PhD DISSERTATION PROJECTS

Development of organogels containing bioactive compounds from agri-food by-products and their application for innovative and sustainable foods formulation

Giulia Salvatori (giulia.salvatori5@unibo.it)

Dept. Food Science and Technology, *Alma Mater Studiorum*-Università di Bologna, Viale Fanin 40, 40127, Bologna, Italy

Tutor: Prof. Maria Teresa Rodriguez Estrada

Co-Tutor: Dr. Dario Mercatante

This PhD thesis aims at developing organogels containing bioactive compounds from agri-food by-products, in order to obtain an innovative and sustainable solution for the replacement of traditional solid fats currently employed in food formulations. This project can help valorizing agri-food by-products and developing innovative food products that are safe, stable (from a physico-chemical and oxidative standpoint), with at least the same, or even better, shelf-life, organoleptic and nutritional characteristics of the corresponding conventional products.

Sviluppo di organogel contenenti composti bioattivi da sottoprodotti e loro applicazione per la formulazione di alimenti innovativi e sostenibili

Il presente progetto di ricerca si propone di sviluppare organogel contenenti composti bioattivi derivanti da sottoprodotti della filiera agro-alimentare, che forniscano una soluzione innovativa e sostenibile per la sostituzione di grassi solidi tradizionaliattualmente impiegati nelle formulazioni alimentari, permettendo così di valorizzare i suddetti sottoprodotti e di sviluppare alimenti innovativi che siano sicuri, stabili da un punto di vista chimico-fisico ed ossidativo, e che abbiano almeno le stesse, se non superiori, caratteristiche di conservabilità, organolettiche e nutrizionali dei prodotti convenzionali.

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

In the past few years, legislative limitations to the use of fats rich in *trans* fatty acids (TFA) in food, the rising awareness of consumers regarding the negative effects of TFA and saturated fatty acids (SFA) on human health and the environmental impact related to the large use of palm oil in food and biodiesel productions, oriented researchers to study alternative lipid-based structures that were healthier and had a lower environmental impact (Li *et al*., 2022). However, SFA and TFA play an important role in foods, as they confer different properties such as plasticity, taste, flavor, mouthfeel, texture, etc. Thus, there is a real need to find solutions for the replacement of the so-called “hard” fats (generally with a high content of SFA and/or TFA) in foods, but without compromising technological and sensory characteristics of the later. One of the main alternatives that have been proposed are organogels, which are gels in which a continuous liquid phase (vegetable oil or water) is entrapped and immobilized in a thermo-reversible three-dimensional network through the use of non-triglyceridic organogelators (Bascuas *et al.*, 2020). Organogels have been used as replacers of traditional solid fats in several food products (baked products, meat products, dairy products etc.) to reduce the total amount of fat (particularly of SFA and TFA), still giving a solid texture. In fact, the structuring mechanism of organogels does not change the chemical composition of the starting liquid phase nor its nutritional value, which is one of the main advantages with respect to other widely used fat structuring processes in food industry, such as hydrogenation and interesterification (Li *et al*., 2022). Moreover, many studies have positively evaluated their utilization as “carrier systems” for the transport and retention of bioactive compounds. Indeed, organogels may represent a system potentially capable to increase their solubility and dispersibility within food matrix and their bioavailability in the gastro-intestinal tract, by controlling their release and protecting them from oxidation and loss of functionality (Orhan and Eroglu, 2022). In this context, the agri-food by-products, to which are attributed high disposal costs and a low market value for their reuse, represent a significant source of bioactive compounds with high biological value; in fact, thanks to their proven antioxidant, antimicrobial and health properties, they could be used as ingredients and/or additives in food formulations (Fritsch *et al*., 2017). Therefore, adhering to circular economy, green economy and sustainability concepts, organogels represent an interesting alternative for the inclusion and subsequent valorization of agri-food by-products. The main by-products at both Italian and European levels are those from grain, olive oil, tomato and potatoes (Fritsch *et al*., 2017), which are rich in bioactive compounds such as carotenoids, phenolic compounds, etc. Lastly, organogels may be used in the formulation of plant-based food, an emerging market trend that is perceived by the consumers as more sustainable food solutions and more adherent to ethical, environmental sustainability, and health-nutritional aspects (McClements and Grossmann, 2021). These products could represent an interesting application for bioactive compounds-loaded organogels, especially if we consider that they have to deal with a “flavor challenge” as they are often characterized by a high presence of off-flavors that can be generated by lipid and/or protein oxidation during processing (Leonard *et al*., 2022; Wehrmaker *et al*., 2022). In the formulation of innovative foods (conventional and/or plant-based), the use of organogels rich in bioactive compounds from agri-food by-products may represent an application capable of improving the shelf-life, slowing and/or drastically reducing oxidative and hydrolytic processes of lipids and proteins, with positive impact on organoleptic quality and health-nutritional characteristics of these food products, while valorizing agri-food by-products and enhancing the sustainability of the supply chain.

