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

Project title: *Membrane-supported and non-membrane-supported techniques for preparation of oil formulation for potential application in agriculture and cosmetics*

1.1. Project goals

The goal of the PhD project is to create an innovative platform for multi- and interdisciplinary research to develop oil-based bio-pesticides formulations with acceleration and adoption of membrane technology-innovative solutions. The membrane technology is expected to provide a significant contribution to the sustainable formulation of bio-pesticides and agricultural crops management plan and high input on Environmental Objectives of Polish Agriculture strategy under the Common Agricultural Policy 2023-0 (the goal will be developed within the international cooperation between leading institute in Europe in Membrane and Encapsulation Technologies, Eurecat (Spain) and Nicolaus Copernicus University in Torun (NCU), Poland). The PhD project proposes use of essential oils as a biopesticide and bioadditive to cosmetic products e.g. emollients. The emulsion will be prepared by membrane technology, including premix membrane emulsification (PME) and stirred cell membrane emulsification. In order to stabilize the emulsion, appropriate surfactants approved for agriculture applications (superior goal) must be tested and selected. The important aim will focus on the generation of the membrane with enhanced affinity and biocompatibility to the separated system assessed by Hansen Solubility Parameters-HSP. The additional goal will be the formation of silica nanoparticles with tuned morphology for the purpose of emulsion stabilization. The cognitive goal will be understanding how the membrane features (morphology, wettability, surface charge, functional groups) and structure of stabilizers will influence the stability and quality of the generated emulsions.

1.2. Outline

Membranes are core of membrane-based separation process, including membrane emulsification. Depending on membrane material features, it is possible to modify emulsions. The chemical composition of membrane is significant for PME process. A membrane with an affinity for continuous phase should be used, and thus, hydrophilic and hydrophobic membranes are needed to manufacture O/W and W/O emulsion, respectively. The biggest advantage of PME to direct membrane emulsification is much higher flux and possible reduction of fouling as a consequence of transport features improvement. However, the membrane wettability must be tuned to fulfill the requirement of enhanced transport.

Membrane separation techniques in essential oil production have a significant benefit: they do not affect the essential oil's organoleptic and physicochemical features. Therefore, membrane technology is considered a highly competitive method. Compared to traditional processes, membrane techniques have numerous advantages that allow for the concentration and isolation/fractionation of aroma raw materials at mild temperature conditions without additional extracting agents.

Considering the fundamental research, a better understanding of emulsion stabilization will be provided. Specifically, the nanoparticles of silica will be modified and tested as a stabilizer with tuned morphology. The following method will be related to the test of Pickering emulsions which offer many interesting properties compared to conventional ones, including superior stability against coalescence, minimization of the Ostwald ripening phenomena, higher biocompatibility, and recently used for emulsification with essential oils.

1.3. Work plan

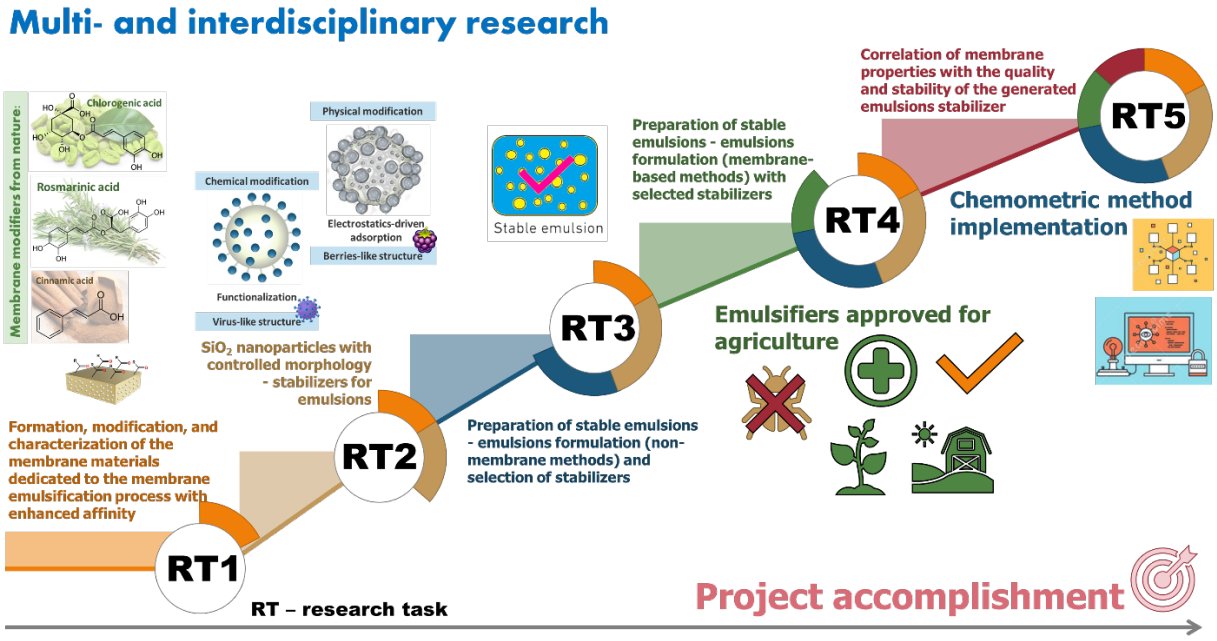
The proposed doctoral project will be accomplished according to the following 5 research tasks (RT).

