



<b>General data</b>	
PPP number	<b>AF-15506</b>
Title	<b>Safeguarding product structure and mechanical properties while using new sustainable sources and processing steps: a multiscale and interdisciplinary approach</b>
Theme	<b>Gezond&amp;Veilig</b>
Executing research organisation(s)	<b>TiFN, Wageningen University and Research, University of Amsterdam</b>
Project leader research (name + email address)	<b>Marcel Meinders Marcel.meinders@wur.nl</b>
Coordinator (on behalf of private parties)	<b>TiFN</b>
Contact person of government	
Total project budget (k€)	<b>3846000 euro</b>
Project website address	<b><a href="https://www.tifn.nl/project/sustainable-ingredients/">https://www.tifn.nl/project/sustainable-ingredients/</a></b>
Starting date	<b>1-1-2017</b>
Final date	<b>1-1-2021</b>

<b>Approval coordinator/consortium</b>	
The annual report has to be discussed with the coordinator/consortium. The TKI(s) like to be informed regarding potential comments on the annual report.	
The annual report is ..... by the coordinator on behalf of the consortium	<input type="checkbox"/> approved <input type="checkbox"/> not approved
Potential comments regarding the final report	This PPP annual report is a summary of the combined TiFN and NWO report.

<b>Brief description content/aim PPP</b>
<p><b>Key objectives</b></p> <p>In this project we investigate the effects of more sustainable sourced materials and more sustainable process operations on food ingredient composition, and the consequences for the structural and mechanical properties of multiphase food products (emulsions/foams/filled gels). We identify the key objective as:</p> <ul style="list-style-type: none"> <li>To investigate to what extent more sustainable ingredient sources and processes can be used to manufacture products with desirable structural and mechanical properties.</li> </ul> <p>Hereto we distinguish the following project objectives:</p> <ul style="list-style-type: none"> <li>Understand the conditions to produce products with desirable structural and mechanical properties from more sustainable ingredient sources.</li> <li>To quantify sustainability effects of source and processing methods for a set of sources and processes.</li> </ul> <p>To formulate main lever rules that relate the properties of sustainable produced complex ingredient mixtures for a given source, to desired product properties like structure and rheological and mechanical properties on all length scales relevant to the product.</p> <p><b>Main deliverables</b></p> <ul style="list-style-type: none"> <li>List of ingredient and ingredient sources that will be used in the project, based on maximal expected sustainability gain when using less refinement and/or replacement by animal protein as well as on commercial availability</li> <li>Insights* in to what extent mild refinement of chosen plant sources can be used to produce food products with desired structural and mechanical properties</li> </ul>

- Insights\* in possible sustainability gain when using mild refinement and/or replacement of animal by plant proteins in production of food with desired structural and mechanical properties
- Insights\* in the relations between ingredient composition of complex mixtures of plant proteins (SP2)†, plant and dairy proteins (SP3, SP5) †, and plant ingredients (SP1, SP4) †, interfacial, film, and food product structure and mechanical properties
- Insights\* in to what extent local pressures can be measured in foods (SP6) †
- Local dynamics measured and related to rheology for liquids that contain non-refined plant material and dairy protein mixtures (SP 6) †
- Generic knowledge\* and a set of rules relating the key structural and mechanical properties of a specific set of products to those of the complex ingredient mixture and processing routes, including a quantification of sustainability

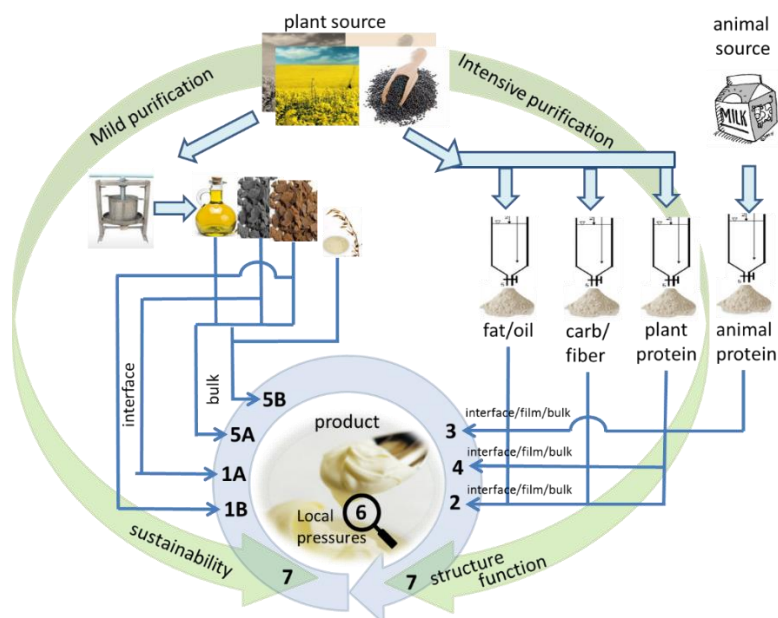
\* in terms of scientific papers, reports, papers, etc..

