1. PHD PROJECT DESCRIPTION (4000 characters max., including the aims and work plan)

Project title: Encapsulation of the phenolic compounds from food industry by-products: Characterisation and potential applications

1.1. Project goals

The main goal of the project is the extraction and characterisation of new encapsulated antioxidant compounds obtained from food industry by-products with specifically designed properties, such as a defined release time. The capsule size and shape play an important role in diffusion, permeability and controlled release of antioxidants. Therefore, factorial design analysis will be used with the purpose of identification, evaluation and optimisation of factors that affect these physicochemical properties of encapsulated antioxidants. Finally, encapsulated phenolic compounds will be used to extend the shelf life of food industry products and/or as additives in new functional foods.

1.2. Outline

Encapsulation is a rapidly increasing technique in food, cosmetic, and pharmaceutical industries where core material, including an antioxidant agent, is packed into wall materials (typically macromolecules such as alginate or chitosan) to form solid or liquid capsules. Due to consumers' demand for less-processed, natural food, the encapsulation of novel antioxidants in natural wall material is a value-added feature of this type of additive, in contrast to well-known artificial phenolic antioxidants.

Agro-food by-products are rich sources of natural bioactive compounds with antioxidant and antimicrobial properties that can improve the quality of food products and extend their shelf life. These functional features can be enhanced by encapsulation, allowing controlled release into the products and helping reduce their sometimes unfavourable sensory attributes. Moreover, the encapsulation can stabilise the bioactive compounds, which are sensitive to heating, exposure to light, oxygen, and pH changes. The addition of the encapsulated bioactive compounds to food products can inhibit lipid oxidation, limiting the generation of rancid odours and flavours and changes in texture and colour, which affect their shelf life and nutritional value. Therefore, it can be assumed that oil industry by-products such as meals or press-cakes, which consist of vast amounts of phenolic antioxidants, proteins and fibres, can be applied as active matters (phenolic extracts) and coating materials (meal proteins) in the encapsulation process. Additionally, recovering substances from by-products that can be designed as food additives promotes the "zero waste" movement.

In the project, the obtained and characterised novel encapsulated antioxidants from the oil and agro-food by-products are planned. Many factors, including encapsulation techniques, properties of active compounds and coating materials, and interactions between compounds influencing the encapsulation efficiency, will be optimised and evaluated using different statistical tools and artificial intelligence, particularly machine learning methods. Moreover, the effect of these innovative food additives in encapsulated form on shelf life and the usefulness of frying oil will be estimated. The encapsulation of phenolic compounds into biopolymeric matrices from proposed by-products will also be

studied to improve their bioaccessibility after digestion, allowing these compounds to remain stable, protected from external factors and to be released into a specific location in the gastrointestinal tract to exert their beneficial effect. The application of the proposed novel encapsulated antioxidants with potential activity and enhanced bioaccessibility is expected to be a promising alternative to commercially available antioxidants in the food industry.

1.3. Work plan

- Implementation and optimisation of effective extraction methods of antioxidants from oil and agro-food by-products.
- Preparation of encapsulated antioxidants from oil and agro-food by-products.
- Characterisation of the obtained encapsulated antioxidants by spectroscopic, imaging, thermal, and chromatographic methods.
- Investigation of the influence of new encapsulated antioxidants on the quality of stored and fried food products.
- Determination of bioaccessibility of new encapsulated antioxidants.
- Application of statistical and chemometric tools, and artificial intelligence, particularly machine learning methods to data analysis and optimisation of the encapsulation parameters, prediction of antioxidant release, storage conditions of food products with new encapsulated antioxidants.

1.4. Literature (max. 7 listed, as a suggestion for a PhD candidate preliminary study)

1. Mohammadi, A.; Jafari, S. M.; Esfanjani, A. F.; Akhavan, S. Application of Nano-Encapsulated Olive Leaf Extract in Controlling the Oxidative Stability of Soybean Oil. *Food Chemistry* 2016, 190, 513–519.
2. Estakhr, P.; Tavakoli, J.; Beigmohammadi, F.; Alaei, S.; Mousavi Khaneghah, A. Incorporation of the Nanoencapsulated Polyphenolic Extract of Ferula Persica into Soybean Oil: Assessment of Oil Oxidative Stability. *Food Science & Nutrition* 2020, 8, 2817–2826.
3. Ramaswamy, S.; Dwarampudi, L. P.; Kadiyala, M.; Kuppuswamy, G.; Veera Venkata Satyanarayana Reddy, K.; Kumar, C. K. A.; Paranjothy, M. Formulation and Characterization of Chitosan Encapsulated Phytoconstituents of Curcumin and Rutin Nanoparticles. *International Journal of Biological Macromolecules* 2017, 104, 1807–1812.
4. Hassanein, W. S.; Meral, R.; Ceylan, Z.; Ahmed, M. M.; Yilmaz, M. T. Use of Encapsulated Pomegranate Seed Oil in Novel Coarse and Nanosized Materials for Improving the Storage Life of Strawberry. *Food Chemistry* 2024, 441, 138251.
5. Kenari, R. E.; Amiri, Z. R.; Motamedzadegan, A.; Milani, J. M.; Farmani, J.; Farahmandfar, R. Optimization of Iranian Golpar (Heracleum Persicum) Extract Encapsulation Using Sage (Salvia Macrosiphon) Seed Gum: Chitosan as a Wall Materials and Its Effect on the Shelf Life of Soybean Oil during Storage. *Food Measure* 2020, 14, 2828–2839.
6. Soni, M.; Yadav, A.; Maurya, A.; Das, S.; Dubey, N.K.; Dwivedy, A.K. Advances in Designing Essential Oil Nanoformulations: An Integrative Approach to Mathematical Modeling

with Potential Application in Food Preservation. *Foods* 2023, 12, 4017.
7. Rodríguez-Dorado, R.; Landín, M.; Altai, A.; Russo, P.; Aquino, R. P.; Del Gaudio, P. A Novel Method for the Production of Core-Shell Microparticles by Inverse Gelation Optimized with Artificial Intelligent Tools. *International Journal of Pharmaceutics*, 2018, 538, 97-104.

1.5. Required initial knowledge and skills of the PhD candidate

- Basic knowledge in the field of analytical and food chemistry.
- Basic knowledge of the instrumental techniques characterising food products and waste extracts.
- The ability to interpret and describe experimental results and draw conclusions.
- Knowledge of speaking and writing English.
- Commitment to scientific work, permanent self-education and ability to cooperate in a team.

1.6. Expected development of the PhD candidate's knowledge and skills

- The ability to practical skills:
  - methodology for the extraction of active components from oil and agro-food residuals;
  - encapsulation of antioxidant extracts obtained from by-products;
  - application of new techniques and instrumentations for qualitative and quantitative analysis of the obtained capsules;
  - application of new techniques and instrumentations for the determination of food quality.
- The ability to write scientific publications, scientific projects (grant applications) and presentation of results at international conferences, workshops and tutorials.
- Preparation for hard work, formulation and solving scientific problems related to food science and technology trends.