Biobased Chemistry and Technology
Annual report 2019

WAGENINGEN
UNIVERSITY & RESEARCH

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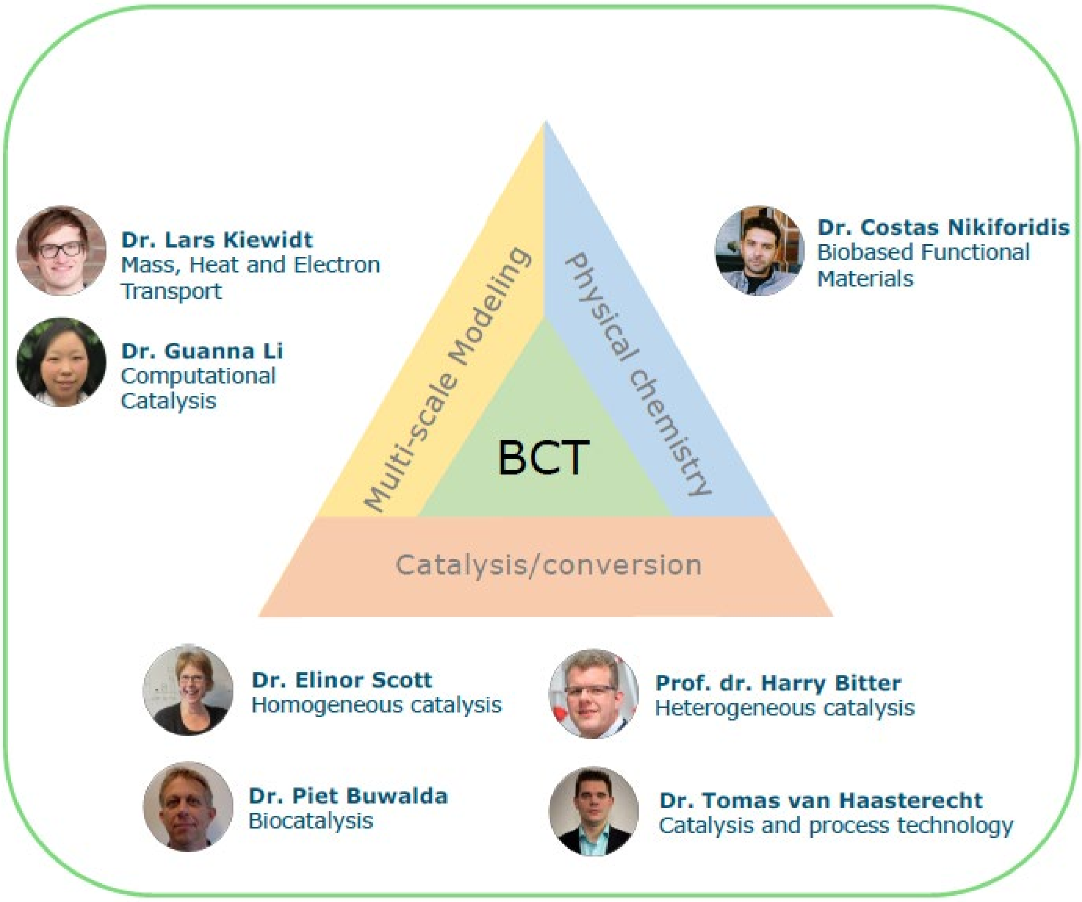
Introduction

It is my pleasure to present to you the annual report 2019 of the Biobased Chemistry and Technology (BCT) group.
In 2019 the group focusses more towards molecules and modeling. Especially in the modeling field we strengthened ourselves at the end of the year with the appointment of Dr. Guanna Li as tenured track staff member in the field of computational chemistry (start date 1/2/2020). Dr. Li will be appointed both at our BCT group and at organic chemistry. We expect a great synergy from that (now even more) close collaboration. The Figure below shows how the BCT group is now organized and shows the key staff members of the group.



In 2018 we started the on-campus master 'biobased sciences'. This is an interdisciplinary master with in-depth scientific building of the students is a specific area. I am happy to see that some courses doubled in number of students in 2019. Biobased sciences is regarded a key area for the future both by students and teachers. I am happy that BCT is a core player in this program.

All this made 2019 an interesting and exiting year again 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.

Collaborating group in Wageningen	Topic
Environmental Technology (ETE)	Combining chemo and bio-electro-catalysis Modeling of water-energy-material nexus in industrial and urban environments
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
Bioprocess Engineering (BPE)	Research collaboration
Microbiology (MIB)	Research Collaboration

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).
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, TTW, 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.

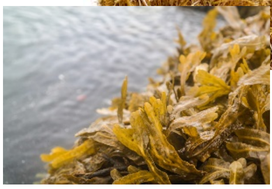
Conversion

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 Fuhrer, Cynthia Kloostermann, Sanne de Smit, Gerben Wierda, Xiaojie Qin
Contact: Elinor.Scott@wur.nl

Background and goal

Society enjoys many comforts due to the development of chemicals, materials and fuels. However many are derived from fossil resources. Due environmental concerns and security of supply we need to investigate alternative renewable feedstocks. Biobased molecules have a variety of functionalities and 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.
We are developing several key research areas:

- Development of catalysts for deoxygenation of biobased molecules.
  - Design, synthesis, characterisation and testing of supported catalysts based on W and Mo.
- Catalytic conversions of biomacromolecules.
  - Synthesis of metal catalysts and studies for selective oxidation reactions of starch as performance material.
  - Enzymatic synthesis of specific amyloses, crystallisation behaviour and structure-function relationship in food applications.
- Novel fractionation technologies for lignocellulosic biomass.
  - Enable specific molecular changes allowing sequential solubilsation and isolation of components and effect on structure-function properties.



- Innovative chemical conversions using seaweed.
  - Controlled conversion to uronic acids and in situ catalytic conversion to chemical building blocks.
- Thermal processing of feathers to feed products and nano-carriers for drug delivery.
- CO2 capture and conversion.
  - Development of modified carbon capture materials.
  - CO2 to chemicals using novel bifunctional catalysts and bioelectrochemical conversion.
- Separation of amino acids mixtures for supplements and chemical intermediates using CO2 expanded alcohol.

Student projects envisioned

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

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

Carbon Dioxide: Capture from Air and Conversion to Chemicals

Name PhD/PD: Nazila Masoud
Involved staff members: Tomas van Haastrecht and Harry Bitter
Project sponsor: European Regional Development Fund
Start/(expected) end date of project: October 2017-October 2021

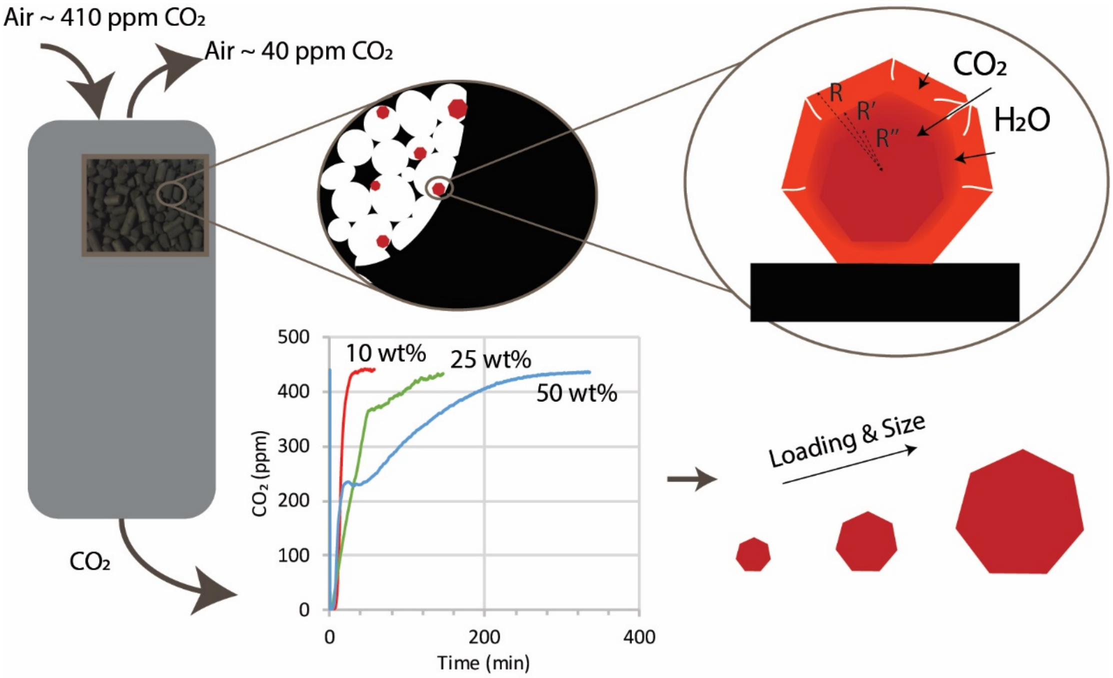
Background and goal of project

Development of technologies that directly capture CO_2 from air is of prime importance to mitigate negative effects of global warming. A first step is to develop suitable sorbents. Potassium carbonate (K_2CO_3) is a promising candidate. It reacts with the CO_2 and makes capturing CO_2 from air in low concentration (410 ppm) possible. To make efficient use of K_2CO_3 it must be dispersed on a support. One important question is that in which microspcopic structure the sorbent perform the best?

In the second step, the captured CO_2 is utilized. CO_2 can be utilized to produce chemicals. The abundance of CO_2 from air opens up opportunities to use this carbon feedstock in a circular economy. However, CO_2 is thermodynamically very stable. Hence, it must be reacted with high energy molecules. This is an activated process that needs catalyst. Development of solid catalysts that function at mild conditions for this conversion is in high demand, and it is one aim of this research.

Highlight of the past year

We successfully prepared a series of carbon supported K_2CO_3 particles with different sizes by varying the K_2CO_3 loading. The size of nano particles was illustrated with different techniques. We further investigated these sorbents for the capture of CO_2 from air in an industrially scalable flow-through setting. The K_2CO_3 with the smallest size showed the fastest sorption. But, the sorbent with the highest K_2CO_3 loading showed the highest uptake, though in expense of a longer time. Therefore, the size of K_2CO_3 particles is an important factor in design of efficient sorbents.



Type of student projects envisioned

The project includes chemical synthesis of inorganic nano materials and application of different chemisorption and spectroscopy techniques.

Selective catalytic transformations of non-edible carbohydrates

Name PhD: Frits van der Klis
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 2020

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
We investigated the oxidation of galacturonic acid, a non-edible carbohydrate present in sugar beet pulp (waste). Gold catalysts showed excellent selectivity and stability for the conversion of this special carbohydrate.[1]

Next, we investigated the influence of the *carbohydrate structure* on the *oxidation rate*. Four carbohydrates were compared, each with different orientations of OH-groups and different functionality at the C6-position (Fig. 1).

