KUNSTSTOFF TECHNIK LEOBEN

Polymer Processing

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Biobased Plastics for a Circular Economy

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Introduction: Biobased and biodegradable bioplastics having the potential for carbon neutrality are the need of the hour. Polyhydroxyalkanoates (PHAs) are an interesting and fast growing member of the bioplastic family.

A class of PHAs, known as Polyhydroxybutyrates (PHBs), have shown great potential for packaging applications. But composting or incineration is still the existing End of Life (EoL) option for these bioplastics. This brings us to the study of mechanical recycling as a candidate for sustainable EoL option, since this method is known to preserve the polymer structure. The properties after such a strenuous process have to be quantitively and qualitatively studied; this is the subject of our research.

The mechanically recycled PHB, characterized by its complex properties, has not been fully investigated. To simulate an industrial recycling process, we extruded the virgin PHB and reprocessed it up to 4 times to study the mechanical, thermal and rheological properties of the recyclates at each stage (Figure 1).

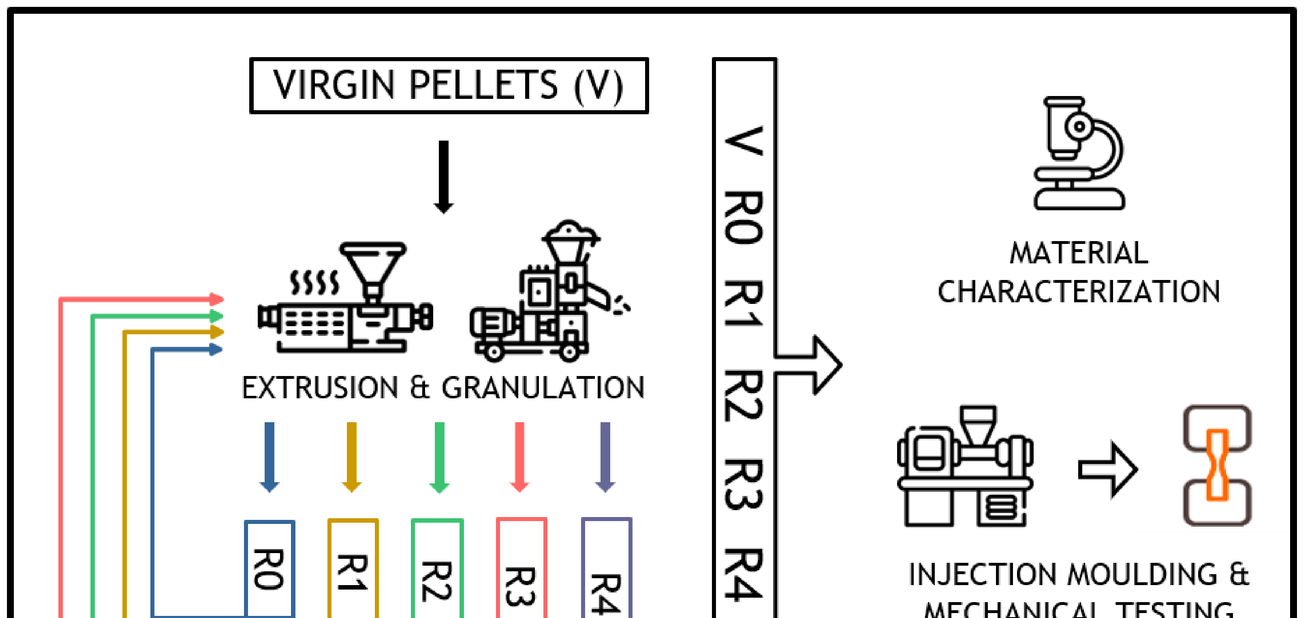


Figure 1. Schematic of the mechanical recycling pathway (left) and material characterization and testing (right). Virgin PHB is processed (R0) and then reprocessed up to 4 times (R1 to R4) on a twin-screw extruder. At each stage, thermal, mechanical and rheological testing was carried out.

