Biobased Chemistry and Technology
Annual report 2017

WAGENINGEN
UNIVERSITY & RESEARCH

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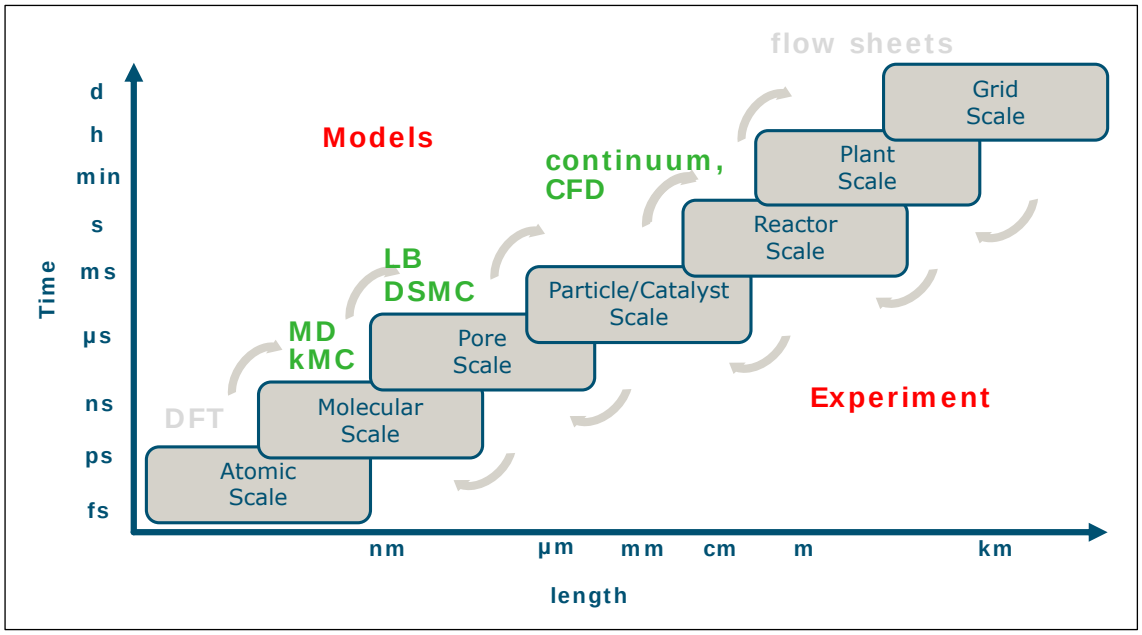
Introduction

It is my pleasure to present to you the annual report 2017 of the Biobased Chemistry and Technology (BCT) group. The two eye catching events were the successful completion and start of the micromaster 'biobased sciences for sustainability', and the strengthening of the group's profile by focusing on the combination of modelling and (chemical) experimentation on multiple length and time scales. We therefore welcome Lars Kiewidt as a new researcher in the group. He will specifically focus on multi-scale modelling. By using the combined potential of experiments and modelling, we want to overcome both fundamental and applied challenges on the way towards a sustainable (biobased) future.



The BCT group was also heavily involved in the application for a new on-campus master program 'biobased sciences', which is expected to start in September 2018. All this made 2017 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
Bioprocess Engineering (BPE)	Modeling of algae systems
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).

Conversion

Staff: Dr. Elinor Scott, Dr. Piet Buwalda, Prof. Harry Bitter
PhD students and post-docs: Piet van der Zaal, Tim Hoogstad (joint technology/conversion), Evie van der Wijst, Luana Souza Macedo, Frits van der Klis, Roxani Chatzipanagiotou, Xinhua Goerner-Hu, Carlos Cabrera Rodriguez (joint technology/conversion), Nazila Masoud, Nathan Bowden, Gerben Wierda, Dr Tomas van Haasterecht
Contact: Elinor.scott@wur.nl

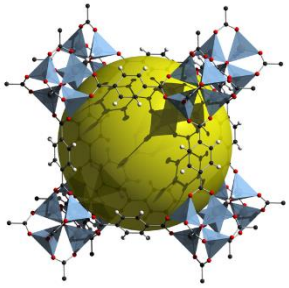
Background and goal
Environmental concerns, fluctuating oil prices and dwindling reserves are leading to the need for the production of biobased chemicals, materials and fuels. In order to achieve this new biomass pretreatments, (bio)chemical conversions and catalyst developments are required. As well as this biobased molecules offer opportunities for the production of novel and functional materials.

Main topics

- Application of homogeneous, heterogeneous and bio-catalysis in biobased reactions
- Developments of non-noble metal based catalysts
- Development of catalysts stable under conditions required for biomass conversion
- Novel functional materials by modification of biomacromolecules (starch, chitin)
- Biorefinery
- Biomass pretreatment and cellulose conversion
- Biomass conversions using catalytic aqueous phase reforming
- In situ product formation and recovery








Direct CO_2 capture from air

Name Postdoc: Nazila Masoud
Involved staff members: Prof.dr. Harry Bitter, Dr.ir. Tomas van Haasterecht, Carlos Cabrera Rodriguez, Dr. Lars Kiewidt, Dr.ir. Ton van Boxtel
Project sponsor: Antecy
Start/(expected) end date of project: October 2017-October 2019

Background and goal of project

Paris climate agreement pledged to keep global warming well below 2°C hotter than pre-industrial times. To fulfil that promise, roughly 810 bn tonnes of CO_2 must be removed from air by 2100, according to *The Economist, November 18th, 2017*. Hence, development of CO_2 capture technology is of prime importance. One very important step is to develop suitable sorbents that can adsorb CO_2 efficiently and desorb it significantly at low temperatures. Carbon supported potassium carbonate is considered as a good candidate. However, its performance is still far from ideal. They are expected to have higher CO_2 uptake per unit mass of the sorbent and to desorb CO_2 at lower temperatures. They are also expected to perform for a longer period of time. Part of this project is devoted to improve the performance of the carbon supported potassium carbonate as a CO_2 sorbent. One very first step is to understand what sites on the sorbent, at microscopic level, are the most effective for CO_2 capture (see Figure). Hence a series of sorbents with diverse properties must be prepared, well characterized, and investigated for CO_2 ad/desorption performance. The other part of the project focuses on kinetics of CO_2 ad/desorption to optimize the CO_2 capture conditions.

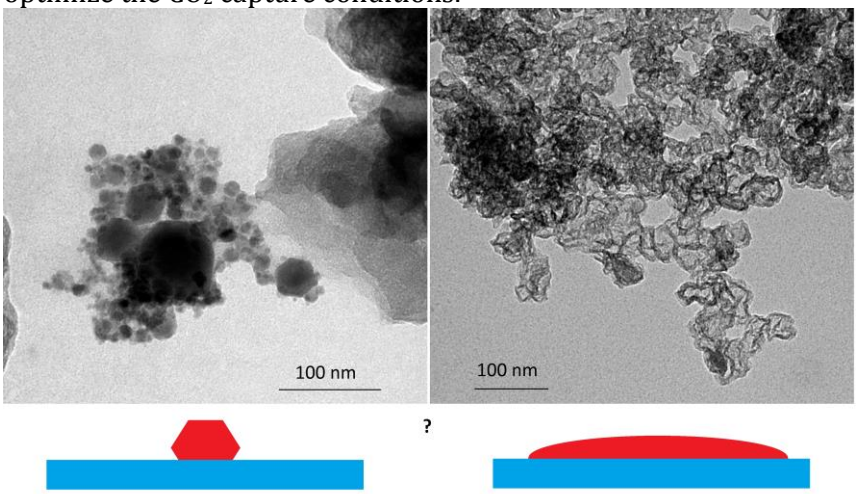


Figure. Transmission electron microscopy images of K_2CO_3 supported on different carbon supports that prepared differently. Crystalline K_2CO_3 (20-60 nm size) can be observed in the left image, but not in the right image. This suggests that in different sorbents, due to support surface properties and/or sample preparation method, K_2CO_3 is shaped differently from nanoparticles of ~40 nm to a thin layer dispersed on the support (see scheme). The question is that which one has the best CO_2 ad/desorption performance?

Highlight of the past year

A bench setup to investigate the CO_2 ad/desorption performance of the model sorbents has been developed. Some model sorbents have been prepared and characterized.

Type of student projects envisioned

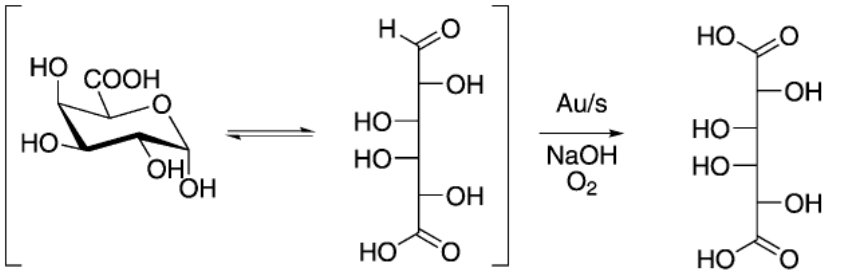
The project includes wet chemical synthesis of inorganic materials and application of different characterisation techniques like X-ray diffraction, physisorption, and spectroscopy. The physical chemistry knowledge of the student will be challenged.

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 2018

Background and goal of project
Carbohydrates are one of the main constituents of renewable biomass. During agro-food production, large side streams rich in non-edible carbohydrates are produced, so-called "2nd generation feedstocks". My work focusses on the conversion of these non-edible carbohydrates into valuable biobased chemicals and materials.

Highlight of the past year
During sugar beet refining, table sugar is extracted, and large amounts of sugar beet pulp are co-produced. This sugar beet pulp is rich in pectin, a polysaccharide build up from "d-galacturonic acid", which is a special carbohydrate with a carboxylic acid group. This carbohydrate can be converted into many high added value biobased chemicals, like polymer building blocks.[1] In the last year, our previously developed method for the oxidation of d-galacturonic acid to galactaric acid[2] (which can act as a metal scavenger or corrosion inhibitor) was further improved.



D-galacturonic acid galactaric acid

Supported Au-catalysts were used for the oxidation, and these catalysts were found to be highly selective and stable under mild conditions, while maintaining a high catalyst activity. Due to the low catalyst consumption / deactivation, and the use of oxygen / air as the sole oxidant, the method provides a green process to obtain galactaric acid.

Type of student projects envisioned
There are no available places this year.

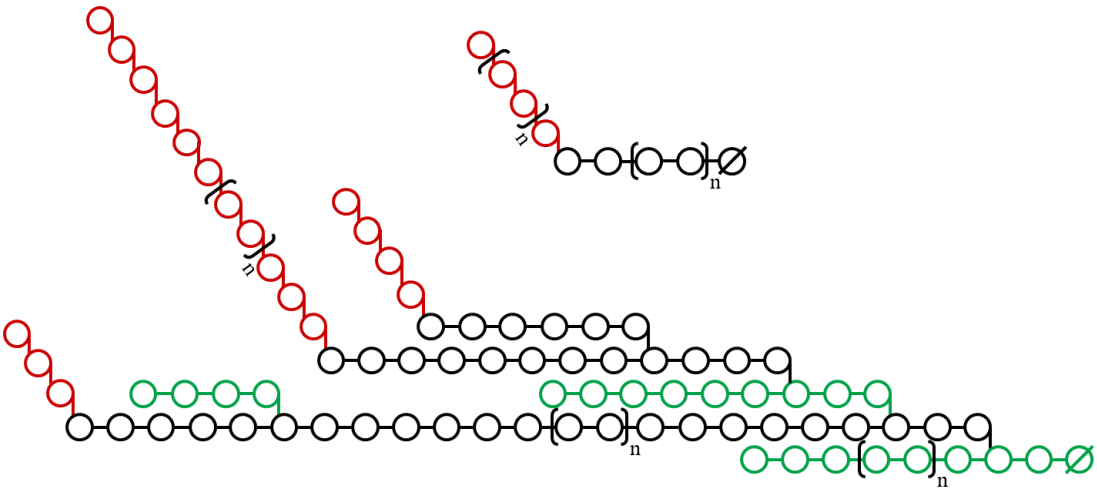
[1] *ChemSusChem* **2017**, *10*, 1460– 1468.
[2] *ChemSusChem* **2013**, *6*, 1640 – 1645.

Isomalto/malto-polysaccharides from starch

Name PhD:	PH (Piet) van der Zaal MSc
Involved staff members:	dr. PL Buwalda, prof. dr. JH Bitter
Project sponsor:	TKI/AVEBE (CCC-B)
Start/(expected) end date of project:	01-10-2013/01-10-2017

Background and goal of project

Starch can be modified with enzymes for improved functionality. In this research we investigated the modification of starch with the 4,6-α-glucanotransferase (GTFB) enzyme. Starches modified by this GTFB enzyme are called isomalto/malto-polysaccharides (IMMPs), the type of IMMPs that are formed depend on the properties of the starch substrate. The relation between IMMP structure and the type of starch substrate was studied in our first publication. During this research we found that some details of the IMMP substructure were lost when using the traditional methods of analysis. Therefore, we developed an enzymatic fingerprinting method to characterize the more subtle IMMP substructures. After this extensive characterization we used our developed methods to study the GTFB reaction over time on simplified substrates. By studying the reaction on different simplified substrates, we found that the GTFB-enzyme displays more conversion in the presence of smaller glucose acceptor molecules. This information was used for the final experiments, were we showed that it is possible to do directed modification with the GTFB-enzyme and to create customized IMMPs.



Highlights of the past year

The successful detection and characterization of different IMMP substructures with the help of enzymatic fingerprinting, shown above (red, green and black). Different enzymes were used separately, in unison or in successive order to specifically degrade and/or reveal these IMMP substructures.

Successfully using GTFB in combination with other enzymes for the directed enzymatic modification of α-glucans, creating customized IMMPs.

Type of student projects envisioned

Currently, there are no available student projects on this topic. However, since research on the enzymatic modification of starch will be continued, there will be projects available in the future.

