Analysis of different polypropylene waste bales – evaluation of the source material for polypropylene recycling

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ABSTRACT: Given the large amount of PP waste generated every year, mechanical recycling of post-consumed PP products is essential. However, the use of the thereof obtained recyclates in more demanding applications is still restricted by their quality. To determine possible reasons for the low and inconsistent quality of recyclates depending on the source material, the aim of this work was to investigate different PP waste bales ("pure", mixed with other polymers), commercially available at different sorting centres. The amount of PP, the content of contaminations (polymeric and foreign impurities) as well as the ratio of differently processed PP products was investigated four times a year. The analysis showed that up to 13% of PE is present in "pure" PP bales. Furthermore, a considerable amount of impurities was found in some bales. The sorting of the obtained PP samples according to their processing methods indicated seasonal fluctuation, which may be one reason for inconsistent recyclate quality. These results highlight the importance of proper sorting and treatment of PP waste bales before reprocessing.

1 INTRODUCTION

In 2020 Polypropylene (PP) accounted for almost 20% of the plastic consumption in Europe, making it the second most used plastic (Plastics Europe 2021). Due to the high volume of PP used as packaging material (Plastics Europe 2021), large amounts of PP waste are generated every year. Therefore, mechanical recycling of PP waste is a crucial step towards a circular economy. Although there are already some well-established recycling techniques, the lower quality of recyclates compared to virgin materials still poses an obstacle for their use in more demanding applications. Improvements of every step of the whole recycling value chain could solve this problem, with proper and more accurate sorting techniques being particularly crucial.
PP is available in many different grades, which differ in their molecular structure and morphology, enabling a wide range of products that can be manufactured using different processing techniques. Each processing technique and application has specific material requirements, with the melt flow rate being a decisive material parameter for the suitability for different processing methods. Recyclates from mixed grades exhibit average properties (e.g. melt flow behaviour) of the grades they contain (Alvarado Chacon et al. 2020), which is why they are often used for other processes and less-demanding applications or with the addition of a high amount of additives and fillers. Therefore, sorting based on processing method is necessary to allow the production of recyclates with the needed processing and application properties.
To get an overview about the source material for sorting and recycling, this work deals with the analysis of different PP containing waste bales. The determination of the amount of PP and impurities (polymeric and foreign) as well as the proportion of differently processed PP types in the bales were the main focus of this work.

2 EXPERIMENTAL

Since for a recycler, PP waste is available in form of different types and qualities of PP waste bales ("pure" PP, PP mixed with other polymers), two "pure" PP bales (PP1, PP2), two mixed polyolefin bales (MPO1, MPO2) and a mixed PP-polystyrene bale (PP/PS) were investigated. From each waste bale samples of 5 to 10 kg material were taken and manually sorted according to polymer type and foreign materials. It was differentiated between target material (in this case

PP), side fractions (PE, PS for the PP/PS bales) and impurities (other polymers, foreign impurities), where foreign impurities included glass, metals, textiles, metallised films, etc. The obtained PP fraction was then further sorted according to the processing method of the individual parts. A distinction was made between extrusion blow moulding (EBM), injection moulding (IM), thermoforming (THF) and films/flexibles (FLEX). To investigate seasonal fluctuations, the described analysis was carried out four times a year. A scheme of the bale analysis is shown in Fig. 1 and typical examples of the above-mentioned processing classes can be found in Tab. 1.

