Sridharan, Lakshminarasimhan; Bitter, J.H.; Nikiforidis, K. 1st International conference on Oil bodies, Wageningen, Netherlands, 15-16 October 2018

SMART detection and real-time learning in water distribution: Pressure Sensor based Monitoring Support. / Geelen, Caspar; Yntema, D.; Molenaar, J.; Keesman, K.J.

37th Benelux Meeting on Systems and Control, Soesterberg, Netherlands, 27-29 March 2018.

Moving away from averages in chemistry – modelling starch oxidation. / Hoogstad, Tim; Buwalda, P.L.; Bitter, J.H.

Netherlands Process Technology Symposium, Enschede, Netherlands, 30-31 May 2018.

Enabling CO₂ capture from air through modelling and experiments. / Kiewidt, Lars; Cabrera Rodriguez, Carlos; Masoud, Nazila; van Haasterecht, T.; Bitter, J.H.

Netherlands Process Technology Symposium, Enschede, Netherlands, 30-31 May 2018.

Minimal separation processing steps for functional rapeseed protein-oil body mixtures. / Ntone, Eleni; Bitter, J.H.; Nikiforidis, K.

1st International conference on Oil bodies, Wageningen, Netherlands, 15-16 October 2018.

Monitoring a catalytic multi-phase reaction with on-flow NMR spectroscopy. / Wierda, G.J.; Bitter, J.H.; Velders, A.H.

Chemistry as Innovating Science 2018, Veldhoven, Netherlands, 3-5 December 2018.

Poster presentations

'Characterisation of rapeseed oil bodies in natural dispersions and dried powders', Fryganas, C, di Bari, V, Sridharan, L, Bitter, JH & Nikiforidis, K, Chemistry as Innovating Science 2018, Veldhoven, Netherlands, 3/12/18 - 5/12/18

'The role of support oxygen groups in carbohydrate oxidation over Pt on carbon catalysts', Führer, M, van der Wijst, E, van Haasterecht, T & Bitter, JH, XIXth NCCC The Netherlands' Catalysis and Chemistry Conference (2018), Noordwijkerhout, Netherlands, 5/03/18 - 7/03/18

'The effects of feedstock polydispersity on conversion kinetics: modelling starch oxidation', Hoogstad, T, Konings, G, van Boxtel, AJB, Buwalda, PL & Bitter, JH, XIXth NCCC The Netherlands' Catalysis and Chemistry Conference (2018), Noordwijkerhout, Netherlands, 5/03/18 - 7/03/18

'Encapsulation kinetics of hydrophobic compounds in oil bodies through molecular dynamic simulations',

Kiewidt, L, Rosenbaum, B, Sridharan, L, Bitter, JH & Nikiforidis, K, 1st International Conference on Oil Bodies, Wageningen, Netherlands, 15/10/18 - 16/10/18

'Tradeoff analysis of monolithic sponges',

Kiewidt, L, Thöming, J & Bitter, JH, XIXth NCCC The Netherlands' Catalysis and Chemistry Conference (2018), Noordwijkerhout, Netherlands, 5/03/18 - 7/03/18

'Direct CO₂ Capture from Air - Challenges and Opportunities of a Solid Sorbent',

Masoud, N, Cabrera Rodriguez, C, van Haasterecht, T, Kiewidt, L, van Boxtel, AJB & Bitter, JH, Chemistry as Innovating Science 2018, Veldhoven, Netherlands, 3/12/18 - 5/12/18

'In vitro lipid digestion in raw and roasted hazelnut particles and oil bodies',

Ntone, E, Capuano, E, Pellegrini, N & Nikiforidis, K, 1st International conference on Oil bodies, Wageningen, Netherlands, 15/10/18 - 16/10/18

'Towards interfacial active rapeseed protein mixtures by applying minimal separation processing steps',

Ntone, E, Bitter, JH & Nikiforidis, K, 32nd EFFoST Conference, Nantes, France, 6/11/18 - 8/11/18

'Towards interfacial active rapeseed protein mixtures by applying minimal separation processing steps',

Ntone, E, Bitter, JH & Nikiforidis, K, Chemistry as Innovating Science 2018, Veldhoven, Netherlands, 3/12/18 - 5/12/18

