

Processing PHA for Extrusion Blow Molding Containers: Applications, Challenges, and Guidelines

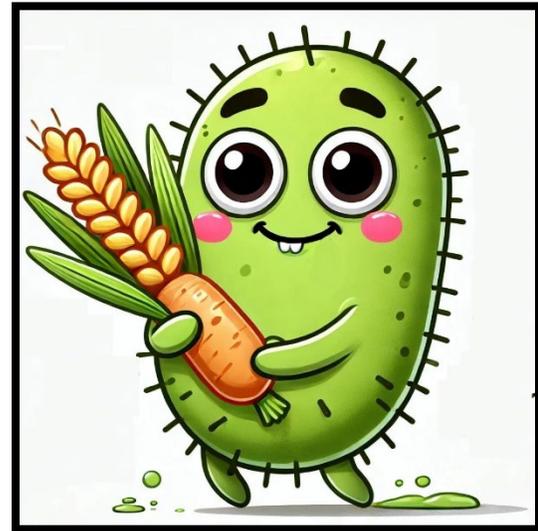
1. Introduction: What are PHAs?

Polyhydroxyalkanoates (PHAs) are a class of naturally occurring polymers produced by bacteria as an energy storage mechanism. Unlike traditional extrusion blow molding materials such as LDPE, HDPE, and other conventional plastics that are synthetically engineered, PHA was discovered rather than invented. First identified in the 1920s by French biologist Maurice Lemoigne, PHA is synthesized when bacteria metabolize biomass sources, including agricultural byproducts and greenhouse gases such as methane and CO₂.

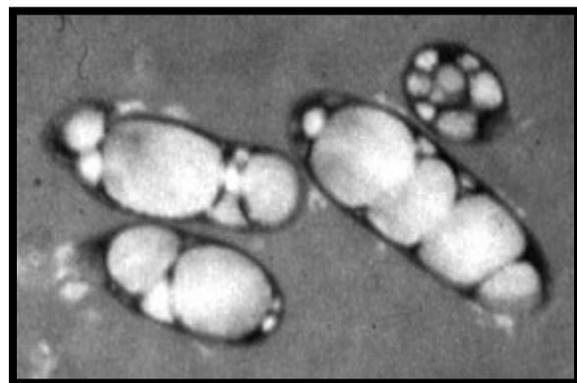
This biological origin makes PHA fundamentally different from petrochemical plastics. Instead of requiring complex chemical catalysts, PHAs are naturally produced and then extracted from microbial cells. When exposed to microbial activity in soil, freshwater, or marine environments, PHAs biodegrade readily without leaving persistent microplastics or toxic residues. They are biodegradable, biocompatible, and non-ecotoxic, making them highly promising for sustainable manufacturing.

PHAs are also recyclable, a crucial feature for processes like extrusion blow molding (EBM), which generates tailings and scrap that must be reintroduced into production. However, PHAs do not currently fit within existing recycling streams and are often categorized as “Other” (#7) plastics. This means that at end-of-life, they are more likely to be landfilled or incinerated, similar to conventional plastics. PHAs are compostable in a variety of conditions, though not widely accepted into commercial composting infrastructure due to a lack of economic incentive and circularity.

Despite these challenges, PHAs provide one unique end-of-life benefit: if mismanaged or littered, they do not worsen the global plastic pollution crisis. Unlike petrochemical plastics, PHAs biodegrade naturally, returning safely to the environment.



PHAtty the Happy Bacteria



Real PHA inside bacteria ready for harvest

2. Defining the Blow Molding Process and Applications

Blow molding is used to manufacture hollow plastic containers through several processes. Injection Stretch Blow Molding (ISBM), commonly used for PET bottles, is not currently suitable for PHAs due to their low glass transition temperature (T_g : $-10\text{ }^{\circ}\text{C}$ to $5\text{ }^{\circ}\text{C}$). While single-step ISBM may one day be feasible, it has not been commercialized.

