Recyclability of PBS

In the production of sustainable and cost-effective materials, both fossil-and bio-based plastics are involved. Thus, the growing utilization of bioplastics and biocomposites has given rise to the necessity of developing an effective recycling technology for bio-based materials. Up to now, **the number of publications in open literature investigating the recyclability of PBS is limited**. Towards establishing a sustainable PBS plastic packaging, in the frame of the project the recyclability of the polyester was studied in detail, since up to now there are no specific guidelines concerning the end life of PBS.

To this direction, three recycling routes were investigated in the SUCCIPAK project, and the overall outcome was the development of the appropriate approach depending on the extent of degradation, from which the waste material suffers:

i) The remelting-restabilization approach in the concept of mechanical recycling
ii) The SSP repairing approach
iii) The oligomerization/monomerization approach in the concept of chemical/feedstock recycling

In particular, the **remelting-restabilization** route was examined, aspiring to be applied for PBS waste of low degradation extent, i.e. on PBS waste with a negligible molecular weight decrease due to usage and disposal. This route involves the addition of re-viving additives (restabilization) in order to protect the material waste when reprocessed during mechanical recycling. During reprocessing at elevated temperatures, PBS of different usage environments was found to undergo mainly a chain branching degradation mechanism. In order to restrict the formation of branches, typical primary and secondary commercial antioxidants were incorporated in PBS at different concentrations, showing that the addition of IRGAFOS® 168 and/or IRGANOX® 1010 limited strikingly PBS thermo-mechanical degradation. As a result, the remelting-restabilization approach was proven to have potential for PBS recycling, a fact which was also supported by the herein conducted LCA and LCC studies indicating the lower environmental impact of restabilized/recycled PBS compared to virgin material.

In cases of noticeable polymer degradation extent, i.e. assessable molecular weight decrease, a **recycling route based on solid state polymerization (SSP)** was suggested. This is especially the case for materials after prolonged storage at environments of increased temperature and humidity. The general concept of this technique was to submit the aged PBS to the SSP process: project runs on aged PBS grades involved heating the material in an inert atmosphere {e.g. 11 $m^3/(kg_{polymer}h)N_2$} at a temperature in the vicinity of the polyester melting point (e.g. T_m-T = 3 ^oC). Under these conditions, recovery of the molecular weight to its initial values and significant increment of the polyester T_m, even up to 10 ^oC, were observed.

Finally, in case of highly degraded PBS the route of **monomerization** is recommended. To this direction the degraded PBS is subjected to extrusion, in the presence of enzymes and breaks into its original monomers. This approach is very effective in terms of monomer recovery; however the high cost of the enzyme may limit its application in the industry.

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In conclusion, (i) The extrusion process showed a significant effect on PBS depolymerization. A higher oligomerization rate was reached by twin screw extruder. This result can be explained by the higher homogenization of the (PBS + lipase) mixture which permitted a good substrate-enzyme contact. The high decrease in M_W and Mn confirms the random PBS chain scissions by lipase.
(ii) The addition of the proposed restabilization system (0.1 wt% Irganox 1010) results in satisfactory retention of the physical, thermal and rheological characteristics of the recyclates subjected up to 5 extrusion cycles.
(iii) Regarding the utilization of solid state polymerization (SSP) technology to deliver high quality restabilized PBS grades, preliminary SSP runs using severely aged prepolymers gave very promising results, in terms of molecular weight and thermal properties recovery.

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