**Physicochemical and rheological properties of Latin American bean protein-enriched ingredients and derived emulsions as influenced by variety and processing.**

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| ***Rationale*** | Over the last decade or so, the increasing awareness towards global issues such as food security and sustainability (Aiking & de Boer, 2020; Day, 2013; Fasolin et al., 2019), animal welfare as well as the health-related hazards caused by excessive consumption of animal products, has led to a growth in the amount of consumers following flexitarian, vegetarian and vegan diets (Derbyshire, 2016; Melina, Craig, & Levin, 2016). This trend has been steering the focus of several food companies towards the development of products based on plant protein-enriched ingredients, including those derived from oilseeds, pulses, cereals, pseudocereals, almonds and nuts (Sá, Moreno, & Carciofi, 2020). Depending on the manufacturing process, ingredients derived from the same source may differ in their level of purity (flours, protein concentrates or isolates), physical state of the proteins (native, denatured or hydrolyzed), functionality (e.g., solubility, emulsifying and rheological properties), nutritional value and allergenicity (Amagliani, Silva, Saffon, & Dombrowski, 2021). It is, therefore, necessary to develop methodologies to adjust processing parameters as a function of ingredient characteristics and the properties of the desired final product in a targeted way (without numerous iterations). A data-driven approach, such as response surface methodology (RSM), can be applied to develop a predictive model (Bonnet, Michon, Jeuffroy, & Blumenthal. 2020).The food research community has recently devoted much attention to the characterization of pulse protein-enriched ingredients, particularly those derived from pea, faba bean and lentil (Boukid, Rosell, & Castellari, 2021; Jarpa-Parra, 2018; Vogelsang-O'Dwyer et al., 2020), due to their relatively high biological value, availability and consumer acceptance. Interestingly, riding the wave of an emerging food science trend, some of these studies centered on the replacement of purified protein ingredients (i.e., protein concentrations >70 wt%) with less refined ones to obtain more affordable products without compromising functionality (Schmitt et al., 2021). However, little is known about the functional properties of other pulse protein-enriched ingredients, such as those derived from common beans (*Phaseolus vulgaris*), how these properties are influenced by variety and processing, and thus the potential of these pulses for the development of food products. Common beans represent staple foods in many Central and South American countries. They are not only recognized as a good source of protein, with a concentration 2-3 times higher compared to cereal grains, but also of dietary fiber, minerals, vitamins and phenolic compounds, their consumption having been associated with various health benefits (Hayat, Ahmad, Masud, Ahmed, & Bashir, 2014).  |
| ***Objective*** | This study aims to investigate the influence of variety and processing on the physicochemical and rheological properties of Latin American bean protein-enriched ingredients and their derived emulsions. We will develop a predictive data-driven model to adjust processing variables based on ingredient properties and desired end-product characteristics during this project. This model will enable the definition of optimal processing conditions for developing plant-based liquid and semi-solid products tailored to the Latin American market. |
| ***Scientific Approach*** | Various Latin American bean varieties will be screened to identify those characterized by: (i) lowest concentration of oligosaccharides responsible for digestive discomfort; (ii) highest protein concentration; (iii) highest antioxidant capacity; (iv) highest digestibility; (v) highest crop yield and tolerance to drought and disease. The impact of processing (i.e., mild or alkaline processing) on nutrient composition (including protein profile), physicochemical and functional properties (i.e., solubility as a function of pH, interfacial, emulsifying and rheological properties) will be investigated using a Design of Experiment (DoE) in a first campaign to achieve emulsion stability for the development of plant-based liquid and semi-solid products. The dataset obtained will be used to build a predictive data-driven model (along with additional data points) to forecast processing targets based on the underlying properties of the ingredients. |
| ***Deliverables and Timing*** | **Year 1*** Five South American bean varieties (pre-selection made by Prof. Fuentes’s group) will be grown in a greenhouse at Pontificia Universidad Católica de Chile and characterized for their nutrient composition (macro- and micronutrients, protein and carbohydrate profile), antioxidant capacity, *in vitro* digestibility, crop yield.
* A Ph.D. student with a background in Chemical Engineering (or equivalent) will prepare a literature review regarding novel and mild processes to obtain protein-enriched ingredients. He(She) will prepare his(her) Ph.D. proposal to defend it in the third semester. The first year will be mainly dedicated to the courses required by the program at PUC.

 **Year 2*** Obtention of flours from the South American bean varieties selected during the first year will be achieved by applying various processing methods, including mild (e.g., roasting), alkaline, and deep eutectic solvent extraction.
* The effect of the raw material characteristics, extraction method, and ingredients properties on emulsion stability will be studied. An experimental Design of Experiment (DoE) will be implemented.
* The impact of variety and processing method on protein profile (i.e., SDS-PAGE, RP-HPLC, LC-MS/MS) and physicochemical properties (i.e., solubility as a function of pH, interfacial and emulsifying properties) of the ingredients obtained will be assessed.

