



## Fostering the Transition to Sustainable Food Systems:

*Embracing Novelty and Overcoming Challenges*

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### Effect of Cold Plasma Treatment on the Properties of Agar-Based Films Enriched with Pineapple Waste

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#### Aim:

This research investigates the development of eco-friendly packaging films derived from agar, a biodegradable polysaccharide, reinforced with powdered pineapple rind. The study aims to valorize fruit processing by-products while enhancing the films' functional properties through cold plasma treatment. This treatment generates reactive species and high-energy particles that can modify the surface chemistry of the films and their characteristics.

#### Method:

Agar-based (blank) films were prepared by dissolving agar (2% w/w) and glycerol (0.2% w/w) in water, followed by heating and stirring. Freeze-dried pineapple skin residues (50–150  $\mu\text{m}$ ) replaced 25% of the agar by weight. Film-forming solutions (20 g) were cast into 9 cm Petri dishes and dried at 35  $^{\circ}\text{C}$  for ~19 hours. Plasma treatment (Enercon Blown-arc<sup>TM</sup>, air, 4 cm distance, 2.5 cm/s, 3 pulses with 30 s rest) was applied to selected films. Samples were analyzed in triplicate for color (Lab\*), thickness, water activity, moisture content, solubility, water vapor permeability, and tensile strength. FTIR was used to assess chemical changes.

#### Results:

Incorporating pineapple waste darkened the films and reduced transparency, while increasing thickness from  $0.060 \pm 0.005$  to  $0.125 \pm 0.008$  mm. It lowered tensile strength by 70% and reduced the Young's modulus from  $27.3 \pm 3.4$  to  $7.3 \pm 2.4$  MPa, indicating enhanced elasticity. Water vapor permeability decreased significantly from  $6.4 \times 10^{-11} \pm 1.6 \times 10^{-11}$  to  $1.1 \times 10^{-11} \pm 0.3 \times 10^{-11}$  g/ms $\cdot$ Pa.

Plasma treatment significantly affected the water-related properties of blank films, increasing solubility from  $11.8 \pm 1.7\%$  to  $14.6 \pm 1.3\%$ , while reducing water activity (from  $0.545 \pm 0.006$  to  $0.539 \pm 0.007$ ) and moisture content (from  $17.4 \pm 0.2\%$  to  $15.8 \pm 0.4\%$ ). FTIR analysis indicates altered hydrogen bonding and increased matrix polarity, enhancing intermolecular interactions and limiting water accessibility. Reduction of moisture retention is also attributed to partial desorption of loosely bound water.

#### Conclusion:

The incorporation of pineapple rind enhanced the films' water-barrier properties and elasticity. Plasma-induced surface modification of agar-based films resulted in improved biodegradability while maintaining mechanical performance.

These findings highlight the potential of plasma technology to optimize and customize biodegradable packaging solutions, as well as to add value to fruit residues.