Institute for Sustainable Process Technology

Public final report

Biorefinery Program

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1. Project data

Project number:	TKIBE01008
Project title:	Programma Bioraffinage
Project partners:	TKI-ISPT (penvoerder), Cosun, DSM, FrieslandCampina, Unilever, Wageningen University
Project period:	1 January 2013 – 31 December 2016 (after extension: 31 December 2018)

2. Summary of results

Bio-refinery is a crucial activity for the food industry. It enables the production of healthy ingredients and the recovery of valuable components (i.e. proteins) out of process streams. The main objective of the program was to realize new production concepts and technologies to harvest or recover valuable components in a sustainable and economical feasible manner. The research program consisted of five projects:

- **Process synthesis in the agro-food chain** - A new *in silico* methodology for optimizing agro-food processing chain for agro-material valorization combining logistics and processing was designed. It has been designed in such a way that it is possible to explore the trade-off between product portfolio value and energy consumption in different processing routes. An industrial case-study showed that with the software tool it is possible to determine the optimal balance between the amount of large production facilities and more smaller production facilities close to the crops.
- **Process selection tool mild fractionation technologies** - After a comprehensive literature study on proven technologies for separation and fractionation in the industry, all the technologies were evaluated on, amongst others, robustness, performance, applicability in food, availability, costs and know applications. This information is transformed into a user-friendly process selection was developed in Excel. With this tool the user can put in the characteristics of the raw material he wants to be fractionated and the desired results. As a result the process selection tool presents a list of most (estimated) appropriate process technologies.
- **High capacity industrial chromatography** – Chromatography is known as an effective method to separate different components on lab-scale. A lab-scale experimental set-up was made for evaluation of phenomena involved with chromatography for large scale separation in the food industry. Several experiments to evaluate the performance (i.e. column efficiency) as a function of process conditions and design were performed. The results were used to construct preliminary process models and design rules for industrial chromatography. This is an important step for robust and economical feasible recovery of high value components (proteins, organic acids) by industrial chromatography.
- **Bio-refinery of solid raw materials for food purposes** - The main goal of this activity was to prove that non-pure fractions of proteins and starches obtained by mild fractionation/bio-refinery techniques, can have good functionality in food products. Tests were executed to evaluate stabilizing and water-binding capacities in food products. In addition, sustainability analysis to verify if the mild bio-refinery process has a lower environmental input than the conventional refinery methods was performed. It was shown that emulsions stabilized by mildly refined protein fractions show good stability properties. In addition, non-starch polysaccharides showed an increasing effect on the shear viscosity, due to their water binding capacity. This is important to create texture in an

efficient and sustainable way. The case-study with a mixture of plant protein isolates and press cake gives improved stabilizer effects.

- **Membrane fractionation at high viscosities** - This activity focused on improving the performance of membrane separation processes: how to increase capacity of membrane operation (less fouling) in relation to physical properties of proteins and carbohydrates. An experimental set-up has been constructed to analyse a system containing proteins, ions and water. The effect of the process parameters on flux and ions rejection was determined. In addition, industrial case studies were defined. The interaction between solutes and membranes during the desalination of lactose has been quantified. This is one of the examples in which the application of membrane processes appeared to be hindered by fouling and inefficiency. Another result is the insight in the effect of viscosity and pore size distribution in the rejection of solutes. This knowledge is essential to come up with adequate measures for better performance of membrane processes. Membrane processes are considered as a key-process to improve the sustainability of the food sector. Several applications are foreseen such as: mild pasteurization, harvesting of valuable fractions from voluminous process streams, water removal, et cetera.

The parties are enthusiastic about the program results. As a consequence, in addition to the initial Bio-refinery Program, the consortium has initiated several new research activities on Bio-refinery related subjects! Besides, this year the partners are actively discussing the update of the technology roadmap for the next decade.

Figure 1 gives an impression of the scope and outlook of the cluster.

