



Sustainable Additives for Food & Beverage Packaging

Enhancing the Recyclability of PET via Performance Additives



INTRODUCTION

PET - A Sustainable Choice

PET, utilized for its recyclability, lightweight properties, strength, durability, and versatility, offers a high sustainability profile. PET bottles are up to 95% lighter than the more common glass and aluminum alternatives and produce 75% fewer greenhouse gases when manufactured. Recyclability is the key differentiating feature for PET vs. alternative packaging materials; 2 out of 3 PET bottles are recycled in Europe, and PET can be recycled back into packaging, a truly circular economy.¹

The PET market is evolving to improve sustainability at its core. New legislation in the European Union requires all PET packaging to contain a minimum of 25% recycled content by 2025, with many large brands pledging significantly higher levels of recycled content up to 100% within the next ten years. This leads to many challenges regarding the availability and quality of recycled polyethylene terephthalate (rPET).¹

Consumer and Market Expectations

The food and beverage market is front and center in the global fight towards achieving a 100% sustainable packaging target. By incorporating sustainable additives into its packaging, the industry has the opportunity to push the needle on sustainability

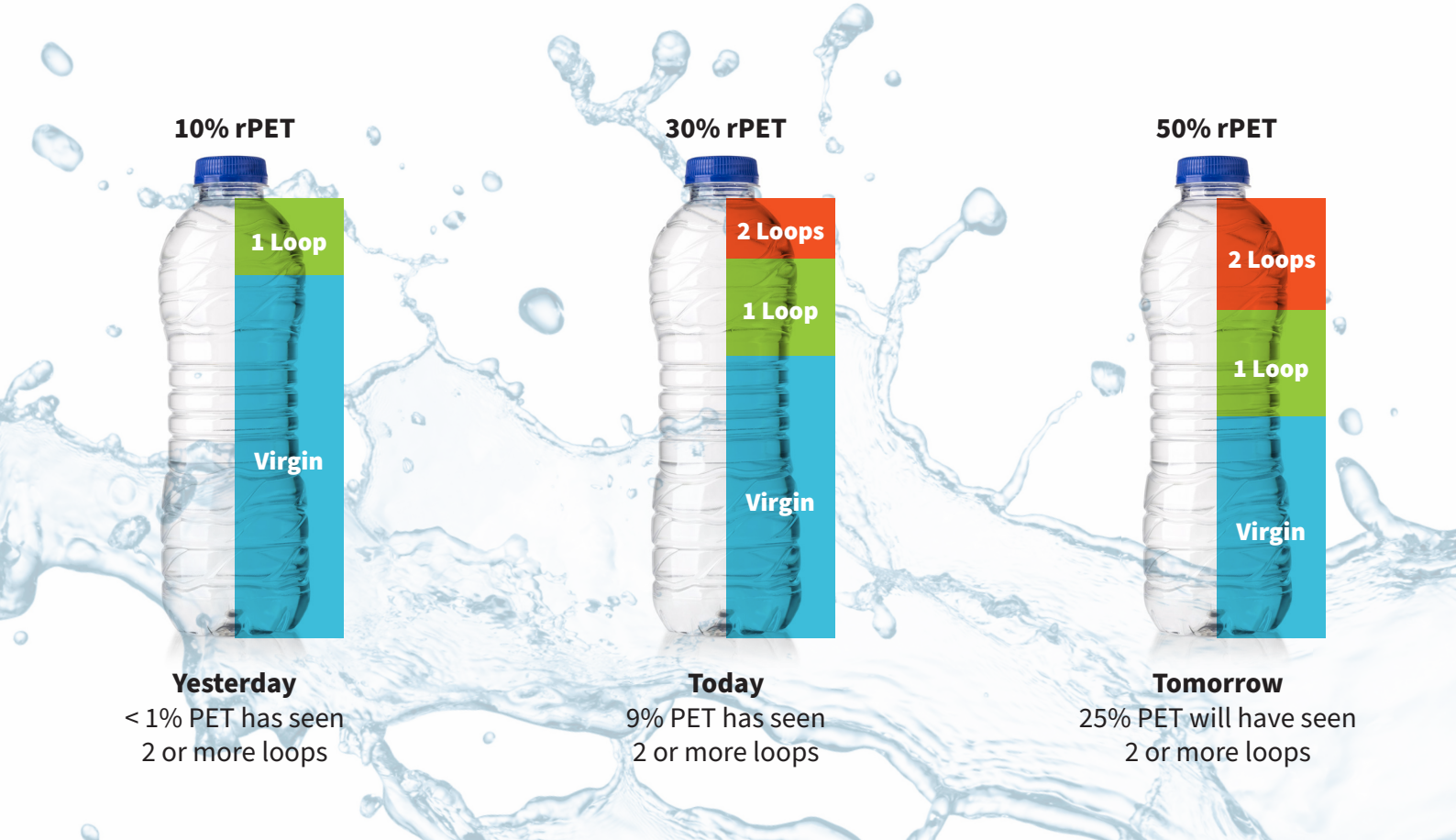
while promoting the circular economy. Consumer needs and demands are setting the bar high for brands, which are challenged to provide sustainable packaging solutions that are aesthetically appealing and also offer adequate protection to preserve shelf life. Brands are being called to the frontline to play a vital role in solving some of the most crucial environmental problems, such as reducing food waste and CO₂ emissions, and helping achieve overall improved product life-cycle.