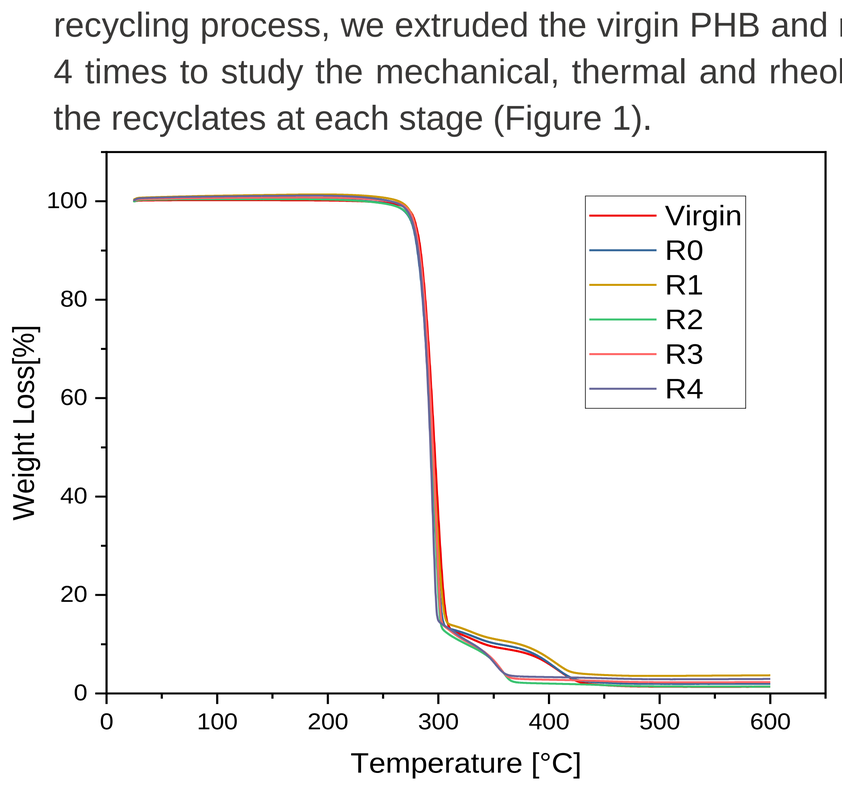


Figure 2. Thermogravimetric analysis (TGA) of Virgin PHB compared with the processed recyclates (R0-R4). Thermal degradation temperature is not affected by our processing stages.