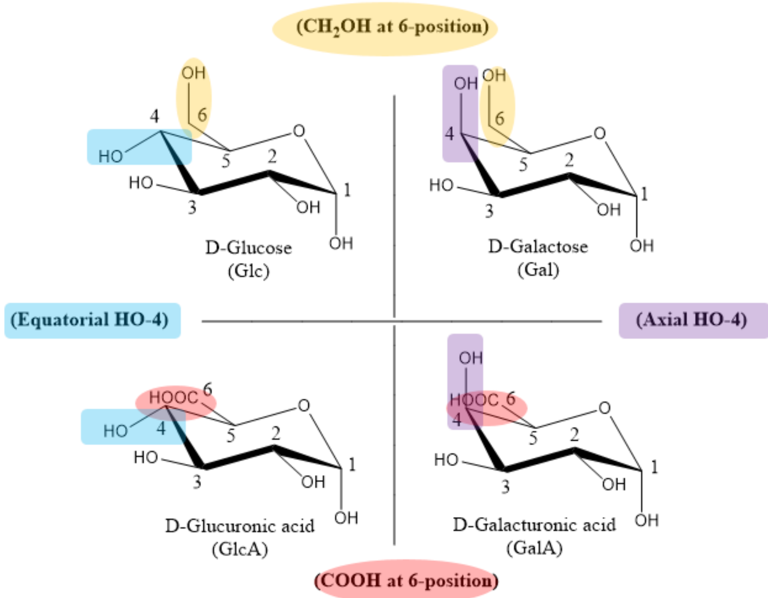
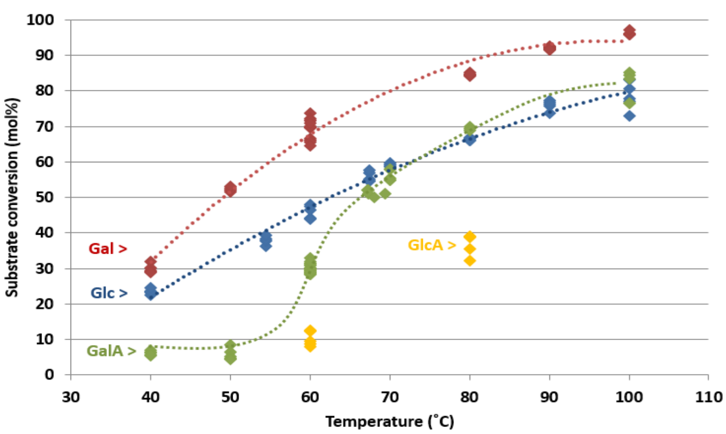


Fig. 1: Carbohydrate structures investigated, represented as α-D-pyranosides.



Reactions were carried out in a continuous flow reactor over a Au-catalyst bed. Each carbohydrate was evaluated over a temperature range between 40 and 100 °C. Conversion as a function of temperature is shown in Fig. 2.

The presence of a carboxylic acid group at C6 has a rate-lowering effect, while an axial orientation of HO-4 leads to higher reaction rates.

Fig. 2: Substrate conversion as a function of reaction temperature; Gal (red), Glc (blue), GalA (green) and GlcA (yellow).

Type of student projects envisioned
Student projects all involve organic chemistry and/or catalysis orientated lab work, focused on the conversion of carbohydrates. Standard analysis during synthesis includes NMR, GC-MS, IR and HPLC. Catalysts will be analyzed by TEM, XRD, chemisorption and physisorption.

[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

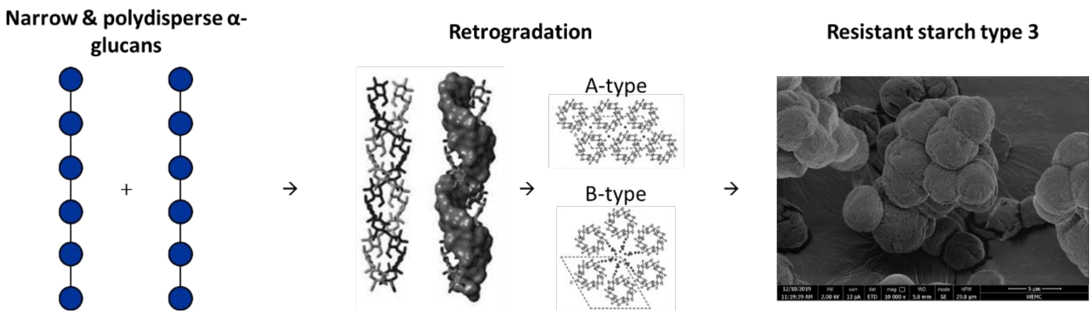
Background and goal of project

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.

One fiber that might be able to counter the side-effects of antibiotics is resistant starch type 3. Resistant starch type 3 is specifically fermented by butyrate-producing gut microbes and for the past 10 years many papers have been published that show the positive effects of butyrate on gut health. However, starch is usually easily digested to glucose in the small intestine, delivering energy to our body. Therefore, the objective of this study is to develop resistant starch type 3 that escapes digestion in the small intestine and enters the colon, ultimately to find out whether specific resistant starch type 3 can counter the side-effects of antibiotics.

Highlight of the past year

Narrow disperse α-1,4 glucans were synthesized using potato glucan phosphorylase and sucrose phosphorylase. These narrow disperse α-glucans were, together with polydisperse α-glucans, crystallized to produce specific resistant starch type 3 that differed in crystal type, polydispersity and molecular weight distribution. The crystalline α-glucans were digested in vitro to show the effect of crystal type, polydispersity and molecular weight on the resistance against digestion.



Student projects envisioned

Research topics involve lab work on chemical and physical characterization of the different dietary fibers (GOS, IMMPs, RS-3) (eg. HPAEC-PAD, HPSEC-RI, 1H-NMR, XRD, DSC, Mastersizer). Also, the enzymatic digestion of these fibers 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 behaviour.

Highlight of the past year
The NMR methods were optimised to obtain reliable spectra from a stable slug-flow. Moreover, the slug composition can now be measured three times per second. The technique was found to be sensitive to small flow rate fluctuations. For example, peristaltic pump fluctuations could be easily recognised. In contrast to conventional off-line GC analysis the NMR method offers continuous and automated in-line monitoring. The 4uL detection volume of the micro-NMR probe allowed for differentiation of the conversion even within a single slug.

No student projects envisioned
This project has finished in 2019

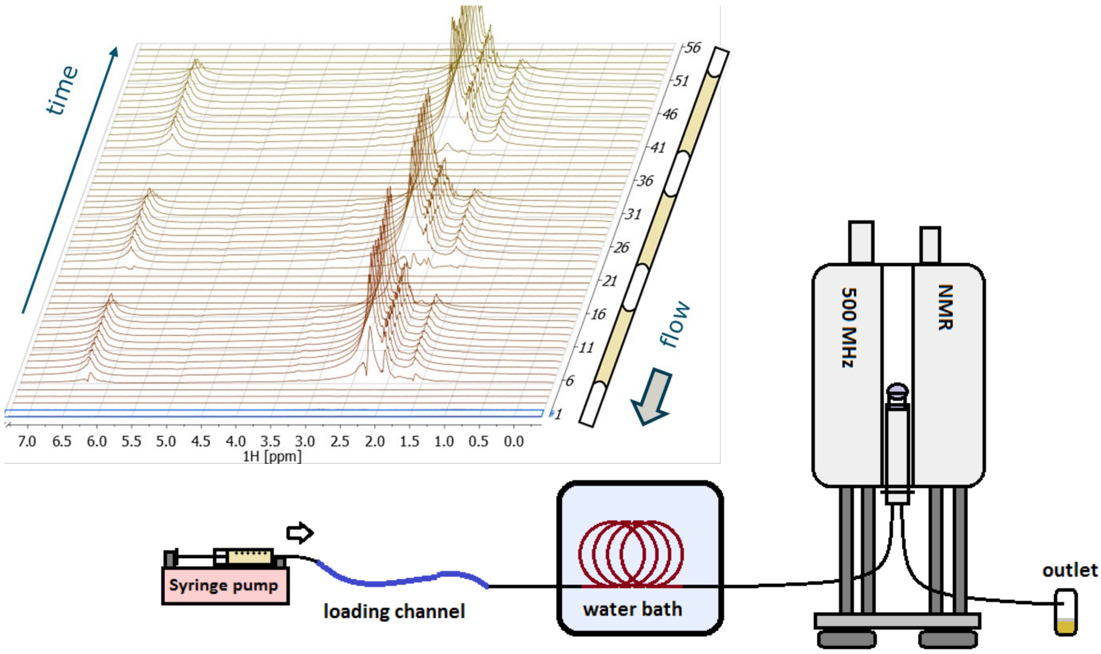


Figure 1, *Top*) NMR spectra collected over allow for a composition analysis of the reaction mixture. *Bottom*) the set-up: a slug flow of reactants is prepared in the loading channel and pushed through reactor and the NMR for in-line detection.

Selective polysaccharide oxidation – new catalysts and new chains

Name PhD/PD: Konstantina-Roxani Chatzipanagiotou
Involved staff members: prof. dr. Harry Bitter
Project sponsor: Avebe
Start/(expected) end date of project: October 2019/April 2021

Background and goal of project

Nowadays, more and more attention is given to bio-based chemicals, as replacement for fossil-based compounds. Starch is an interesting bio-based feedstock to be oxidized to anionic starch. Anionic starch can replace fossil-based poly acrylates and has applications in the food industry, as well as for textiles, packaging material, coatings and adhesives.

Traditionally starch is oxidized (commercially) using bleach as oxidant. This process involves chlorinated reactants and forms large amounts of waste (NaCl). Thus, to improve starch processing, new methods need to be explored. Here, a heterogeneous catalytic method is proposed, in which we use supported platinum-based catalysts and oxygen gas as oxidant.

The objective of this project is to establish property-performance relationships for starch oxidation over heterogeneous Pt-based catalysts. As a first step, we opt to investigate the role of the catalyst's properties (support polarity, Pt particle size) and size of the starch molecule.

Highlight of the past year

We have previously shown that starch can be oxidized using oxygen over a Pt catalyst. The rate and yield of this reaction is determined by the properties of the substrate, such as the size of starch molecule (Figure 1).