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

The goal of this PhD thesis research is to develop organogels containing bioactive compounds from agri-food by-products, in order to find an innovative and sustainable solution for the replacement of traditional solid fats currently used in food formulations. This project may enable the valorization of agri-food by-products and the development of innovative and safe food products, that have to meet the same, if not superior, standards for stability (from a physico-chemical and oxidative point of view), shelf-life, organoleptic and nutritional characteristics as conventional products.

The PhD thesis project can be divided into the following activities, summarized in the Gantt diagram shown in Table 1:

**A1) Bibliografic research**

**A2) Extraction and characterization of bioactive compounds from agri-food by-products**

**A3) Development of organogels including bioactive compounds**

**A4) Formulation of innovative foods (conventional and/or plant based)**

**A5) Shelf-life study of selected products**

**A6) Writing and publication of the PhD thesis, posters, scientific papers and oral presentations**

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

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Activity Months | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** | **11** | **12** | **13** | **14** | **15** | **16** | **17** | **18** | **19** | **20** | **21** | **22** | **23** | **24** |
| A1) | ***Bibliografic research***  |   |   |   |  |  |  |  |   |   |  |  |  |  |   |  |  |  |  |   |   |  |  |  |  |
| A2) | ***Extraction and characterization of bioactive compounds from agri-food by-products***  |   |   |   |  |  |  |  |   |   |  |  |  |  |   |   |   |  |   |   |   |  |  |  |  |
| A3) | ***Development of organogels including bioactive compounds***  |   |  |   |   |   |   |  |   |   |   |   |   |  |   |  |  |  |  |   |   |   |   |   |  |
|  | 1) Evaluation of physico-chemical and oxidative stability |   |  |   |   |   |  |  |   |   |   |   |  |  |   |  |  |  |  |   |   |   |   |  |  |
|  | 2) Evaluation of organogels’ retention efficiency of selected bioactive compounds |   |  |   |  |  |   |  |   |   |  |  |   |  |   |  |  |  |  |   |   |  |  |   |  |
| A4) | ***Formulation of innovative foods*** |   |  |   |  |  |   |   |   |   |  |  |   |   |   |  |  |  |  |   |   |  |  |   |   |
|  | 1) Setting up of products’ formulation/s with pre-selected organogel/s |   |  |   |  |  |   |   |   |   |  |  |   |   |   |  |  |  |  |   |   |  |  |   |   |
|  | 2) Evaluation of the composition, stability (physico-chemical and oxidative) and sensory profile on innovative products |   |  |   |  |  |  |  |   |   |  |  |  |  |   |  |  |  |  |   |   |  |  |  |  |
| A5) | ***Shelf-life study of selected products*** |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| A6) | ***Thesis and Paper Preparation*** |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |  |   |   |   |   |   |   |   |

# **3. Selected References**

Bascuas S, Hernando I, Moraga G, Quiles A (2020) Structure and stability of edible oleogels prepared with different unsaturated oils and hydrocolloids. *Int J Food Sci Technol* **55**(4): 1458-1467.

Fritsch C, Staebler A, Happel A, Cubero Márquez MA, Aguiló-Aguayo I, Abadias M, Gallur M, Cigognini IM, Montanari A, Lopez MJ, Suarez-Estella F, Brunton N, Luengo E, Sisti L, Ferri M, Belotti G (2017) Processing, valorization and application of bio-waste derived compounds from potato, tomato, olive and cereals: A review. *Sustainability* **9**(8): 1492.

Leonard W, Zhang P, Ying D, Fang Z (2022) Surmounting the off-flavor challenge in plant-based foods. *Crit Rev Food Sci Nutr* 1-22.

Li L, Liu G, Bogojevic O, Pedersen JN, Guo Z (2022) Edible oleogels as solid fat alternatives: Composition and oleogelation mechanism implications. *Compr Rev Food Sci Food Saf* **21**(3): 2077-2104.

McClements DJ, Grossmann L (2021) The science of plant‐based foods: Constructing next‐generation meat, fish, milk, and egg analogs. *Compr Rev Food Sci Food Saf* **20**(4): 4049-4100.

Orhan NO, Eroglu Z (2022) Structural characterization and oxidative stability of black cumin oil oleogels prepared with natural waxes. *J Food Process Preserv* **46**(12): e17211.

Wehrmaker AM, Zenker HE, De Groot W, Sanders M, Van Der Goot AJ, Janssen AE, Keppler J, Bosch G (2022) Amino acid modifications during the production (shearing, sterilization) of plant-based meat analogues: An explorative study using pet food production as an example. *ACS Food Sci Technol* **2**(11): 1753−1765.