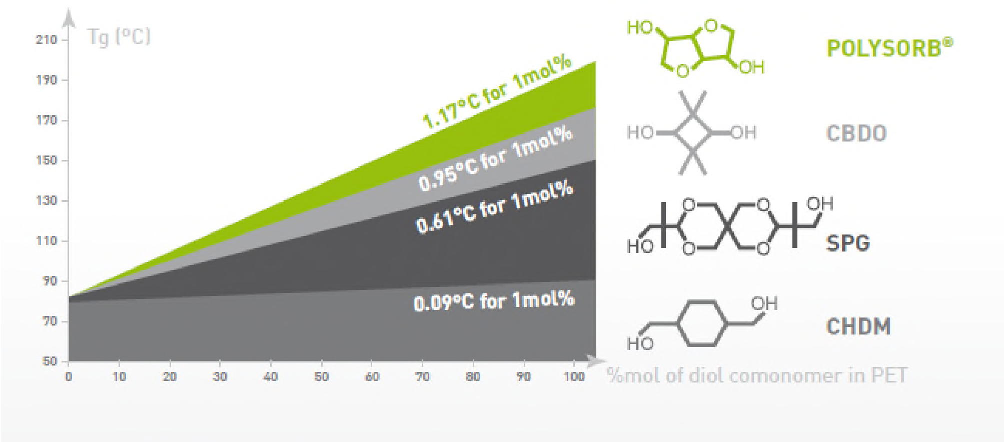
Using Isosorbide To Enhance The Thermal Properties Of Polymers

The thermal properties of polymers routinely define their value for specific applications making them a target for control and enhancement. For example, plastics for aerosol packaging must meet material resistance to temperature criteria[1] while deformation and shrinkage characteristics at elevated temperature are critical for candidates for hot fill packaging applications. Thermal properties that can be controlled to meet specific requirements include heat deflection or distortion temperature and coefficient of linear thermal expansion but often, for amorphous or semi-crystalline polymers it is glass transition temperature, Tg, that holds the key. The Tg of a polymer defines the temperature above which the thermal properties of the material begin to change and more "rubbery" behavior establishes; below their Tg, polymers are more glass-like.

High purity isosorbide is a commercially available bio-based diol (POLYSORB®, Roquette, France) with a very low carbon footprint that can be incorporated in polymers to improve thermal properties, notably to increase Tg, alongside environmental impact. The following examples illustrate what can be achieved.

A PET for aerosol packaging…

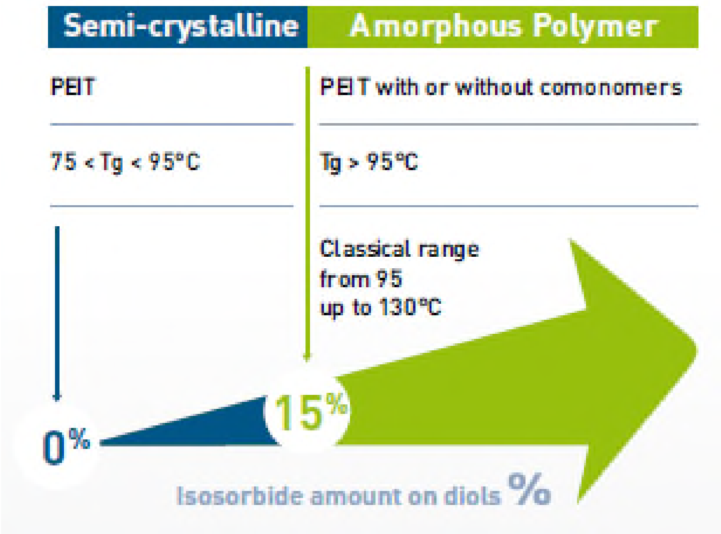
An important limitation of PET (polyethylene terephthalate) as an aerosol packaging material is that it does not have the thermal resistance required to meet the criteria laid out in FEA Standard 647[1]. Incorporating high purity isosorbide, in place of ethylene glycol, increases the Tg of the copolyester, directly addressing this issue. Indeed, isosorbide increases Tg more effectively than any alternative diol including CBDO - 2,2,4,4-Tetramethyl-1,3-cyclobutanediol, SPG – Spiroglycol, and CHDM – Cyclohexanedimethanol (see figure). The resulting polymer - polyethylene-co-isosorbide terephthalate (PEIT) - is a semi-aromatic copolyester with a substantially improved thermal profile.



POLYSORB®, the high purity isosorbide from Roquette, is the most effective diol for increasing the Tg of specialty copolyesters and a bio-based molecule.