† addressed in this subproject (see below in approach)

### Approach

A multiscale interdisciplinary approach will be used, combining process and product analysis with sustainability analysis. Firstly, this approach connects the properties of the system on a molecular level to macroscopic properties and stability of emulsion/foam/gel-based products, using the intermediate colloidal scales to bridge these length scales. Secondly, this approach connects the properties of the respective scales along the food chain, from sustainable source to primary production and final product. Concerning the sustainability of ingredients, two routes will be investigated within the project: one being less refinement of sources and the other being replacement of animal (dairy) proteins by other sustainable protein sources like plants. In order to estimate sustainability (resource efficiency) along the chain – for common processing chains as well as the proposed alternative processing chain configurations - use will be made of exergy sustainability assessment methodology developed within TIFN projects

The experimental approach is summarised in the following figure.



Numbers refer to the various subprojects. The figure displays the focus area of various sub-projects as well as their interconnected nature. The main topic concerns the investigation to what extent more sustainable ingredient sources and processes can be used to manufacture products with desirable structural and mechanical properties. The project distinguishes two strategies to increase sustainability: 1) less refinement and 2) replacement of animal by plant protein. Subprojects 1A, 1B, 5A, and 5B approach the problem starting with plant extracts and decreasing complexity by further refinement. Subprojects 1A and 1B focus more on the interfacial properties. The main difference is the use of the source material group (rapeseed vs yellow pea, for 1A and 1B respectively). Subprojects 5A and 5B focus on the bulk properties and include the effect of heating. Subproject 5A addresses rapeseed and yellow pea, including the effects of fibres from these sources and focus on the proteins as the key ingredients structuring the bulk. Subproject 5B will also address rapeseed and yellow pea, but with special emphasis on the structuring effects of the addition of sources like oat, that can contain a high level of soluble fibres having interesting structuring properties. Sub-projects 2, 3, 4 start with complex mixtures from purified ingredients and increase complexity by adding more components. Subproject 6 is concerned with the

product itself, while subproject 7 is concerned with the quantification of sustainability and structure-function relations. The numbers correspond to the different sub-projects. The blue circle displays the interchange of information between the sub-projects., which are more specified in the detailed sub-project descriptions. The choice of the materials that will be subject of investigation will be made on basis of a study performed at the beginning of the project that maps the sustainability, commercial availability, and functionality of various ingredient sources of interest

## **Results**

### **Expected results 2019**

#### **SP1A**

- Characterize the composition of the mildly purified rapeseed mixtures by analysing in detail the major and minor compounds present in the fractions
- Identify the dominant intermolecular interactions in the obtained fractions
- Make emulsions using the fractions and characterize the emulsifying properties by measuring the critical quality parameters as defined by the industrial partners
- Study the interfacial properties of the mixtures
- Manipulate the factors that influence composition/interactions during extraction based on the performance of the fractions in emulsion systems
- Link composition, interactions and emulsion properties providing qualitative and quantitative results
- Research paper

#### **SP1B**

- Understand the influence of oligosaccharides and other small molecules on the emulsifying ability and properties of the emulsion formed
- Understand the nature of interface that forms at different pH values and non-protein material and relate to the stability of emulsion
- Visualize if there are any structural differences at the interface formed at different pH values and different compositions and the influence of non-protein components
- Research paper

#### **SP2**

- Finalise large-scale fractionation of yellow pea protein.
- Finalize article 1 and 2 in coming period. Focus will be on yellow pea protein isolation, fractionation and characterization of molecular, interfacial and emulsifying properties.
- Start-up activities on rapeseed protein fractionation and characterisation.
- Research paper

#### **SP3**

- Further investigation of interfacial displacement occurred in the blend stabilized emulsions by sequential introduction of the proteins (e.g., one before and one after homogenization).
- Continuation of the microfluidic study to understand the stabilisation mechanism of the blends and the individual proteins. Next to the coalescence chips also rheology chips will be used to link coalescence stability to the rheological properties of the emulsion droplets.

#### **SP4**

- Further purification of our in-house Rapeseed Protein Concentrate by removal of lipids and phenolic components. The final purification step would include the separation of the two major protein fractions in the oilseed: albumins and globulins. To fully understand the functional properties of the proteins, we need to gain knowledge of the properties of the major proteins separately and in mixture.
- Mixing non-proteinaceous compounds with the proteins. These components include (phospho)-lipids and phenols. We will study the interfacial properties using rheology and microstructure imaging. Finally, we will link the findings on the interfacial properties with macroscopic properties in foam and emulsion systems

#### **SP5A**

- Optimize bulk behaviour to understand the bulk behaviour of rapeseed and pea fractions
- Characterize bulk behaviour of plant-dairy mixtures to understand the bulk behaviour of plant dairy mixtures

**SP5B**

- Continue experiments on creaming stability, and emulsion and continuous phase rheology
- Start measurements to study depletion effect
- Perform experiments on creaming stability, emulsion and continuous phase rheology, and depletion
- Biochemical characterize oat fractions

**SP6**

- Further investigations will reveal whether effects of Molecular Rotors (MR) persist during flow and can reliably probe viscosity changes under shear-thinning conditions. The main focus will lie on analysing neat silicon oils as homogeneous shear-thinning systems and emulsions to study flow in continuous phases.

