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<th>General information</th>
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<td>PPP-number</td>
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<td>Project leader research (name + e-mail address)</td>
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<td>Coordinator (on behalf of private partners)</td>
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<td>Project-website address</td>
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<th>Approval by the coordinator of the consortium</th>
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<tr>
<td>The annual report must be discussed with the coordinator of the consortium. The “TKI’s“ appreciate additional comments concerning the annual report.</td>
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<td>Assessment of the report by the coordinator on behalf of the consortium:</td>
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| Additional comments concerning the annual report: |

<table>
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<th>Summary of the project</th>
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<td>Problem definition</td>
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### Project goals

Alternatives for meat, made from sustainably produced proteins for the human diet are urgently needed. PlantPROMISE's focus is to develop novel, high quality products but also to create standards for quality and to optimise production, and, in particular, to develop meat-alternatives which have an optimal digestibility and bioactivity as determined by their peptides.

The PlantPROMISE project aims to develop a new generation of novel, high quality extruded meat analogues using the improved understanding of physico-chemical processing in the extruder, combined with a better understanding of product attributes like texture, flavour, juiciness, digestibility and sustainability that are acceptable to the consumer. The project focusses on pre-competitive technology and know-how in a cross value-chain collaboration to translate fundamental insights to application understanding.

### Results

#### Planned results 2019

PlantPROMISE started the 1st July 2019. At the start of the project, together with the partners a detailed project plan was made with a set of prioritization.

1. **State-of-the-art:** Overview of knowledge available on plant-based meat analogues obtained by extrusion from processing to digestibility
2. **Extrusion trials** to explore range of settings and evaluate consequences on product quality
3. **Ingredient selection**
4. **Analysis to evaluate the textural properties of the extrudate**
5. **Consumer perception of plant-based meat analogues:** focus group organized with different eating pattern and training QDA panel for profiling meat analogues
6. **Development of method to evaluate digestibility of meat analogues** (including mimicking mastication)

#### Achieved results 2019

**State-of-the-art:**

This report describes the state-of-the-art at the start of PlantPROMISE and serves as a basis for the research that will be done in this project. The report is structured around relevant information for the project:

- **WP1:** Production of extruded meat analogues focusing on the processing parameters during extrusion (high and low moisture), physico-chemical changes during the extrusion;
- **WP2:** Product quality focusing on the tenderness and juiciness of meat analogues and the different technologies available to measure them; this section also includes information of the flavouring and the addition of oil;
- **WP2:** Ingredient characteristic focusing on protein (to be used in the project), fibre, starch which are currently used in meat analogues;
- **WP3:** Consumer acceptance and consumer assessment with a focus on the drivers of the consumer to purchase and consume meat analogues and on the consumer liking and acceptance of such products.
- **WP4:** Nutritional quality and digestibility focus the impact of protein structuring on their digestibility.

**WP1: Improve process understanding with small-scale high moisture extrusion**

The aim of WP1 is to obtain insight in extrusion conditions for texturizing protein to meat analogues.

- It was agreed with the partners that the primary focus would be on using soy protein concentrate. Extrusion trials were performed with a set of variables such as moisture content, screw speed and configuration, throughput, heating and cooling temperature and length of the cooling die with the aim of relating processing parameters and final product quality in term of structure and texture.
The results showed that the barrel temperature and temperature had an impact on the product firmness and water adsorption. Further experiment trials are required for understanding the chemical changes taking place in the extrusion barrel and in the cooling die.

- A method to analyse protein-protein interactions in the extrusion barrel and in the cooling die was set.

- Brainstorms on: 1) Translation from high to low moisture and 2) Measurement in- and at-line during extrusion were planned for Q1 2020.

### WP2. Ingredient and quality of extruded plant-based meat analogues

- **Ingredient selection and characterization:** with the partners, it was agreed that the focus of the project will be on protein ingredients (concentrate and isolate) originated from soybean, pea seeds and potato tuber. In addition, fibre and starch ingredients were also collected as a potential ingredient during the extrusion. The characterization is still on going.

- **Flavour:** Flavour in plant-based meat analogues are added to mask off-flavours of plant proteins but more specifically to give it a ‘meaty’ flavour (taste and aroma perception). In 2019, a strategy was made on how and where to add the flavour during the extrusion process or as a post-processing steps. Also a method to prepare and analyse the extrudate was set.

- **Oil/fat:** Addition of oil in plant-based meat analogues is important in term of juiciness and as carrier for flavours. However, free fat is not stable and therefore must be stabilized. In 2019, a strategy was made to better understand the relationship between stability of oil emulsion especially at high shear rate. In 2020, experimental trials will be performed in the department of Physics and Physical Chemistry of Foods (WU).

- **Product quality:** The focus in 2019 was on evaluating a range of methods to evaluate the product quality in terms of texture and water absorption. Based on the size of our extrudate, it was decided to evaluate the degree of texturization by performing a cutting test vertical and parallel to the direction of extrudate outflow from the extruder. Water absorption is defined as the measure of the amount of water which can be absorbed by the extrudate. The aim would be to link the water absorption to the amount and size of the air pocket in the extrudate. Other methods to evaluate the extrudate quality such as image analysis are in progress.