This article focuses on Extrusion Blow Molding (EBM), a versatile process compatible with PHAs. EBM platforms include shuttle systems, reciprocating screw machines, accumulation head systems, and Graham Wheel machines. In EBM, molten plastic is extruded into a hollow tube (parison), which is then enclosed in a mold and expanded with compressed air to form the container. This process naturally produces tailings, requiring polymers that can be reground and reprocessed, an area where PHAs are suitable.

EBM is slower than ISBM in terms of production cadence, but it requires lower capital investment and provides greater flexibility in wall thickness and material selection. For those seeking deeper process details, Ottmar Brandau's *Extrusion Blow Molding, A Practical and Comprehensive Guidebook* remains the most authoritative resource on EBM.

http://www.blowmolding.org/Extrusion_Blow_Molding_Book.html

Applications of EBM

EBM is widely used across several industries:

- Automotive: Windshield washer fluid containers, lubricants, additives containers.
- Cosmetics: Shampoo, lotion, nail polish remover bottles.
- Food & Beverage: Milk, dairy, and protein drink containers, often requiring multi-layer barrier technologies to prevent oxygen ingress and CO_2 loss.

While multilayer EBM packaging offers barrier performance, it is effectively unrecyclable, as separating layers is impractical and offers no economic value.

3. Best Suggested Applications for PHA EBM Containers

The most promising near-term application for PHA containers is the cosmetics industry, a multibillion-dollar sector with recycling rates below 9%⁽¹⁾. In reality, almost none of this packaging is successfully recycled. Converting shampoo, conditioner, lotion, and mouthwash bottles into biodegradable PHA containers offers a clear sustainability advantage, particularly when mismanaged packaging ends up in the environment.

Cosmetics packaging is also less demanding in terms of barrier and performance requirements compared to food or automotive applications, making it an excellent entry market for PHA containers.

Conversely, automotive applications are not ideal due to the risks of leakage of hazardous fluids and the irony of packaging petrochemical products in biopolymers.

4. Food & Beverage Applications

While attractive for marketing, PHA is not a strong fit for mainstream beverage packaging. PET remains superior due to its recyclability and performance. Multilayer dairy applications are unsuitable due to recyclability concerns.

A key limitation of PHA lies in its organic nature and production method. PHAs are made via bacterial fermentation of biomass sources (e.g., sugars, oils, agricultural waste, even sewage solids). After extraction and purification, residual odors often remain, sometimes strongly reminiscent of the feedstock (e.g., Post Industrial cooking oils can impart a “French fry” smell). This poses sensory challenges for sensitive products like drinking water.

Moreover, PHAs are ideal bacterial substrates. In wet environments containing nutrients (juices, dairy, etc.), PHA bottles risk becoming “petri dishes” if not sterilized properly. To mitigate this, aseptic or hot-fill methods must be considered, severely limiting potential beverage applications.



PHA Water Bottle with substantial mold growth

Finally, there are already approved materials that are highly recyclable for these applications. Specifically, PET and HDPE (Clear), both are now protected in California SB54⁽²⁾ mandate as to ensure they continue to support the ever increase rate of recycling (Which is a good thing).

Introducing a PHA beverage container, while being a very disruptive marketing play, would also be seen as a contaminant for the PET and HDPE recycling industry. And we cannot make the claim that these PHA containers will have their proper EOL in the composting world, as they can't tell the difference between PLA, PHA, or just an off-white LDPE or HDPE container.

As opposed to popular beliefs in the biopolymer industry, composters are not plastic experts.

5. Processing Challenges

Consumer Expectations

Replacement packaging must perform identically to the plastic it replaces. Consumers may pay more for biodegradable packaging, but they expect consistent functionality. Poor performance as seen in the “paper straw fiasco” or a flaccid Salad PHA Fork damages consumer trust and brand credibility.