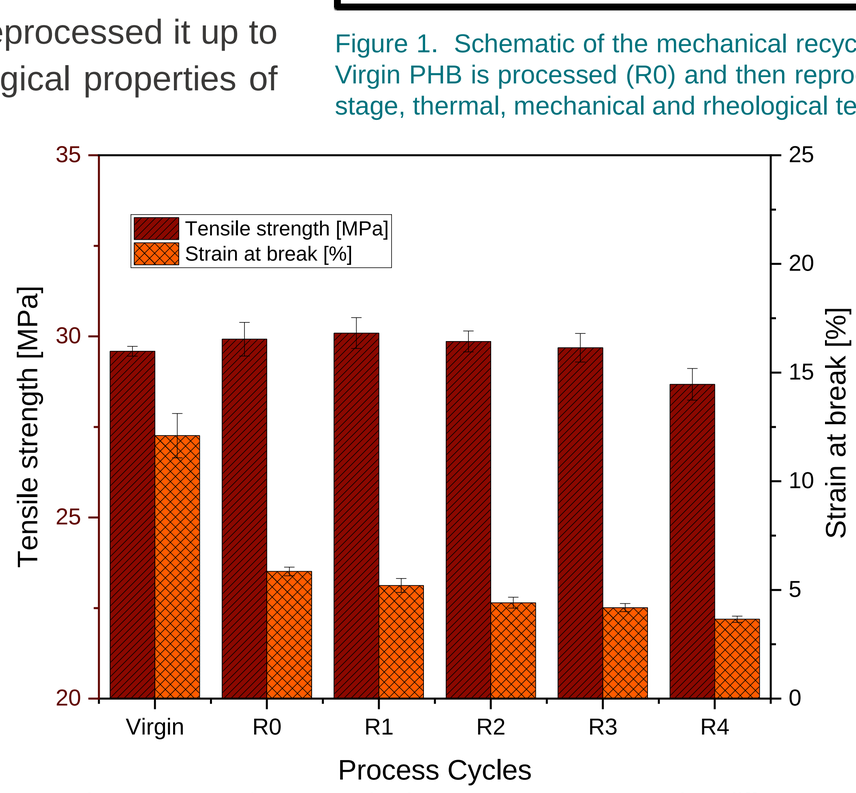


Figure 3. Tensile strength does not vary across the different samples, whereas the strain at break for R0 drops to ~50% of virgin PHB and only gradually decreases for recyclates R1-R4.

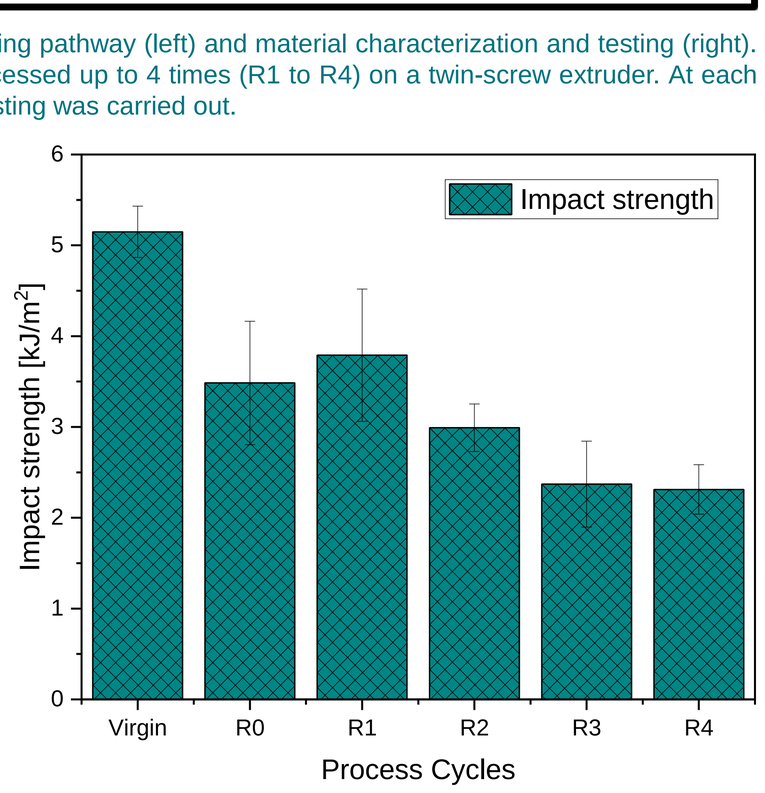
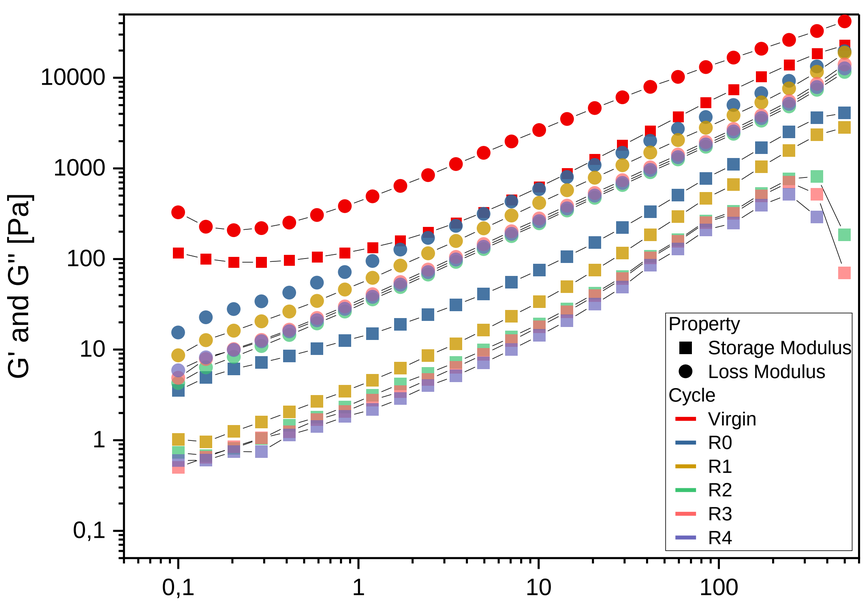