Non noble metal carbides and phosphides to be developed in Brazil and the Netherlands to replace heterogeneous noble metal based catalysts

Name PhD: Luana Souza Macedo
Involved staff members: Harry Bitter, Victor Teixeira da Silva
Project sponsor: UFRJ (Brazil) and Wageningen University
Start/(expected) end date of project: March 2014 – April 2018

Background and goal of project

Catalysts are at the heart of industrial chemical transformations and approximately 90% of all chemical industry products require a catalytic step. In 2014, the global demand of catalysts was about US$ 33.5 billion and a steady increase in this demand is expected in the next years. To meet this growing market demand, both governments and catalyst producers are investing in research and development of new catalysts, products, processes and technologies. However, to advance the catalysis field it is essential to understand the relationship between catalyst properties and performance. It is known that transition metal carbides and phosphides revealed to be efficient catalysts for reactions that involve the transfer of hydrogen, thus being a potential substitute of noble metals. Therefore, in this project we study the relation between transition metal carbides and phosphides properties and performance on stearic acid deoxygenation.

Highlight of the past year

The effect of Ni_2P/AC particle size (10, 20 and 30 wt% Ni_2P/AC – 8, 12 >30 nm, respectively) on the activity and product distribution of deoxygenation of stearic acid was investigated. We concluded that although the particle size does not influence the catalyst intrinsic activity it influences the product distribution.

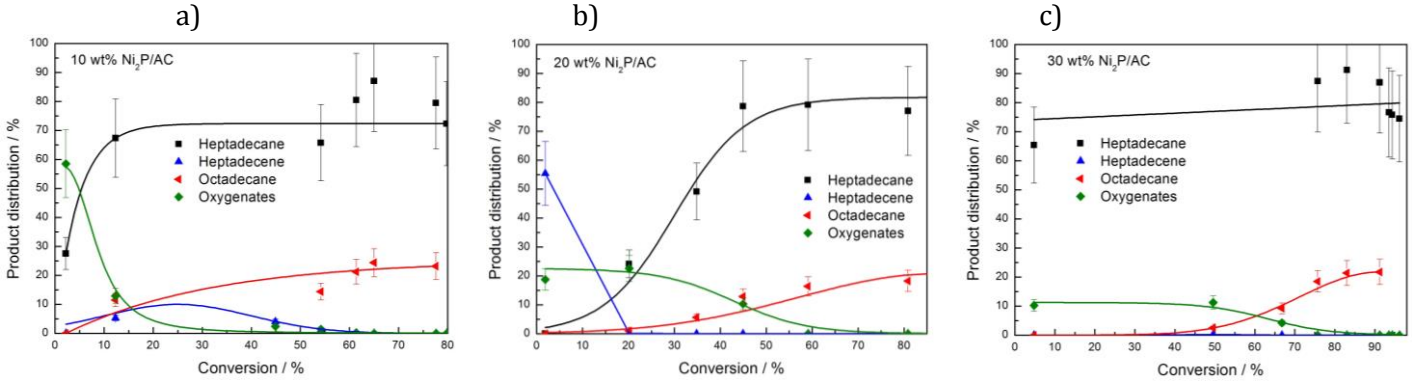


Figure 1. Product distribution in function of conversion of stearic acid HDO at 350 °C and 30 bar H_2 over 10, 20 and 30 wt% Ni_2P/AC catalysts.

Both the decarbonylation/decarboxylation (DCO) and hydrodeoxygenation (HDO) routes occur over the nickel phosphide. However, oxygenates are the major products over 10 wt% Ni_2P/AC while C17 are the major products over 20 and 30 wt% Ni_2P/AC at low conversion (< 10%). This result indicates that the HDO route is more significant over 10 wt% Ni_2P/AC catalyst which has smaller phosphide particles (8 nm) and that the DCO route is more significant over big particles (12 and >30 nm). We suggest that this difference in product distribution is related to differences in concentration of Ni(1) and Ni(2) sites in the catalysts.

Type of student projects envisioned

This project involves mostly lab work, with synthesis and characterization of catalysts added to batch catalytic reactions. As characterization techniques we use mostly N_2 physisorption, microscopy and gas chromatograph analysis.

Towards in situ NMR monitoring of a multi-phase reaction

Name PhD: 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

Inside a plug flow reactor concentrations of products and reactants change as function of the position along the reactor due to conversion. In my project I will study the chemical composition of a reaction mixture as function of position in a wall-coated heterogeneous catalytic reactor by using on-flow NMR spectroscopy. The real-time monitoring of reaction performance will facilitate the improvement of the catalytic reactor.
Fused silica tubes were coated with AlO(OH) on which nanosized Pt particles were deposited. The hydrogenation of mesityl oxide (MO) to methyl isobutyl ketone (MIBK) at mild temperatures is used as model reaction. The reaction requires hydrogen gas, which is provided by creating a Taylor flow (or slug-flow) in the reactor channel. In a later stage a solid base catalyst can be added to also make MO by the self-condensation (and dehydration) of acetone.

Highlight of the past year

Home-built flow NMR was developed and will be used in future experiments. Furthermore, we were able to obtain reliable NMR spectra in a three phase microreactor (Figure 1). Additionally the microreactors have been tested and a conversion of 4% was achieved.

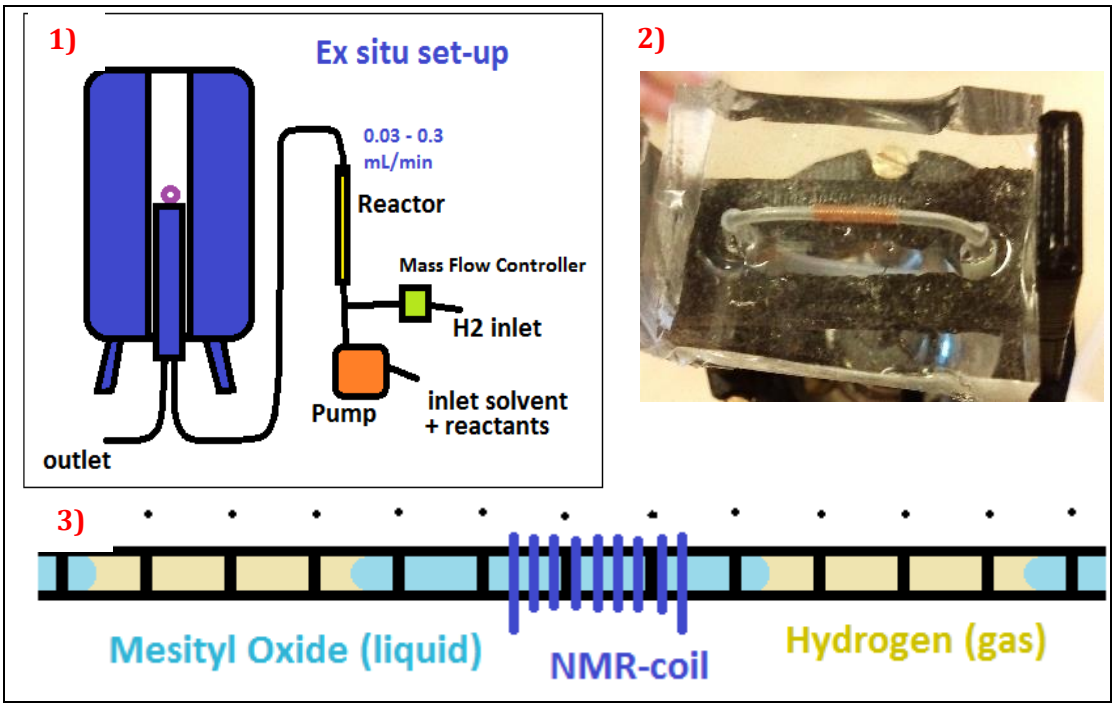


Figure 1; 1) Overview of the NMR set-up, 2) NMR channel, with measuring coil, 3) bubble flow scheme

Type of student projects envisioned

A student on this project could work with microreactors, using supported metal catalyst nanoparticles. The design, preparation and characterisation of the coated reactor can have unexpected results. Additionally, the combination of experimental results with reactor and reaction modelling will add to our understanding of the multi-phase system. Would you work on the frontier of catalysis research in Wageningen? Send an e-mail to gerben.wierda@wur.nl

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

Name PhD: 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 (CO_2) is the primary contributor to climate change. One way to mitigate the problem is by using CO_2 and renewable electricity to produce chemicals. In **Microbial Electro-Synthesis (MES**, Figure 1), bacteria use electricity to convert CO_2 in useful organic molecules. A key challenge for up-scaling MES is to improve the attachment and electron transfer between the cathode and bacteria. Metal nanoparticles have been previously shown to increase acetate yield by improving the attachment of bacteria on the electrode, and facilitating the electron transfer [1,2]. This project aims to investigate whether and how metal addition affects CO_2 conversion during MES.

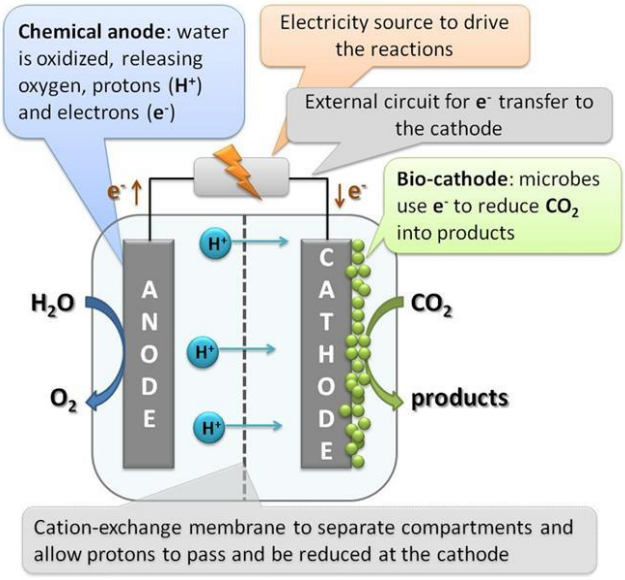


Figure 1: The MES cell schematic

Highlight of the past year

We have previously hypothesized that we can tune MES to either H_2 or acetate production, by modifying the metal loading. We compared graphitic cathodes with no metal (control), low (0.01 wt%) and high (10 wt%) nickel loading. Low nickel loading leads to a **two-fold increase in acetate yield**, attributed to **improved bacterial attachment** (Figure 2). Acetate production and bacteria attachment are instead inhibited with high nickel loading, while H_2 yield increases by a six-fold. Inhibition could be due to the nano-structure or catalytic activity of 10 wt% nickel cathodes for H_2 production, which results in electron competition and high catholyte pH. Thus, **the various effects** of metal nanoparticles need to be considered to fully understand the effects of metal addition on CO_2 conversion during MES.

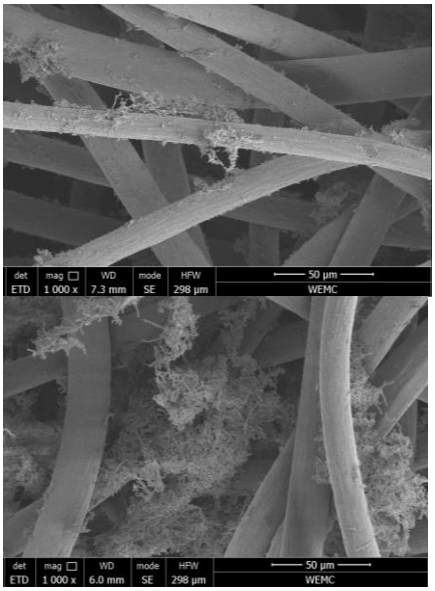


Figure 2: Scanning Electron Microscopy images of bacterial attachment on control (top) and nickel-modified (bottom) cathodes

Type of student projects envisioned

The individual and combined catalytic processes can be investigated using both modeling and 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.

[1] Nie, H., Zhang, T., Cui, M., Lu, H., Lovley, D.R. and Russell T.P., Phys. Chem. Chem. Phys. 15 (2013) 14290.

[2] Zhang, T., Nie, H., Bain, T.S., Lu, H., Cui, M., Snoeyenbos-West, O.L., Franks, A.E., Nevin, K.P., Russell, T.P. and Lovley D.R., Energy Environ. Sci. 6 (2013) 217.

Processing of feathers to proteins – from fundamental insight to application

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

Background and goal of project

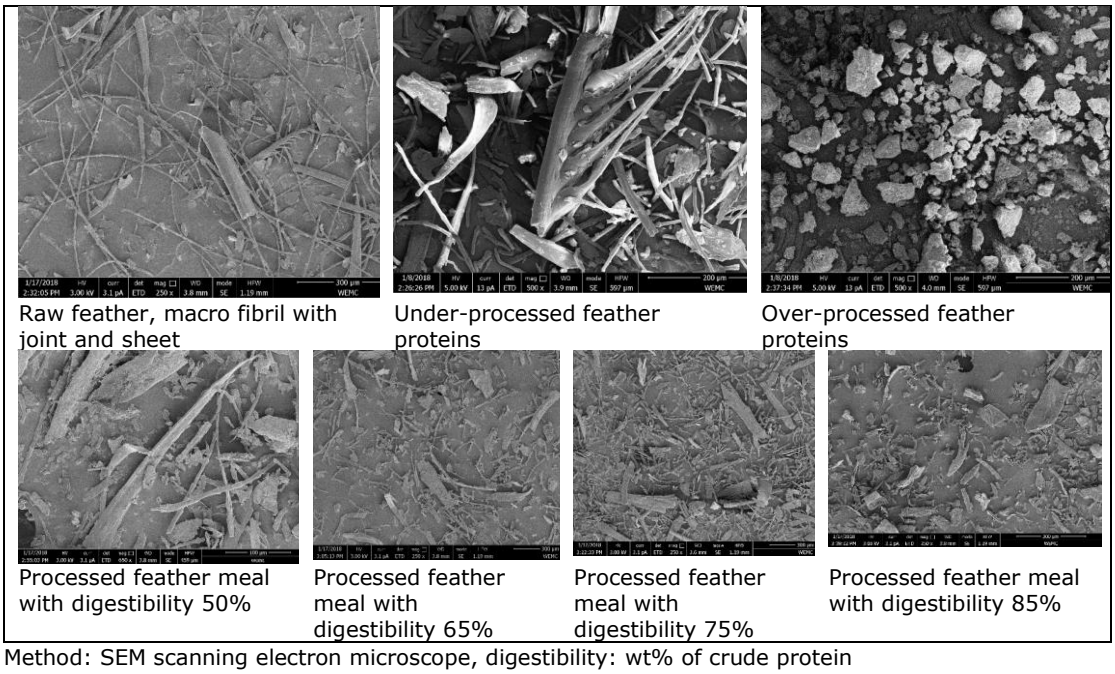
Feathers contain high amounts of protein (>85%) and can therefore be an excellent protein source for feed applications. However, feathers are not digestible and have no nutritional value in their native state.

