Based on the retrieved documents, the brittleness of polylactic acid (PLA) can be improved through several strategies, primarily focusing on enhancing its flexibility and impact resistance:

Key Approaches to Reduce PLA Brittleness:

1. **Plasticization**

- Adding low-molecular-weight **plasticizers** (e.g., lactides, oligomeric lactic acid, citrate esters, polyethylene glycol) lowers the glass transition temperature ((T_g)), increasing chain mobility and ductility (reference_156.pdf, page 1051).

2. **Copolymerization**

- Incorporating flexible comonomers (e.g., caprolactone, ethylene oxide) disrupts PLA's rigid chain structure, improving elongation-at-break and impact resistance (reference_156.pdf, page 1051).

3. **Blending with Flexible Polymers/Rubbers**

- Melt blending PLA with **toughening agents** such as:
  - Biodegradable polyesters (e.g., poly(butylene adipate-co-terephthalate) (PBAT), polycaprolactone (PCL)).
    - Elastomers (e.g., natural rubber, acrylic rubber).
- These form a dispersed rubbery phase that absorbs impact energy and arrests crack propagation (reference_156.pdf, page 1051; reference_30.pdf, page 369).

4. **Reactive Blending**

- Using **reactive compatibilizers** (e.g., peroxides, multifunctional epoxies) during melt blending promotes *in-situ* copolymer formation. This enhances interfacial adhesion between PLA and toughening phases, significantly improving impact strength (e.g., achieving >500% increase in notched Izod impact) (reference_156.pdf, page 1051).

Additional Notes:

- **Stereochemistry/Molecular Weight**: Adjusting L/D-lactide ratios or increasing molecular weight offers marginal improvements but is insufficient alone for high-toughness applications.
- **Crystallinity Control**: Annealing can increase crystallinity but may exacerbate brittleness; plasticizers/copolymerization counterbalance this effect.

These methods