Figure 4. Effect of reprocessing on Charpy impact strength. From R0 to R4, values are varying only slightly with R4 values retaining 66% of the impact strength of R0.



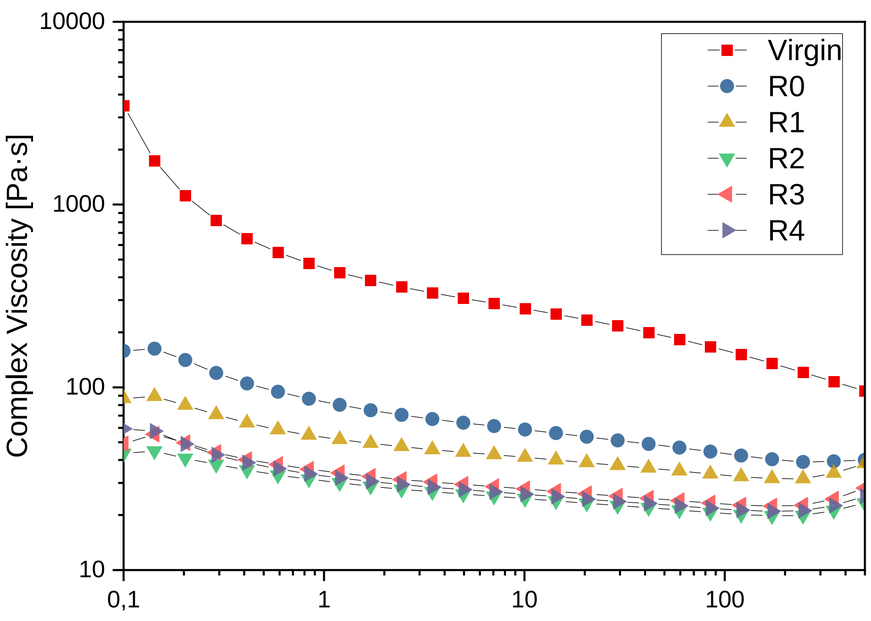


Figure 5 and 6. Parallel Plate Rheometer test conducted to obtain Frequency sweep curves for all stages of reprocessing. The test was conducted at 190°C for all samples. The modulus curves decrease with each processing cycle and no crossover point was observed. From the Virgin to R0 there is a significant drop in viscosity at 0.1 rad/s which largely levels off from R2-R4 which could be due to molecular degradation.

Summary: In this study, several thermal, mechanical and rheological properties of mechanically recycled PHB, sampled at one processing and four reprocessing stages, were measured and compared to its virgin counterpart. We found that:

- Viscosity and moduli decreased as the cycles progressed. This could arise due to the degradation of the polymer molecular weights as PHB is undergoing chain scission during the multiple extrusion cycles.
- Tensile strength remained mostly constant and degradation temperature remained stable for all the cycles. This shows promise for PHB to be mechanically recycled and the addition of chain extenders will be the next steps of this work.

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