Therefore, feathers have to be processed into more digestible proteins, peptides and amino acids. There are different process methods, the most important ones are physical methods (grinding, milling), chemical methods (base/acid treatments) and, enzymatic methods. Commercially feathers are currently processed by thermal hydrolysis. In that process essential parameters are temperature, pressure, time, moisture, pH as well as enzymatic post-treatment.

Goal of our project is to fundamentally understand the influence of these parameters on the properties of the obtained protein meal. That knowledge will be used for further improving the current practice of feather hydrolysis.

Highlight of the past year

Feathers consist of mainly ß-sheet structure (>70%), as well as an alpha-helix and disordered structure. The molecular structure of feathers is influenced by process conditions. Both under- and over-processed feather proteins have low nutritional value as feed ingredient. Therefore, there is an optimal range for process conditions between under- and over-processed feather proteins. The core is to find the optimal process conditions from that both nutritional value and industrial production benefit.



Raw feather, macro fibril with joint and sheet

Under-processed feather proteins

Over-processed feather proteins

Processed feather meal with digestibility 50%

Processed feather meal with digestibility 65%

Processed feather meal with digestibility 75%

Processed feather meal with digestibility 85%

Method: SEM scanning electron microscope, digestibility: wt% of crude protein

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: Evie van der Wijst
Described work from M. Fuhrer, MSc student
Involved staff members: Prof. Harry Bitter, Dr. Piet Buwalda
Project sponsor: NWO, Avebe
Start/(expected) end date of project: 01.01.2016 – 31-12-2019

Background and goal of project

Polyacrylates and polyacrylamides are currently produced petrochemically but anionic (negatively-charged) polysaccharides, such as oxidised starch, could be a more sustainable alternative. Applications of oxidised starch include the use as adhesive, as superabsorbents in nappies or as coating agent in the paper- and textile industry. In this project we aim a.o., to establish the relation between feedstock properties e.g. molecular weight and support properties e.g. support polarity for heterogeneous catalyst to be used for starch oxidation. In this project, I collaborate closely with Tim Hoogstad. In general, where he studies the implications of the heterogeneously-catalysed process via a modelling approach, I focus on the development of a suitable heterogeneous catalyst.
This year one of the major projects was focussed on understanding the role of support oxygen groups on Pt nanoparticles supported on (oxidized) carbon nanofibers.

Highlight of the past year

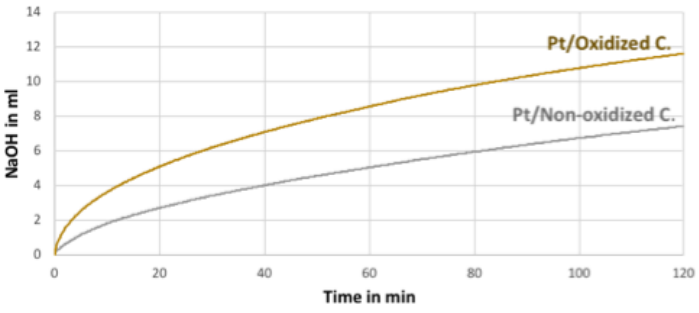


Figure 1: Pt on oxidzed carbon more active compared to Pt on non-oxidzed carbon. SX-ultra is used as support. Glucose as reactant.

Figure 1 shows the impact of support oxidation on the activity of Pt/carbon for the oxidation of glucose. The activity is expressed in ml of NaOH uptake which is a measure of activity. Clearly the oxidized Pt/carbon performs better compared to the non-oxidized catalyst. The reason of that is currently under investigation. Please note that also the feedstock plays a role here since we have shown before (Figure 2) that the activity of Au/carbon catalysts also depends on the nature of the feedstock.

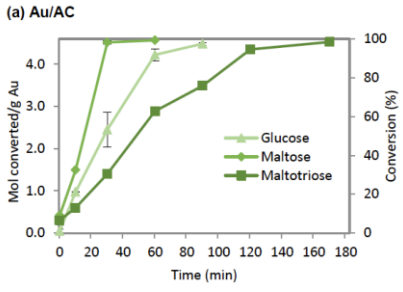


Figure 2: role of feedstock on oxidation rate over

Type of student projects envisioned

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

Biobased Functional Materials

Staff/Theme Leader: Dr. Costas Nikiforidis

PhD students and post-docs: Dr. Christos Fryganas, Dr. Andres Francisc Torres Salvador, Laura Schijven, Eleni Ntone, Lakshminarasimh Sridharan, Juliana Romero Guzman (FPE), Dimitris Karefyllakis (FPE)

Contact:
costas.nikiforidis@wur.nl

Background and goal

The technological development of humanity was originally supported by natural materials, like wood, animal skins and bones. During the years, the advances in technology resulted in synthetic materials that performed better than the natural ones. However, scientists are still intrigued by the elegant complexity of natural architectures. The understanding of the properties of the natural complexes will in general lead in sights in the property-performance relationships and will in turn to new functional materials for foods and health related applications.
In other words, the Biobased Functional Materials theme, aims to overcome 3 challenges:
(1) understand the function of natural structural motifs
(2) translate the natural architectures into a wider range of molecular combinations and
(3) design practical methods to construct bioderived and bioinspired inspired materials in bulk.

Main topics

- Sustainable recovery of functional protein based mixtures from biomass
- Sustainable recovery of oil bodies/oleosomes from seeds and nuts
- Exploit native protein mixtures and oil bodies/oleosomes to construct novel functional materials (emulsions, gels, nanocarriers) for food and medical applications

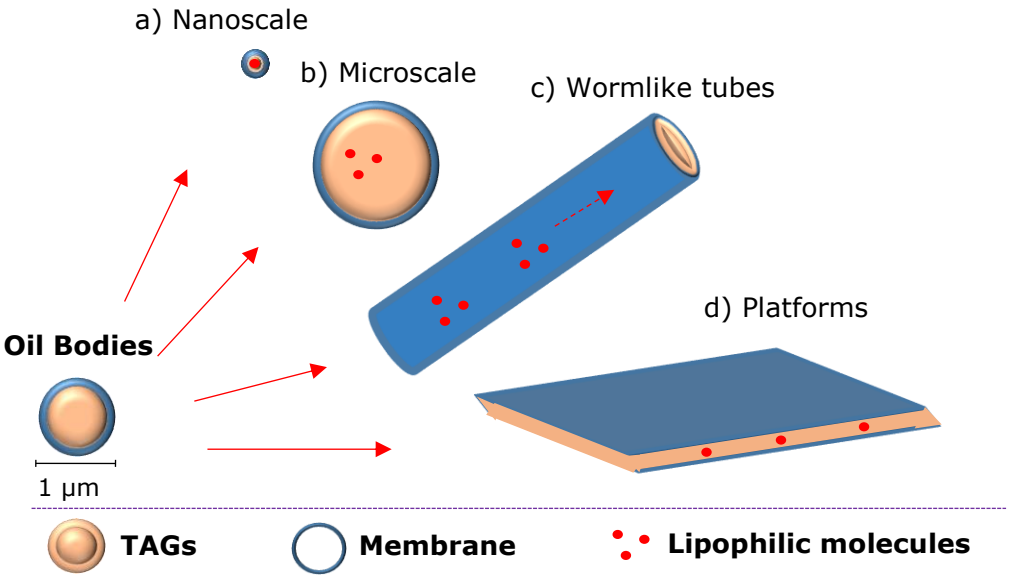


Figure: *A graphical example of potential materials derived or inspired by oil bodies/oleosomes*

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. K. V. Nikiforidis
Project sponsor: Givaudan Flavors Corp.
Start/(expected) end date of project: 21/09/2017 – 21/03/2019

Background and goal of project

Drying of oil-in-water emulsions can enhance the entrapment of functional ingredients and bioactives and therefore, it is widely applied in the food, pharma and cosmetic industries.[1] However, the conventional extraction and emulsification methods of plant oils are hazardous and cost-inefficient.[2] Furthermore, the use of chemicals to stabilise the dried emulsions[3] may not comply with consumer demands for green labeled products. Natural oil-body based emulsions from oleaginous seeds can replace the harsh oil extraction and the laborious emulsification procedures.[2] It is also conceivable, that the innate stability of the dried oil body based emulsions could further promote the sustainable encapsulation of targeted molecules.

The aim of this study is to develop a dry oil-body based delivery system from rapeseed (*Brassica napus*). This can be only achieved by probing the relationship between oil body recovery parameters and the variables of the drying method.

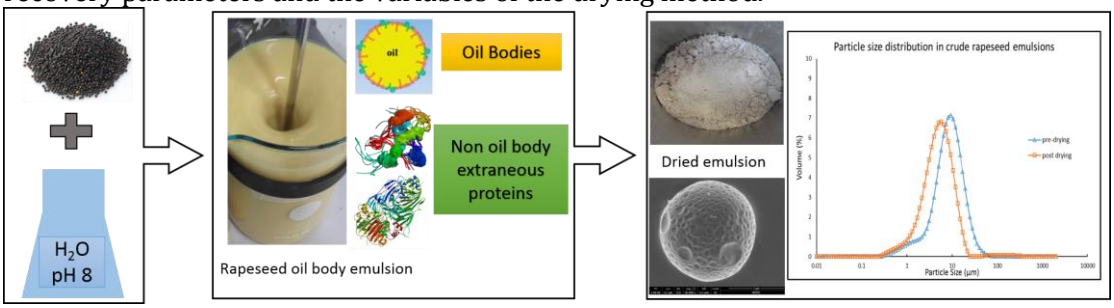


Figure 3: Flow diagram depicts the extraction, drying and analysis of natural oil body based emulsions from rapeseed

Highlight of the past year

Optimising the extraction of the oil body based emulsion from rapeseed resulted in the production of stable powders (Figure 1). No visible agglomeration of particles or phase separation was observed when the dried oil body based emulsions were dissolved in water. Particle size distribution in the emulsions displayed similar profiles before and after drying (~10 μm, Figure 1).

Type of student projects envisioned

Students interested in novel biofunctional materials will work in the lab and will use different analytical techniques to explain how interactions between emulsion components improve or hamper drying.

References

(1) Gharsallaoui, A.; Roudaut, G.; Chambin, O.; Voilley, A.; Saurel, R. Applications of spray-drying in microencapsulation of food ingredients: An overview. *Food Research International* **2007,** *40* (9), 1107-1121.

(2) Nikiforidis, C. V.; Matsakidou, A.; Kiosseoglou, V. Composition, properties and potential food applications of natural emulsions and cream materials based on oil bodies. *RSC Advances* **2014,** *4* (48), 25067-25078.

(3) Pongsamart, K.; Kleinebudde, P.; Puttipipatkhachorn, S. Preparation of fenofibrate dry emulsion and dry suspension using octenyl succinic anhydride starch as emulsifying agent and solid carrier. *International Journal of Pharmaceutics* **2016,** *498* (1), 347-354.

Developing low-impact biorefineries through synergy between plant breeding and post-harvest process technology

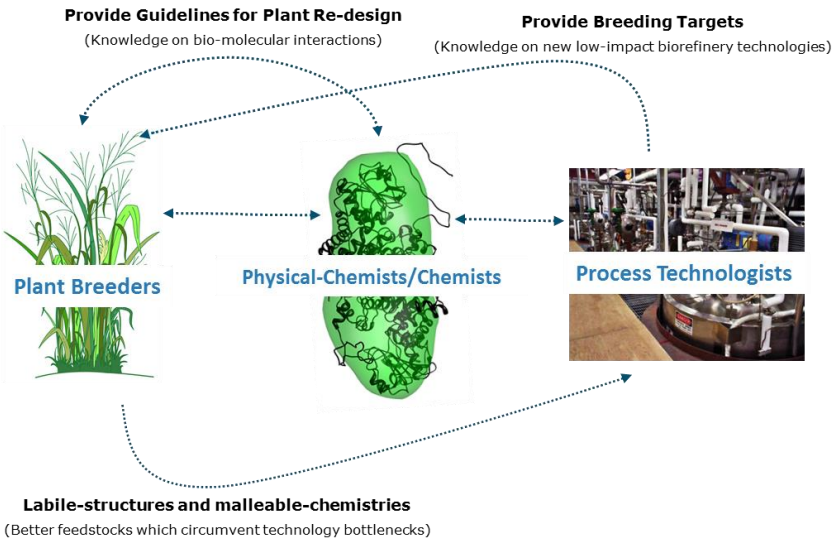
Name Postdoc: Andrés Torres Salvador
Involved staff members: Kostas Nikiforidis, Harry Bitter
Project sponsor: Wageningen University and Research (RUE-Program 2017)
Start/(expected) end date of project: 1/2/2017 – 31/12/2017

Background and goal of project

Integrated biorefineries aim to extract all components out of biomass in their highest possible value, with minimum waste production, and by utilizing the lowest possible amount of energetic and material inputs. However, biomass polymers are sophisticatedly interconnected, making their extraction in native form (*i.e., preservering in so far as possible their original chemistry*) extremely difficult.
Remarkably, plants can be vastly diverse in their chemistry. By mining the genetic diversity of plants, breeders can modify *in planta* the composition, structure and bioavailability of valuable biomass components (*i.e., polymers, metabolites, etc.*) so that these require lower inputs for effective extraction and conversion. Thus, the aim of this project was to explore possibilities for interconnecting modern plant breeding with post-harvest process technology to deliver resource-use efficient biorefineries.