**SP7A**

- Implement and perform in collaboration with the subprojects the screening design of experiments
- Implement mechanistic model on emulsion formation
- Collect data from other subprojects and make available for data analysis
- Set up frame for model

**SP7B**

- Adapt/extend product formulation models (separate process and by-product valorisation)
- Test and verify approach with the examples used in the project.
- Write manual to be able to use the tool.
- Write and publish paper on extended model: effects of by-product valorisation
- Make flow schemes more specific
- Obtain scenarios for ingredient processing from WP 1A, 1B and 5A
- Obtain data on product + product processing from WP 7A
- Obtain from WP 7A: parameters, ingredients, processes for foams, emulsions, and gels

**Achieved results 2019****SP1A**

- Mild extraction of protein/oil body mixtures of different composition and purity
- Characterization of composition of the obtained mixtures
- Sustainability analysis of the extraction process
- Emulsion properties of the different extracted protein/oil body-rich mixtures

**SP1B**

- The project has realized the first scientific publication on the topic of using pea flour as emulsifier of oil-in-water emulsions. The emulsifying properties of pea flour and the physical properties of the resulting emulsions were studied at pH 7 and pH 3.
- Pea flour as such can produce stable oil-in-water emulsions at pH 7 and pH 3
- Proteins in pea flour are the primary interfacial active agent
- Starch granules and other non-protein molecules do not influence the emulsifying ability of proteins
- Pea flour emulsions also behave quite similar to emulsions made with purified pea proteins (85% purity)
- The mechanism of stabilization of pea flour emulsions at pH 3 seems that of Pickering stabilization since most proteins are poorly soluble in this condition
- Emulsions at pH 3 are more viscous than emulsions at pH 7- possibly due to lower solubility of proteins at pH 3

**SP2**

- Finished large scale isolation of yellow pea protein concentrate (YPPC,  $\pm$  260 g) and fractionation of yellow pea legumin ( $\pm$  45 gram) and yellow pea vicilin ( $\pm$  100 gram).
- Characterisation of yellow pea protein concentrate, legumin and vicilin: protein content and composition (SDS-PAGE and SEC), carbohydrate content and composition, moisture content.
- Characterisation of yellow pea protein concentrate, legumin and vicilin as function of ionic strength: protein solubility, protein composition, zeta-potential, hydrophobicity (ANSA). Data

was collected in MQ and diluted McIlvaine buffer (20 mM Na<sub>2</sub>HPO<sub>4</sub> + 10 mM citric acid) at pH 7.0. Samples will also be analysed at buffer + 200 mM NaCl.

- Mixtures of legumin and vicilin (80:20, 70:30, 50:50, 30:70, 20:80) were characterised under the same conditions and using the same methods as described above.
- The interfacial tension and elastic modulus of YPPC, legumin, vicilin and L:V blends (70:30, 50:50, 30:70) were measured at 0.05 g/L in MQ and diluted McIlvaine buffer at pH 7.0.
  - In milliQ water: Legumin has a lag time of +/- 800 s, vicilin does not. Mixtures show intermediate behaviour, indicative of additive effect.
  - At higher ionic strength, 20 mM McIlvaine buffer, or in 20 mM NaCl, legumin does not have a lag time. In consequence, there was also no difference in surface pressure-time curves for pure and mixed vicilin/ legumin samples.
- Emulsion properties (individual droplet size and flocculation) were analysed for 10 % (v/v) oil-in-water emulsions made with 0.5, 1.0, 2.5, 5.0, 10.0 g/L YPPC, legumin, vicilin and L:V blend (30:70). Samples were measured in MQ and diluted McIlvaine buffer at pH 7.0.
  - In buffer, all samples show similar  $d_{3,2}$  versus concentration curves.
  - In water, at low concentrations, issues with the efficiency of emulsification lead to macroscopic phase separation/ coalescence that result in small droplet sizes. These small droplet sizes normally would be associated with good emulsification, but in this case are considered an artefact.

