Sorption and migration behavior of polylactic acid (PLA) bottles in comparison to PET bottles

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Introduction

Bottles manufactured from the biodegradable polymer polylactide acid (PLA) are under discussion as an alternative for polyethylene terephthalate (PET) softdrink bottles. For PET bottles the sorption and migration behavior has been investigated in detail [1,2]. On the other hand, the sorption and migration behavior of PLA is not systematically investigated till now. Only a few studies dealing with the migration of monomers and oligomers are available in the literature [3]. However, first PLA bottles for softdrinks are entering the market.
Aim of the study was the determination of the sorption and migration behavior of PLA bottles in comparison to PET bottles.

Results

The sorption and migration behavior of packaging materials is correlating with the diffusivity of the polymer or in other words with its inertness. For a given migrant at a certain concentration, a higher diffusivity of the packaging material will lead to a higher migration into the foodstuff or vice versa a higher sorption of food ingredients into the polymer. In order to quantify these interactions, the so-called inertness test has been developed [4]. The idea of such a test was to evaluate of the suitability of PET materials for refillable softdrink and mineral water bottles. Multi-use beverage bottles might absorb during the first use substances from the beverages into the bottle wall. These substances can be remigrate into the foodstuff after refilling the bottle, which was simulated by the inertness test under worst case conditions. The test can be also applied for the investigation of non refillable PET as well as other polymers.
Within the study, a PLA bottle was investigated with the inertness test as described in the literature [4]. As reference materials, a refillable PET bottle as well as a non-refillable PET bottle were investigated. The results show a significantly lower inertness of the PLA bottle in comparison to the PET reference bottles (Figure 1). The sorption/remigration behavior is a factor of about 6 to 8 for polar compounds and about 12 to 16 for non-polar substances higher than for the non-refillable PET bottle.
An internal coating of PLA bottles (for example with SiOx barrier layer) might increase the inertness of the bottle wall. For such non symmetric bottle wall samples, the above mentioned inertness test is not suitable due to the total immersion of bottle wall stripes during the sorption and extraction phase. Therefore, PLA bottles (500 ml) were filled with a mixture of model compounds in *n*-heptane as solvent. Subsequently, the bottles were stored for 10 d at 40 °C. The concentrations of the model compounds were determined in the bottle wall by headspace gas chromatography (Figure 2). The SiOx coated PLA bottle has a similar sorption behavior than the PET reference bottle. As expected, the non coated PLA bottle shows a significantly higher sorption of the chemical compounds. The internal SiOx coating reduces the sorption by a factor of 20 to 30 for toluene, chlorobenzene and methyl salicylate and up to a factor of about 140 for phenyl cyclohexane.

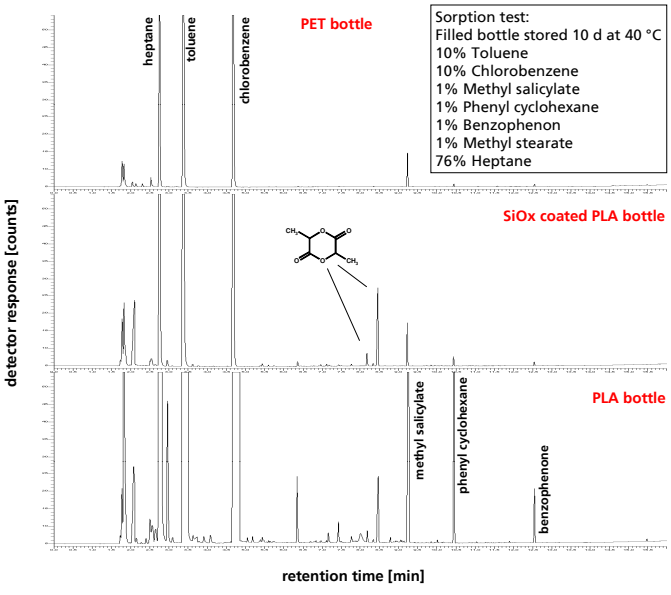

Figure 2: Headspace gas chromatogram of PLA bottle, SiOx coated PLA bottle in comparison to PET after sorption with model compounds in *n*-heptane as solvent

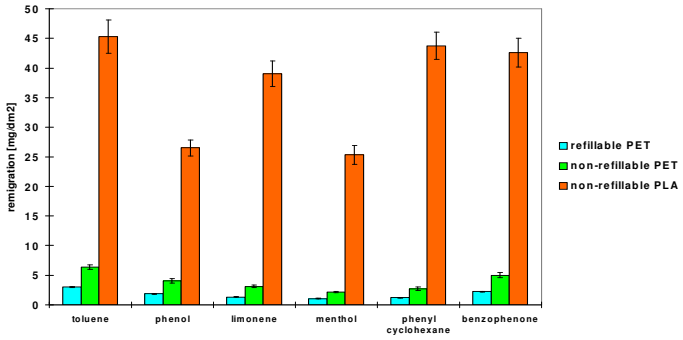

Figure 1: Results of the inertness test for PLA bottle in comparison to PET bottles

It's interesting to note, that in the headspace gas chromatograms (Figure 2) also the cyclic dimer of lactide acid could be determined. Therefore the higher diffusivity and the higher amount of migration relevant compounds in the PLA bottle wall will lead to a higher migration potential of the PLA bottle in comparison to PET.
The results from the inertness test as well as from the sorption test are in agreement with the permeation of oxygen through the bottle walls. For a PET bottle (500 ml, 33 g) an oxygen intake of 0.03 cm^3 per package and day was determined. The oxygen permeation of a similar PLA bottle (500 ml, 26 g) was determined to 0.36 cm^3 per package and day. The internal coating of the PLA bottle with an SiOx layer reduces the oxygen intake to <0.01 cm^3 per package and day. The SiOx layer acts therefore as a barrier towards sorption of chemical compounds as well as for the oxygen.

Conclusions

The results of this study show, that the migration and the sorption behavior of PLA beverage bottles is significantly higher than for PET. An internal coating with a SiOx barrier layer reduces the sorption of compounds into the bottle significantly. The SiOx coated PLA bottle has a similar sorption behavior as the PET reference bottle. The lower inertness of PLA is in agreement with the oxygen transmission of PLA, which is also about a factor 10 higher than for PET. PLA appears therefore to be not suitable for oxygen sensitive beverages. However, an internal coating of the PLA bottle increases the inertness significantly.

References

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