

Chemical Recycling of Polylactic Acid (PLA)

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DOI: <https://doi.org/10.15480/882.8787>



Introduction

- ✓ Plastics are important widespread materials that have many benefits over other established materials (e.g. glass and paper).
- ✓ Most plastics are non-renewable, which causes problems like pollution, shortage of fossil resources and climate change.
- ✓ Bioplastics such as poly(lactic acid)/(lactide) (PLA), derived from renewable agricultural resources, have more benefits compared with non-renewable plastics including biodegradability and compostability.
- ✓ Recycling of PLA is important to close the loop of circular economy and overcome the shortage/competition with food resources.

Motivation for the Chemical Recycling of PLA

- 300,000 Tons: PLA production/year
- 18%: Production increase/year
- 24%: Portion of PLA in the bioplastics market
- 5.9 Tons: PLA production /10,000 m² corn field

PLA

- Benefits:**
 - Made from renewable biobased materials
 - Very good plastic properties
 - Wide range of applications (packaging, 3D-printing, medicine, etc.)
- Drawbacks:**
 - Requirement of big land area and long cultivation time
 - Competition with food production
 - 633 Mio. € per year for new PLA production
 - „short-living“ Products
 - No commercial recycling system yet for PLA

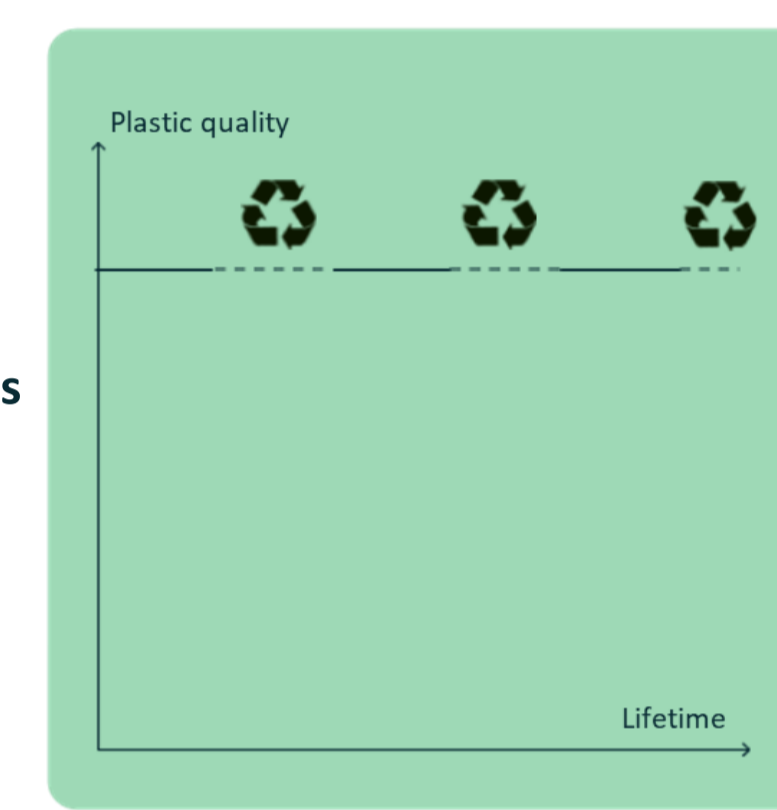
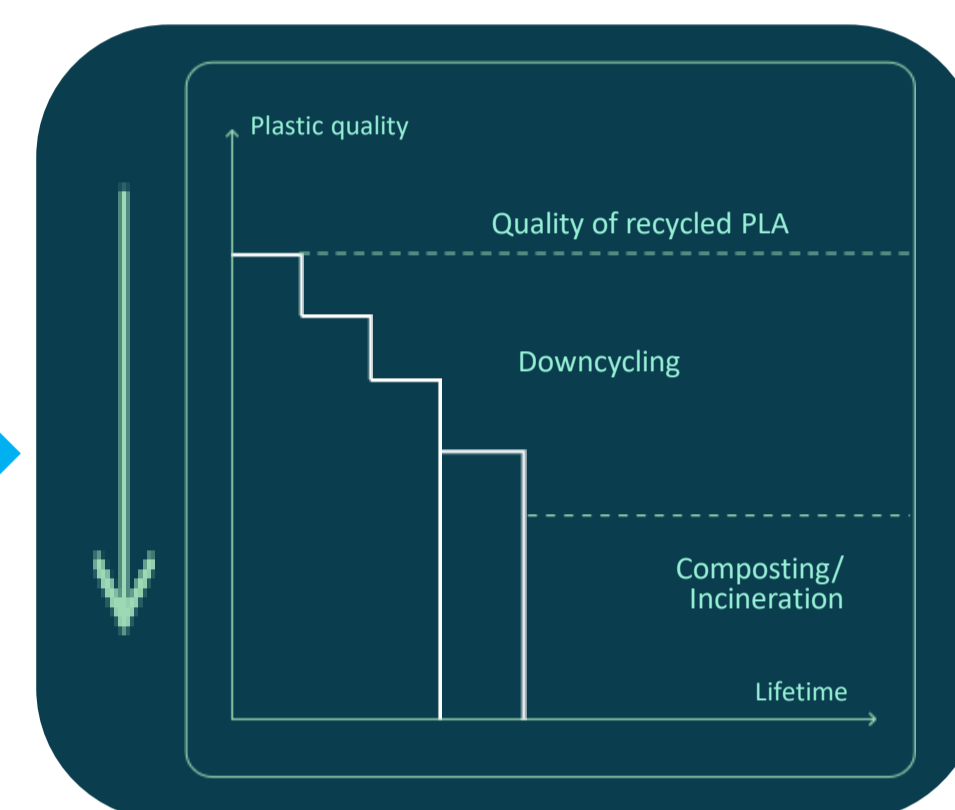
Solution:
mechanical or chemical
Recycling?