### SP3

- In the first year of the subproject we found that interfacial displacement occurred in the dairy-plant protein blend stabilized emulsions. We further investigated this effect by sequential addition of the proteins (e.g., one before and one after homogenization). After addition of the second protein the surface load increased significantly for all systems tested. However only the  $\beta$ -Lactoglobulin (as present in WPI) displaced the other proteins present at the interface. We found that the main driver for the interfacial displacement is the continuous phase concentration of the  $\beta$ -Lactoglobulin rather than its initial interfacial concentration.
- In a different line of experiments we measured the coalescence stability of WPI, PPI and WPI-PPI stabilised interfaces with a microfluidic tool. In this so-called coalescence chip, we can apply conditions resembling those in a homogenizer. We found that WPI was superior compared to PPI (e.g., higher concentrations of PPI were needed compared to WPI). When used in a blend, PPI hindered the WPI and high total protein concentrations were needed to stabilise emulsion droplets. Droplet-droplet bridging of the PPI aggregates was probably the main driving force for increased coalescence in the PPI-containing systems.
- To better understand the PPI behaviour we added salt to de-aggregate legumin, used homogenisation to de-aggregate supramolecular structures, and used different isolates. We found that both treatments improved the coalescence stability, with addition of salt being most effective. The size of the proteins reduced, therewith decreasing droplet-droplet bridging at low protein concentrations. We still aim to also test the in house produced PPI (WP 2) and chromatography purified vicilin and legumin to investigate the effect of supramolecular structure of the proteins on their functional properties.

### SP 4

- Mildly purified rapeseed protein concentrate (RPC) was studied for its interfacial and foam properties. The RPC was also defatted to study the effect of lipids on the functional properties of the proteins. We discovered that the interfacial layer strength decreases with increasing RPC bulk concentrations. Non-protein components increase at higher concentrations, and may influence the connectivity of the protein layer at the interface. The presence of non-protein components was confirmed using atomic force microscopy. We also found that the lipids in RPC do not influence the foaming properties, as the lipids are in the form of oil bodies, the oil storage organelle in plants. Currently, we are writing an article on the data.
- The effect of rapeseed phenol sinapic acid on whey protein interfacial and foam properties was studied. In short, the sinapic acid negatively influences the interfacial layer strength and foam properties of whey proteins. This is still ongoing research.

### SP5A

- Five different fractions of Yellow Pea with different purities were obtained. From these fractions the chemical composition was determined (i.e. protein, polysaccharide, ash, hydrophobicity, thiol groups etc.). Rheological characterization of dispersions were studied for heated and unheated systems. It was found that less pure fractions outperform highly purified yellow pea fractions in

terms of gel elasticity. There is an indication that impurities in milder processed fractions, such as polysaccharides and salts, influence gel elasticity.

- Five different fractions of Rapeseed with different purities were obtained. From these fractions the chemical composition was determined. Rheological characterization of dispersions were studied for heated and unheated systems at different pH values. It was found that the gel elasticity after heating is strongly dependent on pH and that the most elastic gels were obtained at alkaline pH.
- Experiments were performed on yellow pea fractions to explain the effect of purification on gelation behaviour on a molecular level. These experiments included rheological measurement, studying the effect of S-S bonding on gelation by addition of NEM, the effect of isoelectric precipitation on the functionality of proteins, combining different pea fractions to understand the effect of processing history. Also, the effect of solvent conditions (i.e. pH and ionic strength) on the viscosity and gelation behaviour have been studied
- Different ratios of yellow pea fractions and WPI are studied on their viscoelastic behaviour during and after heating. Some of the yellow pea fractions increase the elastic modulus of WPI. At fixed weight percentages it was found that certain mixtures result in firmer gels after heating than pure WPI. However, this could be related to the effect of ionic strength present in the pea fractions, rather than the pea proteins themselves
- Different pea protein isolates (commercial, diafiltrated and precipitated) in combination with WPI are investigated. Heat-induced aggregation behaviour is studied at low concentrations ( $\sim 2\%$  w/w) and gelation at high concentration ( $\sim 15\%$  w/w).
- The emulsifying properties of different yellow pea fractions are studied. The same purification process is used to obtain pea fractions varying in purity. Both the emulsion stability and interfacial behaviour are investigated.

#### **SP5B**

- The influence of oat (and other) beta-glucans on the stability of whey protein stabilized O/W emulsions, for beta-glucans of different degrees of purification were experimentally characterized
- Theoretical model is under development to describe the kinetics of gravitational instabilities in emulsions, in particular flocculation-induced creaming
- A new set-up has been developed to characterize the kinetics of flocculation-induced creaming at high throughput and with greater accuracy, in order to obtain ample high quality data that can be compared with theoretical models (including models to be developed, see below). The method has successfully been applied to whey protein -stabilized emulsions mixed with highly pure beta-glucan. Precise lag times and rates of creaming are now available as a function of the amount of added beta-glucan.
- With the previous lower throughput and less precise method it has been established for beta-glucans of intermediate purity, results are as expected when normalization is done with respect to the actual amount of beta-glucan, providing confidence that also for even less purified beta-glucan sources, the instabilities in emulsions can be understood purely on the basis of the amounts of beta-glucan.
- A start has been made to investigate the effects of oat meals (milled to smaller particles sizes by various means) on emulsion stability, and on the biochemical characterization of these meals and of the other beta-glucan sources used.
- A start has been made to work on developing theoretical models to quantitatively explain the obtained kinetic data on flocculation-induced creaming.