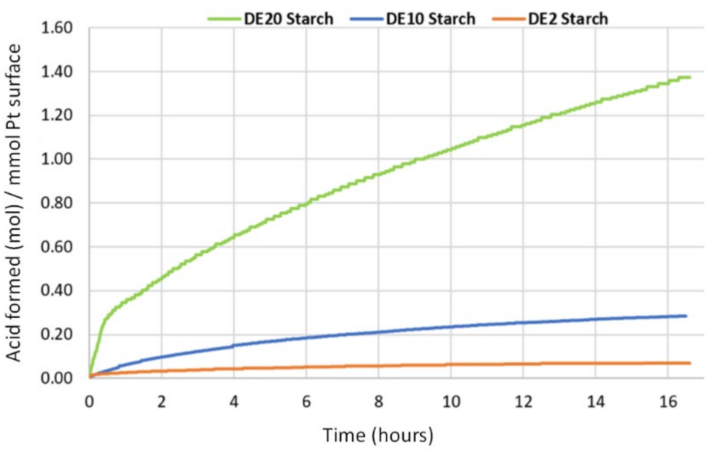


Figure 1: Oxidation of 3 starches with different size (DE2>DE10>DE20) over time with a Pt catalyst. The amount of acid formed (Y-axis) is indicative of the amount of oxidized substrate

Currently, more research is performed on the following aspects:

- Controlled modification of the catalyst properties, in order to establish a correlation between the properties and the catalytic activity for the desired reaction
- Pre-treatment of starch, in order to identify substrate-related factors that control the rate and selectivity for the desired reaction

Type of student projects envisioned

This research is part of an interdisciplinary study, which combines experimental and modeling methodologies. Here, the focus is on the former. Research projects within this topic can involve laboratory techniques for catalyst synthesis and surface characterization, chemical modification of starch, and laboratory-scale experiments for glucose and starch conversion, using novel catalysts.

Mixed metal carbides for biomass

Name PhD/PD: Marlene Führer
Involved staff members: Prof. dr. Harry Bitter, dr.ir. Tomas van Haasterecht
Project sponsor: NWO & FAPESP
Start/(expected) end date of project: September 2018- September 2022

Background and goal of project

Transition metal carbides are viable replacements for scare noble metals in catalysts. For example, it has been shown that transition metal carbides catalysts were active for decarboxylation/ decarbonylation and hydrodeoxygenation of triglyceride-based feedstock to alkanes and alkenes.[1] Interestingly, when comparing the supported W-carbides to the supported Mo-carbides catalysts the former ones were more selective (>50%) towards the higher valued alkenes, while the latter were more active but less selective to the desired alkenes. In our research we want to combine the benefits of both catalysts by using mixed MoW carbides.

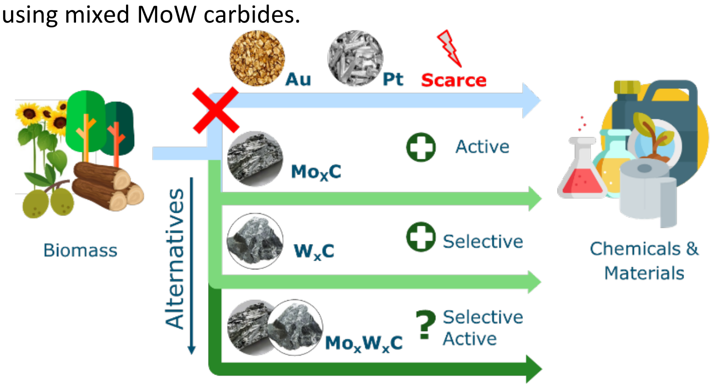


Figure 1. Alternative hetergenous catalyst for deoxygenation reactions

Highlight of the past year

Bimetallic MoW-carbide supported on carbon nanofibers were prepared by the temperature programmed reduction method while using methane as carbon source. So far, we focused on catalysts with a 1:1 molar ration of Mo and W. Figure 2 displays the catalytic performance of the monometallic catalysts and that of the bimetallic catalyst for the hydrodeoxygenation of stearic acid. The catalytic activity of the bimetallic carbide is close to that of W-carbide catalyst. Interestingly, the bimetallic catalyst has a high selectivity towards C18-oxygenates, such as octadecanol and octadecanal, even after longer reaction times (4h) and high conversion (100%). In comparison, Mo-carbide also produces C18-oxygenates in high yields as initial intermediate, but after 4 h C18-oxygenates were not observed anymore. The W-carbide shows only small amounts of C18-oxygenates in the first 2 h.
In the next period we will investigate to which extent the selectivity is tunable by changing the synthesis method (e.g. using different metal ratio) and/or using different reaction conditions (e.g. H_2 pressure).

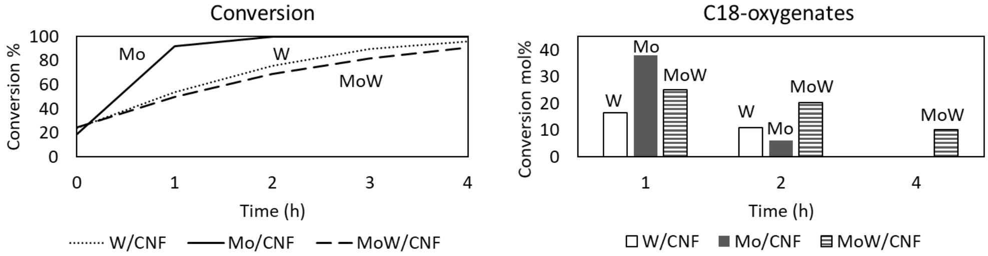


Figure 2. Stearic acid conversion over Mo/CNF, W/CNF and MoW/CNF (250 mg catalyst, 2 g stearic acid, 50 mL solvent, 30 bar H_2, T = 350 °C).

Type of student projects envisioned

A thesis within this project involves mostly lab work including catalyst synthesis, characterization with techniques like XRD, TEM, N_2 physiporption and chemisoprtion. Sofar the deoxygenation reactions are evaluated in a batch system. However, we are aiming to set up a plug flow system in the following year.

Processing of feathers to proteins – from fundamental insight to application

Name PhD: Xinhua Goerner-Hu
Involved staff members: Scott, E; Schneider, O; Haasterecht, T; Bitter,H
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, the secondary structure. Goal of our project is to understand the change of secondary structure of feathers during the processing, to investigate the effect of selected process parameters on structural change, the effect of structural change on availability for enzymatic hydrolysis (AEH) and to adapt and implement the knowledge into commercial feather production.

Highlight of the past year

The relationship between industrially relevant process conditions and changes in the secondary structure of feathers during thermal pressure hydrolysis was investigated. The content of ß-sheet decreased under prolonged process conditions whereas the content of α-helix increased (Fig. 1). The decreased ß-sheet content and increased α-helix content affected positively the availability for enzymatic hydrolysis (Fig. 2).

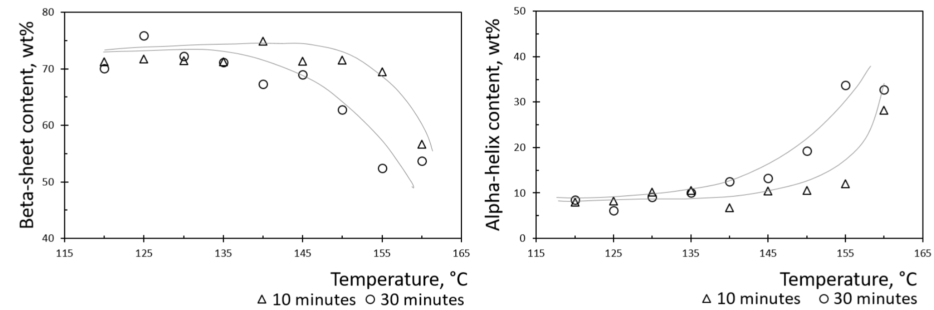


Figure 1: The effect of temperature on ß-sheet and α-helix.

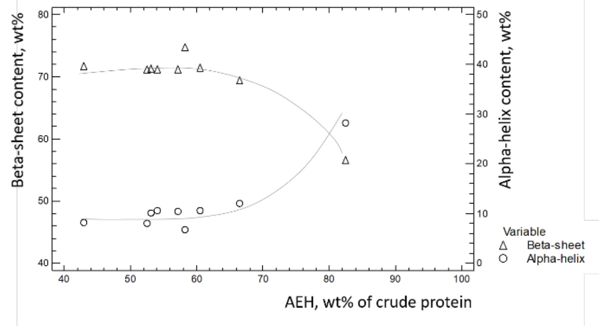


Figure 2: The inverse structural change of ß-sheet and α-helix content during the processing as well as the effect of structural change on AEH.

Type of student projects envisioned

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

Bioelectrochemical chain elongation of CO2 to caproate: Electrification of biotechnology

Name PhD: 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

As the world population increases, more sustainable ways to produce chemicals are needed. The emmisions of greenhouse gases such as CO_2 need to be decreased enable to circulize our economy. A promising process for the decrease of CO_2 emissions is carbon capture and utilization. During our study, CO_2 is fed to a microbial electrosynthesis system. This system consists of an anode where an electron flow is created that is supplied to the cathode, where a biofilm grows (Figure 1). The biofilm uses the electrons for the elongation of CO_2 to fatty acids. The desired end product of the microbial conversions is caproate, a six-carbon fatty acid that can be used as platform chemical, animal feed additive or as precursor for fuel production.

The goal of the PhD project is to study the role of the biofilm and the changes therein in the optimization of the electron flux between the cathode and the biofilm. Gaining insights on the working mechanisms will provide steering tools to optimize the system in the lab and work towards practical application.

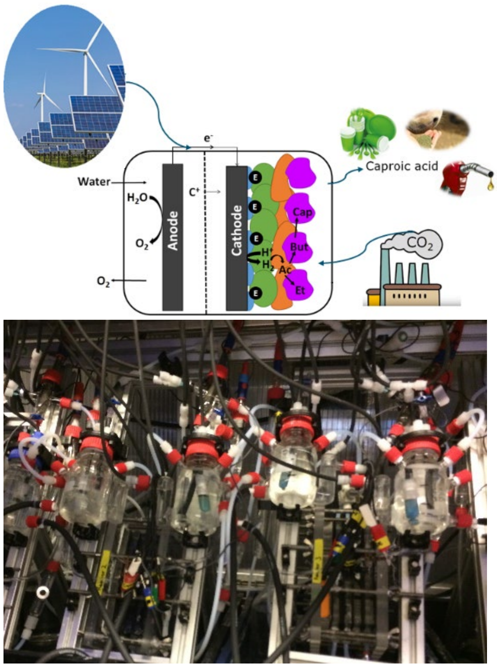


Figure 1. Schematic (top) and lab (bottom) setup of the microbial electrosynthesis system.

Highlight of the past year

We found out that with the reductive conditions at the cathode, the concentrations of metals that are supplied as trace elements for the bacteria decrease in the catholyte (Figure 2). Possibly the reduction of the metal species from the medium causes their deposition on the cathode. The current increases during the decrease of metal species from the catholyte, suggesting that the deposited metals can form electrocatalysts.