Drawbacks of Mechanical Recycling:

- Mechanical recycling puts stress on the PLA molecules (partial destruction)
- Dyes and other additives cannot be removed => affect the properties of the new PLA

Benefits of Chemical Recycling:

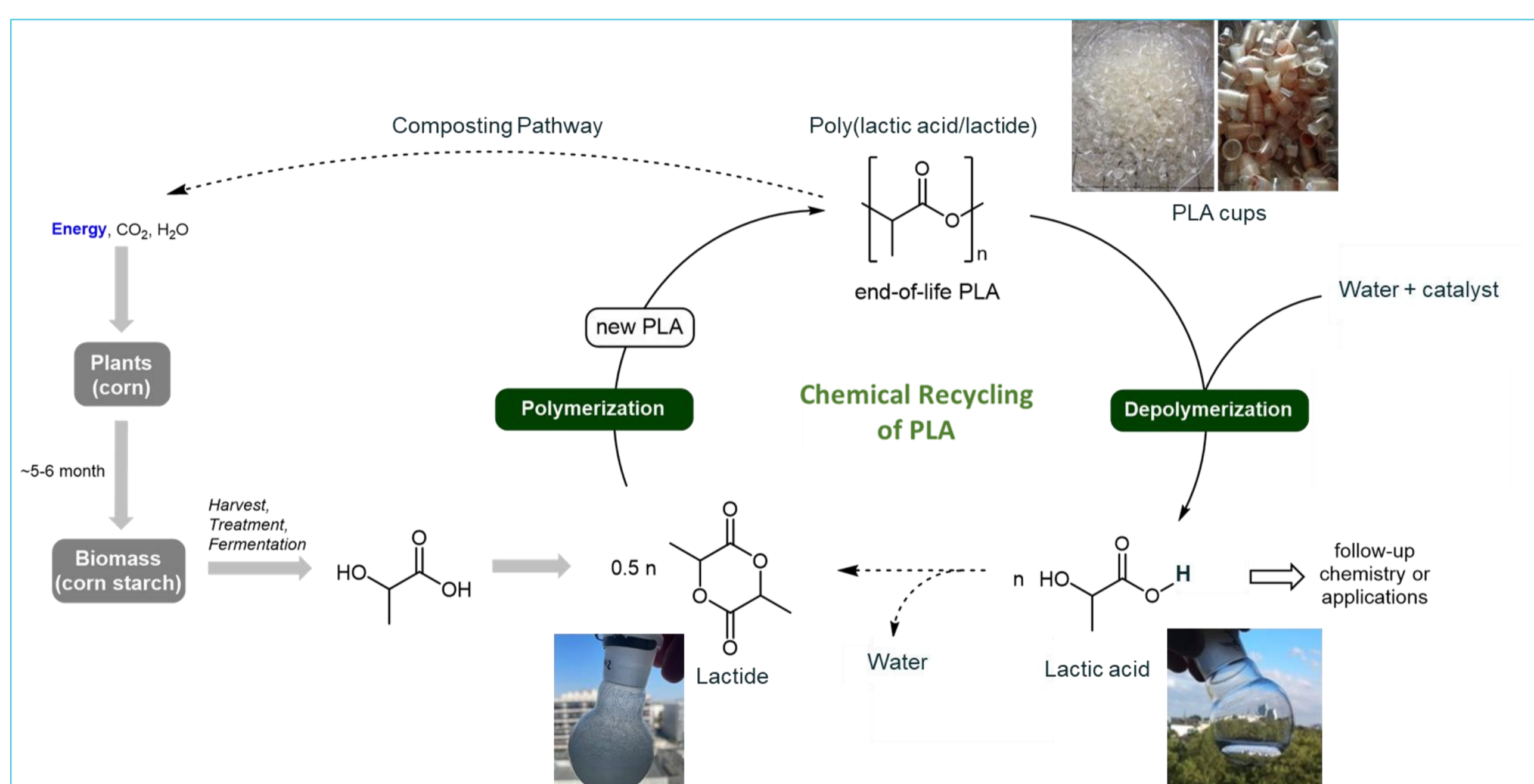
- Constant high quality of the recycled PLA
- Overcomes the long biodegradability time of PLA in nature
- More profitable than composting
- Saves a renewable input of PLA material



