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

Oriana Sánchez, Cristina L.M. Silva, Teresa R.S. Brandão*

Universidade Católica Portuguesa, CBQF - Centro de Biotecnologia e Química Fina – Laboratório Associado, Escola Superior de Biotecnologia, Porto, Portugal

* tbrandao@ucp.pt

Introduction

- The use of food processing by-products in developing bioplastics and organic films represents a promising strategy for reducing waste and creating value-added products.
- Pineapple rind, for instance, is rich in fibers and bioactive compounds, making it an ideal candidate for incorporation into biopolymer films.
- Films' functional properties can be modified through cold plasma technology.
- Cold plasma generates reactive species and high-energy particles that can modify the surface chemistry of the films and their characteristics.

Objectives

- To valorize pineapple by-products while enhancing the films' functional properties through cold plasma treatment.
- To characterize the films' physical, chemical, and mechanical properties through various tests including color, thickness, water activity, moisture content, water solubility, water vapor permeability, tensile strength, Young's modulus, and Fourier Transform Infrared Spectroscopy (FTIR) analysis for comprehensive comparison.

Materials & Methods

1. Pineapple waste parts

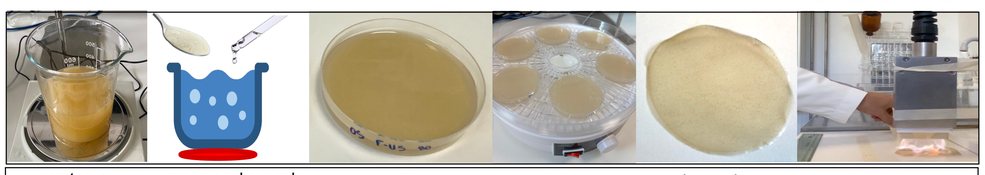
2. Films preparation

Blank samples	agar	+ glycerol	+ water	…in weight/weight
	2%	0.2%	97.8%	

Pineapple samples	agar + glycerol + water + **pineapple peel powder** 25% of agar substitution

3. Film development

Enercon Blown-arc™



4. Characterization tests

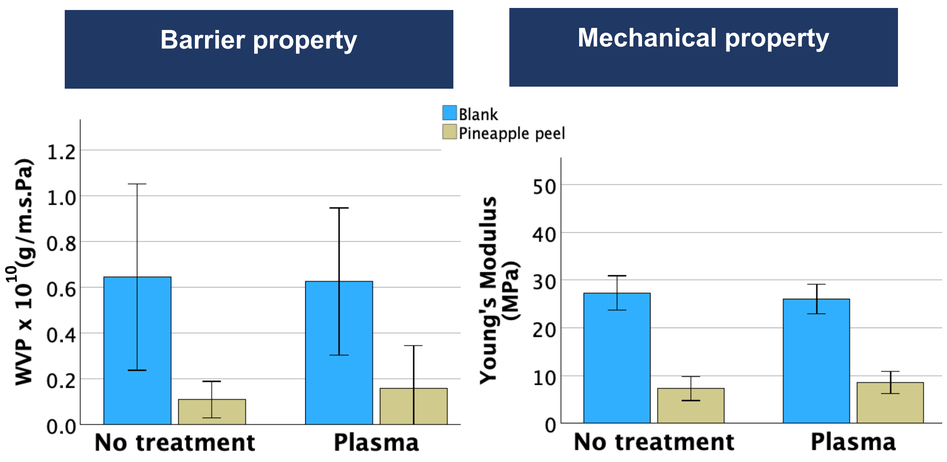
Physico-chemical properties	Barrier property	Mechanical properties
• FTIR spectra • Color (L* a* b*) • Thickness • Water activity • Moisture Content • Water Solubility	• Water vapor permeability	• Tensile strength • Young's modulus (elasticity)

All analyses were conducted at least in triplicate → T-Student test & ANOVA + Post-hoc tests

Results

Incorporation of pineapple peel powder

- darkened the films and reduced transparency
- increased thickness from 0.060 ± 0.005 to 0.125 ± 0.008 mm
- lowered tensile strength by 70%
- reduced the Young's modulus from 27.3 ± 3.4 to 7.3 ± 2.4 MPa, indicating enhanced elasticity
- decreased water vapor permeability (WVP) significantly from $6.4\times10^{-11} \pm 1.6\times10^{-11}$ to $1.1\times10^{-11} \pm 0.3\times10^{-11}$ g/m·s·Pa



error bars indicate 95% confidence intervals around the mean

Plasma treatment

- significantly affected the water-related properties of blank films
- increased solubility from 11.8 ± 1.7% to 14.6 ± 1.3% (↑ biodegradability)
- reduced water activity from 0.545 ± 0.006 to 0.539 ± 0.007
- reduced moisture content from 17.4 ± 0.2% to 15.8 ± 0.4%

FTIR analysis indicates altered hydrogen bonding and increased matrix polarity, enhancing intermolecular interactions and limiting water accessibility.

Main conclusions

- 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.

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