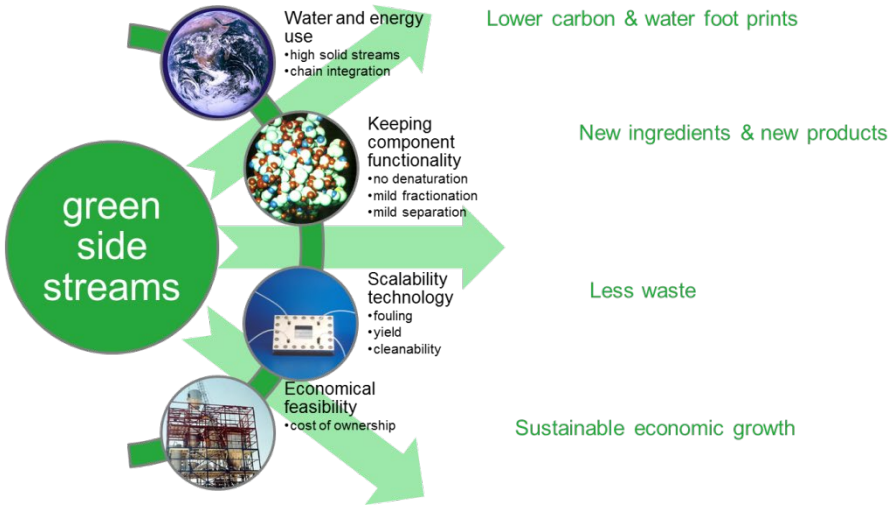

Figure 1. Illustration of the scope of activities within the program

3. Knowledge dissemination

The results of the program were published in several ways: scientific journals, theses, posters, papers at conference. In Appendix I a complete list of publication can be found.
Knowledge transfer was an essential part of the program execution. ISPT drafted a standard communication plan that provides some guidance and can be used as a 'template'. The goals and results of this project were shared with the ISPT community through newsflashes. The results of this project were disseminated in peer-reviewed literature and on (inter)national conferences, and with news items aimed at the general public.

4. Appendix I: Publications and communications

1. Jonkman, Jochem; Kanellopoulos, Argyris; Bloemhof, Jacqueline M.. 2019. "Designing an eco-efficient biomass-based supply chain using a multi-actor optimisation model". *Journal of Cleaner Production* 210: 1065-1075.
2. Jonkman, J.; Barbosa-Póvoa, A.P.; Bloemhof, J.M.. 2019. "Integrating harvesting decisions in the design of agro-food supply chains". *European Journal of Operational Research*.
3. Jochem Jonkman; Jacqueline M. Bloemhof; Jack G.A.J. van der Vorst; Albert van der Padt. 2017. "Selecting food process designs from a supply chain perspective". *Journal of Food Engineering* 195: 52-60
4. Lena Jankowiak; Jochem Jonkman; Francisco J. Rossier-Miranda; Atze Jan van der Goot; Remko M. Boom. 2014. "Exergy driven process synthesis for isoflavone recovery from okara". *Energy* 74: 471-483.
5. Jonkman, Jochem; Geerts, Marlies E.J.. 2017. "'Clean label' door milde raffinage – Mild fractioneren verduurzaamt bestanddelen". *VMT*, 2017/10/02: 32-33.
6. Jonkman, Jochem. 2017. "Niet blindstaren op procesefficiëntie – Logistieke verschuiving biedt kansen voor agrofood". *VMT*, 2017/06/02: 32-33.
7. Castiglioni, Alberto; Jonkman, Jochem; Akkerman, Renzo; van der Padt, Albert. 2018. "Selection of fractionation pathways and intermediates for mixed consumer products". In *Computer Aided Chemical Engineering*, editado por Friedl, Anton; Klemeš, Jirí J.; Radl, Stefan; Varbanov, Petar S.; Wallek, Thomas, 651-656. Elsevier
8. Jonkman, Jochem; Bloemhof, Jacqueline M.; van der Vorst, Jack G.A.J; van der Padt, Albert. 2015. "A Sustainability Driven Methodology for Process Synthesis in Agro-Food Industry". In *Computer Aided Chemical Engineering*, 1289-1294. Elsevier
9. Jonkman, Jochem; Kanellopoulos, Argyris; Bloemhof, Jacqueline M.; van der Padt, Albert. 2016. "Multi-actor logistic network design for sustainable agro-food processing chains". Trabalho apresentado em *1st Conference of the EURO Working Group on Sustainable Supply Chains*.
10. Jonkman, Jochem; Bloemhof, Jacqueline M.; van der Vorst, J.G.A.J.; van der Padt, Albert. 2015. "A sustainability driven methodology for process synthesis in agro-food industry". Trabalho apresentado em *12TH INTERNATIONAL SYMPOSIUM ON PROCESS SYSTEMS ENGINEERING & 25th EUROPEAN SYMPOSIUM ON COMPUTER AIDED PROCESS ENGINEERING*.
11. Jonkman, J. Bridging process engineering and supply chain design for agro-food processing chains. PhD Thesis Wageningen University 2018
12. Lecture: Decision support modelling for food processing chains. EURO2018 29th European Conference on Operational Research 2018
13. Lecture: Selection of fractionation pathways and intermediates for mixed consumer products. 28th European Symposium on Computer Aided Process Engineering 2018
14. Lecture: Evaluating new process configurations within the supply chain. ISPT Day 2017