Objectives:

- Optimization of the recycling process of PLA
- Validation of the process with different/heterogenous PLA materials
- Scale up of the process
- Production of new biobased products with recycled PLA

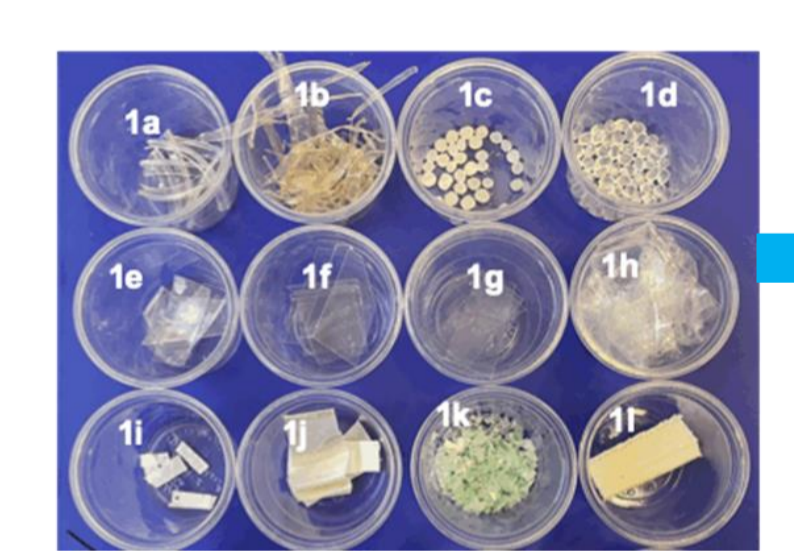
Chemical Recycling of PLA



The depolymerization process was optimized and led to:

- Efficient and selective process for PLA recycling
- Low cost catalyst
- Solvent free process (hydrolysis)
- Short depolymerization time
- Validation of the process with different PLA sources
- **Scale-up of PLA depolymerization: high lactic acid yield**
- **Production of new bio-based materials, e.g. recycled PLA-Lignin**

