Shelf-life extension of food by using of innovative biodegradable packaging

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This PhD thesis research project is aimed at evaluating the effects of the use of biodegradable packaging, edible coatings and films, possibly added with natural bioactive compounds, on the shelf life of food. A study of the degradation kinetics will be carried out, based on the monitoring of the main qualitative indices, to find effective and sustainable solutions to be used as an alternative to the use of non-degradable plastic polymers, with the aim of prolonging the shelf life of food maintaining high quality and obtaining benefits for the environment and health.

Estensione della shelf-life degli alimenti tramite l’impiego di packaging innovativo biodegradabile

Questo progetto di tesi di dottorato ha lo scopo di valutare gli effetti dell’uso di imballaggi biodegradabili, rivestimenti e film edibili, eventualmente addizionati con composti bioattivi naturali, sulla shelf life degli alimenti. Verrà effettuato uno studio delle cinetiche di degradazione, basato sul monitoraggio dei principali indici qualitativi, al fine di trovare soluzioni efficaci e sostenibili da utilizzare in alternativa all’utilizzo di polimeri plastici non degradabili, con l’obiettivo di prolungare la durata di conservazione degli alimenti mantenendo un’elevata qualità e ottenendo benefici per l’ambiente e la salute.

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

Packaging is an essential element in the food chain as it plays the fundamental role of protecting and preserving the qualitative characteristics of the food product from production to distribution and consumption, delaying the deterioration of the product, extending the shelf-life, limiting food waste and ensuring food safety. Synthetic packaging materials obtained from limited and non-renewable petroleum-based resources such as polyethylene (PE), polypropylene (PP), polyethylene terephthalate (PET), are among the preferred ones due to their mechanical properties, durability over time, ease of processing and cheapest production costs. The intensive use of these materials constitutes one of the most criticized environmental challenges due to the serious consequences on the environment due to their synthetic nature. In addition to the emission of toxic gases during production and disposal, by accumulating in the environment, they lead to the formation of microplastics and chemical substances that damage human health and threaten natural balances (Nilsen-Nygaard *et al*., 2021; Kumar *et al*., 2022).

Nowadays, the consumer is increasingly attentive to health, food safety, sustainability, and environmental concerns. The increased awareness and the change in lifestyles have led to the research and development of sustainable food packaging systems capable to less impact on the environment. Replacing plastic packaging with bio-based and biodegradable materials could help reduce problems such as depletion of natural resources, waste management and disposal, global warming, etc. To meet these expectations, research is focused on the use of biopolymers combination for the formation of biodegradable packaging materials and edible coatings as substitutes for synthetic polymers. Moreover, the possibility to add natural and bioactive substances on the packaging formulation results as a valid opportunity to extend the food shelf life and reduce the food wastes. This new concept of packaging has aroused considerable interest thanks to the advantages related to biocompatibility, economy, and non-toxicity (Kumar *et al*., 2022).

An edible coating solution can be used for the formation of coatings which are formed directly on the surface of the product by dipping or spraying in the form of a thin film which it covers them or films which are produced starting from the solution with the obtainment of a preformed thin layer in which food can be wrapped (Grzebieniarz *et al*., 2023). The application of edible coatings to foods dates to the 12th and 13th centuries when wax was applied to citrus fruit in China. Later, waxes became commercially available as food coatings (Park, 1999).

