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Starch-Based Biodegradable Foams: Effect of Thermally Expandable Microspheres and Fillers

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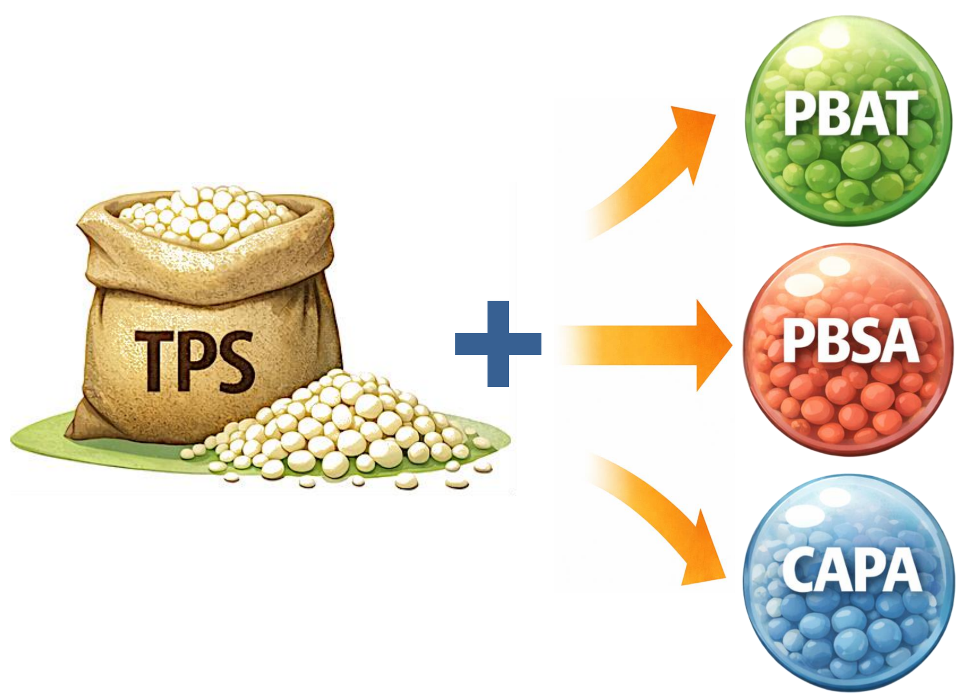
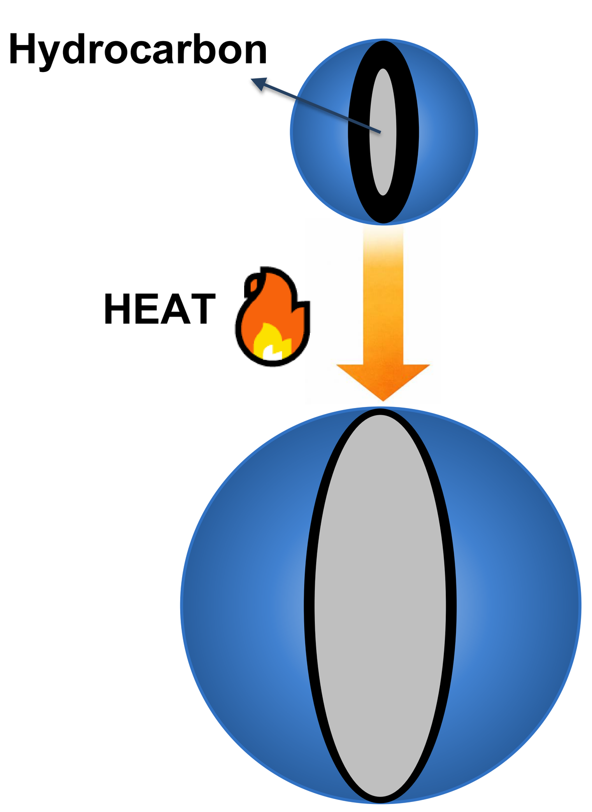
INTRODUCTION

Petrochemical-Based Rigid Polymer Foam Substitute



- **Petrochemical** rigid polymer foams are typically non-biodegradable.
- **TPS** is renewable/low-cost, but hard to foam alone due to poor foaming properties.