These needs are cascaded down industry value chains, where different players are required to develop solutions to solve these challenges and reconcile the need for an ever-improved performance with a stronger sustainability focus.

Functionality and the Future

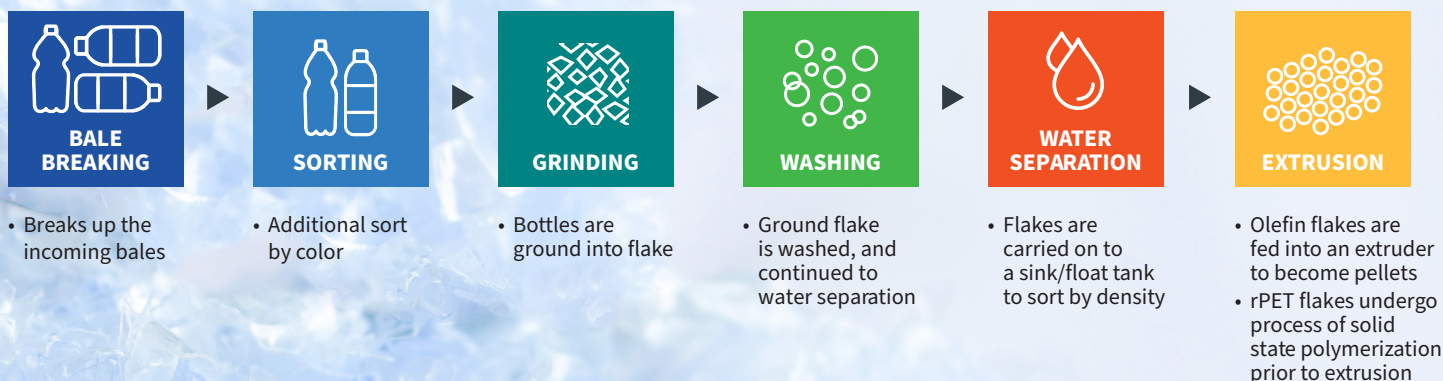
Functional additives are crucial to making PET such a versatile packaging material. Additives can extend the performance of PET by protecting against food spoilage caused by oxygen ingress, UV radiation, visible light, and/or by-product migration. They can also help retain mechanical properties in packaging materials.

As rPET usage increases in the industry, bottles will increasingly contain PET that has passed through the recycle loop two or more times.



This circular use of PET will significantly reduce reliance on fossil fuels in the manufacturing process as recycled PET use yields 79% less CO₂ emissions than virgin PET.² However, the recycled material has different qualities to virgin PET, it is often darker or yellow in color with lower intrinsic viscosity, and is also more challenging to process.

Current recycling legislation and protocols only consider the impact of additive use after one recycle loop. Still, as the 25% minimum is introduced in the EU, at least half of the rPET used in packaging will have been recycled two or more times. When assessing additives, it will become more important to consider the impact on recycling over at least two loops.