#### **SP5A**

- **Molecular Rotors.** In the past period the focus was set on probing dilute, high-molecular weight polyethylene glycol polymer solutions as model systems for more complex foods. Measuring steady-state fluorescence emission spectra of the molecular rotor 4-DASPI embedded in the dilute polymer solution reveals a rigidochromic effect as the fluorescence quantum yield increases with the concentration of the polymer (Fig. 1 & 2). However, the emission intensity is not proportional to the macroscopic viscosity of the sample as intensity-viscosity curves of different molecular weights do not overlap and show different sensitivities towards the molecular rotor. These results confirm the applicability of molecular rotors to probe (micro-)viscosities in dilute polymer solutions.

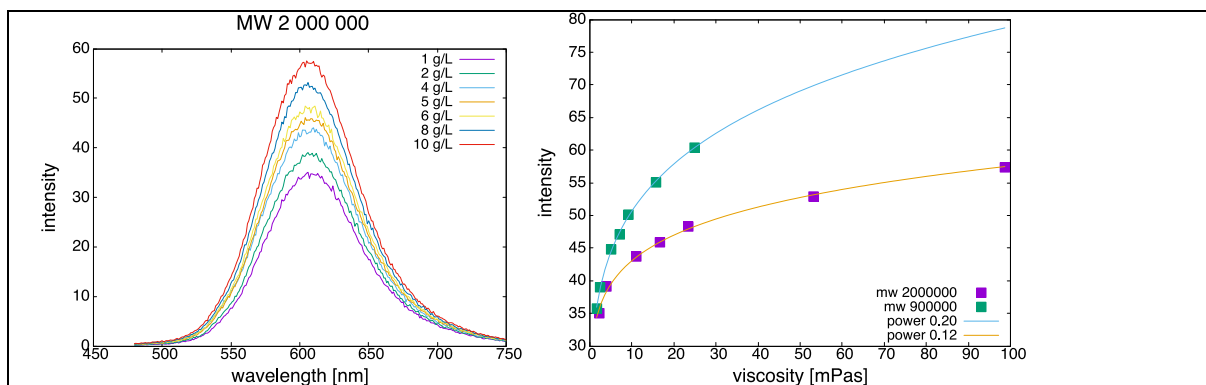


Fig. 1 & 2: The fluorescence intensity increases with PEO concentration (spectra shown for a molecular weight of 2000000). Intensity-viscosity curves reveal a power-law relation with lower sensitivity towards the higher molecular weight polymer solution.

- **Emulsion destabilization by drop evaporation.** Evaporating emulsion drops were analysed on different substrates by combining confocal- and video microscopy. The measurements reveal a drastic dependence on the mode of destabilization on the wettability of the substrate. Substrates exhibiting high contact angles effectuate slow evaporation by a steadily decreasing water front, while evaporation from wetting surfaces destabilizes the emulsion drop faster and leaves behind a coffee-ring like deposit on the substrate (Fig. 3). These results can be of importance for industrial applications as evaporation from low-wettability substrates leads to more uniform oil deposition.

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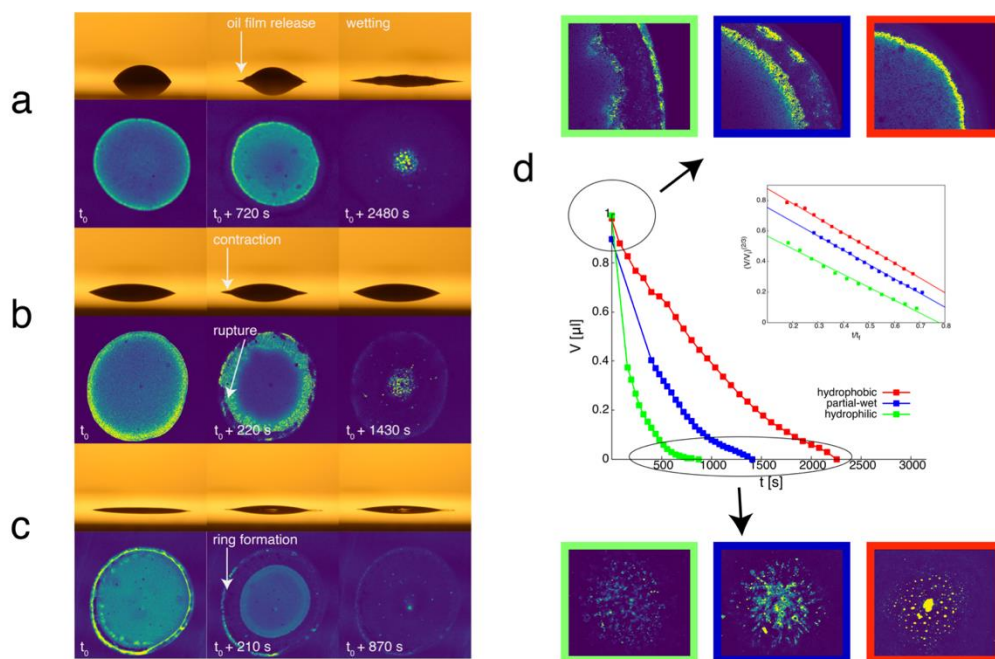