**Year 3*** A predictive model will be built using the dataset generated with the DoE. Its prediction capacity will be validated using an additional bean variety.
* To understand their potential to replace animal-based proteins in semi-solid food applications, the rheological properties upon shear and heat treatment of the most promising bean protein-enriched ingredients and derived emulsions will be investigated as a function of pH, protein, and oil concentration and compared with those of dairy proteins.

**Year 4*** Select optimal manufacturing conditions to be used at pilot scale to develop plant-based -liquid and semi-solid products.
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| ***Potential Applications*** | The main focus of the study will be the identification of processing methods to obtain South American bean protein-enriched ingredients with the desired functionality, as well as the manufacturing conditions for the development of plant-based liquid and semi-solid products for the Latin American market. The outcomes of this study could be used to develop different types of liquid and semi-solid food products, including, but not limited to, RTD beverages, yogurts, coffee creamers, culinary solutions, and confectionery fillings.  |
| ***Location*** | During the first three years of the project, the Ph.D. student will be based at Pontificia Universidad Católica de Chile under the supervision of Prof. Francisco Fuentes and Prof. José Ricardo Pérez Correa, with the support of Prof. Mario Aranda. If relevant, a data scientist can complement the group of investigators to cover the expertise on DoE and predictive modeling. The Ph.D. student will spend the fourth year of the project at Nestlé Research Lausanne focusing on the rheological characterization of the Chilean bean protein-enriched ingredients and derived emulsions and the investigation at the pilot scale of their potential for developing plant-based liquid and semi-solid-products.  |

References

Aiking, H., & de Boer, J. (2020). The next protein transition. *Trends in Food Science & Technology, 105*, 515-522.

Amagliani, L., Silva, J. V. C., Saffon, M., & Dombrowski, J. (2021). On the foaming properties of plant proteins: Current status and future opportunities. *Trends in Food Science & Technology*.

Bonnet, A.F., Michon, C., Jeuffroy, M.H., Blumenthal, D. (2019), Taking into account upstream variability of flours with processing variables in legume-enriched soft cakes: Conception of a multi-objective model for the monitoring of physical properties. *Food and Bioprocess Technology*.

Boukid, F., Rosell, C. M., & Castellari, M. (2021). Pea protein ingredients: A mainstream ingredient to (re)formulate innovative foods and beverages. *Trends in Food Science & Technology, 110*, 729-742.

Day, L. (2013). Proteins from land plants – Potential resources for human nutrition and food security. *Trends in Food Science & Technology, 32*(1), 25-42.

Derbyshire, E. J. (2016). Flexitarian Diets and Health: A Review of the Evidence-Based Literature. *Front Nutr, 3*, 55.

Fasolin, L. H., Pereira, R. N., Pinheiro, A. C., Martins, J. T., Andrade, C. C. P., Ramos, O. L., & Vicente, A. A. (2019). Emergent food proteins - Towards sustainability, health and innovation. *Food Res Int, 125*, 108586.

Hayat, I., Ahmad, A., Masud, T., Ahmed, A., & Bashir, S. (2014). Nutritional and health perspectives of beans (Phaseolus vulgaris L.): an overview. *Crit Rev Food Sci Nutr, 54*(5), 580-592.

Jarpa-Parra, M. (2018). Lentil protein: a review of functional properties and food application. An overview of lentil protein functionality. *International journal of food science & technology, 53*(4), 892-903.

Melina, V., Craig, W., & Levin, S. (2016). Position of the Academy of Nutrition and Dietetics: Vegetarian Diets. *J Acad Nutr Diet, 116*(12), 1970-1980.

Sá, A. G. A., Moreno, Y. M. F., & Carciofi, B. A. M. (2020). Plant proteins as high-quality nutritional source for human diet. *Trends in Food Science & Technology, 97*, 170-184.

Schmitt, C., Bovetto, L., Buczkowski, J., De Oliveira Reis, G., Pibarot, P., Amagliani, L., & Dombrowski, J. (2021). Plant proteins and their colloidal state. *Current Opinion in Colloid & Interface Science, 56*, 101510.

Vogelsang-O'Dwyer, M., Petersen, I. L., Joehnke, M. S., Sorensen, J. C., Bez, J., Detzel, A., . . . Zannini, E. (2020). Comparison of Faba Bean Protein Ingredients Produced Using Dry Fractionation and Isoelectric Precipitation: Techno-Functional, Nutritional and Environmental Performance. *Foods, 9*(3).