Supercritical CO_2 impregnation of PLA based films with olive leaf extract: A scalable approach to active food packaging

Food packaging is crucial for the food industry, serving essential roles for consumers and producers. Its primary role lies in safeguarding food products from external contaminants and environmental factors, thus ensuring their safety, quality, and longevity. Incorporating bioactive compounds in packaging is a novel concept that has gained attention in the food industry. Active packaging utilizes active agents to enhance shelf-life, safety and product quality, thereby significantly improving sustainability, minimizing environmental effects and reducing food waste.

Supercritical fluid technology has been widely used to obtain active packing. It uses supercritical carbon dioxide ($scCO_2$) as a carrier of the active substance that diffuses and penetrates polymers. $scCO_2$ also presents a plasticizing/swelling effect on polymers since it increases their free molecular volume. This modifies the porosity and permeability of the polymers and facilitates the diffusion of the active agent into the polymeric matrix. In addition, $scCO_2$ is a green and inert solvent, it is low cost, minimizes organic solvent consumption, and preserves thermolabile compounds since it operates at mild temperatures.

In the present research, the scaling up of the supercritical impregnation of polylactic acid (PLA) films was explored using olive leaf extract (OLE). OLE was selected as a source of bioactive compounds with strong antioxidant activity. The initial amount of OLE added to the impregnation cell was evaluated while keeping the film area, pressure and temperature conditions constant. The impregnated films were analyzed based on the total OLE loading, the antioxidant activity (%AA), and the impregnation homogeneity. Additionally, a scaling-up study was conducted in vessels of different volumes (0.5 L, 2 L, and 5 L) while maintaining geometric similarity criteria based on the ratio of the internal diameter and height of the impregnation cells. Finally, the impregnated film was assessed for its effectiveness in preserving foods such as lettuce and blueberries, using the non-impregnated film as a control.

The findings indicated that when the scale-up was increased 4-fold by maintaining the ratio of film area to OLE volume, the resulting %AA remained stable, indicating that the scaling criteria were appropriate. Moreover, a 10-factor scaling up produced a homogeneous film with an AA of ~50%. The analysis of food preservation revealed that the impregnated film extended the shelf life of lettuce and blueberries by one week compared to the non-impregnated film.

These findings underscore the potential of supercritical impregnation with bioactive compounds as a scalable and sustainable solution for active food packaging, offering extended shelf life and enhanced food preservation.

The results of this paper are framed PROYEXCEL_00920 supported by the Programme of aid for Research Projects of Excellence, on a Competitive Concurrecence Basis, aimed at Entities Qualified as Agents of The Andalusian Knowledge System, within the scope of The Andalusian Plan For Research, Development and Innovation and in the Im-pack Project, which is supported by the PRIMA Programme. The PRIMA programme is supported by the European Union.