RT1. Formation, modification, and characterization of the membrane materials dedicated to the membrane emulsification process with enhanced affinity.

RT2. Production of nanoparticles with controlled morphology - stabilizers for Pickering emulsions.

RT3,4. Preparation of stable emulsions - emulsions formulation (non-membrane-RT3, membrane-based-RT4 methods) and selection of stabilizers.

RT5. Correlation of membrane properties with the quality and stability of the generated emulsions stabilizers.



1.4. Literature *(max. 10 listed, as a suggestion for a PhD candidate)*

[1] A. Ali, U.T. Syed, T.S. Bak, C.A. Quist-Jensen, Membrane emulsification—a novel solution for treatment and reuse of produced water from oil field, Membranes, 12 (2022) 971.

[2] N. Somala, C. Laosinwattana, J. Dimak, M. Teerarak, Formulation and application of clove essential oil-based nanoemulsion against ruellia tuberosa l, in: Acta Horticulturae, International Society for Horticultural Science, 2023, pp. 203-210.

[3] J. Xu, J. Cui, H. Sun, Y. Wu, C. Xue, A. Xie, C. Li, Facile preparation of hydrophilic pvdf membrane via tea polyphenols modification for efficient oil-water emulsion separation, Colloids Surf. A Physicochem. Eng. Asp., 657 (2023).

[4] X. Qi, S. Zhong, P. Schwarz, B. Chen, J. Rao, Mechanisms of antifungal and mycotoxin inhibitory properties of thymus vulgaris l. Essential oil and their major chemical constituents in emulsion-based delivery system, Ind. Crops Prod., 197 (2023).

[5] A.A. Wardana, L.P. Wigati, T.T. Van, F. Tanaka, F. Tanaka, Antifungal features and properties of pickering emulsion coating from alginate/lemongrass oil/cellulose nanofibers, Int. J. Food Sci. Technol., 58 (2023) 966-978.

[6] B. Sasikumar, S.A.G. Krishnan, M. Afnas, G. Arthanareeswaran, P.S. Goh, A.F. Ismail, A comprehensive performance comparison on the impact of mof-71, hnt, sio2, and activated carbon nanomaterials in polyetherimide membranes for treating oil-in-water contaminants, J. Environ. Chem. Eng., 11 (2023).
[7] B. Tylkowski, A. Trojanowska, M. Olkiewicz, I. Cota, A. Nogalska, R.G. Valls, M. Giamberini, J.M. Montornes, 5 polymer chemistry in development of encapsulation technologies, in: T. Bartosz, W. Karolina, J. Renata, M. Xavier (Eds.) Polymer engineering, De Gruyter, Berlin, Boston, 2022, pp. 143-176.
[8] J. Genova, M. Dencheva-Zarkova, I. Cota, M. Olkiewicz, J.M. Montornes, M. Luczak, A. Bajek, S. Roszkowski, K. Bialczyk, G. Zukowska, B. Tylkowski, I. Tsibranska, 9 application of polymers for separation/ filtration of biologically active compounds, in: T. Bartosz, W. Karolina, J. Renata, M. Xavier (Eds.) Polymer engineering, De Gruyter, Berlin, Boston, 2022, pp. 309-328.
[9] S. Al-Gharabli, Z. Flanc, K. Pianka, A.P. Terzyk, W. Kujawski, J. Kujawa, Porcupine quills-like-structures containing smart pvdf/chitosan hybrids for anti-fouling membrane applications and removal of hazardous vocs, Chem. Eng. J., 452 (2023) 139281.

1.5. Required initial knowledge and skills of the PhD candidate

- Basic knowledge in the field of membrane separation techniques, membrane formation and modification
- Elementary knowledge in the field of emulsion formulation, characterization, including stability and quality
- Basic knowledge of the analytical techniques used for membrane characterization, SEM, AFM, zeta potential, porosimetry, DLS and ELS
- The ability to cooperate in a team, also in an international one

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

- The ability to analytical thinking
- Keen to learn new techniques and instrumentations
- Eager to work hard and contribute to the success of the project
- Be interested in interdisciplinary science fields from the borderline of material chemistry (membranes, separation techniques) and cosmetic chemistry (emulsion formation and stabilization)