Biocomposites Based on Biopolymers and Waste Products for Food Packaging

Student: Erika Lunetta

Industrial and Civil Engineering, PhD level, Engineering Department,
Niccolò Cusano University, INSTM RU, Via Don Carlo Gnocchi 3, 00166 Rome, Italy
erika.lunetta@unicusano.it

Mentor: Ilaria Cacciotti

Engineering Department, Niccolò Cusano University, INSTM RU,
Via Don Carlo Gnocchi 3, 00166 Rome, Italy
ilaria.cacciotti@unicusano.it

Abstract*. The employment of biopolymers in the food sector has grown widely in recent times since petrochemical plastic products caused a significant environmental impact. This work will be aimed at the development of innovative compostable ecosustainable systems, based on biopolymers and agri-food waste extracts and fillers, in order to find a new use for them in the Circular Economy and in the zero-waste standard context. The introduction of natural fillers into a biopolymeric material could lead to the realization of a packaging with good thermal, mechanical and antimicrobial properties, with the ability of preserving the food and extending its shelf-life.*

Keywords. Biopolymers, agri-food waste, circular economy, ecosustainability, food packaging

University of Maribor Press

DOI https://doi.org/10.18690/um.4.2023.44
ISBN 978-961-286-783-6

1 Introduction

Multiple types of plastics are being used as materials for food applications. Traditional plastic is made of non-biodegradable petrochemical-derived polymers, which cause dramatic environmental impact [1]. For these reasons, the employment of biodegradable and/or compostable polymers has widely spread in recent times [2]. Biopolymers can be extracted from biomass, synthesized from bioderived monomers or produced by microorganisms. They are non-toxic eco-sustainable materials and they can reduce the environmental burden since they are derived from renewable and sustainable raw materials. The present PhD project involves the use of biopolymers in the food sector for food packaging applications and for the clarification of beverages in fluidized-bed reactors (FBR), as schematized in Fig. 1.

An ideal packaging material must have gas, vapor, aroma barrier abilities, antimicrobial function and good mechanical, optical and thermal properties. However, some biopolymers present drawbacks, such as low mechanical and gas barrier properties [3]. In order to overcome these limits, agricultural and food industry waste extracts and inorganic fillers (e.g., diatomite, calcium carbonate extracted from egg shell/clams, coffee ground extracts) can be added to the polymeric matrix [4]. The idea is to add them in different materials based on natural and synthetic biopolymers, such as polylactic acid (PLA), poly caprolactone (PCL), chitosan, zein, alginate.

Figure 1. A visual schematization of the possible sources and compositions of the polymeric films with the potential to be applied in food packaging.

2 Materials and methods

Specific agri-food waste materials and inorganic components (e.g., shellfish, coffee grounds and eggshells extracts, diatomite) were selected to confer antioxidant and antimicrobial properties to the films. The filler particles (1-10 wt%) were dispersed in the polymer solvent by ultrasonication for 60 minutes. Biopolymers (e.g., PLA, zein, chitosan), in powder or pellet form, were added to the prepared suspensions to realize different film formulations. After magnetically stirring up to polymer dissolution, the solutions were cast on Petri dishes and maintained under fume hood until complete solvent evaporation. As a reference, neat polymeric films were also prepared, following the same procedure. The influence of the additives on the morphology, thermal and mechanical properties was investigated by Scanning Electron Microscopy (SEM), Differential Scanning Calorimetry (DSC) and uniaxial tensile tests.

3 Results and discussion

The good dispersion of the fillers into the biopolymeric matrix was demonstrated by the observation at SEM. It was evidenced from the acquired SEM micrographs that the filler presence caused a higher surface roughness of the film than the neat one, as in the case of zein films with and without diatomite (Figure 2).

