Dachzeile

Circular Economy – Considerations on PET Recycling

Frank Welle*

Information

Keywords
Circular economy, PET recycling, food safety regulations, diffusion modelling

Introduction

The actual discussion on circular economy gives pressure to the packaging industry to recycle their packaging polymers. Nearly all big players and industrial federations published their recollection and recycling goals for 2025 and beyond. PET is the most promising packaging polymer for a closed-loop recycling of post-consumer waste into new packaging applications. Recycling of post-consumer PET mineral water and soft drink bottles were established in Europe since two decades. However, also PET trays should be recycled or should contain a significant amount of post-consumer recyclates. At the moment, in Germany PET trays are classified as not recyclable by the "Stiftung Zentrale Stelle Verpackungsregister". This is due to the fact that PET trays are often not sorted out of the post-consumer packaging streams and are not recycled into new PET products. However, recycling of packaging waste is not only a question of circular economy, efficiencies of sorting and recycling processes. It is also a question of food safety and consumer protection. Ten years before the European Commission published their circular economy claims; the Recycling Regulation 282/2008 came into force. According to this regulation, every recycling process which produces recyclates for direct food contact applications from post-consumer waste must be individually approved by the European Food Safety Authority (EFSA). To show the consumer safety of the recycling processes is definitively necessary, but is also a big work package which slows down innovation processes. On the other hand, two decades of PET recycling showed no significant problems or risks in PET closed-loop recycling. So it's time to think about the evaluation of EFSA regarding post-consumer PET in food contact.

EFSA Evaluation Criteria

The EFSA evaluation of the suitability of post-consumer PET for food contact (or packaging polymers in general) is based on three criteria:

- Input concentration of post-consumer substances in recollected and washed PET flakes
- Cleaning efficiency of the applied super-clean recycling process
- Exposure of the consumer towards residual post-consumer substances depending on the packaging application

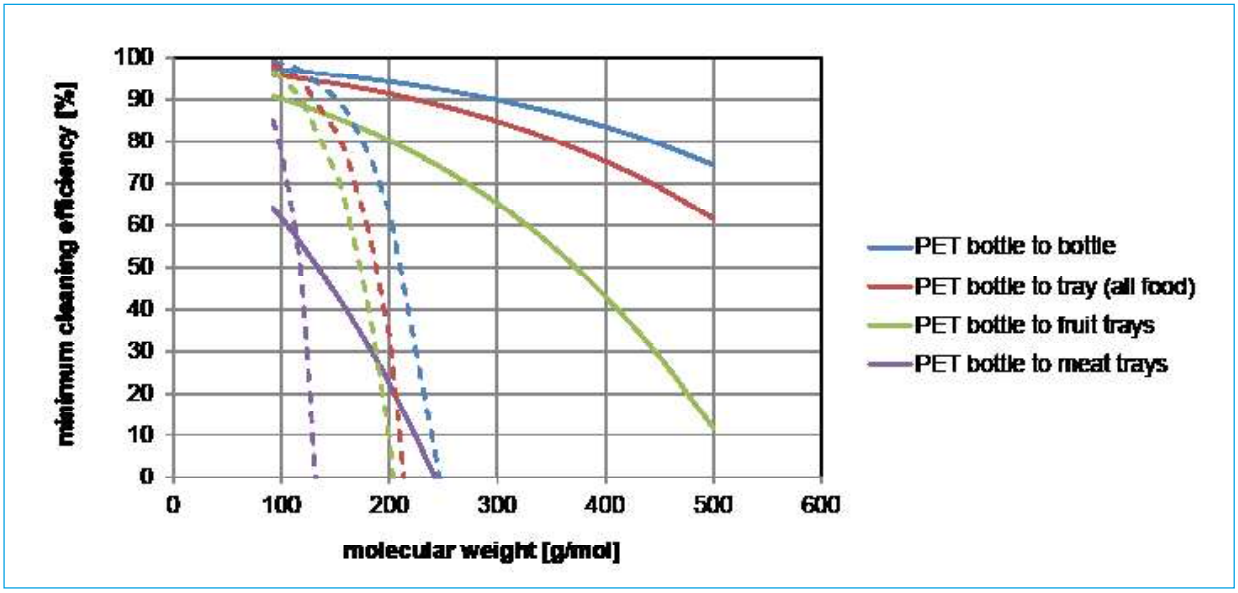
In the first step, the input concentration of any post-consumer substances is evaluated. Post-consumer substances in recyclates include also degradation products of the polymers or additives during recycling steps. For post-consumer PET bottle flakes, EFSA assumes a maximum concentration of 3 mg/kg. This value was determined on a statistical basis within the European "Recyclatbility" Project [1]. In the second step EFSA is evaluating the cleaning efficiency of the applied super-clean recycling process. The cleaning efficiency is determined by artificial contamination of post-consumer PET flakes. The contaminated flakes are subsequently processed within the recycling process. The cleaning efficiencies for each tested subs-