15. Lecture: Integrated Process and Network Optimisation for Sustainable Food Supply Chains. EURO2015, 27th EUROPEAN CONFERENCE ON OPERATIONAL RESEARCH 2015
16. Assema, F. van. Process screening tool for next generation recovery. Poster ISPT dag 2016
17. Schultze-Jena A, Boon MA, Bussmann PJTh, Janssen AEM, Padt A van der. 2017. The counterintuitive role of extra-column volume in the determination of column efficiency and scaling of chromatographic processes, Journal of Chromatography A 1493: 49-56.
18. Schultze-Jena A, Boon MA, Winter, DAM de, Bussmann PJTh, Janssen AEM, Padt A van der. Submitted as Predicting intraparticle diffusivity as function of stationary phase characteristics in preparative chromatography.
19. Schultze-Jena A, Boon MA, Vroon RC, Bussmann PJTh, Janssen AEM, Padt A van der. Submitted as High viscosity preparative chromatography for food applications.
20. Schultze-Jena A, Boon MA, Vroon RC, Bussmann PJTh, Janssen AEM, Padt A van der. Submitted as Elevated viscosities in a simulated moving bed using ino-exclusion chromatography: a case study on gamma-aminobutyric acid recovery from tomato serum.
21. Schultze-Jena A, High viscosity industrial chromatography for mild food fractionation. PhD Thesis, Wageningen University 2019.
22. D. Karefyllakis, A.J. van der Goot, C.V. Nikiforidis, 2019, The behaviour of sunflower oil bodies at the interfaces, Soft Matter, accepted
23. D. Karefyllakis, H. Octaviana, A.J. van der Goot, C.V. Nikiforidis, 2019, The emulsifying performance of mildly derived mixtures from sunflower seeds, Food Hydrocolloids, 88 (2019) 75–85
24. M.E.J. Geerts, A. van Veghel, F.K. Zisopoulos, A. van der Padt, A.J. van der Goot, 2018, Exergetic comparison of three different processing routes for yellow pea (Pisum sativum): Functionality as driver in sustainable process design, Journal of Cleaner Production, 183: 979-987
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27. M.E.J. Geerts, B.L. Dekkers, A. van der Padt, A.J. van der Goot, 2018, Aqueous fractionation processes of soy protein for fibrous structure formation, Innovative Food Science and Emerging Technologies, 45: 313–319
28. M.E.J. Geerts, C.V. Nikiforidis, A.J van der Goot, A. van der Padt, 2017, Protein nativity explains emulsifying properties of aqueous extracted protein components from yellow pea, Food Structure, 14: 104-111
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30. M.E.J. Geerts, M. Strijbos, A. van der Padt, A.J. van der Goot, 2017, Understanding functional properties of mildly refined starch fractions of yellow pea, Journal of Cereal Science, 75: 116-123
31. M.E.J. Geerts, E. Mienis, C.V. Nikiforidis, A. van der Padt, A.J. van der Goot 2017 Mildly refined fractions of yellow peas show richer behavior in thickened oil-in-water emulsions than highly purified pea fractions, Innovative Food Science and Emerging Technologies, 41: 251-258
32. 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 2016, Concepts for further sustainable production of foods, Journal of Food Engineering: 168, 42-51
33. M.E.J. Geerts, Functionality-driven fractionation. The need for mild food processing. PhD Thesis Wageningen University 2018
34. Interview “Levensmiddelen van milder geraffineerde ingrediënten” by Judith Witte, Voedingsindustrie, 2016, nr 3, p. 10-14. http://www.vakbladvoedingsindustrie.nl/archief/levensmiddelen-van-minder-geraffineerde-ingredienten
35. Aguirre, V, Padt, A. van der, Boom, R.M, Janssen, A.E.M. Modelling of membrane cascades for the purification of oligosaccharides. Journal of Membrane Science 520 (2016) 712 – 722
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39. Aguirre, V, Boom, R.M, Janssen, A.E.M., Padt, A. van der, Hydration effects in the NF of concentrated solutions. Euromembrane 2018. EMS / Universitait Politecnica de Valencia
40. Aguirre, V, Membrane filtration of food streams: mechanisms and modelling. PhD Thesis Wageningen University 2018