Influence of biorientation and humidity on PLA films and PVA coatings for enhanced performances

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Résumé :

Flexible packaging offers various benefits, including lighter options that cut costs and carbon footprint. However, present multi-layer flexible packaging is rarely recyclable, making it single-use and unsustainable. Therefore, sustainable flexible materials, those that are often more ecologically friendly and safe for consumers, will be preferred, with a focus on biomaterials (biopolymers)[1].

Commercially available biomaterials that meet food-contact requirements (safe for consumer) are mainly limited to starches and their derivatives, polylactides, polyalkanoates (PHA, PHBV, etc.), and cellulose-based materials [2]. Even though they are biodegradable and/or biosourced, their use in food sector remains very limited due to their quite poor functional properties, particularly barrier properties. Indeed, PLA films have low water and oxygen barrier properties compared to most of the oil-based plastic polymers, which reduces their use in the food industry. The biaxial orientation process (stretching in 2D) is known to improve these properties for many synthetic materials [3–5]. This study aims to better understand how the stretching ratio, as well as the type of PLA used (amorphous or crystallized) and the humidity level, affects water vapor and oxygen permeabilities. Moreover, application of PVA coatings onto PLA is studied to decrease oxygen permeability.

Two PLA grades were used, one able to crystallize during orientation process and the other totally amorphous. Bi-orientation ranged from unstretched to 3.5x3.5 on semi-crystalline PLA films. A further step of annealing at 130°C have also been tested. Water vapour permeability was measured according to the ISO 2528 method at two RH differential [6] and oxygen permeability at 50% and 85% RH using the ISO 15.105 method [7].

The results show that the grade, the relative humidity and bi-orientation (stretching) ratio significantly impact oxygen permeability, but have little effect on water vapor permeability due to plasticization dominant effects during moisture permeation. PVA coating could reduce from 3 to 300 times the oxygen transfers depending on the RH. Both biorientation and coating seem like an efficient strategy for performing bio-based food packaging.

Références :

(1) Packaging Materials and Processing for Food, Pharmaceuticals and Cosmetics; Debeaufort, F., Galić, K., Kurek, M., Benbettaieb, N., Ščetar, M., Eds.; ISTE Ltd / John Wiley and Sons Inc: Hoboken, 2021.

(2) Sinha, S. An Overview of Biopolymer-Derived Packaging Material. Polym. Renew. Resour. 2024, 20412479241226884. https://doi.org/10.1177/20412479241226884.

(3) Delpouve, N.; Stoclet, G.; Saiter, A.; Dargent, E.; Marais, S. Water Barrier Properties in Biaxially Drawn Poly(Lactic Acid) Films. J. Phys. Chem. B 2012, 116 (15), 4615–4625. https://doi.org/10.1021/jp211670g.

(4) Safandowska, M.; Makarewicz, C.; Rozanski, A.; Idczak, R. Barrier Properties of Semicrystalline Polylactide: The Role of the Density of the Amorphous Regions. Macromolecules 2022, 55 (22), 10077–10089. https://doi.org/10.1021/acs.macromol.2c01490.

(5) Louisy, E.; Fontaine, G.; Gaucher, V.; Bonnet, F.; Stoclet, G. Comparative Studies of Thermal and Mechanical Properties of Macrocyclic versus Linear Polylactide. Polym. Bull. 2021, 78 (7), 3763–3783. https://doi.org/10.1007/s00289-020-03290-5.

(6) International Standard Organisation. ISO 2528:2017 Sheet materials — Determination of water vapour transmission rate (WVTR) — Gravimetric (dish) method. ISO. https://www.iso.org/cms/render/live/en/sites/isoorg/contents/data/standard/07/23/72382.html (accessed 2022-06-09).

(7) International Standard Organisation. ISO 15105-1:2007 Plastics — Film and sheeting — Determination of gas-transmission rate — Part 1: Differential-pressure methods. https://www.iso.org/cms/render/live/en/sites/isoorg/contents/data/standard/04/16/41677.html (accessed 2022-06-09).