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Biobased and Home-Compostable Blend Films and Layers for Protecting Perishable Foods

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INTRODUCTION & AIM

The need to prevent food loss through the use of sustainable packaging is becoming increasingly urgent, driven by the imperative to reduce environmental pollution and address the demands of a growing global population. Thanks to its favorable climatic conditions, the Mediterranean region produces a wide variety and large quantities of food products [1].

Currently, research aimed at protecting perishable foods is focusing on the development of novel multilayer systems composed of biobased and compostable polymers [2]. The use of renewable resources ensures that these materials are carbon-neutral, thereby mitigating their contribution to climate change. Furthermore, packaging made from compostable materials can be industrially composted after undergoing appropriate recycling processes, supporting a fully biocircular approach and contributing to soil quality enhancement [3].

Nevertheless, the barrier properties of many biobased and biodegradable formulations remain inferior to those of conventional fossil-derived films, such as low-density polyethylene (LDPE). In this context, the potential of blending different biobased polyesters to enhance performance has yet to be systematically investigated.

To address this gap, biobased and home-compostable films were developed by blending poly(lactic acid) (PLA) with poly(butylene succinate-co-adipate) (PBSA). Specifically, the PLA/PBSA 60/40 blend demonstrated suitability for industrial film production, offering enhanced flexibility [4] and impact resistance [5]. These films, which leverage their thermoplastic nature for application on various substrates, were found to be readily recyclable in industrial settings [6]. However, their barrier properties in the packaging of perishable liquid or semi-liquid foods remain unexplored.

In this study, the PLA/PBSA 60/40-based film was evaluated for its effectiveness in limiting the diffusion of perishable food components. Furthermore, PLA/PBSA blends were prepared using a mini-extruder, with variations in composition to identify formulations exhibiting optimal barrier performance for liquid foods such as whey. The mass retention of whey sealed within the films was measured over time. Additionally, the blends were assessed for their melt fluidity and surface properties via infrared spectroscopy. The findings revealed that the blend composition exerted a significant influence on the barrier characteristics of the films.

These results not only hold relevance for dairy product packaging but also present promising applications for the preservation of perishable Mediterranean fruits, including those perishable like for instance strawberries, dates, and tangerines. Given the abundant availability of these fruits in the region, the proposed packaging solution is particularly pertinent. The development of such films could contribute to reducing food waste and extending the shelf life of perishable goods, thereby offering a sustainable and practical alternative. This research underscores the critical role of material composition in the design of effective and environmentally responsible packaging solutions.

METHOD

The blends were prepared by using a micro–compounder Haake Minilab II (Thermo Scientific Haake GmbH, Karlsruhe, Germany). After the introduction of the material, the melt, pushed by the screws, runs through a closed circuit (with the valve closed) for 1 min. In the tests, the rotating speed was 100 rpm and the processing temperature was 190 °C.

The investigation of flow behavior was carried out with a CEAST Melt Flow Tester M20 (Instron, Canton, MA, USA) equipped with an encoder. The ISO1133D custom TTT was followed at 190 °C with a weight of 2.160 kg. Through the encoder Melt Volume Rate (MVR) was recorded and the Melt Flow Rate (MFR) was determined weighing the material.

Infrared spectra were recorded in the 550–4000 cm−1 range with a Nicolet 380 Thermo Corporation Fourier Transform Infrared (FTIR) Spectrometer (Thermo Fisher Scientific, Waltham, MA, USA) equipped with smart Itx ATR (Attenuated Total Reflection) accessory with a diamond plate, collecting 256 scans at 4 cm^{-1} resolutions. ONMIC software was used to compare different spectra profiles. Two films, fabricated using a Noselab compression molding press, were sealed along three edges. A predetermined quantity of whey was then introduced into the partially sealed container, after which the final sealing was performed. The weight of the sealed samples was measured after a 30-day period and compared to their initial weights.

