REPORT

A report on the Compatibilization of Starch/Synthetic Biodegradable Polymer Blends for Packaging Applications

1. Introduction & Objective

This report addresses the critical environmental issue of petroleum-based plastic waste by exploring biodegradable alternatives, specifically blends of starch and synthetic biodegradable polymers. The primary challenge is the inherent **immiscibility** between hydrophilic starch and hydrophobic synthetic polymers, leading to poor mechanical and barrier properties. The project objective is to comprehensively review various **compatibilization techniques** used to overcome this immiscibility and enhance the properties of these blends for packaging applications.

2. The Core Problem: Immiscibility

- **Starch:** A renewable, cheap, and biodegradable polymer. However, native starch is brittle and has poor process ability. It is often converted into **Thermoplastic Starch (TPS)** using plasticizers like glycerol, but TPS alone still suffers from poor mechanical strength and high water sensitivity.
- **Synthetic Biodegradable Polymers:** Polymers like PLA, PCL, PVA, PBS, PHBV, PBAT, and PHB are biodegradable but are often more expensive and can have drawbacks like brittleness (PLA, PHB) or low melting points (PCL).
- **The Blend:** Combining TPS with synthetic polymers aims to create a material that is cost-effective, highly biodegradable, and has improved mechanical properties. However, their

mixing results in **phase separation** due to differing hydrophilicity, leading to weak interfaces and poor performance.

3. The Solution: Compatibilization

Compatibilization is the process of adding an agent (compatibilizer) to stabilize the blend, creating a finer and more homogeneous morphology. This leads to:

- Improved interfacial adhesion between starch and the synthetic polymer.
- Enhanced mechanical properties (tensile strength, elongation at break).
- Better barrier properties (against water vapour and gases).
- Increased water resistance.
- Maintained or improved biodegradability.

Key Compatibilization Methods:

1. **In Situ Compatibilization:** The compatibilizer is formed during blending through reactions between the two polymers (e.g., using maleic anhydride).
2. **Ex Situ Compatibilization:** A pre-synthesized block or graft copolymer (e.g., Starch-g-PCL) is added.
3. **Dynamic Vulcanization:** Cross-linking the dispersed phase to stabilize the blend morphology.

4. Key Blends and Compatibilizer Effects

The report provides a detailed analysis of seven major starch/synthetic polymer blends:

Polymer Blend	Key Compatibilizers Used	Key Improvements after Compatibilization
Starch/PCL	Starch-g-PCL, PCL-g-GMA, PCL-g-DEM, PAA-g-PCL	• Finer morphology & better dispersion. • Tensile strength increased from ~8 MPa to ~16 MPa. • Improved oxygen and water vapor barrier.
Starch/PVA	CNTs, Glutaraldehyde, Borax, Nano-SiO_2	• Significant increase in tensile strength and thermal stability. • Reduction in water absorption (from 60% to 43%). • Added functionalities (e.g., antibacterial with Ag NPs).
Starch/PBS	MA-g-PBS, Starch-g-PBS	• Elongation at break increased from 4% to ~20%. • Tensile strength increased over two-fold. • Suitable melt viscosity for processing.

Starch/PLA	PLA-g-MA, PLA-g-GMA, mPEG-g-St	• Drastic reduction in TPS particle size (from 5-30μm to 2.2-4.2μm). • Massive increase in elongation at break (from 10-20% to over 150%). • Improved chemical resistance.
Starch/PHBV	Organically Modified Montmorillonite (clay)	• Enhanced tensile strength and modulus. • Faster biodegradation rate (up to 90%). • Reduced humidity adsorption.
Starch/PBAT	PBAT-g-MA, Citric Acid (CA), Maleic Anhydride (MA	• PBAT-g-MA was most effective, yielding high elongation (380%) and strength. • Citric acid improved tensile strength but reduced elongation. • Significant reduction in water vapour permeability.
Starch/PHB	Maleic Anhydride (MA)	• Improved phase adhesion and migration of starch. • Optimized compatibilizer content increased tensile strength to ~16.5 MPa and toughness.

5. Commercial Applications

The review highlights that starch-based blends are already commercially viable for packaging, with products on the market used for:

- **Loose-fill packaging** (e.g., foam peanuts).
- **Compost bags** and films.
- **Flexible and rigid packaging**.

Examples of commercial brands include **Mater-Bi** (Novamont), **Bionolle** (Showa Denko), and **Biolice** (Limagrain).

6. Challenges and Future Perspectives

- **Performance Gap:** While compatibilization brings significant improvements, the performance of these blends still lags behind conventional plastics, especially in **water barrier properties**.
- **High Starch Content:** Incorporating high amounts of starch (>25-30%) without compromising properties remains difficult.
- **Future Focus:** Research should focus on:
  - Improving hydrophobicity (e.g., via starch esterification).
  - Incorporating antimicrobial properties.
  - Optimizing sealing properties.
  - Utilizing specific starch sources like **cassava starch**, which has favourable properties like low gelatinization temperature and high availability.

7. Conclusion

The report concludes that compatibilization is a vital and effective strategy for developing viable starch/synthetic biodegradable polymer blends. These compatibilized blends show a promising combination of enhanced mechanical properties, improved water resistance, good barrier properties, and maintained biodegradability. With ongoing research to address existing challenges, these materials hold strong potential to replace petroleum-based single-use plastics, particularly in packaging applications, contributing to a more sustainable future.