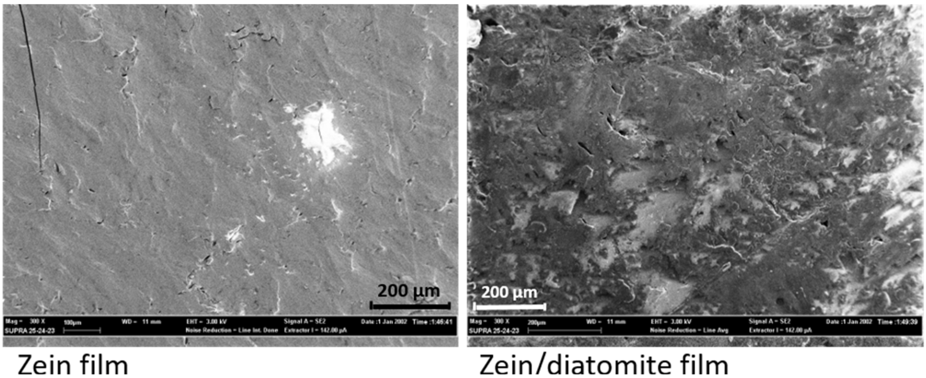
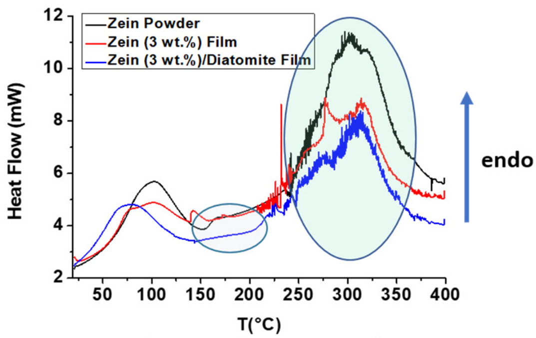


Figure 2. SEM micrographs of zein based films.

The thermal properties of the manufactured films were also influenced by the filler introduction. The smoothing of the curves in the area of the glass transition temperature (T_g) for the films seemingly implied an alteration of the protein amorphous structure, as evident from the comparison between the DSC thermograms related to neat and composite zein films in Figure 3.



Sample	T_g (°C)	$T_{degradation}$(°C)	$\Delta H_{degradation}$ (J/g)
Zein Powder	160.8	296.9	356.0
Zein film (3 wt.%)	-	276.9	331.4
Zein/Diatomite film	-	312.9	353.2

Figure 3. DSC thermograms and related temperatures and enthalpies for zein powder, neat zein film and composite zein/diatomite film.

The good dispersion of diatomite fillers within the polymeric matrix and the high filler/polymer wettability allowed to obtain and increment of the mechanical properties [5]. The influence of the diatomite fillers on the barrier properties of the produced films will be investigated in future, since it is expected that the presence of the dispersed fillers within the polymeric matrix creates a tortuous path to the gases, blocking their diffusion and avoiding their contact with the food inside the package [5].

4 Conclusions

Ecosustainable systems based on biopolymers and natural fillers were obtained. A good fillers dispersion, as well as their influence on the thermal and mechanical properties, was demonstrated. On the basis of the collected results, it is possible to conclude that different materials based on biopolymers can be considered as an innovative promising and performing alternative to the non-biodegradable petrochemical-derived polymers, commonly used in food applications.

References

[1] K. Marsh and B. Bugusu, “Food packaging - Roles, materials, and environmental issues: Scientific status summary,” *J. Food Sci.*, vol. 72, no. 3, 2007, doi: 10.1111/j.1750-3841.2007.00301.x.

[2] S. Sid, R. S. Mor, A. Kishore, and V. S. Sharanagat, “Bio-sourced polymers as alternatives to conventional food packaging materials: A review,” *Trends Food Sci. Technol.*, vol. 115, no. May, pp. 87–104, 2021, doi: 10.1016/j.tifs.2021.06.026.

[3] P. R. Salgado, L. Di Giorgio, Y. S. Musso, and A. N. Mauri, “Recent Developments in Smart Food Packaging Focused on Biobased and Biodegradable Polymers,” *Front. Sustain. Food Syst.*, vol. 5, no. April, pp. 1–30, 2021, doi: 10.3389/fsufs.2021.630393.

[4] C. L. Reichert *et al.*, *Bio-based packaging: Materials, modifications, industrial applications and sustainability*, vol. 12, no. 7. 2020. doi: 10.3390/polym12071558.

[5] M. Pinelo, B. Zeuner, and A. S. Meyer, “Juice clarification by protease and pectinase treatments indicates new roles of pectin and protein in cherry juice turbidity,” *Food Bioprod. Process.*, vol. 88, no. 2–3, pp. 259–265, 2010, doi: 10.1016/j.fbp.2009.03.005.[5] Cacciotti, I., Fortunati, E., Puglia, D., Kenny, J. M., & Nanni, F. (2014). Effect of silver nanoparticles and cellulose nanocrystals on electrospun poly (lactic) acid mats: Morphology, thermal properties and mechanical behavior. Carbohydrate polymers, 103, 22-31. doi: 10.1016/j.carbpol.2013.11.052.