Mechanism of Preservative-Induced Bacterial Inactivation

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Why in News?

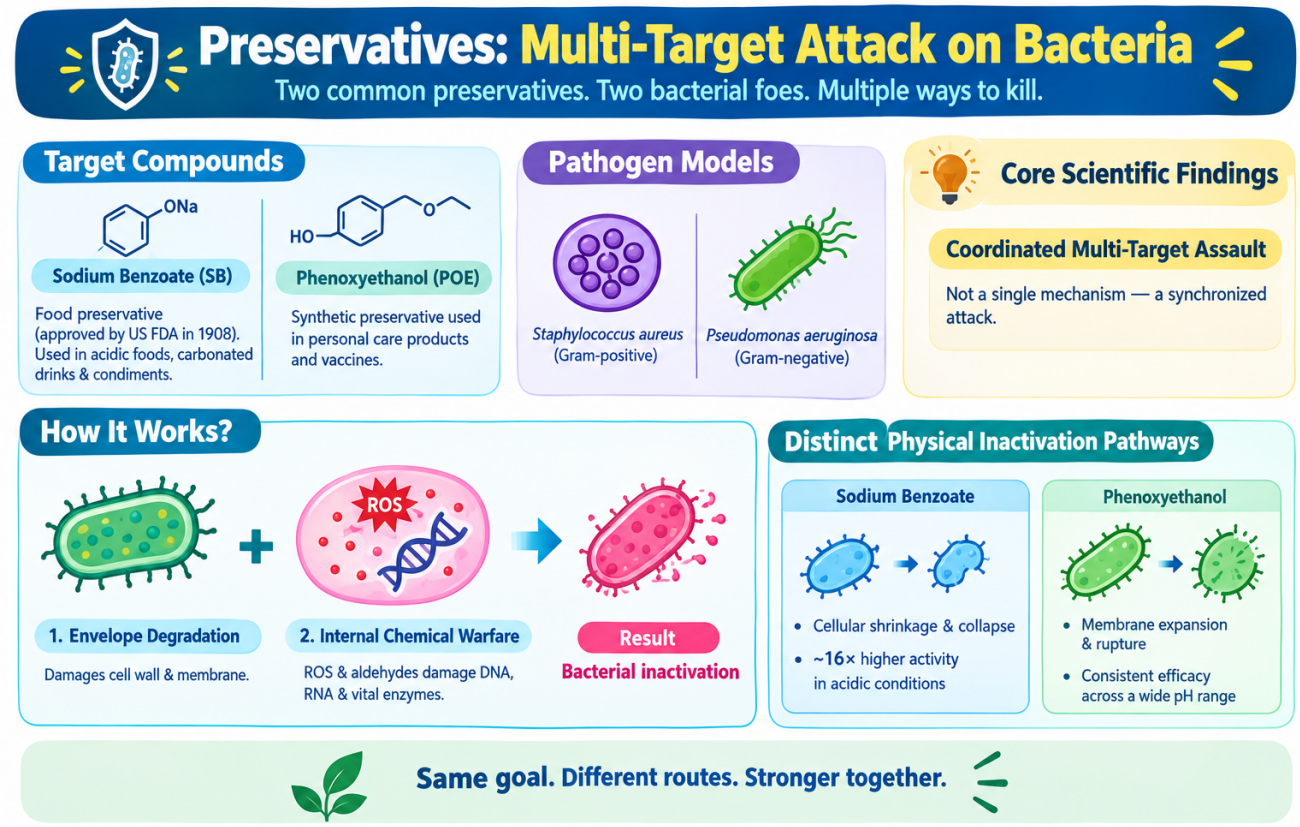
Recently, an academia-industry collaboration decoded the multi-target molecular mechanism through which common preservatives eliminate bacteria.

Target Compounds

- **Preservative Models**
  - **Sodium Benzoate (SB) -** The first food preservative approved by the US FDA (1908); widely used in acidic foods, carbonated drinks, and condiments.
  - **Phenoxyethanol (POE) -** A modern synthetic preservative used extensively in personal care products (shampoos, moisturisers, sunscreens) and vaccines.
- **Pathogen Models -** Evaluated against both Gram-positive (*Staphylococcus aureus*) and Gram-negative (*Pseudomonas aeruginosa*) bacterial strains.

Core Scientific Findings

- **Coordinated Multi-Target Assault -** Preservatives do not rely on a single killing mechanism.
- Instead, they execute a synchronised attack combining physical envelope damage with intracellular oxidative stress.
- **Outer Envelope vs. Intracellular Disruption**
  - **Envelope Degradation -** Preservatives compromise the structural integrity of the bacterial cell wall and plasma membrane.
  - **Internal Chemical Warfare -** Triggers the rapid intracellular accumulation of reactive oxygen species (ROS) and reactive aldehydes, damaging DNA, RNA, and vital metabolic enzymes.
- **Distinct Physical Inactivation Pathways**
  - **Sodium Benzoate-** Induces rapid cellular shrinkage and collapse.
  - Its potency is highly dependent on pH, demonstrating a ~16-fold increase in antimicrobial activity in acidic environments (pH<*4.5*).
  - **Phenoxyethanol-** Triggers membrane expansion and cell rupture.
  - It maintains consistent antimicrobial efficacy across a wide pH spectrum.



Industrial Applications

- Provides a mechanistic basis to select optimal preservatives tailored to specific product pH levels and matrix conditions, avoiding over-preservative loading.
- Understanding multi-target pathways helps design synergistic preservative combinations that prevent bacteria from evolving single-target resistance mechanisms.
- Optimizes preservative concentrations in cosmetics, pharmaceuticals, and packaged foods, extending shelf-life while lowering chemical discharge into environmental wastewater.

Reference

PIB | Preservatives and Bacteria

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