Fig. 3: (a-c) Drying emulsion drop on hydrophobic, partial-wet and hydrophilic surfaces. The top panels show video microscopy snapshots and the bottom panels the corresponding fluorescence images. From these measurements information on the temporal evolution of the drop morphology (height, diameter, contact angle) and its internal structure in terms of evaporation dynamics and destabilization mechanisms can be inferred. (d) Incorporating contact angle and perimeter of the aqueous phase into a simple spherical cap model allows to estimate evaporation rates.

#### SP 7A

- Key parameters, potential relationships/models and application domain identified and described
- Data collection for validation running
- Design of experiments SP1B implemented and additional experiments performed

- Mechanistic model of emulsification process using high pressure homogenizer implemented. Population balance equations are used, including droplet breakup due to shear and droplet coalescence. Key parameters for droplet size distribution calculation are HPH pressure and number of passes, oil volume fraction and dynamical oil/water interfacial tension and coverage, which depend on the interfacial properties of the emulsifier.
- Mechanistic model to describe droplet aggregation and creaming implemented using population balance equations.
- Start has been made with validation of mechanistic models.
- Communication with all SP's on key parameters, relations and data is running.

#### **SP 7A**

- Database containing experimental and literature data to quantify sustainability for the production of foods continuously updated
- Meeting with partners was organized and case scenarios from Danone and Unilever were included.
- Flow schemes for all major crops relevant to the chosen products are in place
- Valorisation of by-products was included in the tool, it now includes economic, exergy allocation and system expansion
- Proof of principle for reverse engineering for sustainable processing shown
- Product composition of two industrial relevant products was included in the calculation
- Manuscript on extended model and effects of by-product valorisation drafted
- Start has been made for the sensitivity/uncertainty analysis
- Flow schemes made more specific
- Scenarios for ingredient processing rapeseed complete
- Scenarios for ingredient processing yellow pea almost complete

#### **Expected results 2020**

##### **SP1A**

- Characterize the composition of the mildly purified mixtures by analysing in detail the major and minor compounds present in the fractions
- Identify the dominant intermolecular interactions in the obtained fractions
- Make emulsions using the fractions and characterize the emulsifying properties by measuring the critical quality parameters as defined by the industrial partners
- Study the interfacial properties of the mixtures
- Manipulate the factors that influence composition/interactions during extraction based on the performance of the fractions in emulsion systems
- Link composition, interactions and emulsion properties providing qualitative and quantitative results

##### **SP1B**

- Study the molecular properties of purified pea protein as a function of pH, to understand how the protein properties influence their emulsification behaviour, giving mechanistic understanding of protein properties at pH 7 and pH 3 and their link to emulsifying property
- Heating the emulsions made at pH 7 and pH 3 and study the changes in physical properties of the emulsion to understand how heat induced changes in protein, non-protein material properties affect the stability and physical properties of the emulsion

##### **SP2**

- Finalize study on the effect of varying legumin/vicilin ratio on emulsion properties.
- Finalize study on the effect of ionic strength on the additivity of the emulsion properties of pea legumin and vicilin blends
- Continue work on foam properties of (heated) pea albumin, legumin, vicilin and blends.
- Start fractionation and study of rapeseed proteins

##### **SP3**

- Further investigation of interfacial composition, which is of great importance for emulsion stability. We will use the phase exchange function in the automated drop tensiometer to study the effect of addition of a second protein on the interfacial rheological properties. This will help us to unravel the interfaces physical organisation.
- Determination of surface loads in different ways: 1) based on the non-adsorbed protein in the continuous phase, 2) based on the cream phase 3) or a washed cream phase. All techniques include a centrifugation step to separate the droplets from the continuous phase. Since we



initially found that surface loads differed per method, we now investigate this in depth. We consider the use of front surface fluorescence for the WPI-PPI systems. With this technique the protein partitioning can be measured within the emulsion, and there is no need to separate the oil droplets from the continuous phase by centrifugation. This will be done in collaboration with INRA-Nantes (France), which can be realized due to the Aalt Dijkhuizen travel grant, that was granted to the PhD-student Emma Hinderink.

- Study droplet relaxation patterns that can be linked to the interfacial organisation of WPI, PPI and WPI-PPI containing systems, using the newly developed next generation microfluidic chips that induce droplet deformation (but not coalescence). Relaxation patterns are studied after various times ranging from milliseconds to seconds after droplet formation to evaluate interface composition changes. We aim to link the relaxation patterns to droplet coalescence stability and ultimately to industrial homogenization.

#### **SP4**

- Finish the work on WPI-sinapic acid mixtures. We will initiate new projects on the functionality of 1) pea protein concentrations at different purity, 2) protein-lipid mixtures, and 3) rapeseed protein napin and cruciferin.

