Research paper **P 9**

EDIBLE CHITOSAN FILMS CONTAINING PROPOLIS AND *Fumaria officinalis* BIOACTIVES

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DOI: 10.68725/FDSQ_WORKSHOP.2026.9.20

ABSTRACT

Chitosan-based edible films plasticized with ethyl lactate and enriched with propolis and *Fumaria officinalis* extract (4 and 8 wt%) were developed and characterized as potential active food packaging materials. Film morphology was analyzed by optical microscopy and SEM, while antioxidant activity was evaluated using DPPH• and ABTS•$^{+}$ assays. The 4 wt% film exhibited a compact and homogeneous structure, indicating good dispersion of bioactive compounds within the chitosan matrix. In contrast, the 8 wt% film showed increased heterogeneity and visible aggregates, suggesting partial extract agglomeration at higher concentrations. Both films demonstrated strong antioxidant activity, which increased with extract content. The 8 wt% film showed significantly higher DPPH• scavenging activity, while ABTS•$^{+}$ inhibition remained above 95% for both samples.

INTRODUCTION

Edible films are biodegradable biopolymer-based layers applied directly to food surfaces to improve quality, extend shelf life, and reduce moisture and oxygen transfer. Among biopolymers, chitosan is widely used due to its excellent film-forming ability, biocompatibility, biodegradability, and suitability for various bioactive compounds that can enhance functional performance [1,2]. Natural additives such as *Fumaria officinalis* extract and propolis are of particular interest, as both are rich in phenolic compounds, responsible for strong antioxidant and antimicrobial properties, contributing to additional protective and bioactive effects in food packaging applications [3,4]. This study aimed to develop chitosan-based edible films plasticized with ethyl lactate and enriched with *F. officinalis* extract and propolis, and to evaluate their functional and structural properties. The films were characterized in terms of antioxidant

activity, surface morphology using optical microscopy and scanning electron microscopy (SEM), and swelling behavior to assess their suitability for potential application as active food packaging materials.

EXPERIMENTAL

The aerial part of *F. officinalis* was extracted with 50% ethanol (ultrasound-assisted, 15 min), followed by solvent removal *via* rotary evaporation and storage of the dried extract at 4°C [5]. Chitosan-based film-forming solutions were prepared in aqueous lactic acid with triglyceryl citrate as a plasticizer. Propolis, pre-emulsified with ethyl lactate and Glucopon®, was added to the chitosan solution, followed by incorporation of fumitory extract at 4 and 8 wt%. The mixtures were cast and dried to form films. Film morphology was analyzed by optical microscopy and SEM. Antioxidant activity of the films was evaluated using DPPH• and ABTS•$^{+}$ assays by measuring absorbance changes at 517 and 734 nm, respectively. Film samples (3 mg) were dissolved in PBS and reacted with radical solutions prepared according to standard methods [5].

RESULTS AND DISCUSSION

At 4 wt%, the film surface is relatively uniform and compact, indicating good dispersion of the extract in the chitosan matrix, with only minor irregularities likely due to natural heterogeneity of chitosan films (Figure 1a).

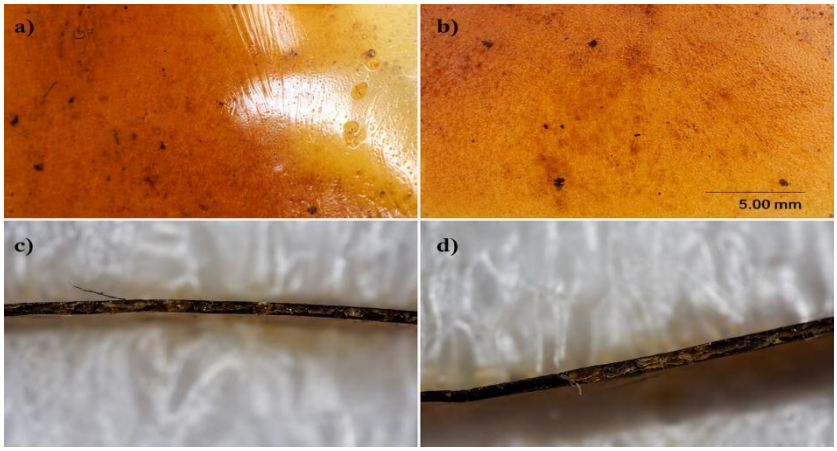

Figure 1. Optical micrographs of films with propolis and *Fumaria officinalis* extract: 4 wt% (a and c) and 8 wt% (b and d).

