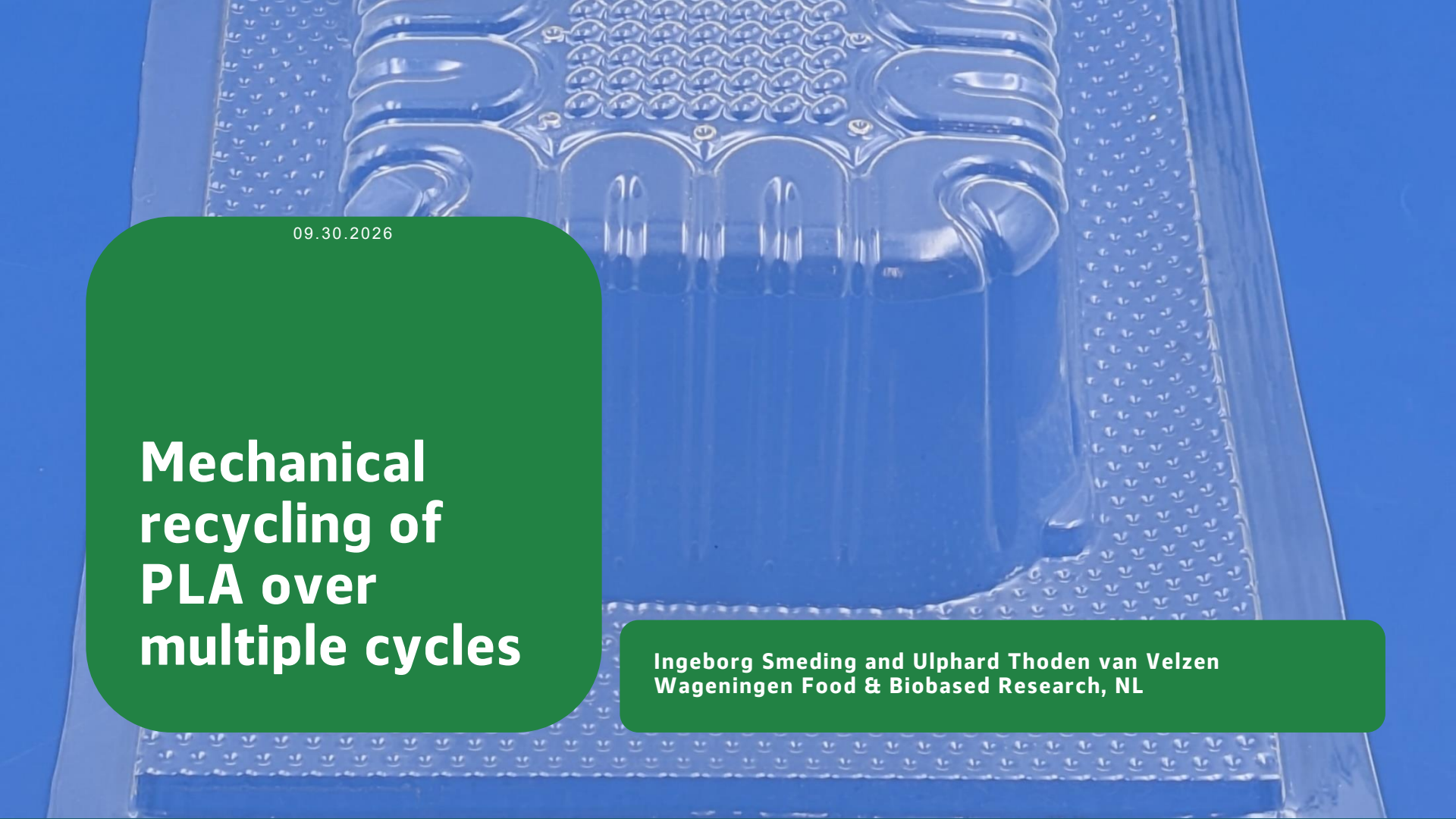

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Mechanical recycling of PLA over multiple cycles

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The project is supported by the Circular Bio-based Europe Joint Undertaking and its members under grant agreement Nº 101157907. Funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or CBE JU. Neither the European Union nor the CBE JU can be held responsible for them.

The ambition of PROSPER is to demonstrate a successful solution of technically feasible and affordable bio-based plastic sorting and recycling infrastructure

Circular Bio-based Europe Joint Undertaking

Bio-based Industries Consortium

Co-funded by the European Union

Prosper partners



































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Imperative

Packages need to contain recycled content from 2030 on, PPWR article 7.