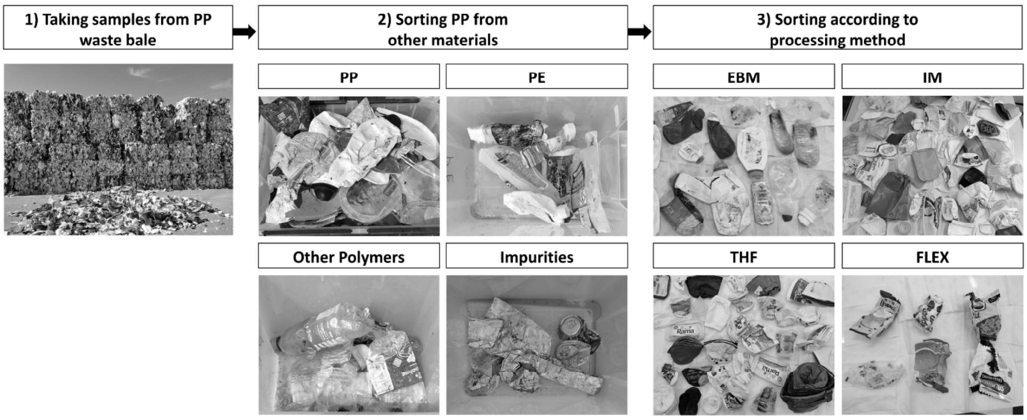

Fig. 1: Schematic of the bale analysis performed

Tab. 1: Examples of PP articles of each processing method class

Processing method	Examples
IM	Food container (ice cream, spreads) and lids, buckets
EBM	Detergent bottles, ketchup bottles, shampoo bottles
THF	Thin-walled plant pots, yoghurt cups, trays
FLEX	Pasta packaging, sweets wrapping, toys packaging

3 RESULTS

In Fig. 2 the amounts of the sorted fractions for different bales are shown, where the impurities include both the polymeric and the foreign impurities. As can be seen, the amount of PE in PP bales ranged between 0 to 13%. As expected, the MPO bales had a higher PE content (between 20 to 70%), with the MPO2 bales having the highest PE content. The proportion of other polymers in MPO bales was higher compared to the PP bales. In the PP/PS bales, the PS content ranged from 5 to 31% and the PE content from 0 to 15%. The proportion of impurities (other polymers and foreign materials) in the bales ranged from 0 to 44%, depending on the bale type and time of sampling. Comparison of different sampling times draws the attention to a significant seasonal variation in the composition of PP waste bales.

The further separation of the PP fraction according to the different processing types showed that IM is the predominant processing method, followed by EBM and THF, while only a small percentage of FLEX samples were found. Furthermore, the proportion of the processing classes was found to vary with sampling time (see example of PP1 bale for three sampling times in Fig. 3).