#### **SP5A**

- Characterize bulk behaviour of plant-dairy mixtures
- Characterize bulk behaviour of plant-dairy-oil/air mixtures
- Publish one manuscripts on bulk gelling behaviour of pea fractions
- Publish one manuscripts on bulk gelling behaviour of plant-dairy mixtures
- Draft one manuscript on bulk gelling behaviour of plant-dairy-oil/water mixtures

#### **SP6**

- Regarding the molecular rotors, time-resolved fluorescence experiments will complement the steady-state fluorescence data and shed more light on the partition of the dye molecules within the dilute polymer solutions. Time-resolved measurements will also give more insight into possible viscosity heterogeneities in emulsion systems (as stated in the annual report of 2018) and polymer solutions in shear flow.

#### **SP7A**

- Validate mechanistic model on emulsion formation
- Further develop and implement mechanistic model on flocculation and creaming of emulsions (collaboration sub-project 5B)
- Implement mechanistic model on aggregation and gelling
- Implement and develop mechanistic model on emulsifier adsorption and interfacial rheology
- Collect data from other subprojects and make available for data analysis
- Perform additional studies not performed in the subprojects but relevant for model validation and industrial applications (e.g. effect of temperature treatment on functionality)
- Set up frame for model

#### **SP7B**

- Improving quality of the tool in cooperation with SP 7A (sensitivity analysis, validation)
- Obtain data on product + product processing from SP 7A
- Obtain from SP 7A: parameters, ingredients, processes for foams, emulsions, and gels
- Obtain processing scheme pea protein mildly fractionated
- Obtain scenarios for product formulation from SP 7A
- Obtain recipes + formulations from SP 7A
- Write paper on effects of by-product valorisation on outcome

**Delivered products in 2019** (give titles and/or description of products, or a link to the products on the project website, or other public websites).

#### Scientific articles:

- Ntone, Bitter, Nikiforidis (2019). Not sequentially but simultaneously: Facile extraction of proteins and oleosomes from oilseeds (Food Hydrocolloids, Accepted for publication)

- Ntone, Van Wessel, Sagis, Bitter, Nikiforidis (2020), Napins adsorb at oil/water interface when using rapeseed protein mixtures (In preparation)
- Sridharan, Meinders, Bitter, Nikiforidis (2020), Pea flour as stabilizer of oil-in-water emulsions: Protein purification unnecessary, *Food Hydrocolloids* 101, <https://doi.org/10.1016/j.foodhyd.2019.105533>
- Dynamic heterogeneity in complex interfaces of soft interface-dominated materials. Sagis, L. M. C., Liu, B., Li, Y., Essers, J., Yang, J., Moghimikheirabadi, A., Hinderink, E., Berton-Carabin, C., Schroen, K. (2019). *Scientific Reports*, 9(1), 2938. <https://doi.org/10.1038/s41598-019-39761-7>
- Synergistic stabilisation of emulsions by blends of dairy and soluble pea proteins : Contribution of the interfacial composition. Hinderink, E. B. A., Münch, K., Sagis, L., Schroën, K., & Berton-Carabin, C. C. (2019). *Food Hydrocolloids*, 97. <https://doi.org/10.1016/j.foodhyd.2019.105206>
- Jack Yang, Ilonka Thielen, Claire C. Berton-Carabin, Erik van der Linden, Leonard M.C. Sagis, Nonlinear interfacial rheology and atomic force microscopy of air-water interfaces stabilized by whey protein beads and their constituents, *Food Hydrocolloids* (2019) <https://doi.org/10.1016/j.foodhyd.2019.105466>
- Kornet, Venema, Nijse, van der Linden, van der Goot, Meinders, *Yellow pea aqueous fractionation increases the specific volume fractions and viscosity of its dispersions*, *Food Hydrocolloids*, 99, 2019 <https://doi.org/10.1016/j.foodhyd.2019.105332>)

#### External reports:

- Van Wessel, *Emulsifying properties of mildly extracted rapeseed protein mixtures*, MSc. Thesis WUR, 2019
- de Leeuw, *Coalescence stability of emulsions stabilised by whey-pea protein blends studied using micro-fluidics*, MSc. Thesis WUR, 2019
- Sluijter, *Rheological behaviour of yellow pea protein fractions of varying purity under different pH and ionic strength*, BSc. Thesis WUR, 2019
- Faber, *The effect of purification on the emulsifying and foaming properties of rapeseed proteins*, BSc. Thesis WUR, 2019
- Wibbels, *The effect of pH, extract composition and homogenisation on the emulsifying properties of yellow pea protein: a review study*, BSc. Thesis WUR, 2019
- Dierkes, *Comparison of theoretical and experimental data of the solubility of plant protein*, BSc. Thesis WUR, 2019
- Derwig, *The effect of pre-processing of pea legumin and vicilin on the molecular, interfacial and foaming properties*, MSc. Thesis WUR, 2019
- Zhang, *Foam properties of pea albumin*, MSc. Thesis WUR, 2019
- de Boer, *Viscoelastic properties of mildly processed yellow pea fractions combined with micellar casein*, BSc. Thesis WUR, 2019
- Roozalipur, *Influence of rapeseed phenols on interfacial, emulsifying and foaming properties of whey proteins*, BSc. Thesis WUR, 2019
- Singer, *Bulk behaviour of heated rapeseed fractions*, MSc thesis WUR, 2019
- Xu, *The effect of rapeseed purification processes on protein and phenolic content and the resulting viscoelastic properties*, MSc. Thesis WUR, 2019
- Driessen, *Effect of pH and ionic strength on solubility and emulsion properties of legume proteins*, BSc. Thesis WUR, 2019
- Veennemans, *The effect of combining yellow pea protein fractions with whey protein isolate on the viscoelastic properties*, MSc. Thesis WUR, 2019

