Microbial Biopolymers for Innovative Packaging to Increase Food Shelf-life and Safety

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The aim of this PhD research project is to develop the production of biopolymers for the formulation of food packaging from yeast cells or their metabolites, including those with antimicrobial activity, to extend the shelf life and safety of various food matrices. In particular, the biopolymers are produced from components of the cell walls of yeasts (glucans, mannans) or microbial metabolites such as pullulans and/or cellulose.

**Biopolimeri microbici per imballaggi innovativi per aumentare la durata di conservazione e la sicurezza degli alimenti**

Questo progetto di tesi di dottorato mira a mettere a punto la produzione di biopolimeri per la formulazione di un packaging alimentare a partire da cellule di lieviti o loro metaboliti, anche ad azione antimicrobica, al fine di incrementare la shelf-life e sicurezza di diverse matrici alimentari. In particolare, i biopolimeri saranno costituiti a partire da componenti della parte cellulare dei lieviti (glucani, mannani) o da metaboliti microbici quali pullulani e/o cellulosa.

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

In recent decades, research and industry interest in food packaging has increased in the search for viable alternatives to the use of synthetic petroleum-derived films. Although petrochemical polymers such as polyethylene, polypropylene, polystyrene and polyamide are cost-effective products with good mechanical properties and excellent barrier properties to a variety of compounds such as oxygen, carbon dioxide, water vapor, and aromatic compounds, they have a significant negative impact on the environment as they are not biodegradable and come from non-renewable sources. A sustainable solution to reduce the problem of plastic accumulation in the environment and reduce the use of polymers from non-renewable sources could be the development of biodegradable polymers for environmentally friendly food packaging (Siracusa *et al.*, 2008). According to the literature, the natural polymers used to develop biodegradable materials are polysaccharides, proteins and lipids. Biopolymers are becoming increasingly important in food packaging as they can act as carriers for other molecules with antioxidant properties. In addition, thanks to their antimicrobial properties, active packaging can be produced to increase the shelf life and safety of various food products (Cerutti *et al.*, 2016). According to the literature, there are several materials that have the potential to be used as biopolymers, but they have not yet been fully explored. One such material is yeast biomass, whose cell walls are composed of glucans, mannoproteins and chitin. For example, the main polysaccharides that have been shown to be successful candidates for multicomponent film formation in combination with cell wall proteins are β-glucans, which make up about 55-65 % of the yeast cell wall. Using the yeast cell wall to form films that can be used as packaging also has the advantage of avoiding purification steps (Choque *et al.*, 2021). Currently, there are several methods to break down the yeast cell walls and separate the components from the intracellular components, such as sonication, but high-pressure homogenisation treatments may also be a sustainable non-thermal alternative. In addition to yeast cell walls, certain biopolymers such as pullulans produced by *Aureobasidium pullulans* or celluloses produced by various acetic bacteria could also be viable alternatives for obtaining biopolymers of microbial nature for use in packaging (Kraśniewska *et al.*, 2019). The production of yeast biomass and/or its metabolites from waste and by-products of the agri-food industry and their use as culture substrates for microbial growth could be another component of sustainability. Indeed, whey from the dairy industry, some by-products of the wine industry or vegetable and fish waste could be good growth substrates for potentially useful microorganisms due to their high organic matter content. Chitosan is undoubtedly one of the most researched polysaccharides. From 2016 to early 2021, more than 9000 articles have been published on the potential of chitosan in food packaging film formulation due to its non-antigenic, non-toxic, biodegradable, biocompatible, biofunctional and strong antimicrobial properties that can potentially extend the shelf life of food (Crini and Lichtfouse, 2019).

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

Within the overall objective mentioned above this PhD thesis project can be subdivided into the following activities according to the Gantt diagram given in Table 1:

A1) **Bibliographic research** to identify the most suitable microorganisms for the recovery of cell wall constituents or their metabolites**.**

A2) **Screening of selected strains and optimisation of microbial performance** on agri-food industry wastes and by-products.

A3) **Selection of the most suitable methods and technologies** for breaking down cell walls and recovering the fraction of interest.

A4) **Characterisation of the obtained biopolymers** in terms of their antimicrobial and technological performance and film formulation.

A5) **Evaluation of the shelf life and safety of food matrices** in relation to selected packaging conditions.

A6) **Writing and Editing** of the PhD thesis, scientific papers, and oral and/or poster communications.

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

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Activity Months | | **2** | **4** | **6** | **8** | **10** | **12** | **14** | **16** | **18** | **20** | **22** | **24** | **26** | **28** | **30** | **32** | **34** | **36** |
| A1) | ***Bibliographic research*** |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  | 1) Identification of suitable microorganisms |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| A2) | ***Screening of the selected strains and optimization of microbial performance*** |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  | 1)Selection and technological characterisation of selected yeast strains |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  | 2) Optimisation of growth conditions for microorganisms on agri-food industry wastes and by-products |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| A3) | ***Development of biotechnological processes for the recovery of biopolymers of interest*** |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  | 1) Application of microbial enzymes to obtain cellular compounds |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  | 2) Application of high-pressure homogenisation, ultrasonication, pulsed electric fields |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| A4) | ***Antimicrobial and technological characterisation of the obtained biopolymers and film formulation*** |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  | 1) Antimicrobial and antioxidant characterisation of biopolymers |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  | 2) Film formulation and characterisation |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| A5) | ***Evaluation of the shelf life and safety of food matrices in relation to selected packaging conditions*** |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| A6) | ***Thesis and Paper Preparation*** |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |

# **3. Selected References**

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