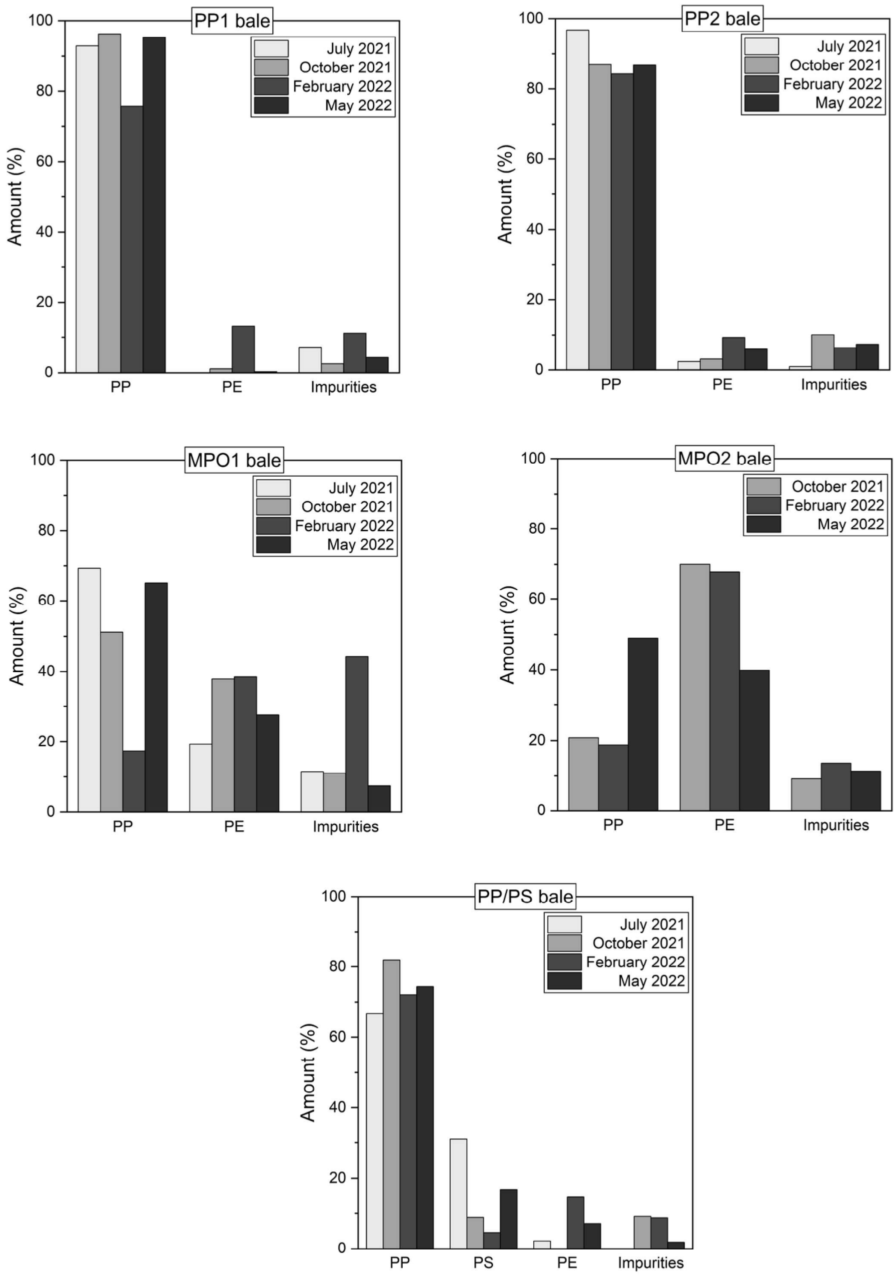

Fig. 2: Material composition of different PP containing waste bales

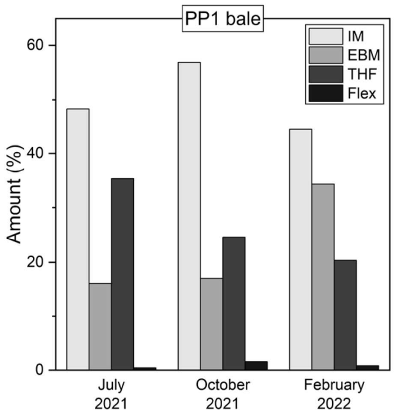

Fig. 3: Results of the sorting according to processing method shown on the example of the PP1 bale

4 CONCLUSION AND OUTLOOK

The bale analysis showed that PP bales contain up to 13% of PE. Some bales were found to have high levels of impurities, which would make it difficult to produce high-quality recycled products, as they can negatively affect the processability of the material and the performance of the produced product. However, with the existing sorting and recycling lines, it should already be possible to remove the PE and other polymers as well as foreign impurities, unless they are part of an inseparable multi-material component.

The proportions of the differently processed PP waste samples showed variations with the sampling time (season), meaning that the recyclates produced at each time of sampling would likely have shown different processability (i.e. melt flow behaviour). A solution to this problem could be achieved by enhanced sorting techniques that allow the sorting according to processing method in order to produce consistent and higher quality recyclates.

This work will serve as a starting point for an upcoming quality evaluation where different sorting criteria (mixed PP grades vs. sorted by processing method) will be assessed based on the performance of the thereof produced recyclates. In addition, the bale analysis will be continued to determine whether the seasonal variations in the proportions of the differently processed samples are random or reproducible.

5 ACKNOWLEDGEMENT

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