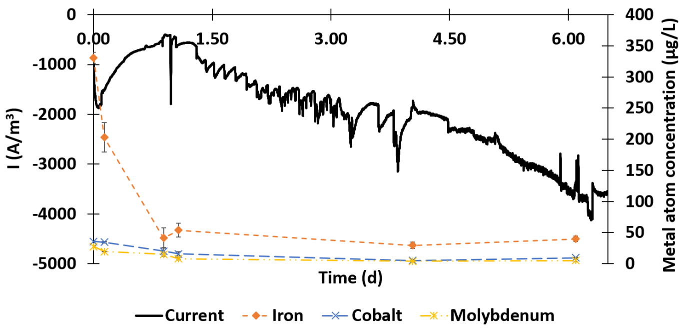


Figure 2. Current and catholyte concentrations of iron, cobalt and molybdenum during startup of an abiotic CO_2 fed reactor.

Type of 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 microbial and electrochemical processes occurring at the cathode. Analysis of the system is done using chromatography, microscopy, sequencing of the microbial community and spectometry. Model studies can be performed to understand underlying chemical or thermodynamic mechanisms.

Biobased Soft Materials

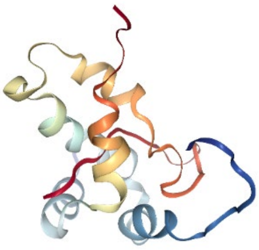
Team Leader: Dr. Costas Nikiforidis
PhD students: Laura Schijven, Eleni Ntone, Simha Sridharan, Umay Sevgi Vardar-Kule
Contact: costas.nikiforidis@wur.nl

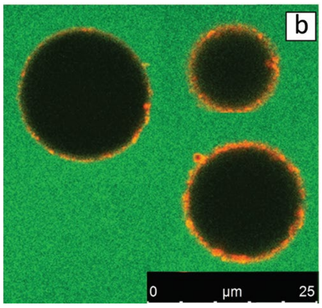
Background and goal

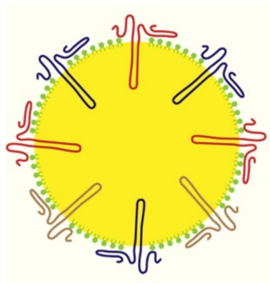
The Biobased Soft Materials team is interested in the understanding at a fundamental level of the structure-properties relationship of complex systems composed by biobased polymers, colloids and surfactants. We extract the natural complex systems from undervalued biomass. Their self-assembly and equilibrium properties are investigated from a soft matter physics and chemistry perspective at multiple length scales, from molecular to macroscopic.

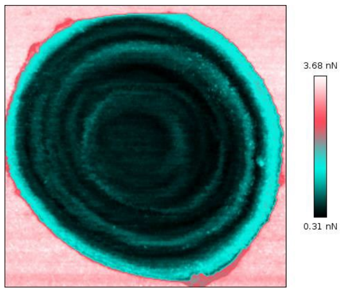
The self-organization of the biobased soft materials is experimentally analysed by employing techniques such as static and dynamic light scattering, interfacial and bulk rheology, as well as atomic force, confocal, scanning and transmission electron microscopy.

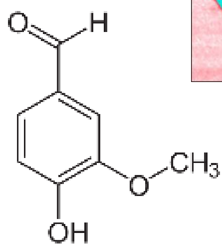
Our research aims to lead towards environmental friendly materials with advanced properties.





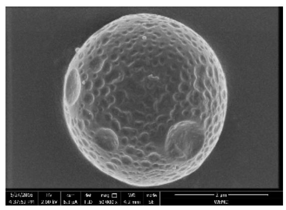






Main topics

- Stimuli responsive protein particles
- Protein/starch complexes for oil-water interfaces
- Protein mixtures to stabilize oil-in-water emulsions
- Behaviour of oleosomes on interfaces
- Molecular interactions on oleosome particle surface
- Natural carriers of hydrophobic molecules
- Design oil droplets resistant to lipid oxidation
- Lipoproteins as nanocarriers of therapeutic agents and diagnostics



Students project envisioned

Thesis subjects are related to the research work of PhD students of the team including experimental work and in some cases numerical modeling.

Hen egg yolk high-density lipoprotein as carrier of nanoparticles

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

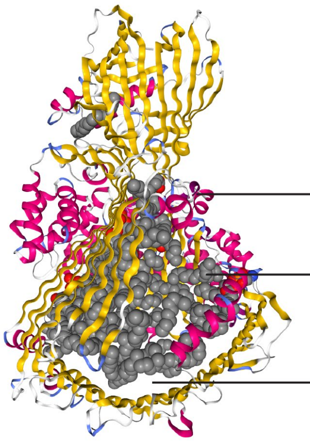
Background and goal of the project

Lipoproteins are assemblies of protein molecules that form a hydrophobic core, which main function is lipid transportation in organisms. Besides lipids, the unique structure of lipoproteins could potentially be used to host hydrophobic (macro)molecules or even nanoparticles. Human-based high-density lipoproteins (HDLs) are already used for encapsulation of therapeutic agents and NPs.[1] Unfortunately, current extraction methods of human HDL are rather complicated, resulting in low yields, and could potentially contain remaining pathogens from blood. Hen egg yolk, however, contains significant amounts of HDL, which is easy to extract and potentially have the same properties.

In this project we study the extraction and characterization of hen egg yolk HDL. This will lead towards the application of HDL as nanocarrier. We aim for incorporation of nanoparticles into HDL by using different methods. The hybrid nanoparticle-HDL structures are characterizated using different methods, like electron microscopy, gel electrophoresis, dynamic light scattering and optical spectroscopy.

Highlight of the past year

- Phospholipids are important for the stability of HDL
- Lipoprotein allows fluorescent labelling
- Different methods were studied to encapsulate nanoparticles
- Different types of nanoparticls were synthesized to study the encapsulation by HDL



Type of student projects envisioned

Available projects for students include lab work, focusing on nanoparticle synthesis (for example, quantum dots or magnetic nanoparticles), encapsulating the nanoparticles by egg yolk HDL and investigation on the nanoparticle-HDL properties under various conditions.

[1] Cormode, D.P., et al., Nanocrystal core high-density lipoproteins: a multimodality contrast agent platform. Nano letters, 2008. 8(11): p. 3715-3723.

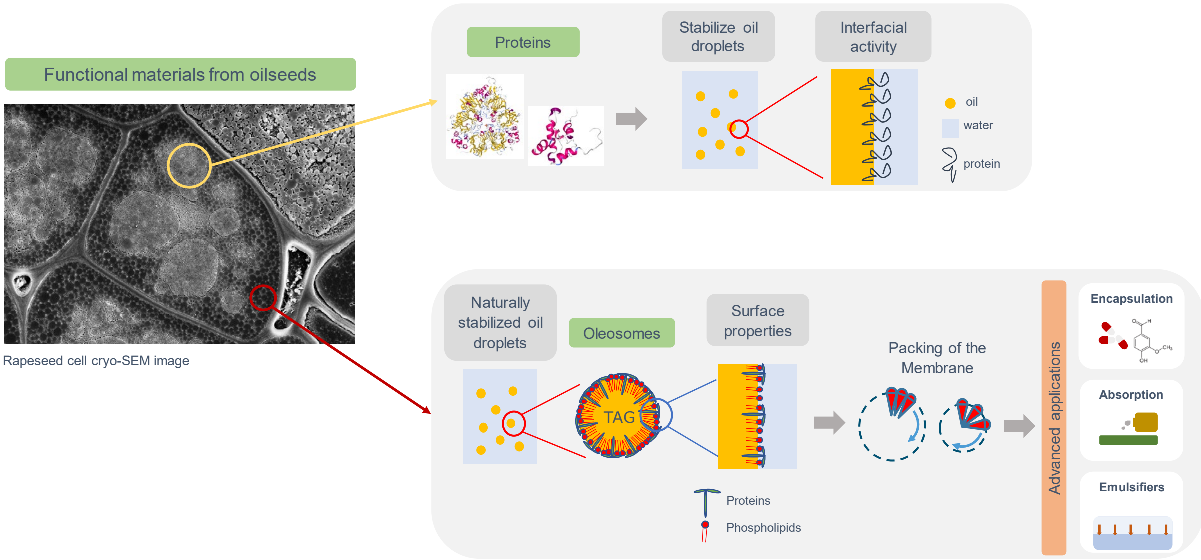
Functional materials from oilseeds for advances applications

Name PhD: Eleni Ntone
Involved staff members: dr. Costas Nikiforidis, Prof. dr.Harry Bitter
Project sponsor: NWO-TIFN
Start/(expected) end date of project: September 2017/September 2021

Background and goal of the project

To meet the future sustainability demands, the transition from animal-derived ingredients to those of plant origin is required[1]. Animal-derived ingredients are being employed both in the food and pharmaceutical industry, with the prominent example of using dairy proteins to stabilize oil-in-water emulsions. However, to obtain proteins from plant matrices requires different treatment routes than those of animal[2], which results in multicomponent mixtures rather than pure protein systems. Therefore, in this project, we aim to investigate the interfacial properties and emulsifying activity of protein mixtures derived from oilseeds (rapeseeds).

Besides proteins, oilseeds store triacylglycerols in particles called oleosomes. Oleosomes have a unique protein/phospholipid monolayer at the surface, which is responsible for their high chemical and physical stability. Thus, intact oleosomes are extracted and the structural role of the molecules on their surface is investigated. This knowledge will be used to tune the physicochemical properties of oleosomes and exploit them in multiple advanced applications, like absorption and carrying of sensitive molecules[3].



Highlights of the past year

- By using an alternative extraction method, rapeseed proteins and oleosomes were simultaneously extracted in high yields while their inherent physicochemical properties were preserved.
- Rapeseed protein mixtures can stabilize O/W interfaces in the same way as pure proteins.
- The oleosome membrane can be tuned by altering the geometry and packing of the molecules on the interface.

Type of student projects envisioned

Available projects for students include lab work, focusing on emulsifying and interfacial properties of the protein mixtures and on the physicochemical properties of the oleosomes.