To address the increased use of rPET, and the multiple processing loops it will undergo, manufacturers will require additives that meet these additional challenges. As rPET content increases, additives need to adapt so that:

- They do not negatively impact rPET aesthetically or during processing
- They function as intended when used in conjunction with rPET
- They have no negative impact on non-intentionally added substances (NIAS) through the recycling process

Recycle performance will have a greater impact on bottle quality by:

- Increased yellowing & color variability
- Increased processing issues
- Increased NIAS risk

**Additives
can address
these issues
and help drive
circularity**

A shift from functional additives to sustainable functional additives will be required in this rapidly changing market. Additives that provide the necessary functionality, have no negative impact on rPET, and show improvements in rPET quality, processability, or performance, are currently available. If adopted globally, additives like these would enable improved quality and availability of bottle grade rPET in the future, enabling the continued circularity of PET through multiple recycle loops.

THE FUTURE OF FUNCTIONAL ADDITIVES: SUSTAINABLE FUNCTIONAL ADDITIVES

The food industry can play its part in assessing both the safety and sustainability of products that reach consumers by monitoring critical parameters of plastic packaging materials. Among these parameters, polymer color, generation of non-intentionally added substances (NIAS), performance, and processability are the most crucial factors. By understanding the impact of material choice on these parameters over the extended circular life cycle of packaging, the industry has the opportunity to utilize materials that help sustain, rather than impair, recyclability of plastics.

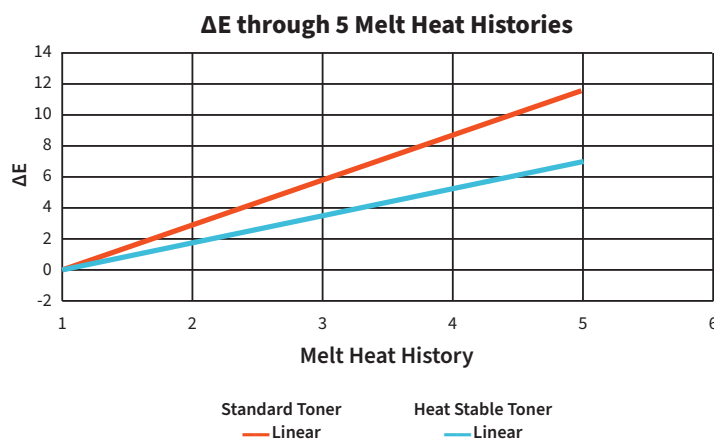
Color

When PET is recycled, degradation reactions can lead to yellowing. In addition, degradation reactions of PET additives can also occur, potentially leading to additional yellowing and color variation. As the levels of rPET used in PET packaging are set to increase, the number of heat exposures of recycled PET will increase; hence, the yellowing and color variation of rPET resin will increase.

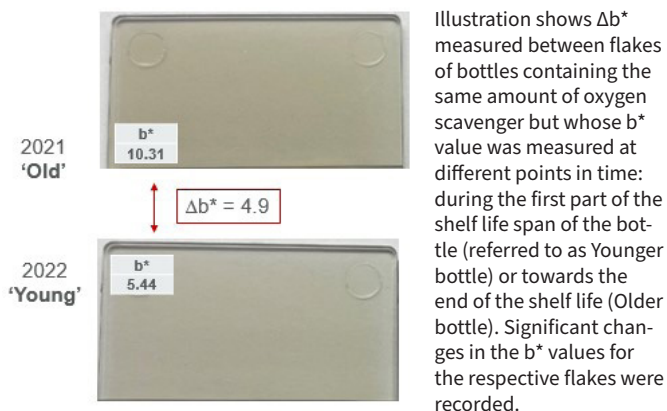
Virgin PET resin producers and additive suppliers are working to ensure additives used in PET packaging are formulated for heat stability with minimal impact on yellowing. Current accredited testing protocols only evaluate yellowing of virgin PET and its additives

through one full recycle loop. However, the impact of performance through two full recycle loops is becoming more critical as the rPET content of PET packaging increases and circularity improves.

To mimic more realistic conditions, color stability should be evaluated as ΔE^* (Delta E) through 5 melt heat histories which is the equivalent of two full recycle loops, focusing on the total color shift of the L^* , a^* , b^* values. This approach can be used to screen the heat stability of additives, such as PET toners, for which an accredited and recommended testing protocol coming from one of the leading organizations does not exist. The below chart is an example of how ΔE^* can be used to compare two toner products, one showing better stability and therefore contributing less to yellowing and color variation in the rPET stream.