- **Structuring Pea Proteins.** A PhD student, in the department of Food Process Engineering, is focusing on means to structure pea proteins either by itself or in the presence of other proteins such as wheat gluten or hydrocolloids such as pectin. This fundamental work aims at generating knowledge in structuring protein and in addition to develop new analytical tools to better understand the structure of plant-based meat analogues, e.g. time domain NMR (see article below).

### WP3. Consumer acceptance and consumer assessment

- The aim of WP3 is to better understand the drivers for a consumer to buy plant-based meat analogues and to the reason behind their preference between one product and the other.

- The aim of the focus groups was to have a range of products varying in convenience of use, ingredients, and sensorial attributes to gain insight in the critical factors for what, why and when people use meat replacers. The results emphasized: 1) the importance of flavouring as too much flavour (too spicy) may be perceived as a cover up; 2) a product mimicking will be compared to meat products and therefore the consumer expectations are high. The expectations are different if the target group are meat eaters, flexitarians or vegetarians; 3) A positive attitude towards a broader range of meat analogues available from different plant origin.
A selection and a training of a sensory panel took place with a large range of plant-based meat analogues with the aim of generating a list of attributes for actual tasting session.

**WP4. Digestibility of extruded products**
- The aim of WP4 is to understand the link between the processing conditions, the structure of the extrudate on the protein digestibility using in vitro model;
- Simulation of oral breakdown: A method to mimic the mastication step was defined. The method was validated using commercial plant-based meat analogues
- In vitro digestibility of commercial products and products generated during the project are ongoing.

**WP5. Sustainability**
- It was agreed with the partners that the work on sustainability in PlantPROMISE will take place later in the project, as data to be generated are required to fill the different model;
- However, a workshop on sustainability was planned to better understand and defined the contour of the work to be performed.

Planned results 2020

**WP1:**
- Perform experiments with pea, potato, and soy
- Improve understanding of chemical interactions that play a role in high-moisture extrusion (Protein-protein interactions)
- Improve understanding of physical interactions that play a role in high-moisture extrusion.
- With WP2B, experiments with flavours will be performed to understand the impact of flavour addition during the extrusion on the structure of the extrudate and the flavour retention due to the processing.

**WP2:**
- Image analysis for texturization;
- Relates juiciness to structure of the extrudate;
- Material properties upon heating;
- Effect of freezing/thawing cycle on the structure of the extrudate;
- **WP2B:** Effect offlavour addition during the extrusion on the structure of the extrudate and the flavour retention due to the processing.
- **WP2C:** Understand the interfacial properties of O/W emulsions depending on the ingredients used to stabilize the emulsion.

**WP3:**
- Sensory profiles of plant-based meat analogs by a trained panel
- Consumers liking and acceptability of meat analogs: Consumer study
- A survey will be performed to better understand the consumer drivers and context where they eat plant-based meat analogues (diner vs lunch, single meal vs family meal). The survey aims at covering a broader range of consumers, not only Wageningen and Dutch.

**WP4:**
- Further understanding link between processing conditions and digestibility of the extrudate;
- For a range of extrudates varying in processing conditions and structure, but also varying in protein sources.

**WP5:**
- A sustainability workshop will be held. Based on the workshop a plan of the activities to be performed in 2021 and 2022 will be made.

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**Deliverables/products in 2019** (provide the titles and/or a brief description of the products/deliverables or a link to a website.)

**Scientific articles:**
Abstract: Blends of different plant proteins can form excellent basis for meat analogues by subjecting those to shear and heating. We here want to obtain more information of the internal structure of pea protein-gluten and soy protein:gluten blends, by using the polymer blending law to explain rheological responses. For this polymer blending law the water distribution over the two phases is the blend was obtained with time domain 1H NMR measurements.
using the NMR measurements of individual protein phases and on the blend. By matching the relaxation rate (R2) of the individual phases with those of the blend, the water distribution over the two phases could be obtained. Water is preferentially taken up by the soy or pea protein phase leaving less water for gluten, which effect strongly changes the volume fractions of the phases. Rheological properties of the separate phases as function of their hydration resulted in higher apparent modulus for the wheat gluten phase, and a lower one for the pea and soy protein phase. From the results, it was concluded that both blends show signs of a bi-continuous morphology. The SPI-WG blend showed an intermediate value between bi-continuous and SPI continuous. PPI-WG at lower temperatures showed a bi-continuous structure, while at higher processing temperatures and time was probably WG continuous.


Abstract: Pea protein isolate can be combined with wheat gluten into materials with a fibrous morphology using shear induced structuring combined with heating. Results are partly in-line with soy protein isolate-wheat gluten blends, but the latter yields anisotropic materials in a much broader temperature range. Both blends also have the ability to include air. Air bubbles were aligned and deformed at process conditions that gave the most pronounce fibrous products. Mechanically, the pea protein-gluten materials processed at 140 °C had a similar strength as soy protein blends. At 110 and 120 °C, the pea protein blends had a strength that was comparable to a chicken meat reference (50–100 kPa) but weaker than their counterparts with soy (220–300 kPa). Blends of pea protein-gluten show potential for preparing structured plant protein materials, but the application area might be different compared with potential applications of soy protein-gluten blends.