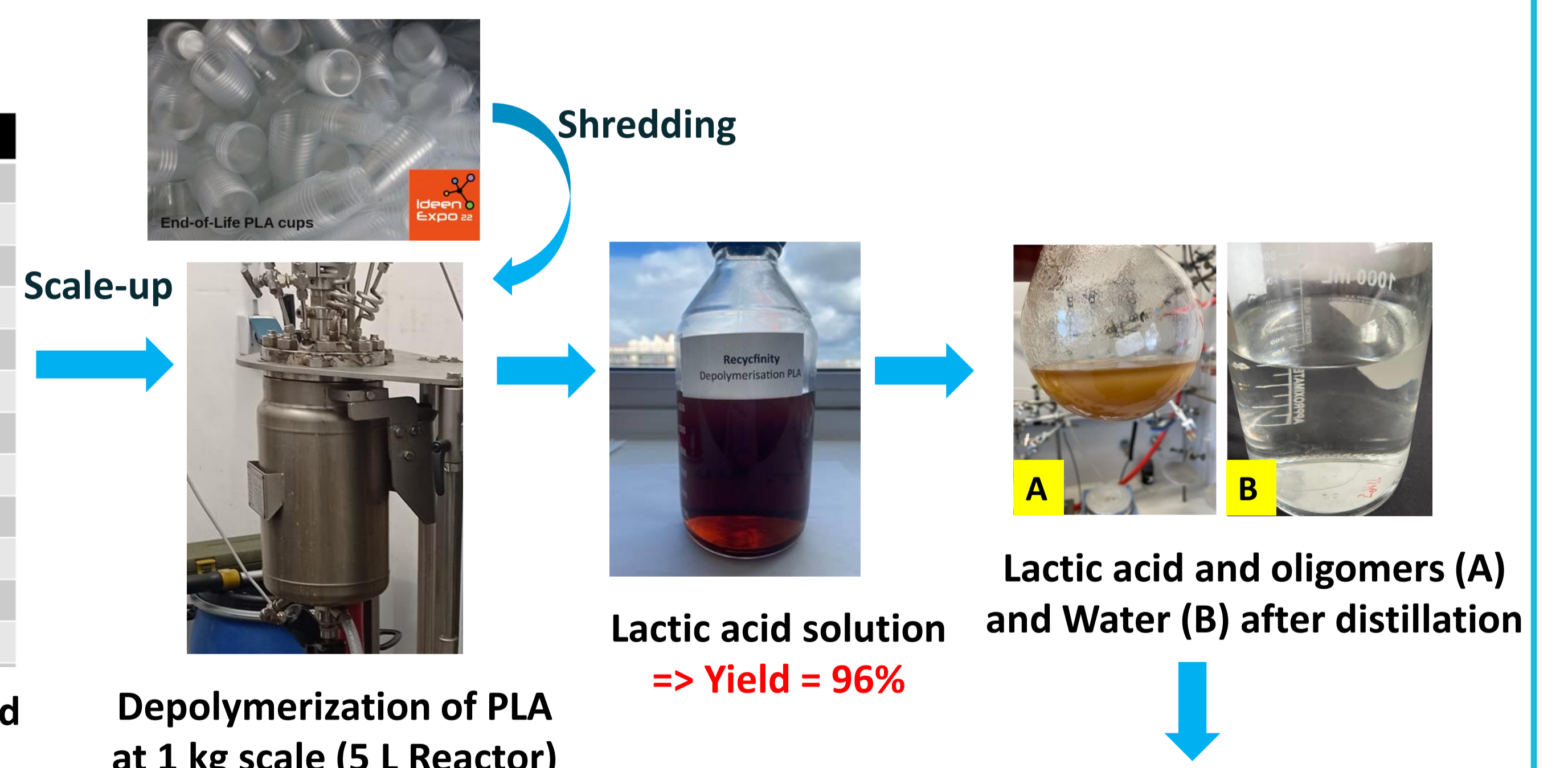
Schematic representation of the chemical recycling of PLA



Sample Number	Product Description	Lactic acid Yield [%]
1	used transparent cup (1a)	86
2	used transparent cups (1b)	78
3	PLA Luminy™ LX175 (colorless) (1c)	66
4	PLA 6302D NatureWorks Ingeo™ (1d)	71
5	transparent bottle (1e)	80
6	transparent disposable food box (1f)	79
7	transparent sushi box cover (1g)	86
8	transparent PLA foil (1h)	99
9	off-white spoon (1i)	92
10	off-white lid for coffee mugs (1j)	49
11	Joghurt beakers without labels (1k)	89
12	PLA sandwich panel (1l)	74

Lactic acid production yield determined using ¹H NMR spectroscopy after PLA depolymerization

Scale-up



Shredding
End-of-Life PLA cups

Lactic acid solution => Yield = 96%

Lactic acid and oligomers (A) and Water (B) after distillation

Further Work and Outlook

- Filament production out of recycled PLA and recycled PLA-biopolymer formulations (e.g. Extrusion, 3 D printing...).
- Investigation of new biopolymers with good plastic properties and biological benefits in combination with PLA for food packaging => active/intelligent packaging.

Search and Offer

- **Search:** Filament maker out of powder material + Analytical methods for the characterization of mechanical and thermal properties of recycled PLA-based products.
- **Offer:** Test/validation of the recycling process for different (commercial) PLA products.



Recycled PLA-Lignin