- In our experience PLA can successfully be mechanically recycled.

- However, 14 scientific articles report degradation during recycling / compounding.
  - Although most dry PLA prior to processing, none report the initial moisture levels.
  - So, compliance to the producers' processing recommendations (<200 ppm) cannot be verified.
  - Apparently, the re-extrusion step would cause most degradation.

- There is a need to prove that PLA can be mechanically recycled once it has been dried properly beforehand.

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Approach

Two pilot tests to study the mechanical recyclability

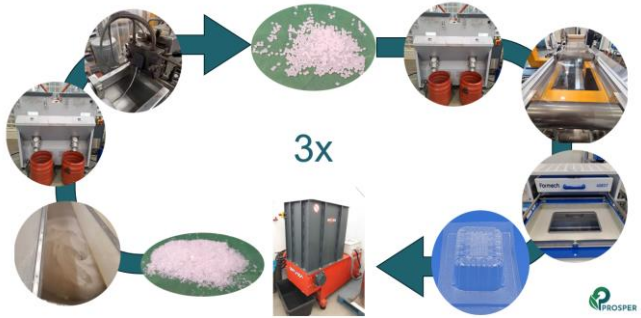
Triple extrusion test

- At the recommended temperature: 210°C
- For 2 different commercial PLA's: A and B
- At 2 different throughputs: 1.5 & 3.0 kg/h
- Dried and non-dried
- The melt flow index (MFI) and molecular weights were determined with GPC



Triple tray-to-tray recycling test

- Thermoformed trays were produced from PLA pellets via sheet extrusion & thermoforming
- These were milled, washed, dried, extruded to pellets, dried and so on in three cycles
- Full analysis of the sheets and pellets during the 3 recycling loops