Highlight of the past year

We have developed a conceptual framework where plant scientists, physical-chemists and catalysis experts collaborate to deploy resource-use efficient biorefineries. By jointly exploring the genetic diversity of crop species at the molecular- and nano-scale, plant scientists and process engineers can gain radically novel insights into the extensive constellation of supramolecular structures available in the plant kingdom, as well as information of how these structures impact the selectivities and yields of biomass conversion processes. This inventoried knowledge can be used to rationally design and specify the supramolecular structures within biomass that yield desired chemical products under specific conversion strategies. In essence, this synergy concept (*which will be soon available to the scientific community in the form of a peer-reviewed opinion paper*) advocates for plant scientists and process technologists to align their innovations in order to create complementary feedstocks and biomass conversion processes.



Food-grade lipoproteins as nanocarriers of diagnostics and therapeutic agents

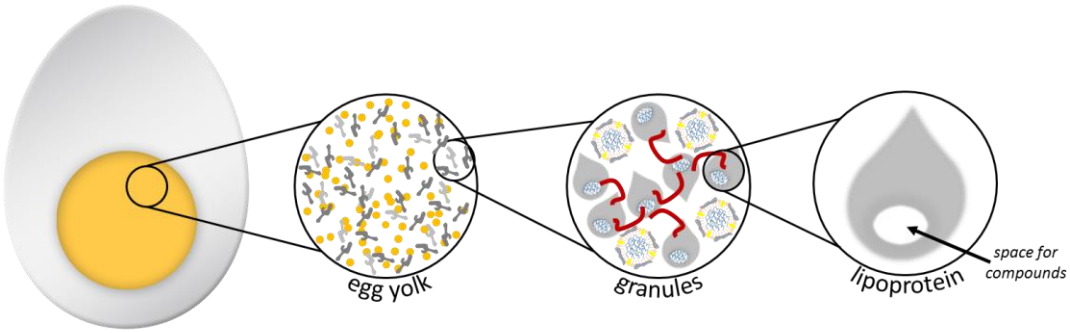
Name PhD:	Laura Schijven
Involved staff members:	dr. Costas Nikiforidis (BCT) dr. Vittorio Saggiomo (BNT) prof. dr. Aldrik Velders (BNT) prof. dr. Harry Bitter (BCT)
Project sponsor:	VLAG Graduate School
Start/(expected) end date of project:	September 2017 – September 2021

Background and goal of project

For many diagnostic and therapeutic compounds, their maximum potency cannot be exploited through the preferred oral administration, because they are chemically labile, can be metabolized and/or will never reach their target. Therefore, nanocarriers are highly desired, which can deliver the compounds by injection. However, many types of synthetic nanocarriers are not applicable and we will replace those by using a nanocarrier from a natural source, such as hen egg yolk.

Hen egg yolk contains natural supramolecular assemblies of lipids and proteins. Moreover, egg yolk is an abundant and inexpensive source of bioactives, which are of great interest for applications in the medical, pharmaceutical and biotechnological field. Remarkably, egg yolk lipoproteins have not yet been explored for such applications. Therefore, the separation of lipoproteins from egg yolk should be efficient and yielding high purity proteins.

The goal of this project is to efficiently isolate lipoproteins from egg yolk and investigate its properties as a nanocarrier. The purified nanocarrier will be tested for encapsulating, carrying and delivering different therapeutic and diagnostic compounds (e.g. nanoparticles), including monitoring the stability and behavior in serum.



Schematic overview of egg yolk content and potential natural nanocarrier

Highlight of the past year

The project just started

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, Kjeldahl/Dumas, FTIR, AFM, XRD, NMR) and synthesis and characterization of nanoparticles (e.g. TEM, UV-Vis, DLS, NMR).

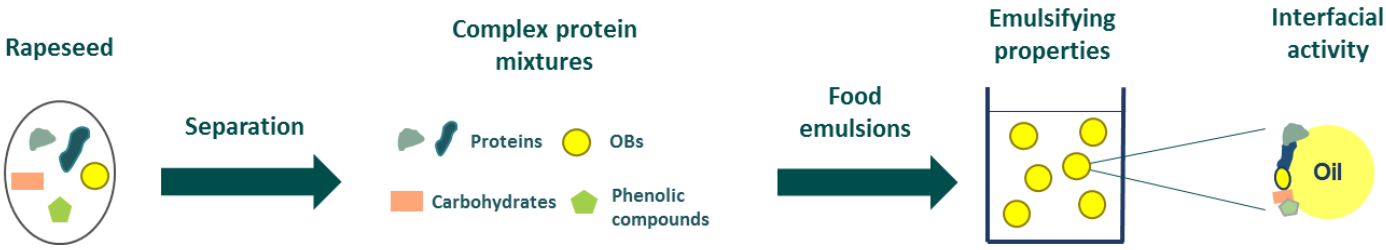
Rapeseed protein/oil body mixtures for food-grade emulsions

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 project

Due to rapid growth on protein demand, an efficient utilization of plant-based proteins in combination with mild processing routes is critical [1,2] . However, mild processing routes lead to protein complex mixtures, which currently have unknown properties.

Therefore, in this project we investigate the functionality of native proteins, as affected by the presence of other compounds. In particular, my study is focused on the effects of sustainable pre-processing on the composition and emulsifying properties of rapeseed proteins natively mixed with oil bodies.



Highlight of the past year

Determination of the factors that influence the extractability of the proteins and the composition of the final extract. In particular, the effect of pH, salt addition and meal:solvent ratio on the purity of the final protein extract has been investigated.

Type of student projects envisioned

Available projects for students include lab work, focusing on separation of rapeseed protein mixtures and investigation of the molecular interactions in the mixtures and their effect on interfacial activity.

1. Aiking H. Future protein supply. *Trends Food Sci Technol*. 2011;22(2-3):112-120. doi:10.1016/j.tifs.2010.04.005.
2. Von Der Haar D, Müller K, Bader-Mittermaier S, Eisner P. Rapeseed proteins – Production methods and possible application ranges. *Oilseeds fats Crop Lipids*. 2014;21(1):1-8. doi:10.1051/ocl/2013038.

Production of starch/protein mixtures for food emulsions from Yellow Peas (Pisum Sativum L.)

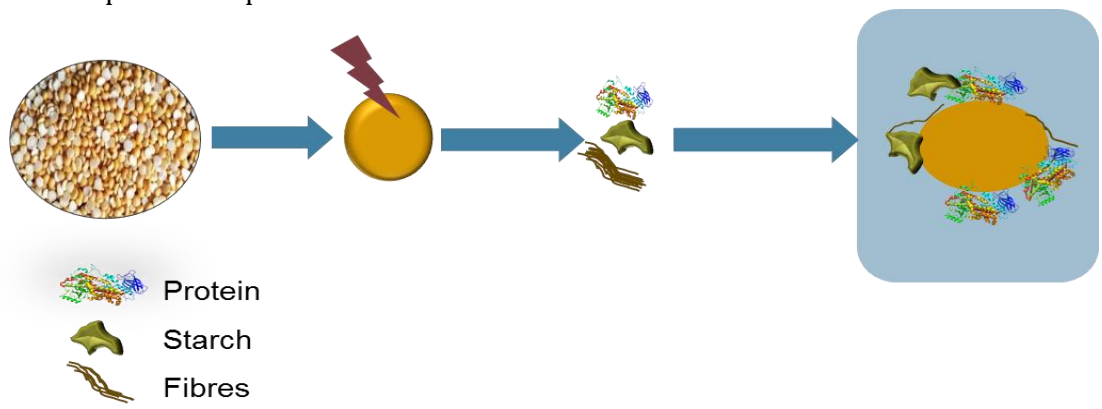
Name PhD:	Lakshminarasimhan Sridharan
Involved staff members:	Dr Costas Nikiforidis, Prof.Dr. Harry Bitter
Project sponsor:	TIFN, Wageningen
Start/(expected) end date of project:	02/10/2017 – 02/10/2021

Background and goal of project

Currently, most food products are produced by mixing relatively pure ingredients such as proteins, carbohydrates and fats. However, this approach creates environmental stress due to energy requirements associated with purification of these components(Geerts, Mienis et al. 2017). Therefore a possible sustainable approach would be to apply milder and less purification steps to obtain mixtures(van der Goot, Pelgrom et al. 2016) that retain the functionality or perform better than pure components. Thus, this project aims to explore the properties and functionality of complex mixtures obtained from yellow peas(Pisum Sativum L.) in model food systems.

Highlight of the past year

We performed an extensive literature review and we have designed a sustainable extraction process for the production of mixtures from yellow peas. Moreover, we have drawn a hypothesis on molecular interaction in the mixture and the possible effect of extraction process steps on the characteristics of mixtures.



Concept of the project: from yellow peas to functional mixture

Type of student projects envisioned

Student projects would be focussed on separation of protein-starch mixtures from yellow peas and investigating their interactions and re-arrangements at the oil-water interfaces

Reference

Geerts, M. E. J., E. Mienis, C. V. Nikiforidis, A. van der Padt and A. J. van der Goot (2017). "Mildly refined fractions of yellow peas show rich behaviour in thickened oil-in-water emulsions." Innovative Food Science & Emerging Technologies **41**: 251-258.

van der Goot, A. J., P. J. M. Pelgrom, J. A. M. Berghout, M. E. J. Geerts, L. Jankowiak, N. A. Hardt, J. Keijer, M. A. I. Schutyser, C. V. Nikiforidis and R. M. Boom (2016). "Concepts for further sustainable production of foods." Journal of Food Engineering **168**: 42-51.

Tailoring the interactions of oil bodies and co-extracted proteins for development of novel food systems

Name PhD: Juliana Romero Guzmán (FPE)
Involved staff members: Costas Nikiforidis
Project sponsor: CONACyT
Start/(expected) end date of project: November 2015 - October 2019

Background and goal of project

Plant oils are organized intracellularly in the form of oil bodies, which are spherical oil droplets surrounded by a phospholipid/protein monolayer. Oil bodies can be aqueously (pH 9) extracted and further used in many different applications as plant-based alternatives to milk and conventional oil droplets. However, their extraction has low yield, below 50 wt%, and requires large amounts of water and base to increase the pH to 9.
Therefore we are aiming in this project to understand the interactions between oil bodies and cell material, in order to efficiently disrupt the cells and obtain intact oil bodies at native pH values

Highlight of the past year

During the past year it was proved that the forces between oil bodies and cell material is mostly of electrostatic nature. The presence of cations like Na^+, K^+, and Mg^{2+} at native pH values (pH 6.7) affected the extraction yield of oil bodies. The monovalent cations significantly increase the extraction yield without disrupting the stability of oil bodies, while the divalent cation acted as a bridge between oil bodies, leading extensive aggregation. With these results we are one step closer towards optimization of oil body extraction through decreasing the amounts of used chemicals and water.

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Valorizing a by-product, sunflower press-cake, through mild processing

Name PhD: Dimitri Karefyllakis (FPE)
Involved staff members: Costas Nikiforidis
Project sponsor: ISPT
Start/(expected) end date of project: 29/01/15-29/01/19

Background and goal of project

Plant based proteins are gaining significant interest since there is a potential to replace less sustainable animal based protein. However, the extraction of the plant protein has to be performed in a sustainable way i.e. with low impact on the environment, without creating waste during extraction and using limited energy in the processing.

Until this point, the primary aim was to extract and obtain pure compounds however it is questionable whether that is really necessary. As a case, we investigate the exploitation of sunflower press cake, which is an oil extraction by-product, to obtain valuable ingredients, such as proteins, polyphenols and phospholipids. We investigate low impact extraction methods which might result in less pure but highly functional products. The more specific aim of this project is to investigate and understand the interaction between individual components in press cakes and in the final products. This research will lead to an efficient of the press-cake and transform it from a by-product to a side product.

Highlight of the past year

Protein-phenol interactions have proven to be the greatest challenge towards the valorization of the press cake. Besides influencing the functional and sensory properties of proteins, they often result in alteration of protein structure as well. Considering that covalent complexes are used more and more in order to develop protein-phenol complexes for the delivery of antioxidant activity in the GI track (phenols are good antioxidants), we tried to investigate in depth the impact of covalent complexation on protein structure. Covalent complexation of sunflower proteins with chlorogenic acid, the main phenol found in sunflower press cake, had a strong impact on protein structure and hydrophobicity.

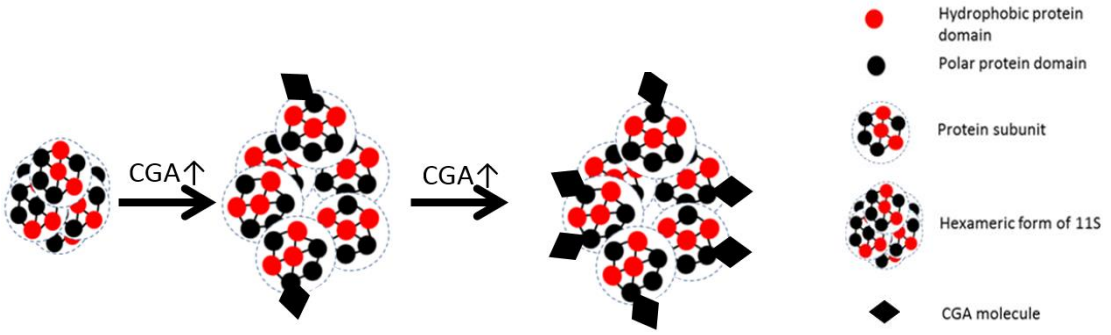


Figure 4 : Illustration of sunflower protein molecule and the impact of covalent complexation with CGA on it. Destructuring was observed and an increase of the exposure of hydrophobic domains influencing the hydrophobicity.