1. Poore J, Nemecek T. Reducing food's environmental impacts through producers and consumers. Science (80-). 2018;360(6392):987-992. doi:10.1126/science.aaq0216
2. Campbell KA, Glatz CE, Johnson LA, et al. Advances in aqueous extraction processing of soybeans. J Am Oil Chem Soc. 2011;88(4):449-465. doi:10.1007/s11746-010-1724-5
3. Nikiforidis C V. Structure and functions of oleosomes (oil bodies). Adv Colloid Interface Sci. 2019;274:102039. doi:10.1016/j.cis.2019.102039

Pea protein mixtures as emulsifiers of oil-water systems

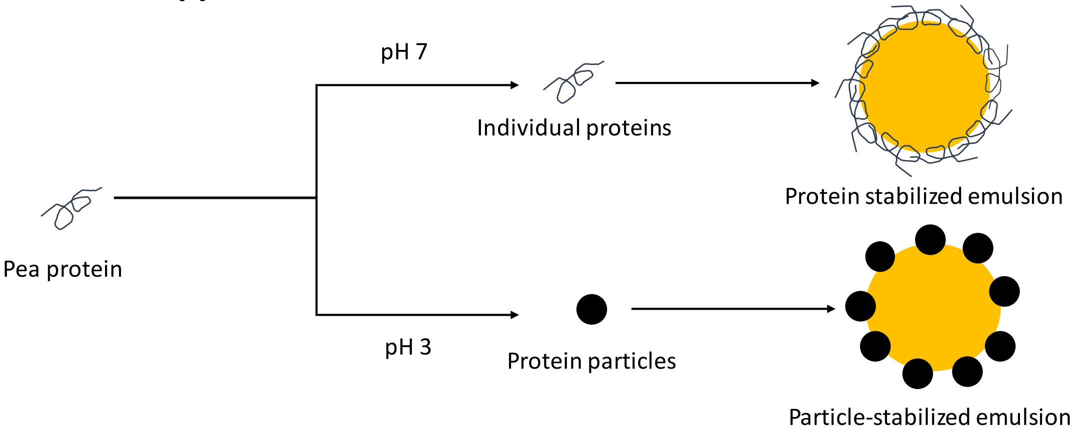
Name PhD: Simha Sridharan
Involved staff members: dr. Costas Nikiforidis, Prof. dr. Harry Bitter
Project sponsor: TiFN
Start/(expected) end date of project: Oct 2017-Oct 2021

Background and goal of the project

Proteins are integral parts of food and pharmaceutical formulations. Traditionally, animal proteins are used, however, demand has been raising for plant-based proteins for health and environmental reasons. Therefore, research in the recent years has focused on the functionality of plant proteins, such as emulsifying, foaming and encapsulation properties. This project focusses on the properties of mildly purified pea protein ingredients and are compared to those of purified protein systems.

Highlight of the past year

- Pea flour can stabilise oil-in-water emulsions, without the necessity to extract the proteins.
- The emulsifying properties of proteins in the pea flour were similar to the purified ones.
- Pea proteins formed low density particles at pH 3 with unique emulsion stabilizing and viscosity modifying properties.
- First article of this research project was published on the use of pea flour as emulsifier of oil-in-water emulsion[2].



Type of student projects envisioned

Student projects will focus on the response of the protein assemblies at different pH values.. The investigation of the underlying mechanism of the formation of the protein particle will help understanding the physicochemical interactions between protein molecules and can be utilized to produce biobased carriers of sensitive molecules. Techniques such as microscopy, Dynamic light scattering would be used for these projects.

[1] A.J. Van Der Goot, 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, R.M. Boom, Concepts for further sustainable production of foods, J. Food Eng. (2016). doi:10.1016/j.jfoodeng.2015.07.010.

[2] S. Sridharan, M.B.J. Meinders, J.H. Bitter, C. V. Nikiforidis, Native pea flour as stabilizer of oil-in-water emulsions: No protein purification necessary, Food Hydrocoll. 101 (2019) 105533. doi:10.1016/j.foodhyd.2019.105533.

Oleosomes as carriers of therapeutics

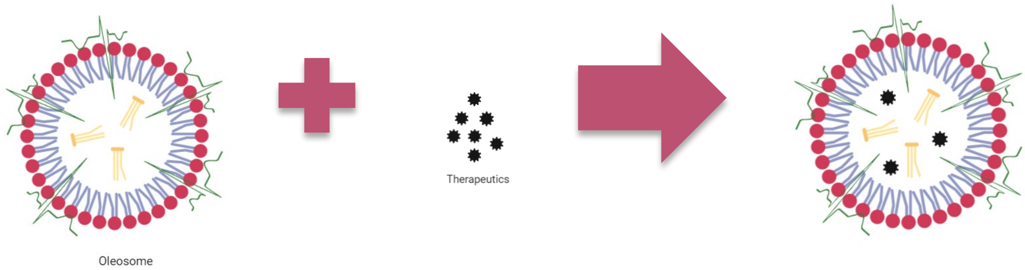
Name PhD/PD: Umay Sevgi Vardar-Kule
Involved staff members: dr. Costas Nikiforidis, prof. dr. Harry Bitter
Project sponsor: Ministry of Education (Republic of Turkey)
Start/(expected) end date of project: September 2019-September 2023

Background and goal of the project

Several lipophilic therapeutics exhibit low bioavailability and cannot reach in their original form their target due to instability or poor solubility[1]. Formulations with a lipid core have been used to overcome the limitations and to improve the bioavailability and stability of the lipophilic compounds, which include micro- or nanoemulsions, micelles, liposomes and solid lipid nanoparticles[1].

An alternative natural carrier, could be oleosomes. Oleosomes have an oil core surrounded by a half-membrane of phospholipids and proteins and are extracted from oleaginous seeds or nuts. The oleosome membrane is selectively permeable to lipophilic molecules, making them great carriers of these molecules[3].

Therefore, the aim of this project is the loading of lipophilic compounds into oleosomes, their physicochemical stability and the targeted delivery and release of the lipophilic compounds. The project also includes the mathematical modeling of the diffusion kinetics through the oleosome membrane.



Highlight of the past year

The project just started.

Type of student projects envisioned

Student projects include lab work (extraction and characterization of oleosomes, encapsulation of lipophilic compounds, investigation of oleosome membrane dynamics) and mathematical modeling of the encapsulation and release kinetics.

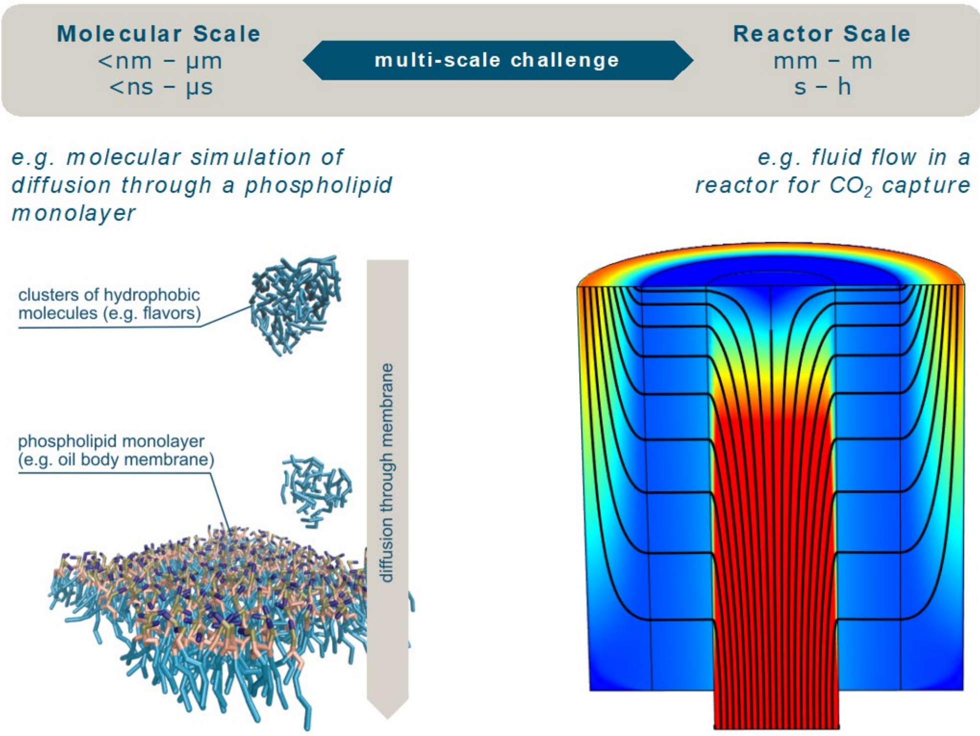
1. Cho H., Lee T., Yoon J., Han Z., Rabie H., Lee K., Su W., and Choi J., Magnetic Oleosome as a 99Functional Lipophilic Drug Carrier for Cancer Therapy, ACS Applied Materials & Interfaces 2018, DOI:10.1021/acsami.7b19255
2. Acevedo F., Rubilar M., Jofré I., Villarroel M.,Navarrete P., Esparza M., Romero F., Vilches E. A., Acevedo V. and Shene C., Oil bodies as a potential microencapsulation carrier for astaxanthin stabilisation and safe delivery, Journal of Microencapsulation 2014, DOI:10.3109/02652048.2013.879931
3. Nikiforidis C.V., Structure and functions of oleosomes (oil bodies), *Advances in Colloid and Interface Science* 2019, https://doi.org/10.1016/j.cis.2019.102039

Technology

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

Background and goal of this theme

In the BCT technology team we make sure that the (electro)catalysts and conversion processes developed in the other themes will also work at the application scale. Therefore, we want to understand, model, and steer the coupled flow, heat and mass transfer, and reaction processes during biomass conversion to improve existing and design new reactor technologies for a circular economy. Within the team, we regularly apply and develop computer models at the molecular (≤ µm) as well as on the reactor scale (mm–m). Recently, we also started to work on electrocatalytic conversions in which charge transport is relevant.



Main topics

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

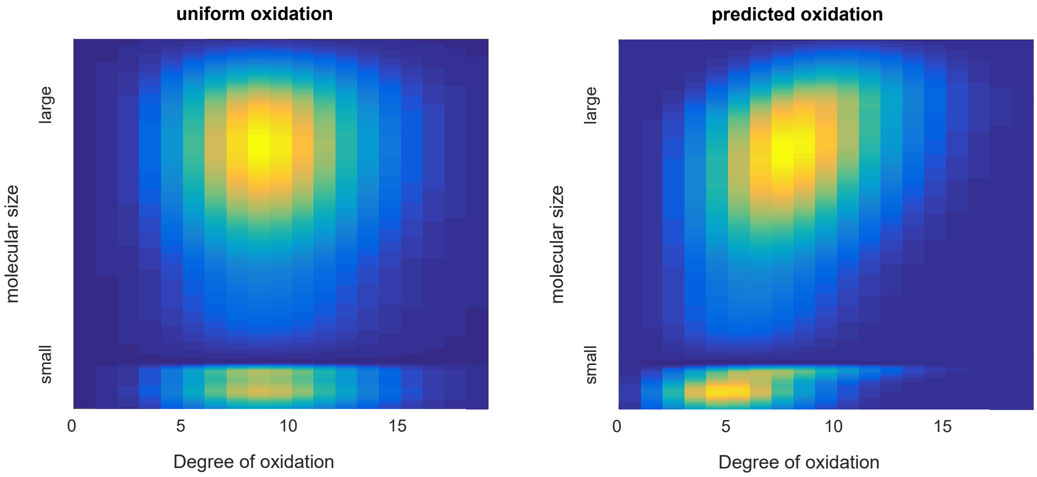
Thesis subjects are related to the research work of PhD-students and Postdocs in the Technology theme or in cooperation to the other BCT themes.