micro–compounder Haake Minilab II

CEAST Melt Flow Tester M20

Nicolet 380 FT-IR

Whey inserted in two sealed films

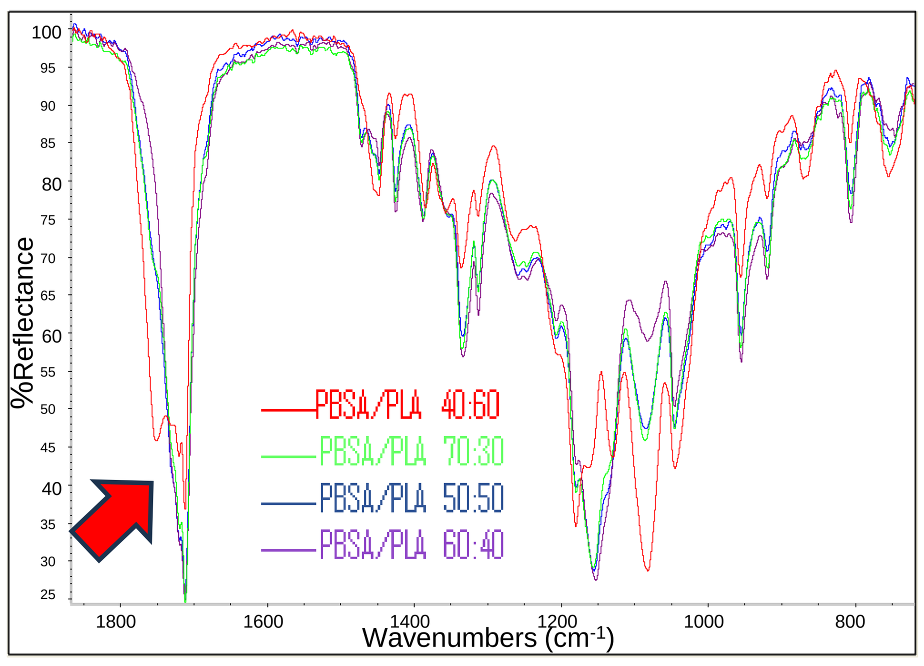
Noselab compression moulding press

RESULTS & DISCUSSION

An increase in PBSA content resulted in a slight decrease in both MVR and MFR values (Table 1). Given that, at 190°C, the MFR of pure PLA was 3 g/10 min, while that of pure PBSA was 4 g/10 min, this trend is not straightforward to interpret. It is worth considering that biopolyesters are susceptible to chain scission during processing, with PLA reportedly being more prone to this degradation mechanism than PBSA

Table 1: MVR and MFR data

% of PBSA	MVR (cm^3/10min)	MFR (g/10min)
40	4.45±0.14	5.00±0.17
50	4.04±0.26	4.45±0.23
60	3.89±0.33	4.23±0.35
70	3.50±0.25	3.71±0.40



ATR-IR spectra of the films (range: 700-1900 cm^{-1})

ATR-IR analysis conducted at multiple points demonstrated good surface composition homogeneity in the PBSA/PLA 70/30 and 60/40 blends, whereas the PBSA/PLA 50/50 and 40/60 blends exhibited lower uniformity. Notably, the PLA/PBSA 60/40 blend displayed a broader peak associated with C=O stretching. Specifically, the characteristic peak for PLA is centered at 1748 cm^{-1}, while that for PBSA appears at approximately 1715 cm^{-1} [6]. As the PLA content increases, the shoulder at 1748 cm^{-1} becomes more pronounced. Overall, these findings warrant further investigation, particularly regarding the phase morphology evolution of the films.

The films exhibited varying barrier properties depending on their composition. The PLA/PBSA 60/40 and 50/50 blends displayed comparable weight loss, while the PLA/PBSA 40/60 blend demonstrated the lowest barrier performance. Interestingly, the PLA/PBSA 70/30 blend exhibited the highest barrier efficiency.To contextualize these findings, a reference test conducted with LDPE films revealed a weight loss of 0.94% after 30 days. Although the investigated PLA/PBSA blends demonstrated appreciable barrier properties, their performance remains inferior to that of conventional fossil-derived films.

Table 2: data of weight loss % related to tests with whey

% of PBSA	%Weight loss at 30 days
40	9.72
50	9.96
60	17.32
70	7.01

CONCLUSION

This study compared the properties of PLA/PBSA blends and films with varying compositions, revealing several key findings. Firstly, the melt fluidity properties exhibited only slight variations, indicating that the processability of the blends remains reasonably similar. Additionally, some surface inhomogeneity was observed in blends with higher PLA content. Moreover, the barrier performance of the films varied depending on composition, with the PLA/PBSA 30/70 blend demonstrating the most effective barrier properties. While further investigation is necessary to fully explain these observations, the findings of this work offer promising insights for the selection of suitable materials for packaging perishable foods.

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