Triple extrusion test



Extruder

3x

Moisture content,
Melt flow index
Molecular weight

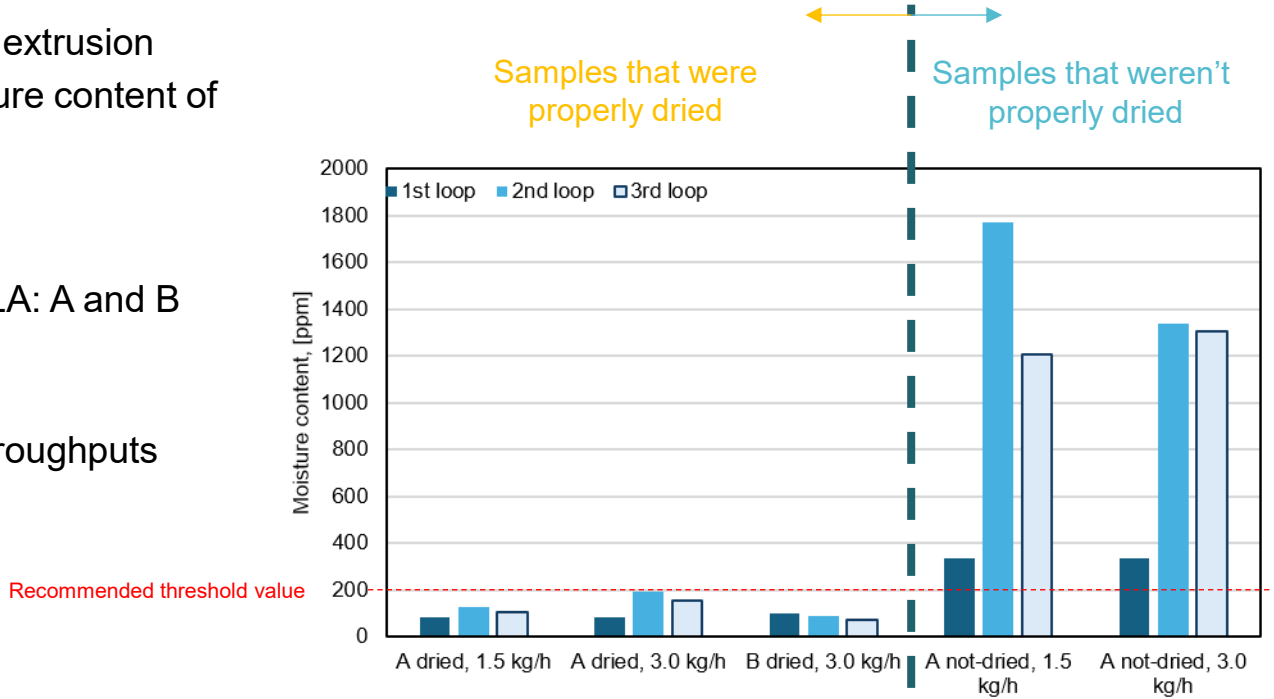


Pellet dryer

Results of the triple extrusion test I

Moisture content, [ppm] of PLA pellets after extrusion at 210°C

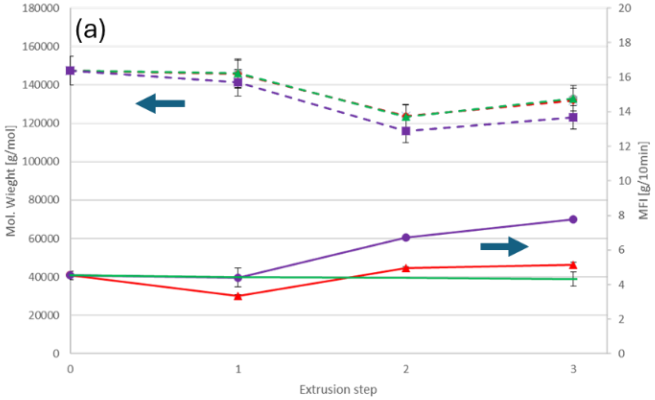
- Drying the pellets prior to extrusion strongly affects the moisture content of the pellets, as expected
- For 2 different types of PLA: A and B
- Executed at 2 different throughputs
  - 1.5 kg/h
  - 3.0 kg/h