Selective polysaccharide oxidation – new catalysts and new chains

Name PhD: Tim Hoogstad
Involved staff members: Lars Kiewidt, Piet Buwalda, Harry Bitter
Project sponsors: NWO, Avebe
Start/(expected) end date of project: 01-2016 till 05-2020

Background and goal of project
Anionic (negatively charged) starches are used as a biobased replacement for the petrochemically based polyacrylates and polyacrylamides. These anionic starches have a wide range of applications. Most notable are the uses in paper industry to improve printability of paper, and as a food additive where they are used as thickener, or vegetarian gelatin replacement. Other niche applications include wastewater treatment, superabsorbents, and drilling fluids.
These anionic starches are produced by oxidising gelatenized starch. Currently, the oxidation is done with bleach, a strong chemical oxidant. However, because of the use of this strong chemical oxidant, and the resulting by-products like salt, this process has a high environmental impact. Therefore, in this project, we aim to develop an alternative oxidation process based on heterogeneous catalysis. This new process would have the advantage of oxidising the starch with molecular oxygen (O_2) instead of bleach, resulting in a more environmentally friendly process. My role in this project is to gain insight in the behaviour of starch during chemical processes through modeling.

Highlight of the past year
I authored a scientific paper that shows the proof of principle of how the polydispersity of starch, i.e. the presence of a wide range of molecular sizes in one mixture, influences the reaction, and how to model these effects.
In the paper we show that starch molecules of different size behave differently during chemical modification and that, as a result, the product distribution becomes skewed. The figure shows a predicted product distribution of a conventional modeling approach using average molecule sizes and reaction rates (left), and of the developed model that takes molecule polydispersity into account (right).



Type of student projects envisioned
Considering the project end-date, no projects are available on this exact topic. However, for related projects on starch oxidation please contact Lars Kiewidt.

Modeling 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/end date of project: November 2017/November 2019

Background and goal of project

The "Carbon Capture from Air" (CAIR) project was a cooperation between our group Biobased Chemistry & Technology (BCT) and the companies Antecy and Bronswerk Heat Transfer. In this DAC process, ambient air is guided through a reactor containing the adsorbent potassium carbonate (K2CO3) on activated carbon (AC) as porous solid support. CO2 is captured from air by adsorption in a packed bed reactor. The aim of this project is to design a CO2 negative technology for CO2 capture from air and subsequent utilization of the CO2. During the project, we were able to identify the main bottlenecks of the process and propose alternatives for its optimization.

Highlight of the past year

In previous years, a fundamental thermodynamic model was created to determine the main bottlenecks of the process and the type of materials that should be developed. Additionally, a heat integration system (heat pump) was designed in Aspen Plus to reduce the energy requirement during desorption. During this last year, different reaction mechanism for the desorption were analyzed and coupled with the desorption energy required. Figure 1 shows the case for the hydrated-reaction mechanism for the desorption with steam and steam+nitrogen.

$$K_2CO_3{*}1.5\ H_2O + CO_2 \leftrightharpoons 2\ KHCO_3 + 0.5\ H_2O$$

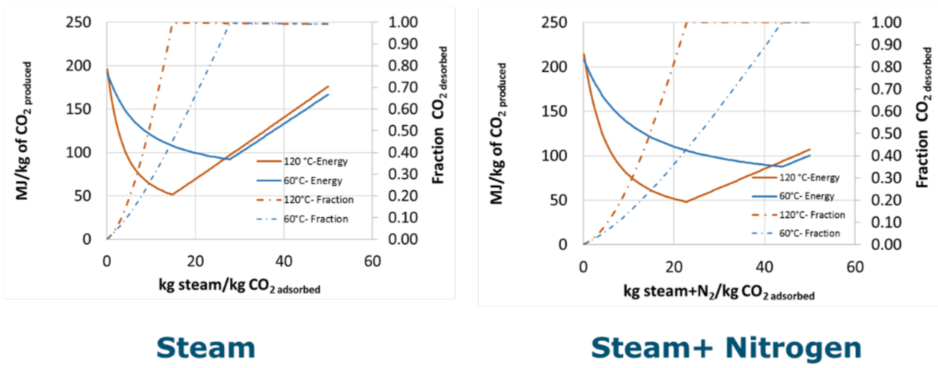


Figure 1. Energy required to desorbed CO2 from an adsorbent with 0.5 mmol/g capacity withiun a 100 mbar vaccuum and final pressure CO2 of 30 bar.

Type of student projects envisioned

The focus of the project was on investigating the reaction mechanism, kinetics, and potential diffusion limitations in the process. Models were created in COMSOL, Matlab and Aspen Plus. Even though the project ended this year, similar approaches are executed for other topics. If you are interest you can contact us.
Contact: carlos.cabrerarodriguez@wur.nl

Electro-conversion of biobased feeds into valuable platform chemicals

Name PhD: Matthijs van der Ham
Involved staff members: Prof. Dr. Harry Bitter (BCT-WUR), Dr. Lars Kiewidt (BCT-WUR), Prof. Dr. Marc Koper (CASC-UL)
Project sponsor: NWO-TTW, AVEBE and TNO
Start/(expected) end date of project: September 2019 - September 2023

Background and goal of project

80% of all industrial processes use one or more catalysts for the production of chemicals. The energy used in these processes is almost exclusively provided by heat generated from fossil resources. As electricity will become the main energy source in the near future, it would be more efficient to use electricity i.e. develop electrochemical processes to make chemicals. Various studies have already demonstrated the electrocatalytic conversions of organic molecules at room temperature (see Figure 1). However, these studies are often limited in three ways: 1) they focus on the conversion of small molecules, 2) they use low surface area electrodes of scarce noble metals and 3) they only concentrate on one half reaction, balancing the reaction with water reduction or oxidation (depending on the reaction of interest).

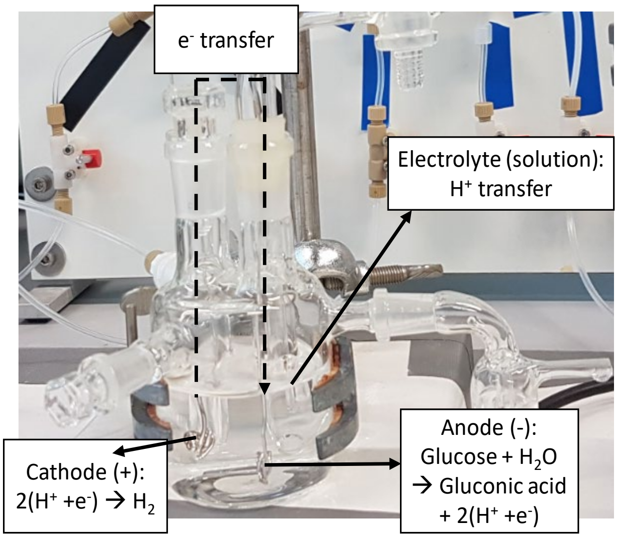


Figure 1. The electrocatalytic oxidation of glucose for the production of gluconic acid, balanced by hydrogen evolution (overall water reduction) using bulk electrodes.

Therefore, to make electrocatalytic processes more efficient with the minimum use of scarce noble metals this project aims at pairing an oxidation and reduction reaction of larger molecules, for the development of a paired electrolysis system (Figure 2) [1]. First, research will be performed to determine which value-added products can be produced with electrocatalytic oxidation and reduction reactions under various operational conditions from biomass-based feedstocks (glucose) using pure noble catalyst (Pt and Pd). The next step will be to synthesise and thoroughly analyse high surface area carbon supports covered with various sizes of nanosized Pt and Pd particles. These materials will be used as high surface area electrodes and used to research the effect of catalyst particle size on catalyst performance, i.e. catalyst stability, selectivity and activity.

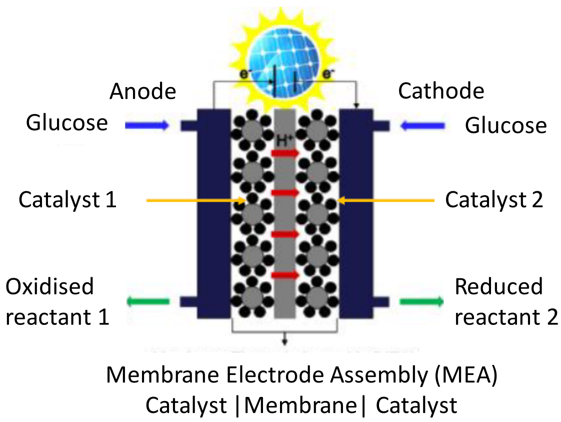


Figure 2. A paired electrolysis cell for the oxidation and reduction of glucose using high surface area electrodes (catalysts deposited on carbon support), separated by a membrane [1].

Type of student projects envisioned

To create a paired electrolysis cell with high surface area electrodes, projects are available that investigate the products that can be produced from glucose under various operational conditions (potential, pH, T, type of catalyst) using electrocatlysis, and synthesise high surface area electrodes and research their catalytic performance.

[1] Kwon, Youngkook, et al. "Electrocatalytic conversion of furanic compounds." *ACS Catalysis* 6.10 (2016): 6704-6717.

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-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
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
YEI-60312	Research Master Cluster: Proposal Writing
YML-31304	Frontiers in Molecular Life Sciences

BCT: Biobased Chemistry and Technology
FTE: Farm Technology
PCC: Physical Chemistry and Soft Matter
YML: Molecular Life Sciences
BPE: Bioprocess Engineering
ORC: Organic Chemistry
YEI: Educational Institute

BSc Theses

- Bootsma, Epke; Chitin nanocrystals as a support structure for copper nanoparticles
- Hooch Antink, Martijn; Modelling a methanol synthesis reactor subsequent to a direct air capture unit
- Cloudt, Hugo; Modelling the use of nitrogen in the desorption medium applied after capturing CO2 from air by adsorption
- Draijer, Koen; Influence of synthesis on carbon supported Mo-W carbide catalysts for the hydrodeoxygenation of stearic acid
- Bakker, Simon; The influence of zinc chloride pre-treatment on lignin oil obtained from wheat straw
- Natrop, Fleur; The effect of protein removal on the hydrogenation of seaweed to sugar alcohols
- Hooch Antink, Bart; Modelling the influence of oxygen solubility and diffusion on the oxidation of starch with molecular oxygen in a porous Pt/C catalyst
- Roekel, Derk van; Bio-refinery of seaweed
- Apon, Peter; Modelling the climatological effects on the variable costs of the KeniAquaPonic System