In contrast, the 8 wt% film shows a more heterogeneous surface with visible aggregates, suggesting partial agglomeration of the extract and increased surface roughness (Figure 1b). Cross-sectional images confirm these findings: the 4 wt% film has a dense, continuous structure and good compatibility between components. The 8 wt% film displays structural irregularities and reduced

uniformity, likely due to saturation of interactions such as hydrogen bonding between chitosan and extract constituents.

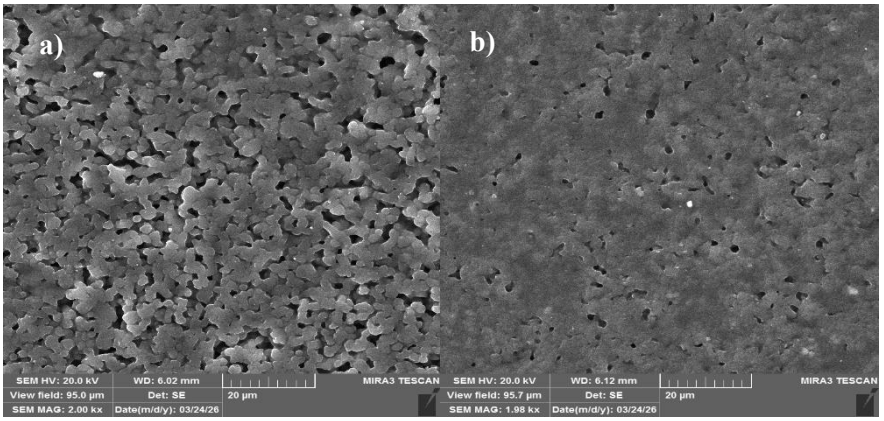

Figure 2. Images of scanning electron microscopy of films with propolis and *Fumaria officinalis* extract: 4 wt% (a) and 8 wt% (b), 2000× magnification.

SEM micrographs revealed differences in the morphology of chitosan films containing 4 and 8 wt% extract (Figure 2). The 4 wt% film exerted a homogeneous, compact surface, indicating good dispersion of the extract within the chitosan matrix. In contrast, the 8 wt% film exhibited a more heterogeneous morphology with visible aggregates, suggesting partial agglomeration and reduced uniformity at higher extract concentration.

Table 1. Antioxidant potential of films with propolis and *Fumaria officinalis* extract (4 and 8 wt%).

Sample	Inhibition of DPPH• (%)	Inhibition of $ABTS^{\bullet+}$ (%)
Film with 4 wt% extract	53.64±1.15	95.33±2.61
Film with 8 wt% extract	89.06±2.13	98.34±1.99

Both films showed strong antioxidant activity, which increased with higher extract concentration (Table 1). The 8 wt% film exhibited significantly higher DPPH• inhibition compared to the 4 wt% film, while both samples showed very high $ABTS^{\bullet+}$ scavenging activity. The enhanced antioxidant potential is attributed to the higher phenolic compound content from propolis and *F. officinalis* extract [3-5]. $ABTS^{\bullet+}$ inhibition values were higher than DPPH• for both samples, suggesting greater effectiveness of the bioactive compounds toward ABTS radicals, likely due to differences in radical solubility and reaction mechanisms [6,7].

CONCLUSION

Chitosan films containing propolis and *F. officinalis* extract exhibited promising antioxidant properties and successful incorporation of bioactive compounds into the polymer matrix. Increasing the extract concentration enhanced radical scavenging activity, particularly against $ABTS^{\bullet+}$. The results indicate that although the extract can be successfully incorporated into chitosan films, higher loading reduces structural homogeneity and increases phase separation, which may negatively influence key properties such as mechanical strength, flexibility, and barrier performance. Nevertheless, the developed films show potential for application as active edible packaging materials.

Acknowledgement

This research was supported by the Ministry of Science, Technological Development, and Innovation of Serbia (451-03-136/2026-03/200019, 451-03-136/2026-03/200135, and 451-03-136/2026-03/200026), United Nations Sustainable Development Goal 3 (Good Health and Well-Being).

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