Table 1: Application of PET recylates (assumed 100%) and testing conditions according to EFSA [1,2]

Application of PET recyclate	Conditions for migration calculation	Real storage conditions	Target limit
PET soft drink and mineral water bottles	365 d at 25 °C [2]	shelf life of 1 year at RT	0.10 µg/L (infant scenario)
PET trays (all kind of applications)	365 d at 25 °C [2]	shelf life of 1 year at RT	0.15 µg/L (toddler)
PET trays (meat)	10 d at 20 °C [5]	up to 30 d at 6 °C	0.15 µg/L (toddler)
PET trays (fruit)	10 d at 40 °C	up to 30 d at RT	0.15 µg/L (toddler)

Quelle:

RT = room temperature



Quelle: IVV

Figure 1: Minimum cleaning efficiencies of the super-clean recycling processes necessary for different applications of the post-consumer recyclate (calculated for 100% recyclate content). Solid lines calculated with the AP model applied by EFSA [2,5]. Dashed lines calculated with realistic diffusion coefficients [6].

tance can be calculated from the difference between the concentrations before and after the recycling steps. The last step in the evaluation process is the exposure scenario for infants, toddlers and adults. This exposure scenario towards post-consumer substances is based on the food consumption versus their body weight of the different groups. Due to the fact, that also unknown post-consumer substances might sporadically occur in the input material of recycling processes, EFSA takes also genotoxic substances into account. For genotoxic substances EFSA assumes that exposure to 0.0025 µg of a substance per kg body weight per day is harmless to human health. For mineral water applications EFSA considers that an infant with a body weight of 5 kg drinks 0.75 L water from a PET bottle made of 100% recyclate. This results in a maximum migration of any post-consumer substance at the end of shelf life of 0.1 µg/L [2]. Due to other body weight and consumption behaviours toddlers and adults have higher migration values of 0.15 µg/L and 0.75 µg/L, respectively. The acceptable migration into food is calculated by the use of diffusion modelling based on the AP model [3]. This allows calculating the minimum cleaning efficiencies of the recycling processes regarding the foreseen packaging applications.

Discussion

Until now, EFSA has published around 140 opinions on recycling processes. The huge majority are on PET recycling processes for the recycling of post-consumer PET bottles into new PET bottles as well as PET trays for general food contact. Only one opinion has been published on PET trays for meat in the cold chain. One opinion has been published on the recycling of HDPE milk bottles into new fresh milk bottles. Even if application options are limited, the major principle of the evaluation is clear and can be used for the prediction of forthcoming applications of post-consumer recyclates.

Information

Abstract

Polyethylenterephthalat (PET) ist das vielversprechendste Verpackungspolymer für das „closed-loop" Recycling (geschlossene Produktkreisläufe) von Altabfällen zu neuen Verpackungen. Die von der EFSA veröffentlichten Bewertungskriterien zur Lebensmittelsicherheit sind unabdingbar für den Schutz der Verbraucher. Die Werte sollten jedoch realistisch bleiben, um die Wiederverwertung im Verpackungssektor zu erleichtern.

Die Anwendung von PET-Rezyklaten mittels von der EFSA vorgegebenen Testbedingungen haben gezeigt, dass sowohl das Vorhandensein kritischer Substanzen in den Rezyklaten als auch die Migration von "post-consumer" Substanzen in Lebensmittel eindeutig überschätzt werden. Mit den dargestellten Ergebnissen wird für eine Anpassung der EFSA-Kriterien appelliert, um den derzeit erforderlichen hohen Reinigungsaufwand sowie die Einschränkungen bei der Verwendung von PET-Flakes für Verpackungszwecke zu reduzieren.