MSc Theses

- Veldhuizen, Zoë; Preventing Chitin Nanoparticle Aggregation for Future Bionanocomposites
- Monkelbaan, Christiaan; Membrane Behaviour of Rapeseed Oleosomes Under Applied Stress Conditions
- Gani, Kindi Pyta; Rapeseed protein mixtures as emulsifiers in oil-in-water systems at pH 3.8
- Leeuwen, Lotta van; Urban bio-waste integration in a PV-wind electricity system
- Azzouani, Achraf; Interfacial properties of pea protein mixtures at oil-water interfaces
- Woolschot, Sep; Catalytic Decarboxylation of Amino Acids
- Noord, Aster van; Transport and conversion of polydisperse feedstock in porous catalysts
- Vossen, Eduard van der, Investigating the intrinsic reaction kinetics of CO2 uptake by K2CO3 in direct air capture
- Rosenbaum, Benjamin: Encapsulation kinetics of hydrophobic compounds in oil bodies through molecular dynamical simulations
- Hijmans, Samuel; The heterogeneously catalysed oxidation of soluble potato starches on Pt/AC
- Meijs, Viktor; Direct air capture energy savings through the use of a heat pump system
- Hommel, Jesper; Yellow pea flour protein mixture as emulsifier in oil-in-water emulsions
- Wesel, Tessa van; Emulsifying properties of mildly extracted rapeseed protein mixtures
- Kakes, Rutger; Prediction of pipe degradation based on inline ultrasonic inspections
- Beelen, Moniek; Travelling acoustic waves for selective particle separation

PhD theses

- Amankwah, Emmanuel; Drying of yam with solar adsorption system
- Karefyllakis, Dimitris; Mildly derived ingredients for the utilization of oilseed material
- Moejes, Sanne; Redesign of the milk powder production chain: assessment of innovative technologies
- Souza Macedo, Luana; Molybdenum/tungsten-carbide and nickel-phosphide as emerging catalysts for deoxygenation reactions

Scientific Publications 2019

Refereed article in a journal

- Experimental Verification of Yam (Dioscorea rotundata) Drying with Solar Adsorption Drying
  Amankwah, Emmanuel ; Kyere, Gloria ; Kyeremateng, Herbert ; Boxtel, Anton Van (2019)
  Applied Sciences 9 (18).
- Beneficial use of dredged sediment to enhance salt marsh development by applying a 'Mud Motor'
  Baptist, Martin J. ; Gerkema, T. ; Prooijen, B.C. van; Maren, D.S. van; Regteren, M. van; Schulz, K. ; Colosimo, I. ; Vroom, J. ; Kessel, T. van; Grasmeijer, B. ; Willemsen, P. ; Elschot, K. ; Groot, A.V. de; Cleveringa, J. ; Eekelen, E.M.M. van; Schuurman, F. ; Lange, H.J. de; Puijenbroek, M.E.B. van (2019)
  Ecological Engineering 127 . - p. 312 - 323.
- Optimal utilization of a boiler, combined heat and power installation, and heat buffers in horticultural greenhouses
  Beveren, P.J.M. van; Bontsema, J. ; Straten, G. van; Henten, E.J. van (2019)
  Computers and Electronics in Agriculture 162 . - p. 1035 - 1048.
- Estimation of the water cycle related to shale gas production under high data uncertainties : Dutch perspective
  Butkovskyi, Andrii ; Cirkel, Gijsbert ; Bozileva, Elvira ; Bruning, Harry ; Wezel, Annemarie P. Van; Rijnaarts, Huub H.M. (2019)
  Journal of Environmental Management 231 . - p. 483 - 493.
- Monitoring Support for Water Distribution Systems based on Pressure Sensor Data
  Geelen, Caspar V.C. ; Yntema, Doekle R. ; Molenaar, Jaap ; Keesman, Karel J. (2019)
  Water Resources Management 33 (10). - p. 3339 - 3353.
- A fully integrated simulation model of multi-loop aquaponics : A case study for system sizing in different environments
  Goddek, Simon ; Körner, Oliver (2019)
  Agricultural Systems 171 . - p. 143 - 154.
- Modelling Potato Protein Content for Large-Scale Bulk Storage Facilities
  Grubben, Nik L.M. ; Heeringen, Luc van; Keesman, Karel J. (2019)
  Potato Research 62 (3). - p. 333 - 344.
- A spatially distributed physical model for dynamic simulation of ventilated agro-material in bulk storage facilities
  Grubben, Nik L.M. ; Keesman, Karel J. (2019)
  Computers and Electronics in Agriculture 157 . - p. 380 - 391.
- Postharvest quality development of frying potatoes in a large-scale bulk storage facility
  Grubben, Nik L.M. ; Witte, Susan C.M. ; Keesman, Karel J. (2019)
  Postharvest Biology and Technology 149 . - p. 90 - 100.
- The effect of polydispersity on the conversion kinetics of starch oxidation and depolymerisation
  Hoogstad, T.M. ; Konings, G. ; Buwalda, P.L. ; Boxtel, A.J.B. ; Kiewidt, L. ; Bitter, J.H. (2019)
  Chemical Engineering Science: X 4 .
- Selective Particle Filtering in a Large Acoustophoretic Serpentine Channel
  Kandemir, M.H. ; Wagterveld, R.M. ; Yntema, D.R. ; Keesman, K.J. (2019)
  Scientific Reports 9 (1). - 1 p.
- Multicomponent emulsifiers from sunflower seeds
  Karefyllakis, Dimitris ; Goot, Atze Jan van der; Nikiforidis, Constantinos V. (2019)
  Current Opinion in Food Science 29 . - p. 35 - 41.
- The behaviour of sunflower oleosomes at the interfaces
  Karefyllakis, Dimitris ; Jan Van Der Goot, Atze ; Nikiforidis, Constantinos V. (2019)
  Soft Matter 15 (23). - p. 4639 - 4646.
- The emulsifying performance of mildly derived mixtures from sunflower seeds
  Karefyllakis, Dimitris ; Octaviana, Heidi ; Goot, Atze Jan van der; Nikiforidis, Constantinos V. (2019)
  Food Hydrocolloids 88 . - p. 75 - 85.

- [Development and validation of a physiologically based kinetic model for starting up and operation of the biological gas desulfurization process under haloalkaline conditions]()
  Kiragosyan, Karine ; Klok, Johannes B.M. ; Keesman, Karel J. ; Roman, P. ; Janssen, Albert J.H. (2019)
  Water Research 4 .
- [Inter-provincial electricity transmissions' co-benefit of national water savings in China]()
  Liao, Xiawei ; Chai, Li ; Jiang, Yu ; Ji, Junping ; Zhao, Xu (2019)
  Journal of Cleaner Production 229 . - p. 350 - 357.
- [Water footprint of the energy sector in China's two megalopolises]()
  Liao, Xiawei ; Zhao, Xu ; Jiang, Yu ; Liu, Yu ; Yi, Yujun ; Tillotson, Martin R. (2019)
  Ecological Modelling 391 . - p. 9 - 15.
- [Higher Chain Length Distribution in Debranched Type-3 Resistant Starches (RS3) Increases TLR Signaling and Supports Dendritic Cell Cytokine Production]()
  Lépine, Alexia F.P. ; Hilster, Roderick H.J. de; Leemhuis, Hans ; Oudhuis, Lizette ; Buwalda, Piet L. ; Vos, Paul de (2019)
  Molecular Nutrition & Food Research 63 (2).
- [Processing of Amaranthus hypochondriacus Biomass for Functional Protein Concentrates Development]()
  Metri-Ojeda, Jorge ; Nikiforidis, Costas ; Sandoval-Peraza, Mutkhar ; Chel-Guerrero, Luis ; Allende, Diana Baigts (2019)
  Journal of Food Research 8 (5).
- [Structure and functions of oleosomes (oil bodies)]()
  Nikiforidis, Constantinos V. (2019)
  Advances in Colloid and Interface Science 274 .
- [Coupled conjugate heat transfer and heat production in open-cell ceramic foams investigated using CFD]()
  Sinn, Christoph ; Pesch, Georg R. ; Thöming, Jorg ; Kiewidt, Lars (2019)
  International Journal of Heat and Mass Transfer 139 . - p. 600 - 612.
- [Activated Carbon, Carbon Nanofibers and Carbon-Covered Alumina as Support for W2C in Stearic Acid Hydrodeoxygenation]()
  Souza Macedo, Luana ; Teixeira Da Silva, Victor ; Bitter, Johannes Hendrik (2019)
  ChemEngineering 3 (1).
- [Influence of synthesis method on molybdenum carbide crystal structure and catalytic performance in stearic acid hydrodeoxygenation]()
  Souza Macedo, Luana ; Oliveira, Ricardo R. ; Haasterecht, Tomas van; Teixeira da Silva, Victor ; Bitter, Harry (2019)
  Applied Catalysis B-Environmental 241 . - p. 81 - 88.
- [Pea flour as stabilizer of oil-in-water emulsions : Protein purification unnecessary]()
  Sridharan, Simha ; Meinders, Marcel B.J. ; Bitter, Johannes H. ; Nikiforidis, Constantinos V. (2019)
  Food Hydrocolloids 101 .
- [An improved methodology to evaluate crop salt tolerance from field trials]()
  Straten, G. van; Vos, A.C. de; Rozema, J. ; Bruning, B. ; Bodegom, P.M. van (2019)
  Agricultural Water Management 213 . - p. 375 - 387.
- [Effect of pore size distribution and particle size of porous metal oxides on phosphate adsorption capacity and kinetics]()
  Suresh Kumar, Prashanth ; Korving, Leon ; Keesman, Karel J. ; Loosdrecht, Mark C.M. van; Witkamp, Geert Jan (2019)
  Chemical Engineering Journal 358 . - p. 160 - 169.
- [Exploring the treasure of plant molecules with integrated biorefineries]()
  Torres, Andres F. ; Xu, Xuan ; Nikiforidis, Constantinos V. ; Bitter, Johannes H. ; Trindade, Luisa M. (2019)
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  Willems, Stan B.J. ; Schijven, Laura M.I. ; Bunschoten, Anton ; Leeuwen, Fijs W.B. Van; Velders, Aldrik H. ; Saggiomo, Vittorio (2019)
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- Enzymatic fingerprinting of isomalto/malto-polysaccharides
  Zaal, P.H. van der; Klostermann, C.E. ; Schols, H.A. ; Bitter, J.H. ; Buwalda, P.L. (2019)
  Carbohydrate Polymers 205 . - p. 279 - 286.