Currently, biopolymers used for the formation of biodegradable packaging or edible coatings can be classified according to their origin as synthetic such as polylactic acid (PLA) or polybutylene succinate (PBS), microbial such as polyhydroxyalkanoates (PHA) or natural such as polysaccharides, proteins, and lipids (Nilsen-Nygaard *et al*., 2021). The properties of interest of the packaging materials are the gas and water vapor barrier properties, the mechanical resistance, the improvement of the visual aspect and the release of compounds of interest such as antioxidants, antimicrobials, anti-browning, nutrients from additives used in their formulation (Iñiguez-Moreno *et al*., 2021). However, single biodegradable materials have limitations due to poor barrier, mechanical and processing properties compared to conventional polymers. In the current scientific panorama, there are many examples of application of single biopolymers such as biodegradable packaging material and edible film and coating to extend the shelf life of food, some applications show a positive effect on food products while others highlight the criticalities of the single material (Nilsen-Nygaard *et al*., 2021; Kumar *et al*., 2022).The formation of composite coatings or multilayer packaging can be an effective solution to combine the characteristics of the single polymers obtaining an improvement of the functional properties of the final film also thanks to the addition of bioactive compounds and additives such as plasticizers and emulsifiers that improve flexibility, extensibility and stability of the coating (Iñiguez-Moreno *et al*., 2021; Grzebieniarz *et al*., 2023). Although several works exist on the application of single and multilayer films (Grzebieniarz et al., 2023), more in-depth research is needed on their larger use and on the monitoring of kinetic processes during their application in food preservation.

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

This PhD thesis project will be directed to evaluate the possible application of single and composite films and coatings in food preservation. The study of the kinetic processes of deterioration and modifications of the chemical, physical, microbiological, and sensorial parameters of foods during the storage time will be carried out. Different types of innovative and biodegradable packaging will be tested to identify the optimal conditions that allow to define and extend the shelf life. Within the overall mentioned objectives, the current PhD thesis project was divided into the following activities according to the Gantt diagram given in Table 1:

A1) **Individuation of biopolymers for food packaging application** through the study of biopolymers properties from bibliographic research (A1.1), and the analysis of the current application of biopolymers to food on the market (A1.2) with the aim to verify the application to the identified food for this research.

A2) **Development of the formulations** **and application of innovative packaging to food systems.**  Single and combined packaging systems will be evaluated for their stability, physical and mechanical properties (thickness, colour, moisture content, water solubility, texture) to find solutions with better functional proprieties (A2.1).

A3) **Monitoring of the products shelf life** to evaluatethe changes in the quality parameters as physical parameters (weight loss, colour, texture analysis), chemical and nutritional (titratable acidity, total soluble solids, water activity, pH, organic acids content, bioactive compounds, antioxidant activity), microbiological and sensorial (flavour, taste, aroma, visual aspect) during the storage time using the different types of innovative and biodegradable packaging (A3.1)

A4) **Definition of the products shelf life** through the study of the degradation kinetics of quality indexes to identify the most suitable packaging systems which allow to extend the shelf life of food maintaining high quality (A4.1)

A5) **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 | **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) | ***Individuation of biopolymers for food packaging application*** |   |   |   |  |    |    |   |   |   |  |    |    |  |   |  |  |  |  |   |   |  |  |  |  |
|  | 1) Study of biopolymers properties |   |  |   |  |  |  |  |   |   |  |  |  |  |   |  |  |  |  |   |   |  |  |  |  |
|  | 2) Analysis of biopolymers food applications on market |   |  |   |  |  |  |  |   |   |  |  |  |  |   |  |  |  |  |   |   |  |  |  |  |
| A2) | ***Application of innovative packaging to food systems*** |   |   |   |  |  |  |  |   |   |  |  |  |  |   |   |   |  |   |   |   |  |  |  |  |
|  | 1) Formulation and characterization of packaging systems |   |   |   |  |  |  |  |   |   |  |  |  |  |   |   |  |  |  |   |   |  |  |  |  |
| A3) | ***Monitoring of the products shelf life*** |   |  |   |   |   |   |  |   |  |  |  |  |  |  |  |  |  |  |  |  |   |   |   |  |
|  | 1) Evaluation of quality parameters change |   |  |   |   |   |  |  |   |   |   |   |   |   |  |   |  |  |  |  |   |   |   |  |  |
| A4) | ***Definition of the products shelf life*** |   |  |   |  |  |   |   |   |   |  |  |   |   |   |  |  |  |  |   |   |  |  |   |   |
|  | 1) Study of the most suitable innovative packaging  |   |  |   |  |  |   |   |   |   |  |  |   |   |   |  |  |  |  |   |   |  |  |   |   |
| A5) | ***Editing of thesis and scientific papers*** |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |  |   |   |   |   |   |   |   |

# **3. Selected References**

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