Likewise, recycle testing for oxygen barrier additives can also be improved. Quick oven tests for oxygen barriers can be misleading, as the impact of aging and oxidation of the package on yellowing is not taken into consideration, leading to results that do not correlate to the impact of the barrier additive under actual use conditions.



Adapting testing to account for the effect of aging, combined with the ΔE^* approach for overall color shift, would significantly improve the recycle evaluation process for these types of additives by making the process more representative of the product recycling environment as sustainability efforts increase.

Product Stewardship and NIAS Generation

NIAS are chemicals that are present in a food contact material (FCM) or food contact articles (FCA) but have not been added for a technical reason during the production process. Presence of NIAS may be a result of interactions between materials in the packaging, between food content and substances in food contact materials (such as additives), from degradation of materials or from impurities present in the raw materials. These substances may go undetected by standard migration testing used for specific food contact compliance. NIAS screening is a requirement for plastic packaging producers since they are responsible for the safety of the articles they produce. Diligent scrutiny of packaging safety involves sophisticated analytics at times, where the nature of specific chemical substances to be detected may be unknown and the quantities that can potentially migrate into the product can be in the orders of ppm or even ppb. Convertors and brand owners alike must make sure all specifications are respected

to guarantee that the safety of the consumers is preserved, and product quality is not impaired.

As the EU mandate for increased rPET in plastic packaging moves to 25% by 2025, convertors are challenged with complying with these regulations while fulfilling existing requirements in terms of safety. Recycled polyethylene terephthalate can currently be sourced from many different suppliers in the market. Quality can vary tremendously, depending on the sorting and reprocessing carried out during the recycling process. In addition, as the industry moves towards an ideal design for recycling where the material is reinserted into the market an indefinite number of times, it is challenged to provide safe-for-use rPET material. This is recycled material not just coming from virgin PET resin but also containing increasing amounts of resin and additives that might have already gone through multiple recycling and melt histories.

It will become increasingly important to provide a quality grade of rPET that can meet health and safety requirements and can pass a robust NIAS screening process. Through this process, important information can be gained on the composition of a material, its impurities, and any resulting toxicological concerns, which can affect consumer safety and for which packaging manufacturers are responsible.

Once a final article is manufactured its composition will include both rPET and any functional additives used in the manufacturing process. One of the crucial aspects in NIAS screening will be the ability to quickly discern between any NIAS content that is generated by the rPET or by additives used in the manufacturing phase. Screening of input material like rPET prior to use to identify potential NIAS should become a routine safety check in the future.

As an additional safeguarding measure to the quality and NIAS content of rPET resins, there are technologies currently under development that specifically target sources of contamination commonly found on PCR flake. These sources of contamination are known to produce excessive yellowing and accelerate NIAS formation. By rendering these sources of contamination 'inactive', then significant improvements to both rPET resin color and NIAS content can be achieved.





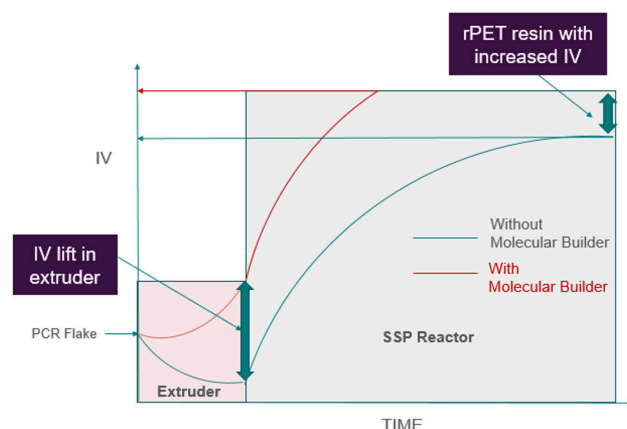
Both additive manufacturers and providers of plastic concentrates (i.e. masterbatches) alike can ease this task for both converters and brand owners by offering data on their products. It would be desirable for masterbatch manufacturers to provide a preliminary NIAS screening to show that their products are not the source of NIAS concern. This practice may simplify the assessment needed to identify the cause for NIAS profiles of concern in finished products and help maintain the highest standards in terms of safety along the value chain.