TEM Expansion Mechanism



- Blend TPS with Other Bio-Polymers:
  - **PBAT** → Toughness / Ductility
  - **PBSA** → Better melt strength
  - **CAPA** → Flexibility
  - **PLA** → Melt strength
- **TEM** → Cell formation in foam extrusion
- **$CaCO_3$** → Filler/Nucleating agent
- **$NaHCO_3$** → Chemical blowing agent
- **Goal:** Low-density Starch-based Foams with:
  - Low-density
  - Stable morphology
  - Mechanical integrity

MATERIALS & PROCESSING

Polymer Blends Extrusion:
- Thermoplastic starch (TPS)
- Poly(butylene adipate-co-terephthalate) (PBAT)
- Poly(butylene succinate-co-adipate) (PBSA)
- Poly(ε-caprolactone) (CAPA)
- Polylactic acid (PLA)

Foam Extrusion:
- Thermally Expandable Microspheres (TEM)
- Calcium Carbonate ($CaCO_3$)
- Sodium bicarbonate ($NaHCO_3$)

Blend TPS/Polymer/PLA → (3:5:1)	Processing Temperature (°C)	TEM (wt%)
Blend 1: TPS + **PBAT** + PLA	140	8
Blend 2: TPS + **PBSA** + PLA	130	8
Blend 3: TPS + **CAPA** + PLA	120	8

+ 5 wt% $NaHCO_3$
+ 10 wt% $CaCO_3$

ABSTRACT

Developing biodegradable starch-based foams with controlled cellular morphology, low density, and improved mechanical strength.

Approach: Blend TPS with PBAT, PBSA, or CAPA and foam extrusion using TEM, $NaHCO_3$ (chemical blowing agent) and $CaCO_3$ (nucleating agent).

Key result:
- TEM foaming significantly reduced density vs unfoamed.
- $NaHCO_3$ further reduced density across blends by releasing CO_2.
- $CaCO_3$ improved expansion for PBAT and PBSA blends but showed no benefit in CAPA, likely due to weaker nucleation that promoted cell coalescence, while the added filler mass offset any density reduction.
- Mechanical trend: Higher expansion/porosity ($NaHCO_3$/$CaCO_3$) generally reduced compressive strength; PBSA had the best elastic recovery.

