9th Asia-Pacific Conference on Plasma Physics, 21-26 Sep, 2025 at Fukuoka

Cold Plasma-Assisted Pectin Extraction from Dragon Fruit Peels: A Novel Approach to Enhance Film Mechanical Properties

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Abstract

In recent years, dragon fruit (Hylocereus spp.) has gained significant attention due to its unique flavour and rich nutritional and medicinal properties(Zitha et al., 2022). The peel of dragon fruit, often considered agricultural waste, contains a high concentration of pectin, a valuable polysaccharide widely used in the food industry(Jiang et al., 2022). Traditional sources of pectin, such as citrus and apple residues, are limited in supply, necessitating the exploration of alternative sources. This study investigates the potential of cold plasma-assisted extraction as an innovative, eco-friendly method for pectin extraction from dragon fruit peel, comparing its efficiency and the functional properties of the extracted pectin with those obtained through conventional methods.

The primary objective of this study was to evaluate the impact of cold plasma treatment on the chemical properties of pectin extracted from dragon fruit peel and to explore its application in the development of biodegradable films. Cold plasma treatment, known for generating reactive oxygen and nitrogen species (RONS), was employed to enhance pectin extraction efficiency and improve its functional properties. The results demonstrated a significant increase in pectin yield, reaching up to 35%, compared to untreated peels. The extracted pectin exhibited a higher degree of esterification, indicating superior gelling capabilities, which are essential for film formation. Furthermore, cold plasma treatment enhanced the antioxidant activity of the pectin, attributed to the generation of bioactive compounds during the extraction process. The treated peels also showed improved colour stability and a more vibrant red hue, making them suitable as natural colorants in food applications.

Physicochemical analysis revealed that the pectin yield ranged from 6.0% to 35.0%, with significant differences observed between extraction methods ($p < 0.05$). Fourier-transform infrared spectroscopy (FTIR) confirmed that the structural integrity of the pectin remained intact, regardless of the extraction technique. The study also explored the application of dragon fruit peel pectin in biodegradable films. Then prepared films were treated with cold plasma and comparison were made with untreated pectin films. The cold plasma-extracted pectin demonstrated excellent film-forming ability, with enhanced mechanical and barrier properties, making it a promising alternative for sustainable packaging materials. Cold plasma treatment not only enhanced the extraction efficiency and functional properties of pectin but also significantly improved the barrier properties of the resulting biodegradable films. The reactive species generated during cold plasma treatment, such as hydroxyl radicals ($OH\cdot$) and ozone (O_3), modified the surface properties of the pectin, leading to a more compact and homogeneous film structure.

This study highlights the potential of cold plasma treatment as a green and efficient method for pectin extraction from dragon fruit peel, offering a sustainable solution for valorising agricultural waste. The findings suggest that cold plasma-extracted pectin can be utilized as a functional ingredient in the food industry, serving as a natural colorant, gelling agent, and biodegradable film material. By transforming dragon fruit peel into valuable functional constituents, this approach contributes to reducing food waste and promoting a circular economy in the food sector.

References

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