

# Functional barrier performance of polyamide-6 and polyethylene terephthalate films towards *n*-alkanes and 1-alcohols

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## Introduction

Polymeric barrier films are widely used in the food packaging area. So-called functional barriers prevent the packed food from contamination of contaminating permeants from the environment or from other packaging components. Polyamide (PA6) or polyethylene terephthalate (PET) films are such candidates for functional barrier applications.

Aim of the study was to determine barrier properties for non-polar *n*-alkanes (*n*-pentane up to *n*-tetradecane) and polar 1-alcohols (1-propanol to 1-octanol) of 12  $\mu\text{m}$  biaxially oriented PA6 and PET films.

## Method

Both films were placed in a permeation cell with a lower and an upper space separated by the functional barrier film. The permeation cell was made of sand-blasted aluminium and had an area of 191  $\text{cm}^2$ . On both sides a Teflon sealant ring is embedded into permeation cell. The films are clamped between both sealant rings. The lower space of the permeation cell with a volume of 7437  $\text{cm}^3$  was spiked after reaching the measuring temperature with the sets of permeants (*n*-alkanes and 1-alcohols) by use of a syringe. The upstream side of the cells was rinsed with pure nitrogen. The constant nitrogen flow moved the permeated substances out of the cell. The nitrogen stream was analysed for the applied permeants by a connected enrichment unit and gas chromatograph with flame ionization detection (GC/FID). From the experimentally determined lag times, the diffusion coefficients  $D_p$  as well as the partition coefficients  $K$  (between the gas phase and the barrier) of the investigated permeants were calculated.

## Results

The permeation curves of ten *n*-alkanes and six 1-alcohols through 12  $\mu\text{m}$  oriented PA6 and PET film were determined within this study [1,2]. In pre-tests the temperature ranges for the permeation testing was determined to 80  $^{\circ}\text{C}$  to 100  $^{\circ}\text{C}$ . The upstream concentrations of the applied permeants were spiked to approximately a factor of 20 below the vapour pressure of the permeant in order to prevent condensation and swelling of the barrier membranes. Therefore, the upstream concentration decreased at lower temperatures which lead to lower permeation rates. At lower temperatures as given above, the permeation rates for the applied *n*-alkanes as well as the 1-alcohols are too low and therefore below the analytical detection limit of the applied method. The experimentally determined lag times are given in Figure 1. From the correlations between the lag times and the molecular volumes of the permeants the lag times are predicted for lower temperatures down to 30  $^{\circ}\text{C}$ .

It is interesting to note, that the *n*-alkanes and the 1-alcohols follow for both barrier films similar correlations at the same temperature. This indicates that the lag time is mainly dependent on the molecular volume  $V$  of the permeant. The polarity of the permeants, which are very different for *n*-alkanes compared to 1-alcohols, plays obviously a minor role in the correlation between the molecular volume and the lag time. Therefore, the correlations given in Figure 1 can be used for the prediction of lag times for other permeants not experimentally tested within this study.

The polarity of the permeant is strongly influencing the partition coefficients  $K_{g/b}$ . The partition coefficients for the *n*-alkanes are in minimum one order of magnitude higher than determined for 1-alcohols of similar molecular volume. In general, a lower partition coefficient  $K_{g/b}$  leads to a higher permeation rate  $P$  as well a higher sorption rate  $S$  by the same factor accordingly.

From the lag times and the permeation rates at the steady state the diffusion coefficients  $D_p$  and the partition coefficients between the gas phase and the barrier membranes  $K_{g/b}$  were calculated. Both parameters are material constants for a given polymer/permeant pair, which fully describe the permeation process of a permeant through a polymer membrane. These diffusion and partition coefficients are given in the corresponding literature [1,2].

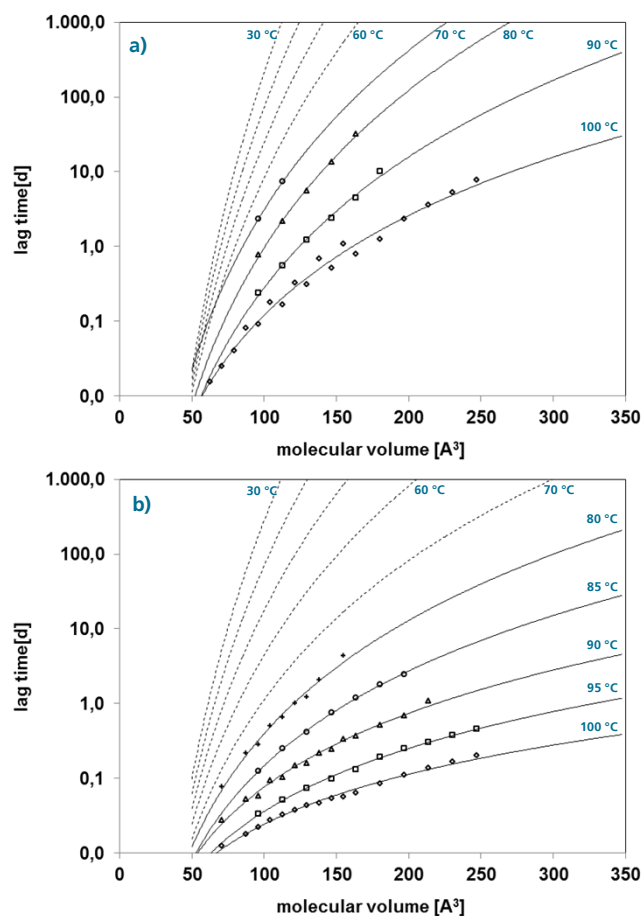


Figure 1: Experimentally determined lag times for *n*-alkanes and 1-alcohols for 12  $\mu\text{m}$  PET (a) and PA6 (b) membranes. Dashed lines: prediction

## Conclusions

In conclusion, the investigated 12  $\mu\text{m}$  biaxial oriented PA6 and PET films are sufficient barriers towards non-polar as well as polar organic compounds represented by homologous rows of *n*-alkanes and 1-alcohols. The lag times for compounds with a molecular volume of  $>100 \text{ \AA}^3$  at temperatures below 30  $^{\circ}\text{C}$  are (far) above of 1000 d (approx. 2.7 years). Therefore the permeation of substances with molecular volumes above 100  $\text{ \AA}^3$  is negligible for a shelf life of three years at room temperature. Such storage conditions are sufficient for nearly all kinds of food packaging applications as long as the diffusivity of the polymers is not affected by strong interactions with foods which for instance may be possible when PA6 is in contact with aqueous foods.

## References

- [1] J. Ewender, F. Welle. Determination and prediction of the lag-times of hydrocarbons through a PET Film. Packaging Technology and Science 2014, 27(12), 963-974.
- [2] J. Ewender, F. Welle. Functional barrier performance of a polyamide 6 membrane towards *n*-alkanes and 1-alcohols. Packaging Technology and Science 2016, 29(6), 277-278.

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