Lectures/posters during workshops, conferences and symposia:

- Meijers, Wierenga, *Predictive estimation of emulsion properties of pea legumin and vicilin blends*, Bubble and Drop Conference, Sofia, Bulgaria, 2019
- Meijers, Wierenga, *The effect of pH and ionic strength on the emulsion properties of pea legumin-vicilin mixtures*, ECIS, Leuven, Belgium, 2019
- Hinderink, Sagis, Schroën, Berton-Carabin, *Food emulsions stabilised by synergistic blends of plant and dairy proteins*, Food Colloids, Leeds, UK, 2019
- Hinderink, Sagis, Schroën, Berton-Carabin, *Synergistic stabilisation of emulsions by blends of dairy and plant proteins: Contribution of the interfacial composition*. Edible soft matter conference, Le Mans, France, 2019
- Hinderink, Schroën, Sagis, Berton-Carabin, *Interfacial behaviour of plant-dairy protein blends: Comparison between oil-water and air-water interfaces*, International Symposium on Food Rheology and Structure, Zürich, Switzerland, 2019
- Yang, Thielen, Berton-Carabin, Van der Linden, Sagis, *Nonlinear surface rheology and interfacial microstructure imaging of WPI particles and their constituents*, Edible Soft Matter, Le Mans, France, 2019
- June – International Symposium on Food Rheology and Structure conference in Zürich
- Kornet, Venema, Van der Goot, Meinders, Van der Linden, *Effect of processing on viscoelastic properties of heat-induced gels, produced from mildly to highly purified yellow pea fractions*, 8<sup>th</sup> International Symposium on Food Rheology and Structure, Zürich, Switzerland, 2019
- Kornet, Venema, Van der Goot, Van der Linden, Meinders, *Viscoelastic behaviour of mildly purified plant fractions with different composition*, Annual European Rheology Conference, Portoroz, Slovenia, 2019
- Kornet, Venema, Van der Goot, Nijse, Van der Linden, Meinders, *Yellow pea protein purification increases the viscosity of its dispersion*, 8th International Symposium on "Delivery of Functionality in Complex Food Systems, Porto, Portugal, 2019
- Kornet, Venema, Van der Goot, Van der Linden, Meinders, 8th International Symposium on Delivery of Functionality in Complex Food Systems, Porto, Portugal, 2019
- Hinderink, *Food emulsions stabilised by synergistic blends of plant and dairy proteins*. Food Colloids 2018 (Leeds, UK)
- November – European Federation of Food Science and Technology conference in Rotterdam
- Ntone, Bitter, Nikiforidis, *Dirty proteins: Rapeseed multicomponent emulsifiers*, TiFN retreat, Hilvarenbeek, the Netherlands, 2019
- Sridharan, Meinders, Bitter, Nikiforidis, *The case of pea flour as emulsifier: Protein Purification unnecessary?*, TiFN retreat, Hilvarenbeek, the Netherlands, 2019
- Meijers, Wierenga, *Towards predicting the stability of plant protein stabilized emulsions*, TiFN retreat, Hilvarenbeek, the Netherlands, 2019
- Yang, Faber, Nikiforidis, Berton-Carabin, Van der Linden, Sagis, *Do lipids destroy plant foams? The effect of defatting on mildly-purified rapeseed protein*, TiFN retreat, Hilvarenbeek, the Netherlands, 2019
- Bitterman, Bonn, *Mapping viscosities in O/W emulsions*, TiFN retreat, Hilvarenbeek, the Netherlands, 2019
- Te Brinke, de Vries, Schols, *Oats: from fundamental physics to functionality in food*, TiFN retreat, Hilvarenbeek, the Netherlands, 2019
- Rodriguez-Illera, Berghout, Meinders, Broeze, *Demystifying the obvious: a quantitative assessment of GHG emissions during early stage (re-)design of agro-food chains*, 33<sup>rd</sup> EFFoST International Conference, Sustainable Food Systems - Performing by Connecting, Rotterdam, The Netherlands, 2019

