**Innovative technological applications of plant-based ingredients**

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This PhD research project is aimed at developing protein and starch ingredients derived from different plant-based raw materials, promoting the applications of local resources e.g., legumes and cereals and by-products following the main principles of green and circular economy. The ingredients will be produced through the dry fractionation process. Technological, nutritional and sensory characteristics of the ingredients will be investigated to produce innovative food products and pursuing the 12 Goal established by the 2030 Agenda “Responsible consumption and production”.

Applicazioni tecnologiche innovative di ingredienti plant-based

Le attività di ricerca saranno volte a sviluppare ingredienti proteici e amidacei, ottenuti attraverso il processo di dry-fractionation, derivanti da diverse materie prime vegetali locali, ad esempio legumi e cereali, nonché scarti e sottoprodotti dell’industria alimentare seguendo i principi di green economy ed economia circolare. Lo studio delle loro caratteristiche nutrizionali, tecnologiche e sensoriali sarà necessario all’impiego in prodotti alimentari innovativi perseguendo così l’obiettivo 12 dell’Agenda 2030 “Garantire modelli di consumo e produzione sostenibili”.

# **1. State-of-the-Art**

Today, consumers are shifting toward a healthy lifestyle, promoting ethical and sustainable behaviors. Plant-based foods earn interest in consumers, because the reduction of animal foods is often associated to well-being (Ma et al., 2021). To support this healthy lifestyle, companies formulate innovative foods with high nutritional value using plant-based protein ingredients marked in the form of flours, concentrates and isolates (Ma et al., 2021). These are usually produced through the wet fractionation technique (Ma et al., 2021), which has the advantage of obtaining ingredients with high protein content (70-90%) through the solubilization of the raw material and the precipitation of proteins using chemicals and a drying step to obtain a powdery ingredient. However, the use of chemicals, energy and water, is in contrast with the aim of promoting a sustainable food system (Schutyser et al., 2011).

A sustainable alternative to produce plant-based protein is the dry-fractionation process, which is based on the solely physical separation of the raw material in two fractions. This technique consists in two steps: milling of the raw materials to obtain a micronized flours and separation with an air-classifier to obtain a starch-rich fraction (coarse fraction) and a protein-rich fraction (fine fraction) (Schutyser et al., 2011; De Angelis et al., 2021). This technique is versatile, and it can be applied to legumes, some cereal crops (e.g., wheat and barley) (Schutyser et al., 2011) and to recover and upcycling different industrial by-products (e.g., bran) (Zhang et al., 2019). Future prospects are linked to the improvement of the application to cereals and pseudocereals in which the separation is difficult due to the inhomogeneous starch particle size distribution (Schutyser et al., 2011). Usually, the protein content is lower compared to the protein isolates (e.g., in legumes 55-60%), but the native structure of the protein is preserved, because no chemicals and high temperature are used. In fact, the native structure leads to a different protein performance from the denatured proteins (e.g., foaming, gelling, solubility) (Schutyser et al., 2011; De Angelis et al., 2021). For example, it has been reported that in denatured state some hydrophobic groups are exposed, compared to the protein native state and may influence some functional performance such as solubility and foaming (Tabtabaei et al., 2019).

The starch-rich fraction produced through the dry fractionation process usually is considered a co-product of the protein production and is destinated to feed industry (Ren et al., 2021). In fact, the starch used for food production is obtained via wet extraction which presents the same problematics described above (Ren et al., 2021). The starch in food can be used as gelling, binder, stabilizer, and thickening ingredient.

Functional performance and food application of protein and starch concentrates obtained through the dry fractionation process have been investigated only in the last few years. Since Apulian region is considered a main Italian region in the production of cereals and legume (Piergiovanni, 2021), dry fractionation technique may be applied to valorise these typical cultivations. Therefore, the aim of this PhD thesis project is to study the protein and starch ingredients obtained through the dry fractionation process. Legumes, cereals and pseudocereals and industrial by-products will be considered as raw materials, in order to promote a responsible production in accordance with the Goal 12 of the 2030 Agenda. Characterization of the ingredients will be necessary to produce innovative foods (e.g., meat, fish or dairy analogues, and egg replacers), promoting the use of local ingredients. The foods produced will have a balanced nutritional profile and will be clean label.

# **2. PhD Thesis Objectives and Milestones**

The PhD thesis project is divided into activities (A) presented in the Table 1 with the aim of set up the dry fractionation process, characterize the protein ingredients that will be used in food production:

**A0) Bibliographic research**

**A1) Application and set-up of the dry fractionation process to local raw materials:** by-products, cereals, and legumes: these activities, carried out in collaboration with Innovaprot srl., will be focused on the set-up of the dry fractionation process applied on different raw materials (e.g., legumes, cereals and by-products) (A1.1) and the subsequent characterization of the obtained fractions (A1.2). Specifically, chemical composition, rheological and functional properties will be determined to better understand their possible application in food products.

**A2) Set-up of the extrusion process to improve sensorial, nutritional, and functional properties:** the aim will be to study the set-up of the extrusion process on the protein and starch fractions (A2.1). The protein fraction will be used to produce textured vegetable proteins (TVP) which will be include as ingredient in food (e.g., meat or fish analogues). The starch fraction will be used to produce ingredients for ready to eat products (e.g., snack). The structured ingredients will be characterized to understand their potentiality in food application (A2.2). This activity will be carried out in collaboration with the Center of Food and Fermentation Technologies (Tallin, Estonia).

**A3) Food application of the ingredients and their characterization:** the protein and starch ingredients in the form of flour and/or structured products will be used to produce foods (A3.1, A3.2) with the purpose of fortify or replace animal proteins in foods (e.g., egg replacers, meat and dairy analogues). Pasteurized fresh pasta filled with TVP frozen stored will be also produced to study the effect of the thermal treatments and freezing on the TVP and food produced (A3.3, A3.4). All the innovative foods will be characterized in their nutritional, textural and sensorial features. These activities will be carried out in collaboration with Gastronomia Frost Srl (Castellana Grotte, Italia).

***Table 1***Gantt diagram for this PhD thesis project.

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **ACTIVITY/ MONTH** | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 |
| **A0** | **Bibliographic research** |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| **A1** | **Application and set-up of the dry fractionation process to local raw materials: by-products, cereals, and legumes** |
| A1.1 | Set up of the dry-fractionation process  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| A1.2 | Characterization of dry-fractionated proteins and starch |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| **A2** | **Set-up of the extrusion process to improve sensorial, nutritional, and functional properties** |
| A2.1 | Set-up of the extrusion process |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| A2.2 | Nutritional and functional characterization of the extruded raw material |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| **A3** | **Food application of the ingredients and their characterization** |
| A3.1 | Application of dry-fractionated protein and starch in foods and their characterization  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| A3.2 | Application of the extruded products to produce innovative foods and their characterization |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| A3.3 | Study of the thermal treatment on the qualitative characteristics of the extruded ingredients and foods |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| A3.4 | Study of the frozen storage on the qualitative characteristics of the extruded ingredients and foods |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| **A4** | **Data analysis, thesis and papers writing** |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |

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