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

Project title:

Intelligent and safe bio-based packaging materials for food and cosmetic industry

1.1. Project goals

The aim of the project is to synthesize new safe packaging materials with a biopolymer matrix (starch, chitosan) and additives that help control food quality: polyphenols, vitamins, salts (in terms of pH control, antibacterial activity, protection against solar radiation, and antioxidant activity). Such packaging will fit the definition of active and intelligent materials intended for contact with food while maintaining the safety of consumers and the natural environment. Designed packaging is expected to control the condition of the packaged product but not interact with the product. A synthesis will be proposed, and a complete characterization of the morphology, functionalization, biodegradation, photodegradation, and physicochemical properties of the obtained composites will be made.

Outline

Technological advances and climate change have forced government organizations to develop new strategies to work harmoniously across multiple industries. Food packaging safety aligns with current trends and the strategy adopted by the European Food Safety Authority (EFSA) in the coming years. In particular, part of this plan addresses the use of chemicals in the food chemistry and food packaging industry. Quality of perishable foods (e.g. fresh fruit, vegetables, raw meat) may be a partially controlled process, and the biological, chemical or physical processes that ultimately lead to product spoilage may be limited. Packaging must fulfill four general functions:

protection, communication, convenience and storage. For this purpose, so-called intelligent packaging concepts can be used. The project will provide innovative, environmentally safe, intelligent packaging materials based on biopolymers. The synthesis and full characterization of the morphology, functionalization, biodegradation, photodegradation and physicochemical properties of starch-based composites for intelligent food packaging will be developed.

1.2. Work plan

In the first stage, up-to-date literature on intelligent packaging based on biopolymers will be reviewed.
Polymer films for use in the packaging industry for perishable products, e.g., for the food and cosmetics industries, will be prepared by solution casting. In the first stage, biopolymers and proposed compositions (starch, cellulose, chitosan, alginate) will be selected to obtain films with features adequate to the proposed applications.
The project will examine physicochemical properties such as mechanical properties, swelling, gas, moisture permeability, antioxidant properties, biodegradability, and susceptibility to photodegradation. The following techniques will be used for chemical tests: FTIR spectroscopy, UV-Vis spectrometry, XRD, GPC chromatography, HPLC. Surface properties will be examined using AFM and SEM microscopy and contact angle measuring equipment. In addition, the thermal properties of new materials will be investigated using DSC and thermal analysis. Biodegradation tests will be conducted in various environments, e.g., soil and activated sludge.

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

1. Müller, P., & Schmid, M. (2019). Intelligent packaging in the food sector: A brief overview. Foods, 8(1), 16. https://doi.org/10.3390/foods8010016
2. Kalpana, S., Priyadarshini, S. R., Maria Leena, M., Moses, J. A., & Anandharamakrishnan, C. (2019). Intelligent packaging: Trends and applications in food systems. Trends in Food Science & Technology, 93, 145–157. https://doi.org/10.1016/j.tifs.2019.09.008
3. Sionkowska, A. (2021). Collagen blended with natural polymers: Recent advances and trends. Progress in Polymer Science, 122, 101452. https://doi.org/10.1016/j.progpolymsci.2021.101452

4. Sionkowska, A. (2011). Current research on the blends of natural and synthetic polymers as new biomaterials: Review. Progress in Polymer Science, 36(9), 1254–1276. https://doi.org/10.1016/j.progpolymsci.2011.05.003
5. Bhattacharjee, A., Savargaonkar, A. V., Tahir, M., Sionkowska, A., & Popat, K. C. (2024). Surface modification strategies for improved hemocompatibility of polymeric materials: A comprehensive review. RSC Advances, 14(11), 7440–7458. https://doi.org/10.1039/d3ra08738g
6. Rostamabadi, H., Bajer, D., Demirkesen, I., Kumar, Y., Su, C., Wang, Y., Nowacka, M., Singha, P., & Falsafi, S. R. (2023). Starch modification through its combination with other molecules: Gums, mucilages, polyphenols and salts. Carbohydrate Polymers, 120905. https://doi.org/10.1016/j.carbpol.2023.120905
7. Sheibani, S., Jafarzadeh, S., Qazanfarzadeh, Z., Wijekoon, J. O., Rozalli, N. H. b. M., & Nafchi, A. M. (2024). Sustainable strategies for using natural extracts in smart food packaging. International Journal of Biological Macromolecules, 131537. https://doi.org/10.1016/j.ijbiomac.2024.131537
8. Bajer, D. (2023). Hypophosphite cross-linked starch succinate/chitosan membranes as alternative for packaging and pharmaceutical application. International Journal of Biological Macromolecules, 126103. https://doi.org/10.1016/j.ijbiomac.2023.126103
9. Bajer, D., & Burkowska-But, A. Innovative and environmentally safe composites based on starch modified with dialdehyde starch, caffeine, or ascorbic acid for applications in the food packaging industry. Food Chemistry, 374, 131639. https://doi.org/10.1016/j.foodchem.2021.131639

1.3. Required initial knowledge and skills of the PhD candidate

Knowledge of biopolymers (structure, occurrence, physico-chemical characteristics, reactivity), and their potential industrial applications (medical, cosmetics, food, packaging). Openness to acquiring new knowledge in the field of polymer modification.

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

Knowledge of modification methods, designing reactions for synthesizing new biomaterials, ability to predict the effects of modification polymers, and ability to combine knowledge with practice. The analyzing and concluding of experimental results. Knowledge of experimental techniques, e.g., spectroscopic, microscopic, mechanical, and thermal analysis methods.