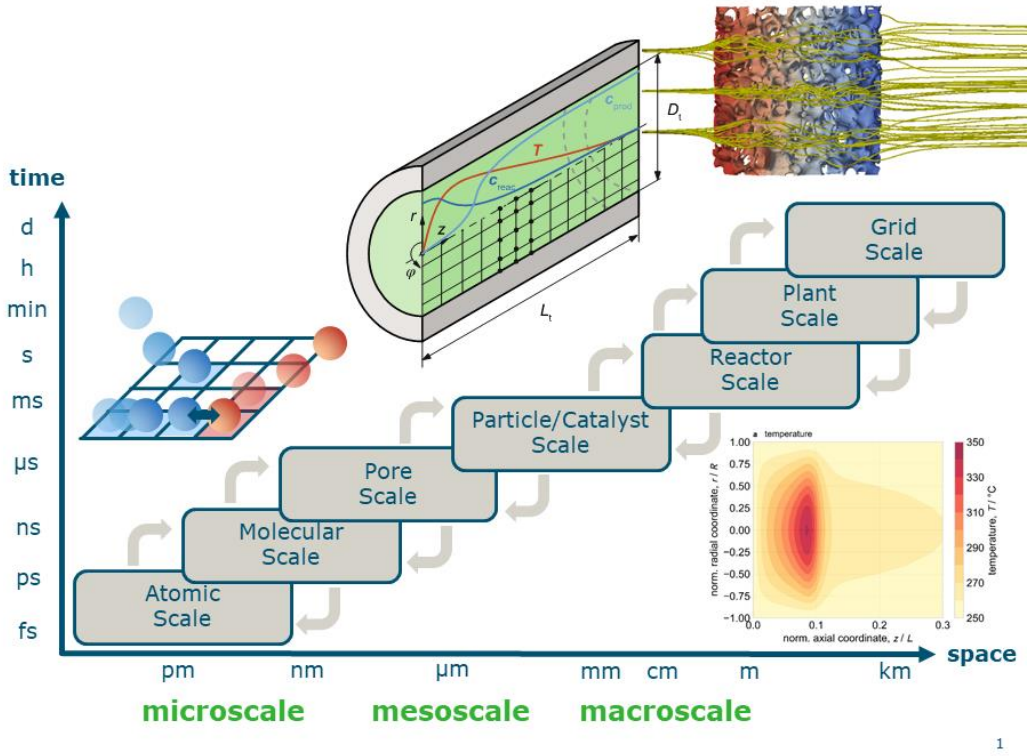
Technology


Theme leaders: L. Kiewidt (lars.kiewidt@wur.nl)
A.J.B. van Boxtel

Background and goal of this theme

The incorporation of biomass into the chemical and fuel production chains and the transition from an oil-based towards a biobased economy require major changes of today's conversion and separation technology. In the Technology theme we use computer models ranging from the molecular scale, over the particle and reactor scale, up to the plant scale to understand the fundamental mechanisms on the molecular scale, and to predict the potential of innovative catalytic materials on the reactor and plant scale. With this multiscale approach we aim to understand and tune each step in the catalytic conversion of biomass.

Within the Biobased Chemistry and Technology group we closely work together with the conversion and extraction themes to validate our models and to guide experiments using sensitivity analysis and model predictions.



Main topics

- Mechanisms and models for sustainable preprocessing and conversion of biomass into chemicals and fuels
- Modeling the influence of multiple time and length scales, and size distributions on biomass conversion
- Catalyst/adsorbent, reactor, and production chain design for
  - catalytic conversion of polysaccharides
  - direct capture of CO_2 from air

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

Redesign and optimization of the milk powder production chain

Name PhD: Sanne Moejes
Involved staff members: Ton van Boxtel, Harry Bitter
Project sponsor: EU FP7
Start/(expected) end date of project: December 2013 - 2017

Background and goal of project

Energy and water reduction are a major topic in policy making. The food industry is responsible for high consumptions of energy and water, especially when many thermal processes are involved. Milk powder production is no exception. Evaporation and spray drying consume over 90% of the energy required for the production process. Introduction of new technologies is required in order to make a next step in energy and environmental impact reduction, as current processes are already optimized to a high extend, and considerable reductions are necessary.
The goal of this project is to use a systematic way to redesign and optimize the milk powder production chain. Objective is to minimize the energy consumption, water consumption, environmental, and economic impact.

Highlight of the past year

During the past year we reported on the simulation and optimization of a closed-loop spray drying network in order to recover the latent and sensible heat from the dryer exhaust (see figure 1). The humid exhaust air of the dryer is dehumidified by an adsorbent, and subsequently recycled to the dryer. The adsorber requires regeneration, and the recovered heat can be applied within other process in the system; like the evaporator. A zeolite wheel and a membrane contactor are used as adsorbent units. By simultaneous optimization of the operational conditions and the heat exchanger network an energy reduction 17 to 42% compared to a conventional milkpowder production system can be realized.

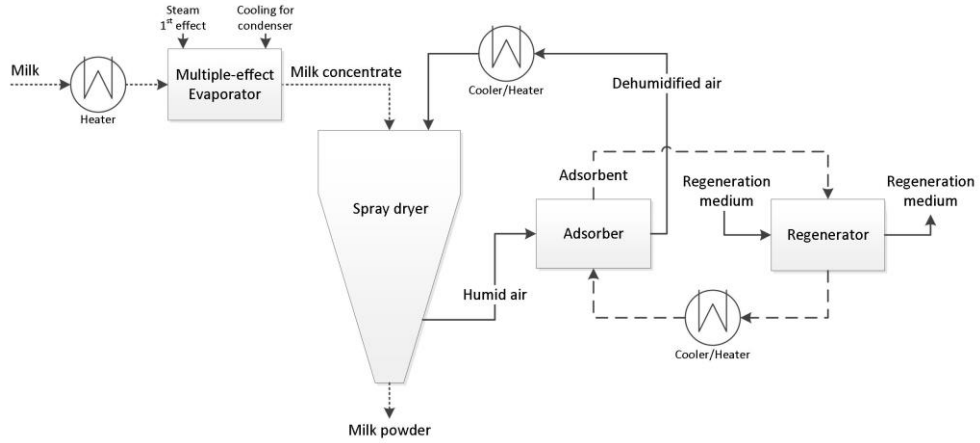


Figure 1. Schematic overview of the proposed closed-loop spray dryer.

Besides optimizing the dryer section of the production process, also the concentration part of the milk powder production process was investigated. Membrane distillation is an interesting alternative for the currently used multistage evaporator. Membrane distillation is thermal driven and has the advantage of reaching high solid contents comparable to evaporators. However, membrane distillation is prone to fouling, which leads to massive flux reduction over time, which cannot be compensated for by increasing pressure like in pressure driven operations. Not only operational conditions influence the effect of fouling on the process, also a good design of the membrane network and scheduling of the units can reduce the reduction in flux due to fouling.

Selective polysaccharide oxidation – new catalysts and new chains

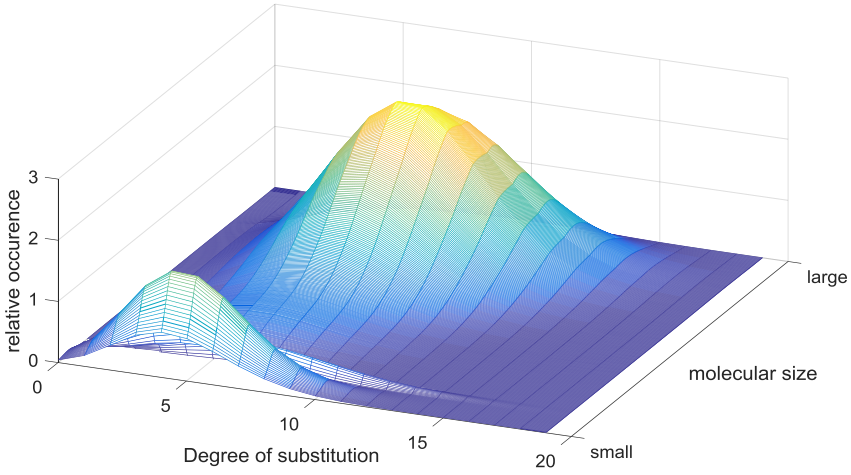
Name PhD: Tim Hoogstad
Involved staff members: Ton van Boxtel, Piet Buwalda, Harry bitter
Project sponsor: NWO, Avebe
Start/(expected) end date of project: 01-2016 till 12-2019

Background and goal of project

Anionic (negatively charged) starches are a biobased and renewable product that can replace petrochemically based polyacrylates and polyacrylamides. Anionic starches have a wide range of applications and are used, amongst others, in wastewater treatment, superabsorbents (diapers), food and coatings for paper. Nowadays these anionic starches are produced by modifying native potato starch using bleach. The production of bleach and the resulting by-products from the conversion are responsible for ± 40% of the environmental impact of the total process. To make this process more environmentally friendly we're working on a catalytic pathway that can use molecular oxygen instead of strong oxidising agents to oxidise the starches. Within this project, I work on developing a kinetic model for the conversion and I look at how this new process will influence the rest of the production chain for anionic starches.

Highlight of the past year

Further progress has been made on the kinetic model that describes the interaction between oxidation and depolymerisation.
By taking the interdependency of oxidation and depolymerisation into account this modelling approach can more accurately predict product distributions and asymmetries therein.



Type of student projects envisioned

My project includes both chemistry and modelling, with an emphasis on the modelling portion. Student projects on the modelling side may include process chain evaluation and kinetic modelling. Projects on the chemical side may include kinetic experiments, substrate and product characterization.

Modelling and process design of CO_2 capture from air

Name Postdoc: Carlos I. Cabrera-Rodriguez
Involved staff members: Ton van Boxtel, 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

CO_2 emissions to the atmosphere increases steadily every year, as a result the CO_2 concentration has risen from a preindustrial value of 280 ppm to 400 ppm. Direct capture of CO_2 from air can contribute to the reduction of emissions on a global scale. The key step to enable the utilization of CO_2 as renewable resource is the cost-effective capturing and concentration of CO_2.

The aim of this project is to design a feasible technology for capturing and concentrating CO_2 from air. In this study, the requirements of new materials and mode of operation are determined. Additionally, process integration alternatives are considered for the process to be energy efficient and CO_2 neutral.

The project is developed in collaboration with our industrial partners Antecy and Bronswerk. A pilot reactor is being constructed by the industrial partners in which the technology (models) will be validated.

Highlight of the past year

The project started recently and several activities have been performed. In the last months, a comparison of different reactor configurations were analysed in relation to their pressure drop, radial velocity, heat transfer and CO_2 uptake (Figure 1). This was performed by computational fluid dynamics studies in COMSOL. Additionally, a multicolumn operation of the adsorption and desorption process is being design to reduce the energy and material requirements of the process.

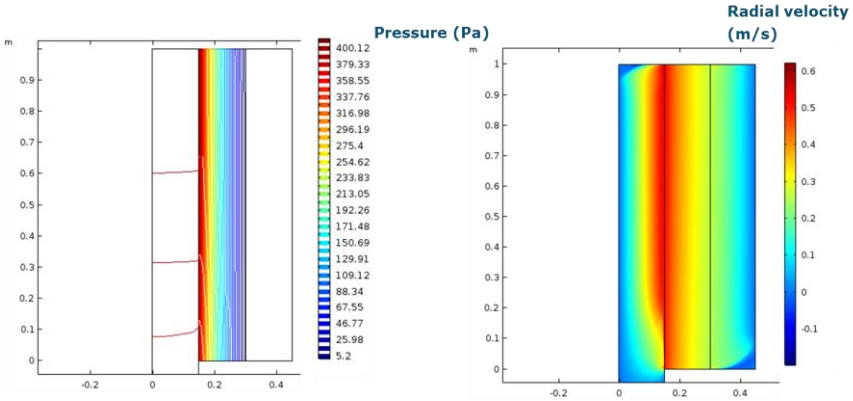


Figure 1. Modelling of the pressure drop and flow distribution of a novel tubular reactor for CO_2 adsorption.

Type of student projects envisioned

To test the boundaries of the system, projects are available which involve modelling of the CO_2 adsorption and desorption process, with main emphasis on investigating the reaction mechanism, kinetics and diffusion of the process. Additionally, we focus on the design of a thermodynamic efficient process by integrating different unit operations. The models will be created in COMSOL, Matlab and Superpro designer and will be validated by experimental and pilot plant studies.

Contact: carlos.cabrerarodriguez@wur.nl

Systems

Staff: Prof. Karel Keesman, Prof. Harry Bitter
PhD students and post-docs: Elvira Bozileva, Nik Grubben, Daniel Reyes Lastiri, Yu Jiang, Simon Goddek, Delaram Azari, Hakan Kandemir, Caspar Geelen, Hans Cappon
Contact: karel.keesman@wur.nl

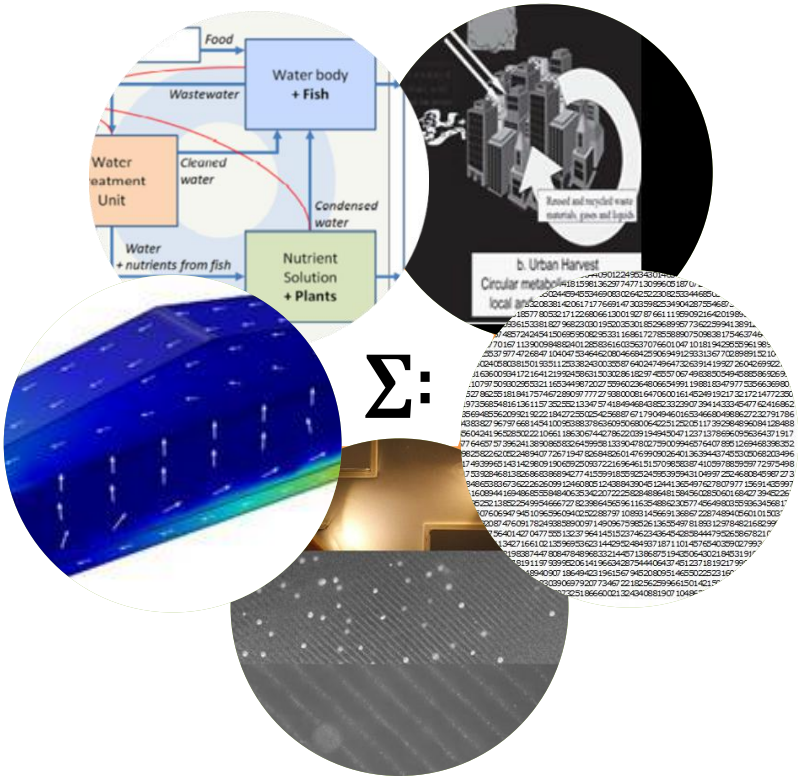
Background and goal

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 possible constrained, systems (**Σ:**) 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

In many cities that are pursuing low-carbon and sustainable development, urban energy systems are in a transition to reduce greenhouse gas emissions, to improve system reliability, and to increase local energy production. This transition contributes to achieving the decarbonization target set in the Paris Agreement in December 2015. Increasing proportion of intermittent renewable energy has been observed in the past decade. This poses challenges to the system balance. Bioenergy has the potential to be both dispatchable and carbon-neutral, therefore can play an important role in balancing the future urban energy system.