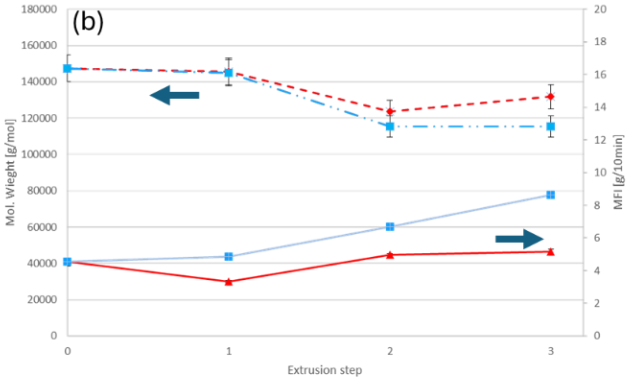


Results of the triple extrusion test II

MFI and molecular weight

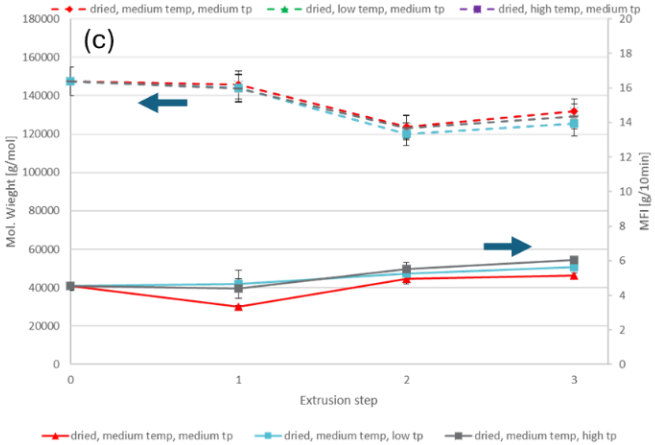
Effect of changing temperature

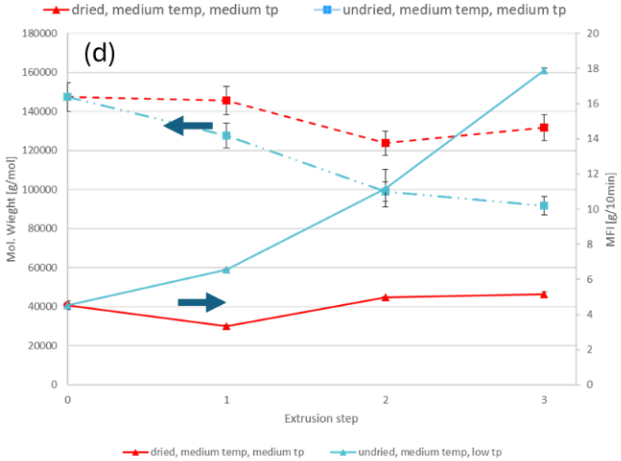




Effect of drying

Effect of changing throughput





Effect of both drying and changing throughput

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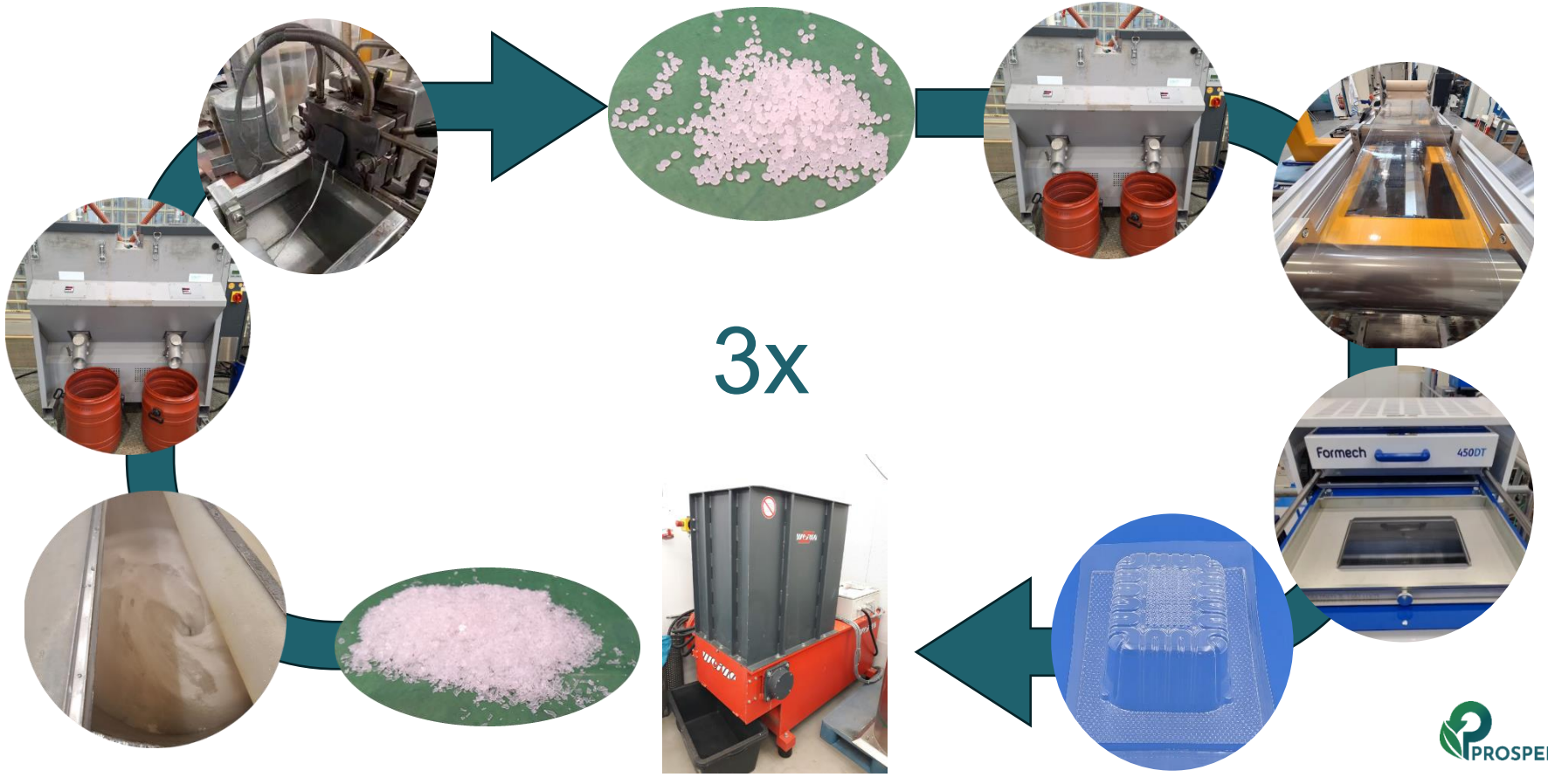
Results of the triple extrusion test III

- In all scenarios a certain level of degradation (decline in molecular weight and increase in MFI) occurs
- Drying on forehand has a large influence on the melt flow index
- When properly dried, PLA can be extruded twice without affecting the melt flow index and there is a marginal increase at the third loop
- High throughputs reduce the residence time and the degradation
- By drying on forehand the loss of molecular weight can be limited to 13% after three loops, instead of 30% for non-drying