Processability

As the number of heat exposures to rPET increases due to rising use levels, the processability of rPET will decrease. Mechanical recycling of PET produces a PET product with a lower mechanical strength compared to that of virgin PET with an equivalent intrinsic viscosity. These materials process differently, particularly during the bottle blowing process. They heat up differently, they stretch differently, and when used in combinations or blends, can lead to a number of bottle-blowing process issues. This significantly narrows the bottle blowing parameters for achieving a good quality PET bottle, resulting in poor quality bottles, reduced line speeds, increased blowouts, increased downtime, and increased scrap rates.

The quality of rPET in terms of intrinsic viscosity can be reinvigorated by using molecular chain builders that help overcome the degradation process that multiple recycling streams will bring along. This will enable availability of first class recycled materials

with an intrinsic viscosity very close—if not equivalent—to virgin grade resins and thus facilitating use of increased amounts of rPET in the market.



Also, bottle blowing process aids can improve the preform heat-up rate and uniformity of heating, allowing for a wider bottle blowing window. This allows for optimization of the bottle blowing process and polymer weight distribution within the bottle sections. This results in bottles with improved quality and mechanical strength, helps to reduce processing issues such as blowouts, downtime, and scrap rates and allows for the use of rPET at higher levels.

Performance

Maintaining the desired processability is not the only challenge that additives will have to face within a market contemplating increased use of rPET. Additive performance with rPET will also have to be addressed.

This is true for oxygen or acetaldehyde scavengers as well as toners or processors. For example, oxygen

scavenger technology is essential to the food packaging industry because it prevents or delays oxygen ingress into plastic packaging to extend shelf life and reduce food waste. Many commercial technologies are based on metal catalysis to function. This catalysis has been proven successful and offers full compatibility and performance when used with virgin resins. As the amount of rPET is set to increase, oxygen scavengers will face the challenge of maintaining performance regardless of the quantity or quality of rPET utilized. Impurities from different rPET grades can cause deactivation of the metal catalysts currently used. Suppliers of oxygen scavenger technologies must help the market implement and achieve their sustainability targets by developing new technologies that can perform equally well with increasing amounts of rPET and with the prospect of utilizing up to 100% recycled content in the future.

The amount and quality of rPET that will be used could also affect specific market segments more than others. Acetaldehyde is intrinsically present in variable quantities in materials such as rPET.³ Its presence can profoundly affect the water bottle market because even a small migration of such substance from packaging can change the organoleptic properties of water.

Use of sustainable additives that can address these types of challenges and help grow the percentage of rPET employed in the future stand to play a fundamental role in the packaging market.

CONCLUSIONS

The coming years will see several significant changes in the packaging market. Sustainability initiatives will be front and center in order to achieve a true circular economy by the middle of the century.

The use of rPET is already being mandated with specific targets in certain regions. Its composition and the number of recycling loops the material goes

through will drastically change the make-up of PET bottles that enter the market.

Additive manufacturers will need to adapt their offering to help converters and brand owners alike operate in such a changing environment. Bottle manufacturers will have to choose products that can help move the industry towards a real circular economy. Selecting the proper additives for PET will enable ease of use of rPET and help maintain PET as the material of choice for the future.

Recycling protocols are currently inadequate, or in some cases do not even exist, for the screening of products like toners or oxygen scavengers. With an increased reliance on these additives to facilitate higher and higher amounts of rPET, these protocols will need to be changed and adapted.

As rPET use increases, NIAS levels are likely to increase. Sustainable additives will need to add no further negatives or complexities in order to reduce the undesirable NIAS risk. Additional screening along the value chain can also help lower these associated risks.

Ultimately, when chosen wisely, sustainable additives will be vital in overcoming many challenges in terms of rPET adoption. Sustainable additives will also ensure that food waste is not just kept under control but progressively reduced. Collectively, sustainable additives are helping to build a world where our planet's resources are utilized judiciously, preserved, and potentially even renewed.

ENDNOTES

- ¹ https://www.petcore-europe.org/images/2021/petcore_infographic_v3_final_21122020-n.pdf
- ² Recycled plastic: An Undervalued Carbon Reduction Strategy - Prevented Ocean Plastic
- ³ Tacker M. et al., Sustainability, 2021, 13, 7370