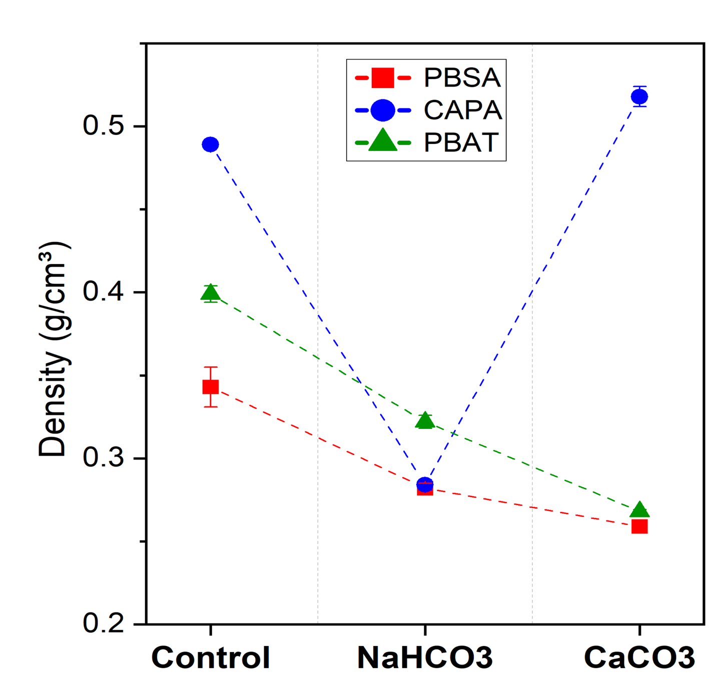
MATERIALS & PROCESSING

Foam Extrusion

CHARACTERIZATION

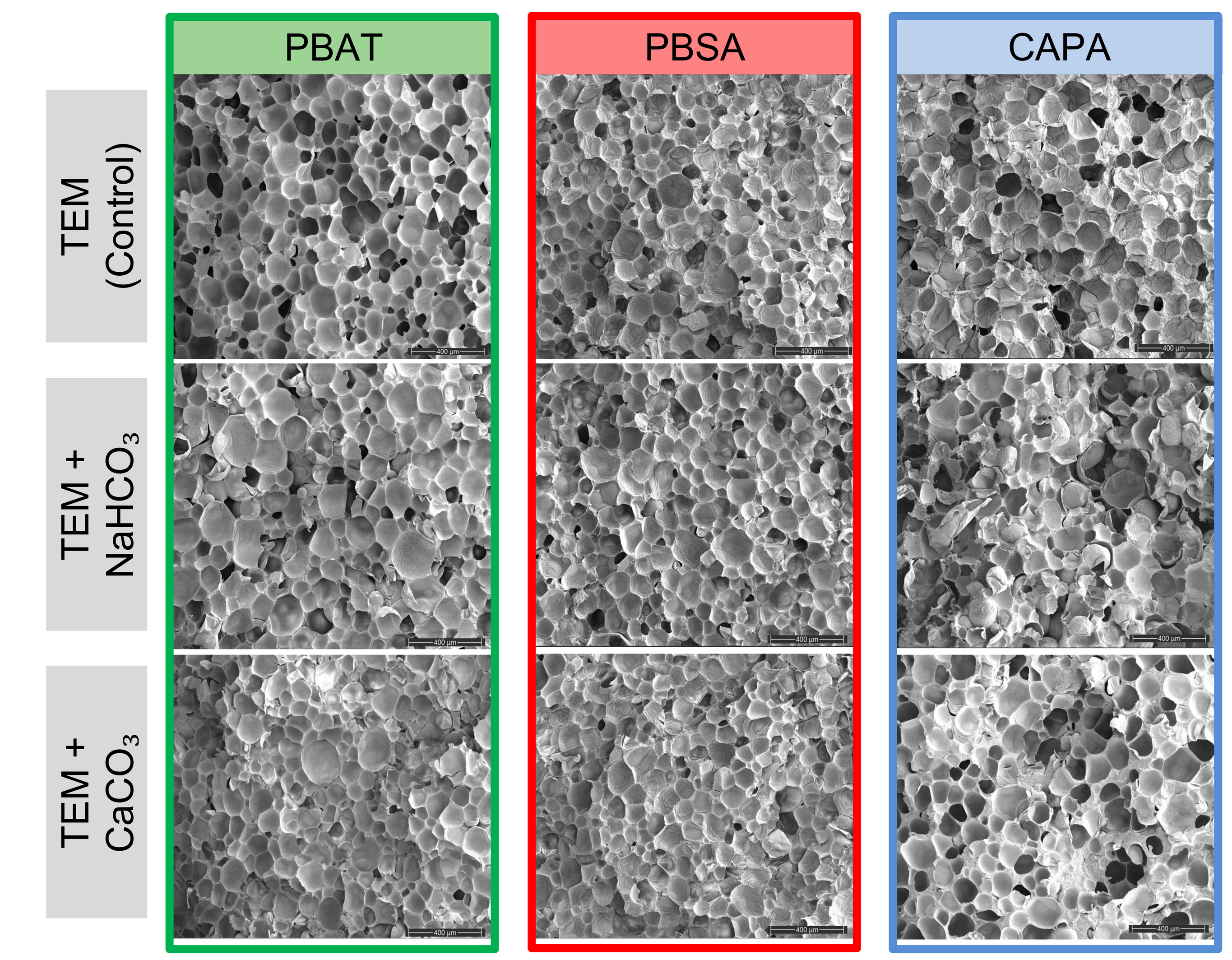
Foam Density

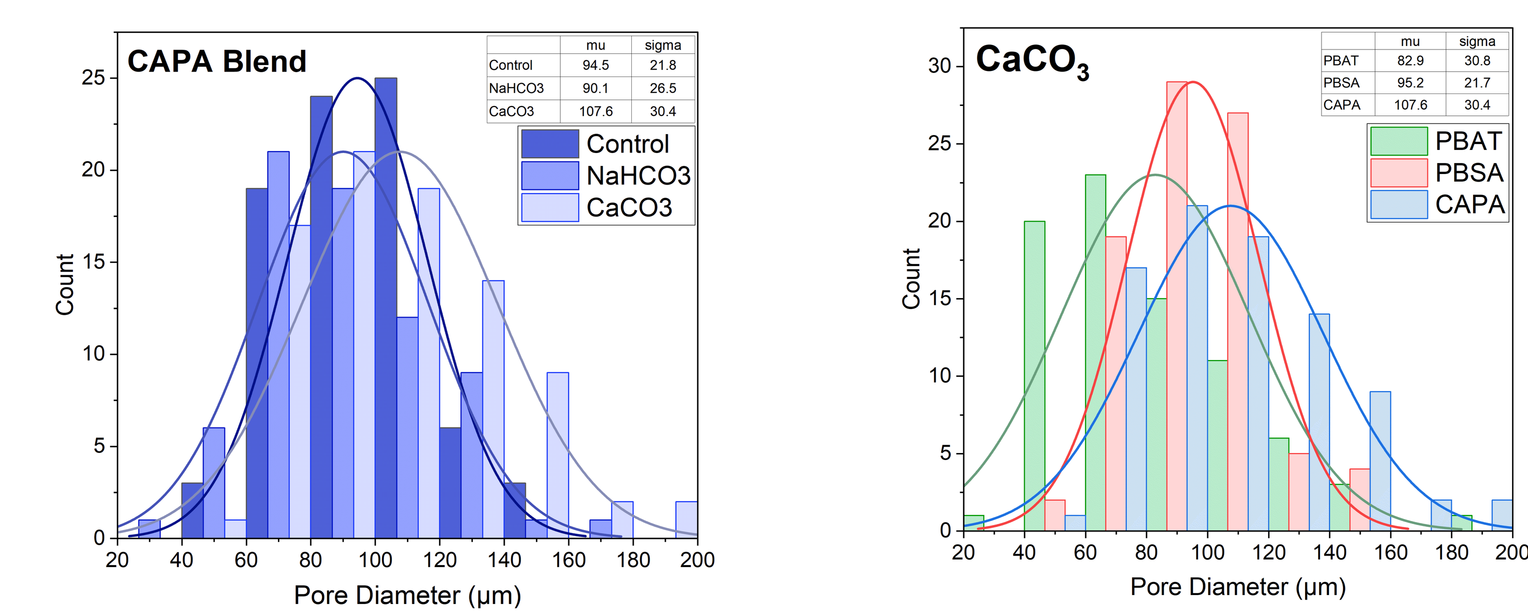
- TEM foaming reduced density by ~60–80% vs unfoamed for all blends.
- $NaHCO_3$ further lowers density by releasing CO_2 → Higher porosity.
- CAPA + $CaCO_3$ produced fewer, larger pores (coalescence) with limited expansion; combined with filler mass, this kept density high.



CHARACTERIZATION