The objective of this project is to investigate the potential role of bioenergy in the transition to a sustainable and smart urban energy system. Methodologies including energy system modelling, agent-based modelling, and inventory modelling 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 to simulate urban smart grids. The components included in the model framework are flexible biogas plant, distributed intermittent renewable energy resources, energy storage (battery), and local electricity exchange mechanism.

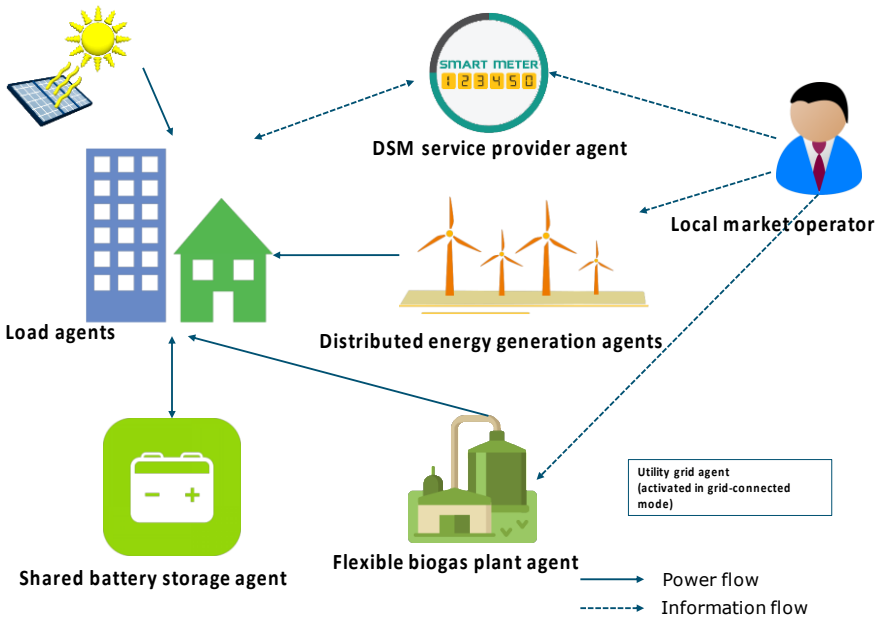


Figure 5 Illustration of urban smart grids

Type of student projects envisioned

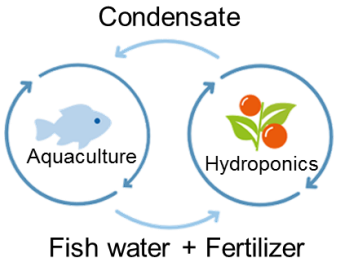
Possible topics for students' thesis: Agent-based modelling for energy system.

Modelling aquaponic systems

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

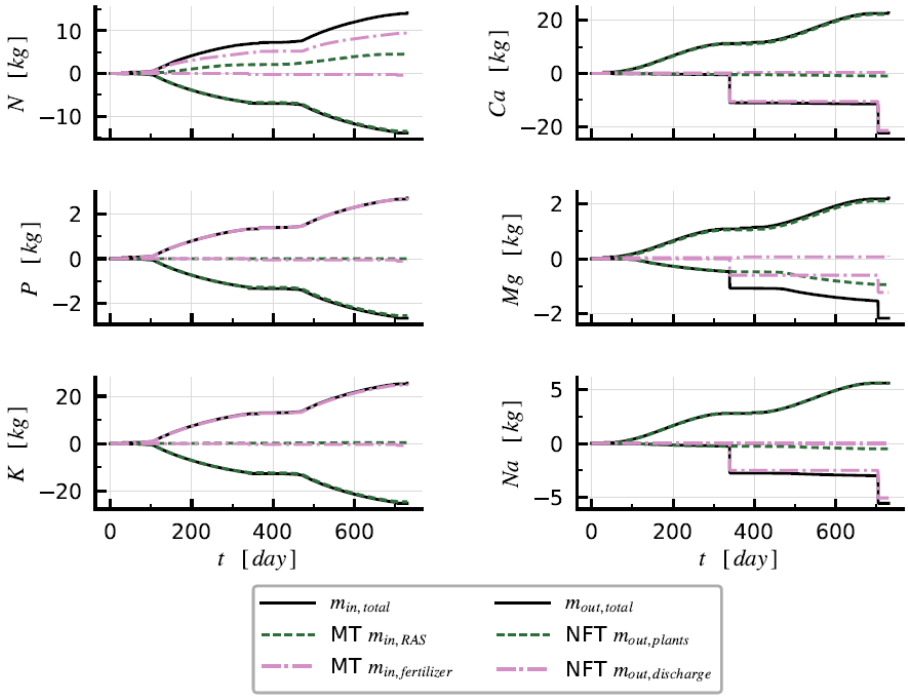
Background and goal of project

Aquaponics combines the production of aquatic species (*aqua*culture) with soilless horticulture (hydro*ponics*), reusing the waste from the aquatic animals to fertilize the plants in a single water cycle. Scaling up the technique to a commercial level can help reducing the demand for water and the environmental impacts resulting from our food production.



Our research is part of the EU project INAPRO, which aims at improving our understanding of aquaponic systems towards commercialization, by means of a modelling and a demonstration approach. INAPRO combines two decoupled loops: a recirculating aquaculture system (RAS) and a greenhouse hydroponic system.

Highlight of the past year



Mass balances for fertilizer. Positive values show inflows in a mixing tank (MT) and negative values show outflows at nutrient film technique channels (NFT) for plant growth.

We developed a model for the INAPRO demonstration system in Abtshagen, Germany. Our simulations show that the system can operate with similar water requirements than current commercial systems of aquaculture and greenhouse horticulture individually.
Also, the system could operate with lower fertilizer requirements than commercial systems available, since they can be supplied by the RAS (see figure).

Modelling ventilated agro-material bulk-storage facilities.

Name PhD: N.L.M. Grubben
Involved staff members: Karel Keesman
Project sponsor: Omnivent techniek b.v.
Start/(expected) end date of project: 01/04/2014-01/04/2018

Background and goal of project

To overcome seasonality of the agricultural products and to guarantee a continuous flow of food products to the industry and consumers, in general storage of primary food products is crucial. This study focuses on the understanding and design of optimal ventilation strategies for safe and sustainable storage of primary food products.
In our specific example of a bulk food-storage facility used for the storage of potatoes, onion or wheat, the practical goal is to maintain the quality of the food products at a certain level for a longer time.

Highlight of the past year

A complete dynamic 3-D CFD simulation model has been developed, including ventilators and moving hatches.

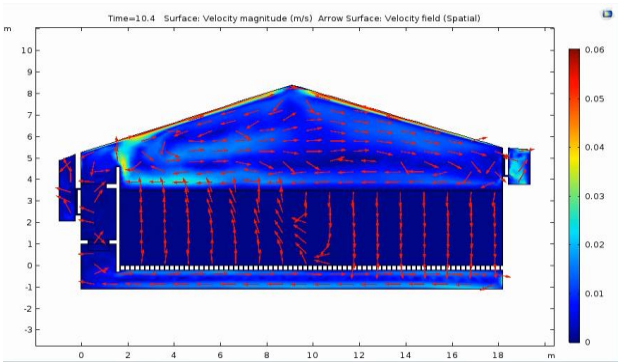


Figure 1. Air velocity profile in a food storage facility obtained by CFD simulation.

To investigate the quality development over time, measurements from experimental setups in several bulk storage facilities were used to calibrate and validate the spatially-distributed model of potatoes in a storage facility.
To control and observe spatially distributed facilities, the controllable field and observable field around actuators and sensors, respectively, are of interest. In a sensitivity study (Grubben & Keesman, 2017), sensitivity fields were used to analyse the behaviour from input to state and from initial state to output.

Type of student projects envisioned

Related to the topic this project, several MSc projects can be defined. Detailed models of product specific processes are often absent but needed for quality control. Modelling these processes can be conducted and implemented in CFD simulations. The validated models can be used for implementing model predictive control strategies.

Grubben, N. L. M., & Keesman, K. J. (2017). Controllability and observability of 2D thermal flow in bulk storage facilities using sensitvity fields. International Journal of Control, ISSN 0020-7179 - p. 1 - 13.

Improving Decoupled Multi-Loop Aquaponics Systems

Name post-doc: Dr Simon Goddek
Involved staff members: Prof. dr.Karel Keesman
Project sponsor: Aquaponik Manufaktur GmbH and others.
Start/(expected) end date of project: -

Background and goal of project

Traditional designs for one-loop aquaponics systems comprise both aquaculture and hydroponics units between which water recirculates. In such traditional systems, it is necessary to make trade-offs in the conditions of both subsystems in terms of pH, temperature, and nutrient concentrations. Decoupled double-loop aquaponics systems separate the aquaculture and hydroponics units from one another, with inherent leads to advantages for both fish and plants. A decoupled three-loop system consists of a recirculating aquaculture system (RAS) loop, a hydroponic (HP) loop, and a mineralization loop. The benefits of a decoupled approach is that environmental conditions of each loop can be adapted to the species-dependent requirements that, by reducing trade-offs, can lead to enhanced growth performance. In our research, we furthermore implemented a desalination/distillation loop to concentrate nutrients in the hydroponic loop and to potentially lead demineralized water to the RAS (Figure 1).

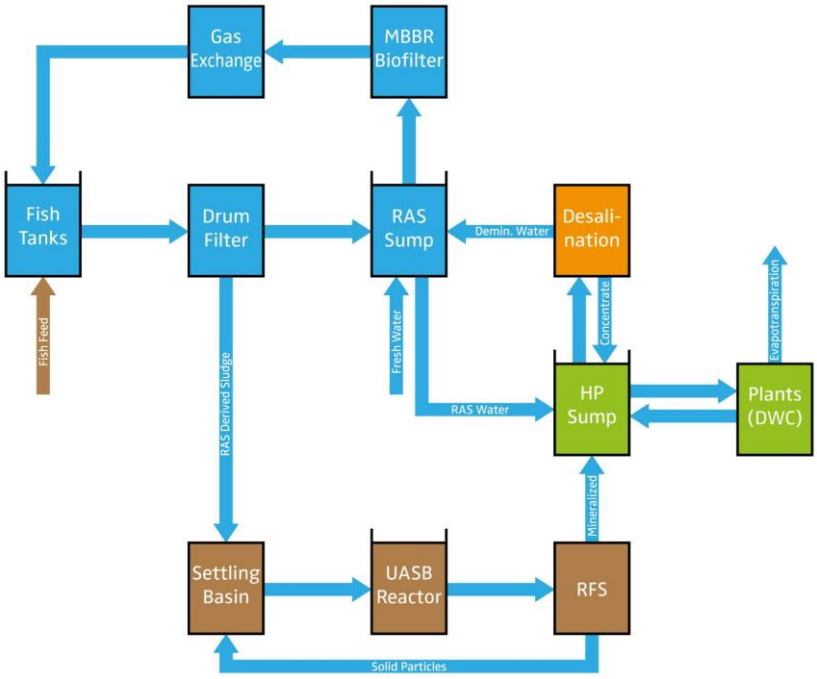


Figure 1. Water flow scheme of a decoupled multi-loop aquaponics system consisting of an aquaculture unit (blue), hydroponic unit (green), mineralization subsystem (brown), and desalination loop (orange) (from Goddek & Keesman, Desalination, 2017).

Highlight of the past year

We found out that desalination technologies can improve the sustainability of multi-loop aquaponic systems, since the nutrient concentration in the hydroponic subsystem gets concentrated (less fertilization required), and the demineralized water can improve the fish water (no water discharge required). We published the corresponding modelling paper in Desalination, Elsevier journal with an IF of >5.5. Furthermore, I had my PhD defence in Wageningen on Oct 24th, 2017.

Type of student projects envisioned

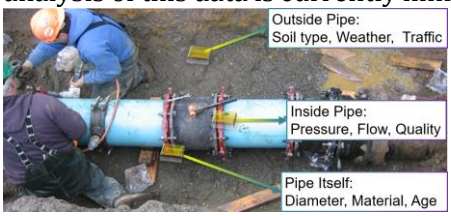
I like to improve existing systems and processes. I use model approaches to see whether my ideas are feasible.

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

Name PhD: Caspar Geelen
Involved staff members: Karel Keesman
Project sponsor: Wetsus
Start/(expected) end date of project: 1/9/17 – 1/9/21

Background and goal of project

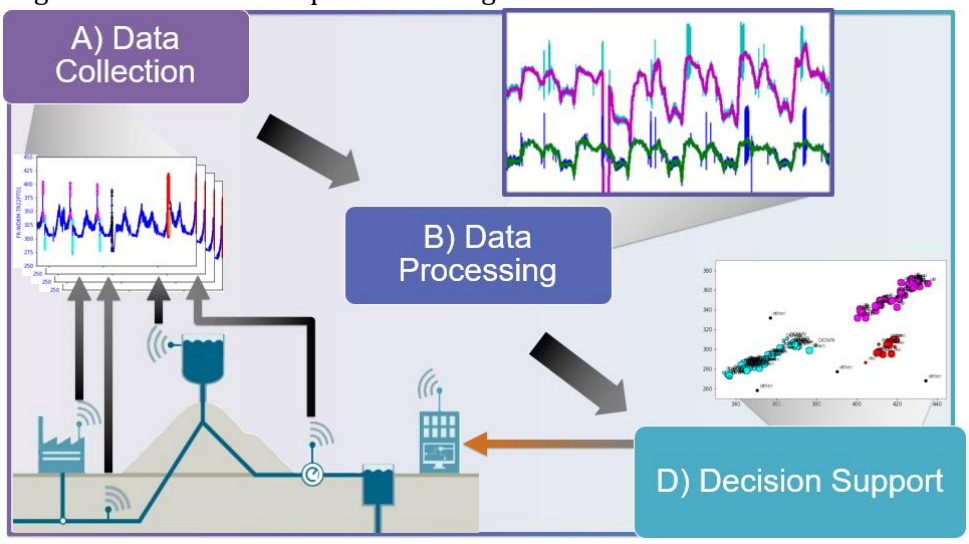
Although Dutch drinking water is of high quality and only 5% of clean drinking water is lost per year, the actual behavior of flows within the distribution network and current state of the pipes remain largely unknown. Due to the unknown state and continuous degradation of pipes, water companies yearly spend millions in investigating the state of water mains, without a detailed strategy to target most likely degraded pipes.
Although increased water sensor placement in water mains yields big & fast data streams, analysis of this data is currently limited to a reactive approach of real-time leak detection.