Material Sensitivity

PHAs are shear- and heat-sensitive. Excess shear generates heat (similar to rubbing hands together), leading to degradation. Residence time the duration material spends above its softening point (~120 °C) must be minimized. Production stops can quickly degrade PHAs, requiring operators to continuously purge or maintain low screw speeds.

Visual indicators of overheating:

- Normal: Slightly opaque finish.
- Warning: Pearlescent sheen (approaching thermal limit).
- Critical: Loss of melt strength, liquefaction, off-gassing.

Thermal Management Strategies

- Pre-heating pellets at 70 °C for 3–4 hours reduces thermal shock.
- Operate at the lowest possible extruder temperatures to avoid degradation.
- Use purge compounds (e.g., LLDPE) for transition between materials, not excess heat.

6. Crystallization and Tg Properties

PHAs have a low Tg (–10 °C to 5 °C), enabling biodegradability by allowing bacterial hydrolysis in natural environments. This contrasts with PLA, which has a high Tg (~60 °C) and requires industrial composting (ASTM 6400) at 58 °C, conditions rarely found in nature.

Key Implications of Low Tg:

- PHA products continue crystallizing for 48–72 hours post-molding, affecting performance tests.
- Accelerated crystallization can be achieved by incubating parts at 70 °C for 4–12 hours.
- Final crystallinity depends on compounding, not mold cooling rates.

PHA cannot be processed effectively in 1-step ISBM systems, as preforms crystallize during storage. 2-step ISBM may be theoretically possible but remains unproven.

Mold Cooling Recommendations:

- Use hot water (55–70 °C) instead of cold water for mold surfaces.
- Maintain contact surface temps at 60 °C+ to induce crystallization and rigidity.
- For large-scale IBM, heated-air tunnels at 55–70 °C can stabilize parts post-ejection.

7. Operator Cheat Sheet (Quick Reference)

Heat & Shear

- Start low, build up: Always run at the lowest temp that fully melts pellets.
- Watch for pearlescence: If surface turns pearly, material is overheating.
- Never stop “cold”: During downtime, keep screw turning slowly or purge.

Pre-Heating

- Use dryer as pre-heater: 70 °C for 3–4 hrs before feeding.
- Do NOT exceed 70 °C: Pellets can clump and block flow.

Mold Cooling

- No cold water: Run hot water (55–70 °C) at the mold surface.
- Target range: 60 °C is a good baseline; adjust up if parts stick or deform.
- Large-scale tip: Use heated-air tunnels (55–70 °C) on takeout conveyors.

Crystallization

- Allow for “post-crystallization”: Parts continue hardening up to 48–72 hrs.
- Speed it up: Incubate molded parts at 70 °C for 4–12 hrs.
- Always drop-test: Use proper water temp during QA —no skipping.

Troubleshooting Quick Signs

- Opaque = good
- Pearly/shiny = overheating
- Sticky/easy deformation = under-crystallized
- Extensive shrinkage = Mold was cut incorrectly

8. Conclusion

PHAs present both opportunity and challenge for extrusion blow molding. Their ecological advantages, biodegradability, non-toxicity, and safety against plastic pollution. Position them as a leading candidate for sustainable packaging. However, their processing sensitivity, crystallization behavior, and incompatibility with certain applications (notably beverages and automotive fluids) require careful consideration and planning.

The best immediate applications lie in cosmetic and personal care packaging, where performance demands align well with PHA's properties and the sustainability benefits can be fully leveraged.

Successful adoption will depend on:

- Careful material compounding.
- Operator training for thermal and shear management.
- Realistic expectations about recycling, composting, and performance.

In short, PHAs are not a “silver bullet,” but they are a meaningful step toward reducing plastic’s environmental burden. They offer something petrochemical plastics never can: the ability to safely disappear when mismanaged. This quality alone makes them a vital material for the future of packaging.

Source:

(1) Terra Cycle Leading Recycle Beaty Product:

<https://www.terracycle.com>

(2) CALRecycle Covered Material Categories

<https://calrecycle.ca.gov/packaging/packaging-epr/cmclist/>

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