Morphology: Scanning Electron Microscopy (SEM)

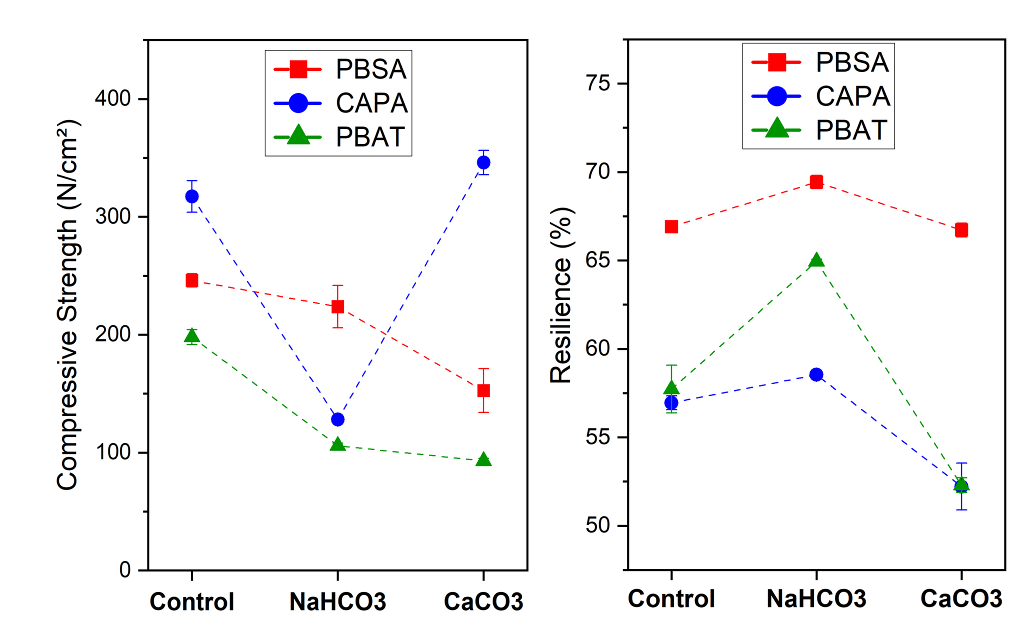




- $NaHCO_3$ ↓ μ → Adding small pores from gas generation.
- CAPA Blend: CaCO3 ↑ μ → Coalescence and weak nucleation.

Mechanical Properties

- $NaHCO_3$/$CaCO_3$ lower PBSA & PBAT strength → by increasing porosity and thinning cell walls.
- PBSA → highest resilience, due to stronger elastic recovery from its elastic network.



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