However, in order to guarantee robust performance and avoid leakages, a more proactive approach is required. Since sensor placement and pipe inspection are costly, the abundance of currently collected sensor data can be further analyzed together with flow dynamics models to facilitate cost-effective monitoring and management of the water supply grid.

Highlight of the past year

Using pressure sensor time series data from water company VItens (A), unwanted and anomalous pressure patterns potentially leading to pipe leakages were identified using data processing and clustering techniques (B). This facilitated real-time detection of new/persistent repetitive pressure patterns. Using this knowledge, an early warning system (EWS) was developed using python in order to provide warning messages for company grid monitoring employees, allowing detection of repetitive patterns and targeted maintenance to prevent leakages.



Type of student projects envisioned

Current stages mainly focus on Data Science and programming (python/R/…), so projects will involve timeseries data processing, anomaly detection, clustering, classification, distance calculations, machine learning models, optimization, etc.
At the second stage water flow dynamic models from the water distribution network will play an important role and the focus will shift from data science to physical modelling using matlab, GIS maps, infoworks, etc.

Selective Particle Control in Suspensions Using Acoustics

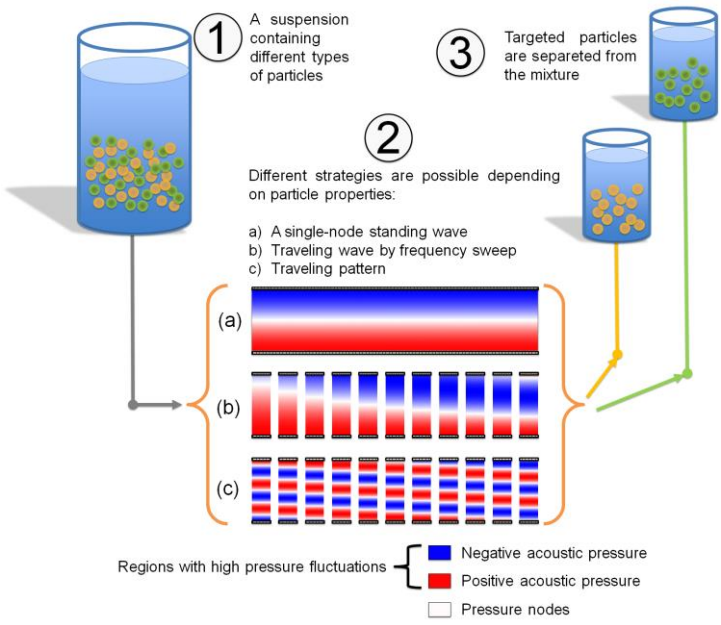
Name PhD: M. Hakan Kandemir
Involved staff members: Karel Keesman
Project sponsor: Wetsus
Start/(expected) end date of project: 01-12-2017/01-09-2020

Background and goal of project

Acoustic separation is a relatively new method for the recovery of valuable particulate matter from suspensions and/or purification of liquid streams.
When a particle is subjected to an acoustic field, it experiences a force called acoustic radiation force. Most of the time the force is weak and it does not do significant effects. In some specific cases, like a standing wave field, however, the acoustic force is strong enough to displace or trap the particles. The amplitude and direction of the acoustic radiation force depends on the particle properties; most particles are forced on the pressure nodes in a standing wave field. In order to separate particles from suspensions, it is important to understand how a particle behaves in a given acoustic field.
This technique of acoustic separation is mainly applied in biotechnology and medical technology. Our aim is to apply this technique on separation of valuable suspensions in small to medium scale industrial water applications.

Highlight of the past year

To be able to selectively separate particles, first the particle behavior should be well understood. If the same acoustic field is applied to different particles, they do not experience the same amount of force. The acoustic force depends on the particle parameters such as size, density and compressibility as well as the acoustic parameters like frequency and amplitude of sound. As a result of those differences in experienced force, particle motion and therefore trajectories will be different.



If we carefully select the parameters for desired particle paths, it is possible to put enough distance between two types of particles and later separate them.
In the past year the theoretical understanding of particle behavior has been improved. Methods have been developed such that it is possible to predict the behavior of a particle in a given field without numerical simulations and/or solving the differential equation of motion of the particle. This will also enable us to predict the unknown system parameters from experiments, and determine the set of parameters in order to separate a given set of particles.

Type of student projects envisioned

The scope of this project still remains broad. Possible student projects include the experimental and theoretical investigation of the sound field under different conditions. Application of a selective separation strategy to several cases is also a possibility. Students (preferably) with a background in acoustics/vibrations or biotechnology and wish to investigate different scenarios for separation are welcome.

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-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-50806	Sustainability Analysis
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-13807	Engineering 2 (Electronics)
FTE-27306	Sensor Technology
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
XWT-21305	Process Dynamics (Wetsus)
YEI-60312	Research Master Cluster: Proposal Writing
YML-30303	Frontiers in Molecular Life Sciences

BCT: Biobased Chemistry and Technology
BPE: Bioprocess Engineering
FTE: Farm Technology
ORC: Organic Chemistry
XWT: Wetsus Academy
YEI: Educational Institute
YML: Molecular Life Sciences

PhD course

Uncertainty analysis of dynamic models
Dynamic modelling plays a crucial role in life science research, for example for predicting or hypothesis testing. A key feature of biosystems is parameter uncertainty, arising from biological variation, or a lack of knowledge. It is generally hard to foresee how parameter uncertainty propagates into model predictions, especially when a model contains a lot of complex interactions. Some predictions may be sharp, others highly uncertain. Some parameter uncertainties make all predictions uncertain, whereas others may have no influence at all.
The purpose of this course is to make the participants familiar with general statistical concepts describing uncertainty, and methods to compute prediction uncertainty coming from uncertain parameter values. We introduce dynamic input-state-output systems and methods to write your model in this format. Also methods are presented to obtain parameter uncertainty from input-output data. The methodology is illustrated with realistic examples.
This course was given in Dec 2017 with Biometris as course coordinator. In total 30 PhD students attended the course.

BSc Theses

- Ros, Pascal; Membrane contactor for air dehumification at elevated temperatures
- Allmenroder, Lola; Acid hydrolysis of A. esculenta and S. latissima as a pre-treatment in biofuel production
- Mesman, Jesse; Combining chemo- and bio-electrosynthesis: investigating electrocatalytic and biocatalytic effects in bioreactors
- Wiltink, Thijmen; Biorefining of duckweed at ECOFERM!
- Linders, Marie-Jose; Selective carbohydrate oxidation on Pt/AC
- Vries, Tijmen; Pyrolysis and catalytic upgrading of poultry litter to produce chemicals
- Hofstede, Jordy; The effect of changes in CO pressure, H2:CO ratio and overall pressure on the metabolism of extremophiles
- Spaans, Gijs; Storage of energy in biogas for dealing with fluctuations in renewable energy production
- Smits, Matthijs; The identification & upgrading of water-soluble products in a pyrolysis waste stream
- Gorter de Vries, Philip; Enzymatic saccharification of the brown seaweed Sacharina latissima for bio-fuel production
- Brouwer, Thijs; Determining the influence of the starch amylose content on the mesoporosity of starbons
- Marrewijk, Bart van; Modelling the production of duckweed in combination with economic possibilities
- Ros, Nardy; Modelling the production of duckweed in combination with economic possibilities
- Ham, Matthijs van der; Modelling excretion of Nile tilapia (Oreochromis niloticus) in a recirculating aquaculture system; dynamic system approach

MSc Theses

- Wiegersma, Tijmen; Investigation of the stability of metal carbide catalysts in aqueous media
- Timmer, Stijn; An environmental impact analysis of the current anionic potato starch production process
- Seelam, Jai Sankar; Dynamic modelling of wastewater treatment systems at domestic scale (15000 PE)
- Linde, Stephan van der; Development of water potential model for (large scale) urban water reuse
- Marwijk, Iris van; Development of a capstone project
- Vestjens, Laura; Sunflower-based protein fractions for food applications
- Bonvie, Martin; Potential of chitin nanocrystals
- Koster, Walter de; Development of the fermentation process for polyhydroxybutyrate production using pyrolytic sugar solution as a substrate
- Kotte Hewa, Dileesha; Removal of phosphonate antiscalants
- Bremenkamp, Ina; Functional properties of extraneous seed proteins for the stability of spray dried oil body powders
- Strik, Judith; Processing of feathers to proteins
- Soekho, Viragni; Chemical and biological-electrochemical reduction of carbon dioxide on copper based electrodes
- Hemming, Sven; Vanadium chloroperoxidase mediated conversion of amino acids and other biobased compounds
- Yulina, Rizka; Selective oxidation of carbohydrates by Au/carbon catalysts: effect of molecular weight of the substrate on the catalyst performance
- Platvoet, Daniel; Simulation of a fixed bed gas adsorption system on two length scales
- Klosterman, Cynthia; Enzymatic fingerprinting of isomalto/malto-polysaccharides
- Ntone, Eleni; The effect of cell wall encapsulation on digestion of macronutrients derived from nuts: lipid bioaccessibility
- Wang, Xun; Model predictive control of a hybrid renewable energy system in an urban environment
- Kelderman, Ko; Pressure flattening of potatoes during bulk storage

PhD Theses

- Khairudin, Nurulhuda; Modelling of Ammonia Volatilisation in Fertilised and Flooded Rice Systems
- Goddek, Simon; Opportunities and Challenges of Multi-Loop Aquaponic Systems

Scientific Publications 2017

Refereed article in a journal

- Distributed mathematical model supporting design and construction of solar collectors for drying
  Amankwah, E.A.Y. ; Dzisi, K.A. ; Straten, G. van; Willigenburg, L.G. van; Boxtel, A.J.B. van (2017)
  Drying Technology 35 (14). - p. 1675 - 1687.
- Assessing the flexibility potential of the residential load in smart electricity grids - A data-driven approach
  Azari, Delaram ; Torbaghan, Shahab Shariat ; Cappon, Hans ; Gibescu, Madeleine ; Keesman, Karel ; Rijnaarts, Huub (2017)
  In: 2017 14th International Conference on the European Energy Market, EEM 2017. - IEEE computer society, 14th International Conference on the European Energy Market, EEM 2017, Dresden, 2017-06-06/2017-06-09
- Enzymatic halogenation and oxidation using an alcohol oxidase-vanadium chloroperoxidase cascade
  But, Andrada ; Noord, Aster Van; Poletto, Francesca ; Sanders, Johan P.M. ; Franssen, Maurice C.R. ; Scott, Elinor L. (2017)
  Molecular Catalysis 443 . - p. 92 - 100.
- Unusual differences in the reactivity of glutamic and aspartic acid in oxidative decarboxylation reactions
  But, Andrada ; Wijst, Evie van der; Notre, Jerome le; Wever, Ron ; Sanders, Johan P.M. ; Bitter, Johannes H. ; Scott, Elinor L. (2017)
  Green Chemistry 19 (21). - p. 5178 - 5186.
- Role of microbial accumulation in biological sulphate reduction using lactate as electron donor in an inversed fluidized bed bioreactor : Operation and dynamic mathematical modelling
  Cassidy, J. ; Frunzo, L. ; Lubberding, H.J. ; Villa-Gomez, D.K. ; Esposito, G. ; Keesman, K.J. ; Lens, P.N.L. (2017)
  International Biodeterioration and Biodegradation 121 . - p. 1 - 10.
- Theory of pH changes in water desalination by capacitive deionization
  Dykstra, J.E. ; Keesman, K.J. ; Biesheuvel, P.M. ; Wal, A. van der (2017)
  Water Research 119 . - p. 178 - 186.
- The effect of food type (formulated diet vs. natural) and fish size on feed utilization in common sole, Solea solea (L.)
  Ende, Stephan S.W. ; Kroeckel, Saskia ; Schrama, Johan W. ; Schneider, Oliver ; Verreth, Johan A.J. (2017)
  Aquaculture Research 48 (9). - p. 4696 - 4706.
- Mildly refined fractions of yellow peas show rich behaviour in thickened oil-in-water emulsions
  Geerts, M. E., Mienis, E., Nikiforidis, C. V., van der Padt, A., van der Goot, A. J.(2017)
  Innovative Food Science and Emerging Technologies 41 . – p. 251 - 258
- Protein nativity explains emulsifying properties of aqueous extracted protein components from yellow pea
  Geerts, Marlies E.J. ; Nikiforidis, Constantinos V. ; Goot, Atze Jan van der; Padt, Albert van der (2017)
  Food Structure 14 . - p. 104 - 111.
- Mildly refined fractions of yellow peas show rich behaviour in thickened oil-in-water emulsions
  Geerts, Marlies E.J. ; Mienis, Esther ; Nikiforidis, Constantinos V. ; Padt, Albert van der; Goot, Atze Jan van der (2017)
  Innovative Food Science and Emerging Technologies 41 . - p. 251 - 258.