PhD Theses

- Drying of yam with solar adsorption system
  Amankwah, Emmanuel Yaw Adu (2019)
  Wageningen University. Promotor(en): K.J. Keesman, co-promotor(en): A.J.B. van Boxtel; K.A. Dzisi; G. van Straten. - Wageningen : Wageningen University, - 138
- Mildly derived ingredients for the utilization of oilseed material
  Karefyllakis, Dimitris (2019)
  Wageningen University. Promotor(en): A.J. van der Goot, co-promotor(en): K. Nikiforidis. - Wageningen : Wageningen University, - 129
- Redesign of the milk powder production chain: assessment of innovative technologies
  Moejes, Sanne N. (2019)
  Wageningen University. Promotor(en): J.H. Bitter, co-promotor(en): A.J.B. van Boxtel. - Wageningen : Wageningen University, - 166
- Molybdenum/tungsten-carbide and nickel-phosphide as emerging catalysts for deoxygenation reactions
  Souza Macedo, Luana (2019)
  Wageningen University. Promotor(en): J.H. Bitter; V. Teixeira da Silva. - Wageningen : Wageningen University, - 195

Other output

Orals invited

Structure and functions of oleosomes (oil bodies)
Costas Nikiforidis, Technical University of Karlsruhe, Germany, 7/11/19

(non) Noble metal catalysts in biobased conversions
Harry Bitter, KU Leuven, Belgium, 27/9/19

From powder to production: supporting heterogeneous catalysts for high performance
Lars Kiewidt, Catalysis Connected, Utrecht, Netherlands, 27/8/19

Women in Science, A leaky pipeline?
Elinor Scott, VLAG, Wageningen, Netherlands, 23/4/19

Carbohydrate conversions: a combination of challenges
Harry Bitter, XXth NCCC The Netherlands' Catalysis and Chemistry Conference (2019), Noordwijkerhout, Netherlands, 6/3/19

Carbohydrate based conversions: From catalyst preparation to reactor design
Harry Bitter, University of Chemistry and Technology, Prague, Czech Republic, 24/1/19

Orals contributed

Circular ingredients: Upgrading food industry's side-streams to valuable ingredients
Carlos Cabrera Rodriguez
Chemistry As INnovating Science (CHAINS) 2019, Veldhoven, Netherlands, 10/12/19 - 11/12/19

Platinum based catalysts for oxidation of (poly)saccharide based feedstocks
Führer, M., van Haasterecht, T., Hijmans, S. & Bitter, J. H.
Chemistry As INnovating Science (CHAINS) 2019, Veldhoven, Netherlands, 10/12/19 - 11/12/19

Realistic energy requirements to recover CO2 from air: Thermodynamics of the adsorption process
Carlos I. Cabrera-Rodriguez, L. Kiewidt, T.van Haasterecht, N. Mosoud, JH. Bitter
Netherlands Process Technology Symposium - NPS16, Eindhoven, Netherlands, 30/10/19 - 31/10/19

Understanding starch oxidation through modelling of homogeneous and heterogeneous catalytic processes
Lars Kiewidt (Speaker)
Netherlands Process Technology Symposium - NPS16, Eindhoven, Netherlands, 30/10/19 - 31/10/19

Catalytic conversions of polydisperse feedstocks
Hoogstad, T., Van Noord, A., Buwalda, P. L., Kiewidt, L. & Bitter, J. H.,
EuropaCat 2019, Aachen, Germany, 18/08/19 - 23/08/19

The behaviour of sunflower oleosomes at the interfaces
Karefyllakis, Dimitris; Jan Van Der Goot, Atze; Nikiforidis, Constantinos V.
Delivery of Functionality 2019, Porto, Portugal, 7/07/19 - 11/07/19

Direct CO_2 capture from air - towards better sorbents
Masoud, N., Bordanaba Florit, G., van Haasterecht, T. & Bitter, J. H.
International Symposium on Green Chemistry 2019, La Rochelle, France, 13/05/19 - 17/05/19

Towards versatile, antibiotic-specific carbohydrate-formulations for decreasing antibiotics-use and side-effects
Silva Lagos, L., Klostermann, C., Schols, H., Bitter, J.H., Buwalda, P.L., Vos, de, P.
Carbohydrate Competence Center Symposium 2019, Groningen, Netherlands, 11/04/19

Assessing the influence of molecular size in the conversion of polydisperse feedstocks
Hoogstad, T., Van Noord, A., Buwalda, P. L., Kiewidt, L. & Bitter, J. H
XXth NCCC The Netherlands' Catalysis and Chemistry Conference (2019), Noordwijkerhout, Netherlands, 4/03/19 - 6/03/19

Monitoring gas/liquid segmented-flow with on-flow NMR spectroscopy
Wierda, G. J., Velders, A. H. & Bitter, J. H.
XXth NCCC The Netherlands' Catalysis and Chemistry Conference (2019), Noordwijkerhout, Netherlands, 4/03/19 - 6/03/19

Poster presentations

'Oxidation of polydisperse starch in porous catalysts: modelling hindered diffusion',
Van Noord, A., Hoogstad, T., Kiewidt, L., Bitter, J.H., XXth NCCC The Netherlands' Catalysis and Chemistry Conference (2019), Noordwijkerhout, Netherlands, 4/03/19 - 6/03/19

'The case of pea flour as emulsifier: Is protein purification necessary?'
Sridharan, L., Meinders, M., Bitter, J.H., Nikiforidis, K.
TiFN Retreat 2019: Success through community thinking, Hilvarenbeek, Netherlands, 11/09/19

'Dirty proteins: Rapeseed multicomponent emulsifiers'
Ntone, E., Bitter, J.H., Nikiforidis, K.
TiFN Retreat 2019: Success through community thinking, Hilvarenbeek, Netherlands, 11/09/19

'Direct CO_2 Capture from Air - Challenges and Opportunities of a Solid Sorbent'
Masoud, N., Cabrera Rodriguez, C., van Haasterecht, T., Kiewidt, L., van Boxtel, A., Bitter, J.H.
XXth NCCC The Netherlands' Catalysis and Chemistry Conference (2019), Noordwijkerhout, Netherlands, 4/03/19 - 6/03/19

'Direct CO_2 Capture from Air - Challenges and Opportunities of a Solid Sorbent'
Masoud, N., Cabrera Rodriguez, C., van Haasterecht, T., Kiewidt, L., van Boxtel, A., Bitter, J.H.
EuropaCat 2019, Aachen, Germany, 18/08/19 - 23/08/19

'Digestibility of resistant starch type 3 is affected by molecular weight, molecular weight distribution and crystal type'
Klostermann, C., Silva Lagos, L., Vos, de, P., Schols, H., Bitter, J.H., Buwalda, P.
7th symposium on the alpha-amylase family - Alamy_7, Smolenice, Slovakia, 29/9/19 - 3/10/19

'Pt on activated carbon for carbohydrate oxidation: effect of particle size and support surface chemistry'
Führer, M., Rodella, C., van Haasterecht, T., Bitter, J.H.
XXth NCCC The Netherlands' Catalysis and Chemistry Conference (2019), Noordwijkerhout, Netherlands, 4/03/19 - 6/03/19

'Pt on activated carbon for carbohydrate oxidation: effect of particle size and support surface chemistry'
Führer, M., Rodella, C., van Haasterecht, T., Bitter, J.H.
EuropaCat 2019, Aachen, Germany, 18/08/19 - 23/08/19

‘Tailoring electro-catalysts to biological conditions’
Chatzipanagiotou, K., Buisman, C., Strik, D., Bitter, J.H.
XXth NCCC The Netherlands' Catalysis and Chemistry Conference (2019), Noordwijkerhout, Netherlands, 4/03/19 - 6/03/19

‘Towards combining electro-catalytic and bio-electro-catalytic CO2 reduction: microbial growth-medium electrolyte enhances electro-catalytic conversion of CO2 to formate’
Chatzipanagiotou, K., Soekhoe, V., Strik, D., Buisman, C., Bitter, J.H.
EuropaCat 2019, Aachen, Germany, 18/08/19 - 23/08/19

‘CO2 capture from air and utilization: Thermodynamic boundaries of adsorption processes’
Cabrera Rodriguez, C., Kiewidt, L., van Haasterecht, T., Masoud, N., Bitter, J.H.
XXth NCCC The Netherlands' Catalysis and Chemistry Conference (2019), Noordwijkerhout, Netherlands, 4/03/19 - 6/03/19

‘Development of a nanoplastic filter by covalent modification of carbon surfaces’
Akkerman, L., Bekkering, E., Westert, D., Smulders, M., de Smet, L., Scott, E.
Chemistry As INnovating Science (CHAINS) 2019, Veldhoven, Netherlands, 10/12/19 - 11/12/19

Press/Media

Team NanopLESStic wins Holland Chemistry Student Competition 2019
https://www.nwo.nl/en/news-and-events/news/2019/12/team-nanoplesstic-wins-holland-chemistry-student-competition-2019.html
NWO, 11/12/19
Laura Akkerman, Ezra Bekkering, Dorien Westert, Louis de Smet, Maarten Smulders & Elinor Scott

Heeft Sint iets groens in petto?
Trouw, 3/12/19
Harry Bitter

Geluidsisolatie met vezels uit varkenspoep
https://edepot.wur.nl/506511
Resource, 7/11/19
Costas Nikiforidis & Martien van den Oever

Bio-ethanol: dit zijn de minpunten
https://www.quest.nl/tech/vervoer/a29315584/bio-ethanol-dit-zijn-de-minpunten/
Quest, 1/10/19
Harry Bitter

Bio-diesel gemaakt van fruitschillen
https://www.bnr.nl/nieuws/mobiliteit/10390811/op-zoek-naar-de-perfecte-katalysator-voor-hernieuwbare-energie
BNR Nieuwsradio, 26/09/19
Jacco van Haveren & Harry Bitter

‘Vergroening chemische industrie vereist radicale keuzes’: hernieuwbare grondstoffen, maar ook nieuwe processen
https://edepot.wur.nl/489160
Agro&Chemie 1/2 2019, 14/06/19
Johan Sanders

Sunflower seed more useful if cold-pressed
https://resource.wur.nl/en/show/Sunflower-seed-more-useful-if-cold-pressed.htm
Resouce, 6/06/19
Dimitris Karefyllakis & Costas Nikiforidis

ENose & NanopLESStic in finale Holland Chemistry Studentencompetitie
https://www.nwo.nl/actueel/nieuws/2019/06/enose--nanoplesstic-in-finale-holland-chemistry-studentencompetitie.html
NWO, 4/06/19
Ezra Bekkering, Dorien Westert, Laura Akkerman, Elinor Scott, Maarten Smulders & Louis de Smet

NWO funds Wageningen start-up's research
https://resource.wur.nl/en/science/show/NWO-funds-Wageningen-start-ups-research.htm
Resource, 11/01/19
Carlos Cabrera Rodriguez & Elinor Scott

Prizes

1st prize Holland Chemistry Student Competition 2019
Laura Akkerman (Recipient), Ezra Bekkering (Recipient) & Dorien Westert (Recipient)
Granting Organisations: Holland Chemistry and NWO
Chemistry As INnovating Science (CHAINS) 2019, Veldhoven, Netherlands, 10/12/19 - 11/12/19

3rd Prize poster: Digestibility of resistant starch type 3 is affected by molecular weight, molecular weight distribution and crystal type
Cynthia Klostermann (Recipient)
Granting Organisations: Slovak Academy of Sciences
7th symposium on the alpha-amylase family - Alamy_7, Smolenice, Slovakia, 29/9/19 - 3/10/19