# PhD thesis (2017-2020)

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| Topic | **Formulation and mechanical behavior of starch-protein composites** |
| Responsables | Principal supervisor: Magdalena Kristiawan (magdalena.kristiawan@inra.fr)<br>PhD advisor: Sofiane Guessasma<br>Co-PhD advisor: Guy Della Valle<br>Co-supervisor: Denis Lourdin |
| Host Institute | Biopolymères, Intéractions, Assemblages **(BIA) - INRA Nantes (France)**<br>Equipe: Matériaux, création & comportement (MC2) |

**Context and issues**

The development of plant-based protein foods is essential to meet the challenges of the protein transition and sustainable agriculture. Pulses legumes (peas, lentils, faba beans, etc.) are an excellent source of protein (20-30% dry matter), fiber (10-30%), starch (40-55%), vitamins and minerals. Their proteins are rich in lysine, an amino acid rather rare in cereals. They are therefore good candidates for supplementing or replacing cereals in the production of "snack" produced by extrusion.

This thesis proposal is supported by the project "Development of extruded products with high protein, based on legumes, through modeling (Protex)" (2016-2018), between INRA units (France) and Karlsruhe Institute Technology (Germany). This project takes particularly into account the chewing properties of foods and their sensory attributes, including texture, which are governed by their mechanical properties. It is therefore essential to understand the effect of protein enrichment on the structure and texture of extruded products.

In the scope of the Protex project, the extruded foods are considered fragile cellular solids (Fig. 1). Multi-scale mechanical modeling, using the finite element method (FEM), makes it possible to predict mechanical properties based on the precise knowledge of 1) the cellular structure and 2) the constitutive laws (stress-strain relationship) of the constitutive material of cell wall, which is as called **parietal material (MP)**.

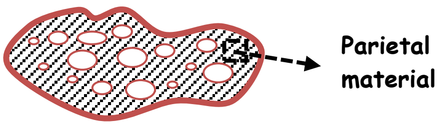


Fig.1. 2D schematic image of the extruded product considered as cellular solid

In perspective, these constitutive laws may be integrated into an expansion model by twin-screw extrusion for the realistic design of innovative foods and materials with targeted properties ("reverse engineering").

**Objective of the thesis and approach**

The aim of the thesis is the accurate determination, through experience and modelling, 1) the morphology and 2) the thermo-rheological behavior of the **parietal material (MP, Fig. 1)**. The MP will be first considered as a dense starch-protein composite, described by the distribution of each constituent and the starch-protein interface. Then, for more realistic products, the morphologies can be addressed by taking into account the location of minor constituents.

The developed methodology will involve: (1) Develop dense starch-protein composites representative **parietal material (MP)** and determine the biochemical modifications of starch and proteins during shaping (extrusion) and the morphology of composites, (2) Develop a method of in situ imaging technique coupled to mechanical loading in order to precisely define the contrast of local mechanical properties, mechanical interactions at the interface and deformation field of composites, (3) Establish a phase diagram representing these properties as a function of protein content, (4) Determine and validate constituent laws of composites in function of multi-scale structure, (5) Determine the rupture mechanisms of these dense composites and cellular solids (issued from the Protex project) using in situ imaging technique (fast camera, micro-X-ray tomography), (6) Model numerically by finite element method (FEM) the mechanical behavior of these composite to obtain constitutive laws. Steps (5) and (6) may be the subject of a choice to be discussed depending on the progress of the work and the training of the PhD student.

To carry out this work, the PhD student will benefit from the scientific environment of the team and will develop a variety of methods: calorimetry, chromatography, mechanical tests, imaging techniques (microscopies and image analysis), and finite element modeling.

**Profile of candidates**

The candidate should have a master (or equivalent) diploma in Food Science or Material Science with interest in biomaterials. The candidate should have a good level in English. He/she should be highly motivated to learn French during thesis. He/she should have skills in one or more of the following areas: food biochemistry, physico-chemical techniques, structural characterization, rheology, and mechanistic modeling.

- Level B1 for French language for non EU nationals

**Advantages**

The PhD student can take advantage of INRA's scientific and industrial network, in national and international levels, to develop his professional career. The obligatory courses during the thesis will be carried out by Doctoral School "Venam" (University of Angers, Nantes, Maine and ONIRIS).

**Salary**

The offer concerns a Doctoral Contract financed by INRA (50%) and the Region of Pays de la Loire (50%). The monthly salary is about 1473 € net.

**Application**

Applications must be sent to the following address: magdalena.kristiawan@inra.fr

The application must contain the following documents:

- CV (including the current situation, curriculum, obtained diploma, research internship during master degree, level of English, and level of French for non-francophone)
- Record of grades of bachelor and master degree
- 2 letters of recommendation, one from supervisor of research internship
- Motivation letter, capable of showing the suitability of candidate profile to research subject

**The deadline is set on April 3, 2017.**

**The start of the thesis is scheduled on October 1, 2017.**

**Some references of research team on the subject:**

1) Della Valle, G., Quillien, L. & Gueguen, J. (1994). Changes in starch and proteins in pea flour during extrusion cooking. *J. Sci.Food Agric.*, 64, 509-517.

2) Chanvrier, H., Della Valle, G., & Lourdin, D. (2006). Mechanical behaviour of corn flour and starch-zein based materials in the glassy state: a matrix-particle response. *Carb. Polymers*, 65, 346-356.

3) Guessasma, S., Chaunier, L., & Lourdin, D. (2010). Finite element modelling of the mechanical behaviour of vitreous starch/protein composite. *J. Food Eng.*, 98, 150-158.

4) Guessasma, S., Chaunier, L., Della Valle, G. & Lourdin, D. (2011). Mechanical modelling of cereal solid foods. *Trends Food Sci. Tech.*, 22, 142-153.

5) Kristiawan, M., Chaunier, L., Della Valle, G., Ndiaye, A., & Vergnes, B. (2016). Modeling of starchy melts expansion by extrusion. *Trends Food Sci. Tech.*, 48, 13-26.