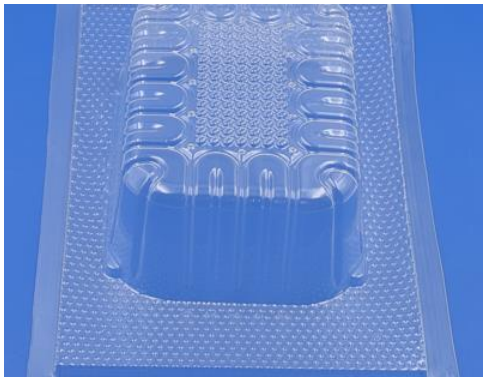
Triple tray-to-tray recycling test



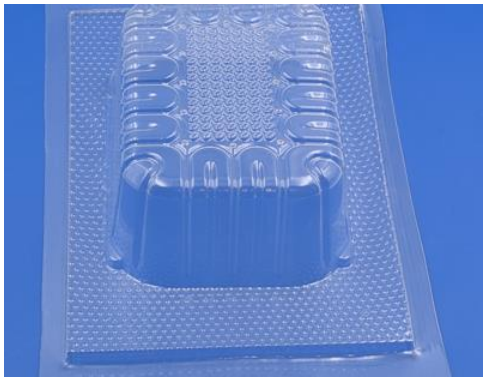
The triple tray-to-tray recycling test went flawless



1st loop



2nd loop



3rd loop

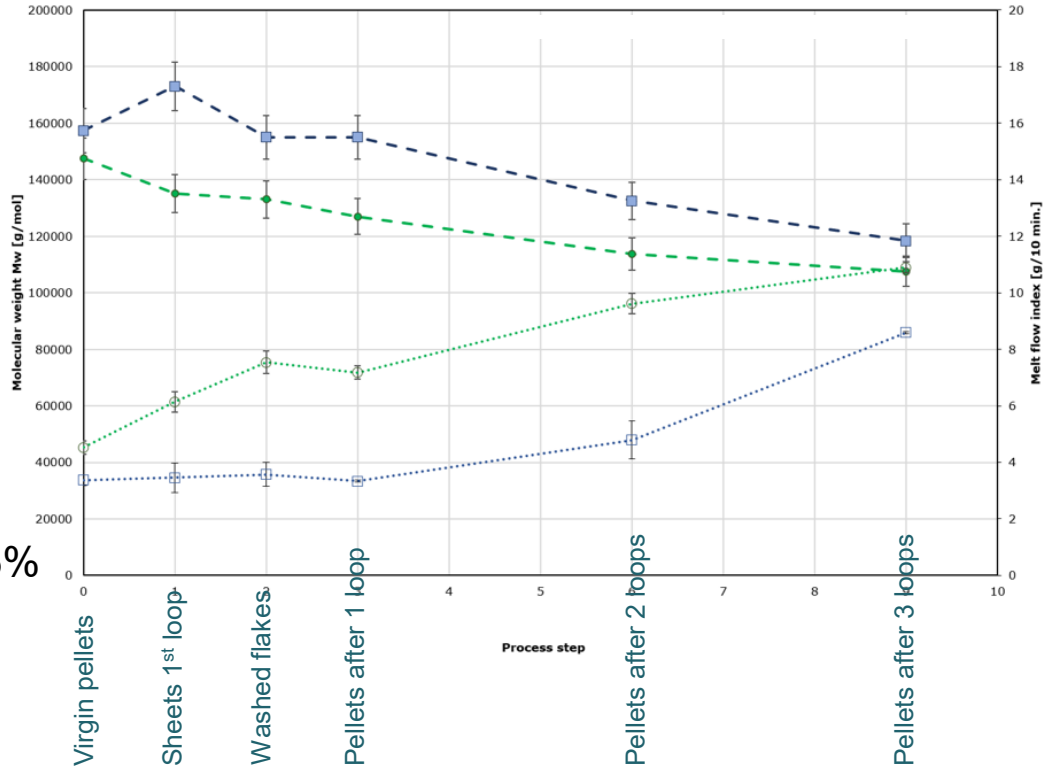
- In case the PLA is properly dried, it can be mechanically recycled three times

Melt-flow index and molecular weight of the pellets

Mw by GPC

B

A



MFI

B

A

Mw reduced with 25% over 3 loops

MFI increases with 145% over 3 loops

Graphs are not shown, but recycling has minimal impact on the thermal properties, colour and mechanical properties

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PLA can be mechanically recycled

Proper drying beforehand is key to limit degradation



Next research steps

Within the EU Prosper project on the mechanical recycling of PLA

SSP

- We are studying solid state processing to restore the molecular weight of PLA
  - Challenges with the rate and the reproducibility

Post-consumer test

- Study the washing and mechanical recycling of post-consumer PLA trays with food residues
  - Removal of sticky food residues works fine
  - Loss of fines requires attention



Intention to Publish

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