Looking into the details of the EFSA evaluation it becomes obvious that the evaluation criteria for post-consumer PET in bottle or tray applications are extremely conservative and unrealistic. For example, EFSA assumes that all post-consumer substances in the input material of a recycling process are genotoxic substances, which means that 1 kg of washed post-consumer PET contains 3 mg of genotoxic substances. However, the Recyclability Project clearly shows that the major fraction of post-consumer substances is a well-known flavor compounds from soft drinks (limonene). Genotoxic compounds were not detected in post-consumer PET flakes [2]. There might be some critical substances in recyclates, however if any, only in traces. Assuming that the input material of recycling processes contains no genotoxic substances would allow Cramer Class III with an exposure of 1.5 µg per kg body weight (b. w.) per day instead of 0.0025 µg/kg b. w. / day.

The migration prediction model used by EFSA presents a second conservatism. It is well known, that the applied AP model is highly over-estimating the migration, especially for higher molecular weight molecules. This leads to a huge over-estimation of the migration of post-consumer substances into food and vice versa into high cleaning efficiencies for the recycling process. Realistic prediction models have been developed in our scientific team and are available in scientific literature [4]. The described alternative prediction model is based on experimentally determined activation energies of diffusion and results in realistic, only slightly over-estimative diffusion coefficients. In order to show the influence of the prediction models, the minimum cleaning efficiencies were calculated (Figure 1). The applications and storage conditions are given in Table 1. As a result, the highest cleaning efficiencies must be applied for PET bottle-to-bottle recycling. This is due to the fact, that infants with only 5 kg b.w. are considered in the exposure scenario and that the shelf life is up to one year. Recycling of PET bottles to produce fruit or meat trays results in much lower minimum cleaning efficiencies due to shorter shelf-life and a lower specific product temperature. The calculated minimum cleaning efficiencies calculated on the basis of realistic diffusion coefficients are shown in Figure 1 (dashed lines). It shows a much stronger decline of the necessary cleaning efficiencies as found for the AP model (solid lines) for the higher molecular weight compounds. Recyclate applications in meat and fruit trays do not need supercleaning of the recyclates up to molecular weights of about 200 g/mol, even under the assumption that the whole input of post-consumer substances are genotoxic compounds.

Conclusions

EFSA is applying extremely conservative evaluation criteria for recycled PET in bottles and trays because (i) a highly over-estimation prediction model to calculate the migration is applied and (ii) it is assumed that the whole amount of post-consumer substances are genotoxic compounds. Both assumptions are conservative, but both together limit the use of post-consumer PET recyclates into new packaging or make the approval process expensive. Assuming a realistic percentage of approx. 2.7% of the post-consumer substances (0.08 mg/kg instead of 3 mg/kg) are genotoxic compounds makes a super-cleaning recycling process superfluous for all applications in Table 1. On the other hand, assuming the whole amount of post-consumer substances of 3 mg/kg as genotoxic compounds in the input material, but going to a realistic prediction model leads to significantly lower minimum cleaning efficiencies. Volatile post-consumer substances below 250 g/mol are already efficiently removed from the polymer during recycling. Especially fruit or meat tray applications with short shelf life or low storage temperatures are uncritical applications for post-consumer PET recyclates. Consumer protection and food safety is most important in packaging recycling, but unrealistic assumptions in compliance evaluation could hinder several essential approaches in closed-loop packaging recycling. ■

*Fraunhofer Institute for Process Engineering and Packaging IVV, Giggenhauser Straße 35, 85354 Freising, Germany

Literature
[1] R. Franz, F. Bayer, F. Welle, Guidance and criteria for safe recycling of post consumer polyethylene terephthalate (PET) into new food packaging applications, EU Report 21155, ISBN 92-894-6776-2, 2004 (26 pages)
[2] Scientific Opinion on the criteria to be used for safety evaluation of a mechanical recycling process to produce recycled PET intended to be used for manufacture of materials and articles in contact with food, EFSA Journal 2011. 9(7), 2184 (25 pages)
[3] Practical guidelines on the application of migration modelling for the estimation of specific migration, EU Report 27529 EN, ISBN 978-92-79-52790-6, 2015 (40 pages)
[4] F. Welle, A new method for the prediction of diffusion coefficients in poly(ethylene terephthalate), Journal of Applied Polymer Science, 2013, 129(4), 1845-1851
[5] Safety assessment of the process 'Linpac', based on Linpac super clean technology, used to recycle post-consumer PET into food contact materials, Journal 2018, 16(7), 5323 (13 pages)
[6] F. Welle, Is PET bottle-to-bottle Recycling Safe? Evaluation of Post-consumer Recycling Processes According to the EFSA Guidelines, Resources Conservation and Recycling, 2013, 73, 41-45