- Controllability and observability of 2D thermal flow in bulk storage facilities using sensitivity fields
  Grubben, Nik L.M. ; Keesman, Karel J. (2017)
  International Journal of Control . - p. 1 - 13.
- Twisted tubular photobioreactor fluid dynamics evaluation for energy consumption minimization
  Gómez-Pérez, C.A. ; Espinosa Oviedo, J.J. ; Montenegro Ruiz, L.C. ; Boxtel, A.J.B. van (2017)
  Algal Research 27 . - p. 65 - 72.
- The potential role of waste biomass in the future urban electricity system
  Jiang, Yu ; Werf, Edwin van der; Ierland, Ekko C. van; Keesman, Karel J. (2017)
  Biomass and Bioenergy 107 . - p. 182 - 190.
- Feeding ragworm (Nereis virens Sars) to common sole (Solea solea L.) alleviates nutritional anaemia and stimulates growth
  Kals, J. ; Blonk, R.J.W. ; Palstra, A.P. ; Sobotta, Tim ; Mongile, Fulvio ; Schneider, O. ; Planas, J.V. ; Schrama, J.W. ; Verreth, J.A.J. (2017)
  Aquaculture Research 48 (3). - p. 752 - 759.
- Physical bonding between sunflower proteins and phenols : Impact on interfacial properties
  Karefyllakis, Dimitris ; Altunkaya, Serkan ; Berton-Carabin, Claire C. ; Goot, Atze Jan van der; Nikiforidis, Constantinos V. (2017)
  Food Hydrocolloids 73 . - p. 326 - 334.
- Efficient and economical way of operating a recirculation aquaculture system in an aquaponics farm
  Karimanzira, Divas ; Keesman, Karel ; Kloas, Werner ; Baganz, Daniela ; Rauschenbach, Thomas (2017)
  Aquaculture Economics & Management 21 (4). - p. 470 - 486.
- Composite gels structured by a gelatin protein matrix filled with oil bodies
  Kirimlidou, Miro ; Matsakidou, Anthia ; Scholten, Elke ; Nikiforidis, Constantinos V. ; Kiosseoglou, Vassilios (2017)
  Food Structure 14 . - p. 46 - 51.
- Synthesis of Furandicarboxylic Acid Esters From Nonfood Feedstocks Without Concomitant Levulinic Acid Formation
  Klis, Frits van der; Haveren, Jacco van; Es, Daan S. van; Bitter, Harry (2017)
  ChemSusChem 10 (7). - p. 1460 - 1468.
- Energy saving potential of emerging technologies in milk powder production
  Moejes, S.N. ; Boxtel, A.J.B. van (2017)
  Trends in Food Science and Technology 60 . - p. 31 - 42.
- Biocatalytic, one-pot diterminal oxidation and esterification of n-alkanes for production of α,ω-diol and α,ω-dicarboxylic acid esters
  Nuland, Youri M. van; Vogel, Fons A. de; Scott, Elinor L. ; Eggink, Gerrit ; Weusthuis, Ruud A. (2017)
  Metabolic Engineering 44 . - p. 134 - 142.
- Set-membership estimation from poor quality data sets : Modelling ammonia volatilisation in flooded rice systems
  Nurulhuda, K. ; Struik, P.C. ; Keesman, K.J. (2017)
  Environmental Modelling & Software 88 . - p. 138 - 150.
- Comparative life cycle assessment of real pilot reactors for microalgae cultivation in different seasons
  Pérez-López, Paula ; Vree, Jeroen H. de; Feijoo, Gumersindo ; Bosma, Rouke ; Barbosa, Maria J. ; Moreira, María Teresa ; Wijffels, René H. ; Boxtel, Anton J.B. van; Kleinegris, Dorinde M.M. (2017)
  Applied energy 205 . - p. 1151 - 1164.
- Day-to-night heat storage in greenhouses : 2 Sub-optimal solution for realistic weather
  Seginer, Ido ; Straten, Gerrit van; Beveren, Peter J.M. van (2017)
  Biosystems Engineering 161 . - p. 188 - 199.
- Day-to-night heat storage in greenhouses : 1 Optimisation for periodic weather

Seginer, Ido ; Straten, Gerrit van; Beveren, Peter J.M. van (2017)
Biosystems Engineering 161 . - p. 174 - 187.

- Day-To-night heat storage in greenhouses : A simulation study
  Seginer, I. ; Straten, G. Van; Beveren, P.J.M. Van (2017)
  In: 5th International Symposium on Models for Plant Growth, Environment Control and Farming Management in Protected Cultivation, HortiModel 2016 International Society for Horticultural Science, (Acta Horticulturae) - p. 119 - 127.
- Improving sustainability of maize to ethanol processing by plant breeding and process optimization
  P.M. Slegers, A.F. Torres, A.J.B. van Boxtel, L.M. Trindade (2017)
  Conference proceedings of 25th EUBCE (June 2017)
- The Future of Ethenolysis in Biobased Chemistry
  Spekreijse, Jurjen ; Sanders, Johan P.M. ; Bitter, Johannes H. ; Scott, Elinor L. (2017)
  ChemSusChem 10 (3). - p. 470 - 482.
- Effect of pore size distribution on iron oxide coated granular activated carbons for phosphate adsorption – Importance of mesopores
  Suresh Kumar, Prashanth ; Prot, Thomas ; Korving, Leon ; Keesman, Karel J. ; Dugulan, Iulian ; Loosdrecht, Mark C.M. van; Witkamp, Geert Jan (2017)
  Chemical Engineering Journal 326 . - p. 231 - 239.
- Interfacial properties of green leaf cellulosic particles
  Tamayo Tenorio, A. ; Gieteling, J. ; Nikiforidis, C.V. ; Boom, R.M. ; Goot, A.J. van der (2017)
  Food Hydrocolloids 71 . - p. 8 - 16.
- Interfacial properties and emulsification performance of thylakoid membrane fragments
  Tamayo Tenorio, A. ; Jong, E.W.M. de; Nikiforidis, K. ; Boom, R.M. ; Goot, A.J. van der (2017)
  Soft Matter 13 (3). - p. 608 - 618.

PhD Theses

- Opportunities and Challenges of Multi-Loop Aquaponic Systems
  Goddek, Simon (2017)
  University. Promotor(en): Johan Verreth, co-promotor(en): Karel Keesman. - Wageningen : Wageningen University, - 171 p.
- Modelling of ammonia volatilisation in fertilised and flooded rice systems
  Khairudin, Nurulhuda (2017)
  University. Promotor(en): Paul Struik, co-promotor(en): Karel Keesman; Mohamad Pauzi Zakaria. - Wageningen : Wageningen University, - 209

Refereed book chapters

- Heterogeneous catalysis
  Bitter, J.H. (2017)
  In: Contemporary Catalysis / Kramer, P.C.J., Vogt, D., Thybaut, J., RSC, - p. 177 - 188.
- Introduction
  Lefferts, L. ; Hanefeld, U. ; Bitter, J.H. (2017)
  In: Catalysis / Hanefeld, Ulf, Lefferts, Leon, Wiley-VCH, - p. 1 - 15.
- Circular economy and economic viability of aquaponic systems : Comparing urban, rural and peri-urban scenarios under Dutch conditions
  Stadler, M.M. ; Baganz, D. ; Vermeulen, T. ; Keesman, K.J. (2017)
  In: Proceedings of ICESC2015. - International Society for Horticultural Science, (Acta Horticulturae) ISHS symposium ICESC 2015: Hydroponics and Aquaponics at the Gold, Jupiter's Gold Coast, 2015-07-05/2015-07-08 - p. 101 - 114.

Non-refereed article in a journal

- Bio-based chemicals: general discussion
  Bitter, Harry et al (2017)
  Faraday Discussions 202 . - p. 227 - 245.

Other output

Orals invited

- Strategies to stabilize supported Ni-nanoparticles in aqueous reaction mixtures; Harry Bitter, RWTH Aachen University, Aachen, Germany, 30 March 2017
- Oil bodies: way more than energy storage droplets, Costas Nikiforidis, Cargill, R&D Headquarters, Belgium, 21 June 2017
- Green conversions and processing, Elinor L Scott, 10th Workshop Bioeconomy (Enzymes and Green Chemistry), University of Campinas, Brazil, 27-29 November 2017
- Metal carbides for deoxygenation of biobased feedstock, Souza Macêdo, L. ; Teixeira da Silva, Victor ; Bitter, J.H., Chemistry As INnovating Science (CHAINS) 2017, Veldhoven, The Netherlands, 5-7 Dec 2017

Orals contributed

- From waste water to chemical building blocks
  Bitter, J.H. ; Spekreijse, J. ; Notre, J.E.L. le; Holgueras Ortega, J. ; Scott, E.L. ; Sanders, J.P.M., International Green Chemistry Symposium 2017, La Rochelle, France, 16-19 May 2017
- A mof immobilized Hoveda-Grubbs metathesis catalyst for the production of methyl acrylate from waste water, Bitter, J.H. ; Spekreijse, J. ; Notre, J.E.L. le; Holgueras Ortega, J. ; Sanders, J.P.M. ; Scott, E.L., Europacat 2017, Florence, Italy, 27-31 Aug 2017
- Influence of synthesis method on Mo2C/CNF phase and its catalytic performance on stearic acid hydrodeoxygenation, Bitter, J.H, Souza Macêdo, L. ; Teixeira da Silva, Victor, North American catalysis society meeting, Denver USA, 4-9 June 2017
- Towards combining heterogeneous electro-catalysis and bio-electro-synthesis Chatzipanagiotou, K.R. ; Jourdin, Ludovic ; Buisman, C.J.N. ; Strik, D.P.B.T.B. ; Bitter, J.H. 4th International Congress on Catalysis for Biorefineries, Lyon, France, 11-15 Dec 2017
- Effect of initial nickel particle size on the stability of nickel catalysts, Haasterecht, T. van; Swart, M. ; Jong, K.P. de; Bitter, J.H., NCCC, The Netherlands' Catalysis and Chemistry Conference, Noordwijkerhout, 6-8 March 2017
- The synergy between chemistry and modelling, Tim Hoogstad, Chemistry As Innovating Science (CHAINS) 2017, Veldhoven, The Netherlands, 6 Dec 2017
- The Potential Role of Waste Biomass in the Future Urban Electricity System, Jiang, Y. ; Werf, E. van der; Ierland, E.C. van; Keesman, K.J., 25th European Biomass Conference & Exhibition, Stockholm, Sweden, 12-15 June 2017
- Oil bodies as carriers of bioactives, Nikiforidis, K., 7th International Symposium on "Delivery of Functionality in Complex Food Systems", Auckland, New Zealand, 5-8 Nov
- Lipid digestion in hazelnuts particles and oil bodies, Nikiforidis, K. ; Ntone, Eleni ; Capuano, E. ; Pellegrini, Nicoletta, 7th International Symposium on "Delivery of Functionality in Complex Food Systems", Auckland, New Zealand, 5-8 Nov 2017
- Innovative water system implementation, New ICT and Data Solutions (remote sending). Innovative Asset management and big data, Geelen, Caspar, Yntema, D. ;, Amsterdam International Water Week conference 2017: AIWW, Amsterdam, The Netherlands, 30 Oct - 1 Nov 2017

- Improving sustainability of maize to ethanol processing by plant breeding and process optimization, P.M. Slegers, 25th EUBCE, Stockholm Sweden, 14 June 2017
- Biocatalytic formation of nitriles from Biomass, Elinor L Scott, Andrada But, Evie vd Wijst, International Symposium on Green Chemistry (ISGC). La Rochelle, France, 16-19 May 2017
- Green conversions and processing, Elinor L Scott, 10th Workshop Bioeconomy (Enzymes and Green Chemistry), University of Campinas, Brazil, 27-29 November 2017

Poster presentations

- Towards combining heterogeneous electro-catalysis and bio-electro-synthesis Chatzipanagiotou, K.R. ; Buisman, C.J.N. ; Strik, D.P.B.T.B. ; Bitter, J.H., NCCC, The Netherlands' Catalysis and Chemistry Conference, Noordwijkerhout, The Netherlands, 6-8 March 2017
- Temperature: crucial factor in feather processing, Goerner-Hu, X. ; Schneider, O. ; Scott, E.L. ; Bitter, J.H., NCCC, The Netherlands' Catalysis and Chemistry Conference, Noordwijkerhout, The Netherlands, 6-8 March 2017
- Starch oxidation as a model reaction for interdependent kinetic pathway modelling, Hoogstad, Tim ; Wijst, Evie van der; Boxtel, A.J.B. van; Buwalda, P.L. ; Bitter, J.H., NCCC, The Netherlands' Catalysis and Chemistry Conference, Noordwijkerhout, The netherlands, 6-8 March 2017
- Synthesis of alpha and beta molybdenum carbide supported on carbon nanofibers catalysts for stearic acid hydrodeoxygenation,Souza Macêdo, L. ; Bitter, J.H. ; Teixeira da Silva, V., 4th International Congress on Catalysis for Biorefineries, Lyon, France, 11-15 Dec 2017
- Selective oxidation of carbohydrates by Au/CNF: effect of molecular weight of the substrate on catalyst performance, Yulina, Rizka ; Wijst, Evie van der; Bitter, J.H., NCCC, The Netherlands' Catalysis and Chemistry Conference, Noordwijkerhout, The Netherlands, 6-8 March 2017

Outreach

- Chemicals from biobased feedstocks; Harry Bitter, Inspiration day Broklede secondary school, 8 Febr 2017
- Gemengd bedrijf 2.0, Harry Bitter, BSc Open day Biosystems Engineering, Wageningen, The Netherlands, 18 Nov 2017
- Harry Bitter, organiser Focus session, Chemistry As INnovating Science (CHAINS) 2017, Veldhoven, The Netherlands, 7 Dec 2017
- Faraday Discussion Bio-resources: feeding a sustainable chemical industry, Harry Bitter, participant
- Kunnen we gras eten, Harry Bitter en Annemarie Hage, Middelbare School Pantarijn Wageningen, 18 Dec 2017
- Duurzame Micromaster, Harry Bitter, Chemisch2Weekblad, nr. 19, 10 Nov 2017
- Amsterdam: biogas as backup energy for electrical systems, Yu Jiang, Biogas Channel (International), Italy, 27 Sept 2017
- A smart, faster path to Zero Lifecycle Emission: advances from the EU in direct carbon capture from air, Harry Bitter, BiofuelsDigest (International), United States, 7 Aug 2017
- Opwinding in speelgoedland: bouwblokje van suikerriet wil Lego aftroeven, Harry Bitter, Trouw, Netherlands, 10 Feb 2017