'Shining light on gold nanoparticles',

Schijven, LMI, Wang, J, ten Hove, JB & Velders, AH, Chemistry as Innovating Science 2018, Veldhoven, Netherlands, 3/12/18 - 5/12/18

'Physical Properties of oil-in-water emulsions prepared by whole yellow pea flour',

Sridharan, L, Meinders, MBJ, Bitter, JH & Nikiforidis, K, Chemistry as Innovating Science 2018, Veldhoven, Netherlands, 3/12/18 - 5/12/18

'Flavour diffusion through oil body membrane',

Sridharan, L, Romero Guzman, J & Nikiforidis, K, 1st International Conference on Oil Bodies, Wageningen, Netherlands, 15/10/18 - 16/10/18

'Physical Properties of oil-in-water emulsions prepared by whole yellow pea flour',

Sridharan, L, Meinders, MBJ, Bitter, JH & Nikiforidis, K, 32nd EFFoST Conference, Nantes, France, 6/11/18 - 8/11/18

'The design of micro-fluidic multi-phase reaction devices for on-flow NMR measurements',

Verboom, S, Wierda, GJ, Kiewidt, L, van Boxtel, AJB & Bitter, JH, XIXth NCCC The Netherlands' Catalysis and Chemistry Conference (2018), Noordwijkerhout, Netherlands, 5/03/18 - 7/03/18

'In-line NMR monitoring of catalytic multiphase reactions',

Wierda, GJ, Gómez, MV, Bitter, JH & Velders, AH, XIXth NCCC The Netherlands' Catalysis and Chemistry Conference (2018), Noordwijkerhout, Netherlands, 5/03/18 - 7/03/18

'On-flow NMR multi-phase reaction-monitoring in a heartbeat',

Wierda, GJ, Gómez, MV, Bitter, JH & Velders, AH, NMR discussion group, Nijmegen, Netherlands, 5/10/18

Outreach

EFCATS Young Scientist Contest

J.H. Bitter (Organiser), EFCATS Board (Organiser), Wageningen, 9 Jul 2018 → 11 Jul 2018

1st International conference on Oil bodies

K. Nikiforidis (organiser), Wageningen, 15 Oct 2018 → 16 Oct 2018

WETSUS Python Programming Course

Caspar Geelen (organiser), Leeuwarden, 13 Nov 2018 → 11 Dec 2018

Cross-Correlation based, regional proactive leakage control methods

Caspar Geelen (Speaker) Vitens, 22 Nov 2018

Predicting Asset Failure based on Real-Time Anomaly Detection and Clustering

Caspar Geelen (Speaker) PWN, 4 Apr 2018

Real-Time Burst Detection, a Friesland Case Study

Caspar Geelen (Speaker) Vitens, 21 Feb 2018

PhD trip Denmark/Sweden 9-15 April 2018:

Gold nanoparticles as model for drug encapsulation

L.M.I. Schijven (Speaker) Novo Nordisk Denmark, 9 April 2018

The effect of polydispersity on conversion kinetics – starch oxidation

Tim Hoogstad (Speaker) Avebe Stadex Sweden, 10 Apr 2018

Protein-starch mixtures from yellow peas for food emulsions

Lakshminarasimhan Sridharan (Speaker) Avebe Stadex Sweden, 11 Apr 2018

Towards combining heterogeneous electro-catalysis and microbial electro-synthesis

K.R. Chatzipanagiotou (Speaker) Technical University of Denmark, Denmark, 11 Apr 2018

Towards combining heterogeneous electro-catalysis and microbial electro-synthesis

K.R. Chatzipanagiotou (Speaker) Max IV Laboratory Sweden, 12 Apr 2018

The effect of polydispersity on conversion kinetics – starch oxidation

Tim Hoogstad (Speaker) Danish Technological Institute Denmark, 13 Apr 2018

Rapeseed protein mixtures for food-grade emulsions

Eleni Ntone (Speaker), DuPont Denmark, 13 Apr 2018

Food-grade lipoproteins as nanocarriers of therapeutic agents and diagnostics

L.M.I. Schijven (Speaker) DuPont Denmark, 13 Apr 2018

On flow NMR monitoring of a Multi-phase reaction

G.J. Wierda (Speaker) Danish Technological Institute Denmark, 13 Apr 2018