Meeting a Tg of ~90°C, as required for aerosol packaging applications, requires less than 15% isosorbide incorporation, i.e., the substitution of less than 15% of the ethylene glycol in conventional PET. The resulting PEIT is therefore semicrystalline and can be mechanically recycled with existing PET waste streams. Recycled materials containing up to 50% modified PET fulfill all the European PET Bottle Platform (EPBP) Testing Protocols for assessing PET recycling compatibility.[2]

This PEIT can also carry the Resin Identification Code #1, as reserved for PET, based on the requirements of ASTM Standard 7611-7611M (Standard Practice for Coding Plastic Manufactured Articles for Resin Identification).[3]

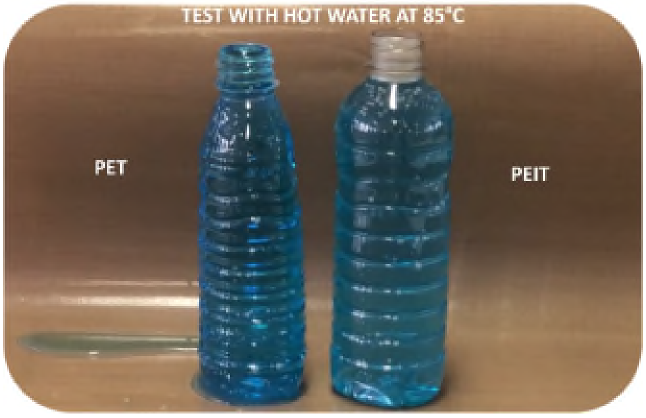


PEIT for aerosol packaging requires less than 15% isosorbide and is therefore semicrystalline. enabling recycle into existing PET streams.

In summary, for aerosol packaging, isosorbide delivers the thermal property profile required while retaining packaging recyclability.

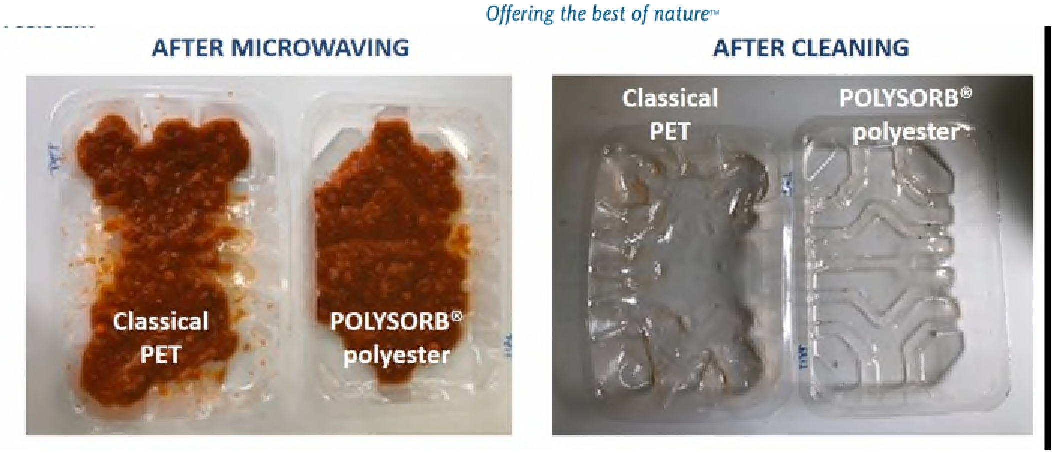
… and hot fill packaging

The image below shows shrinkage results relevant to the use of PET in packaging for hot fill applications, an application where PEIT also offers superior performance. PET has widely recognized limitations for hot filling which is advantageous for many foods and beverages. The shrinkage test involves filling a bottle with hot water (75 – 90°C), allowing it to stand for 2 hours, and then measuring any change in volume, as the water is discarded. The results show how PEIT retains its shape far better than PET which exhibits shrinkage of 7% at 85°C rising to 28% at 90°C[4]. Furthermore, bottles made with PEIT polymers have been shown to have an acceptable burst pressure (of 27 bar) and to exhibit good color and transparency.



PEIT grades exhibit much less shrinkage than PET when subjected to temperatures comparable to those associated with hot fill.

The higher temperature resistance, and improved chemical stability, of PEIT are equally valuable for food packaging. In the figure below PEIT trays holding Bolognese sauce show perfect shape retention and no tainting following microwave heating, as required for product use. In contrast the PET tray is distorted and discolored.

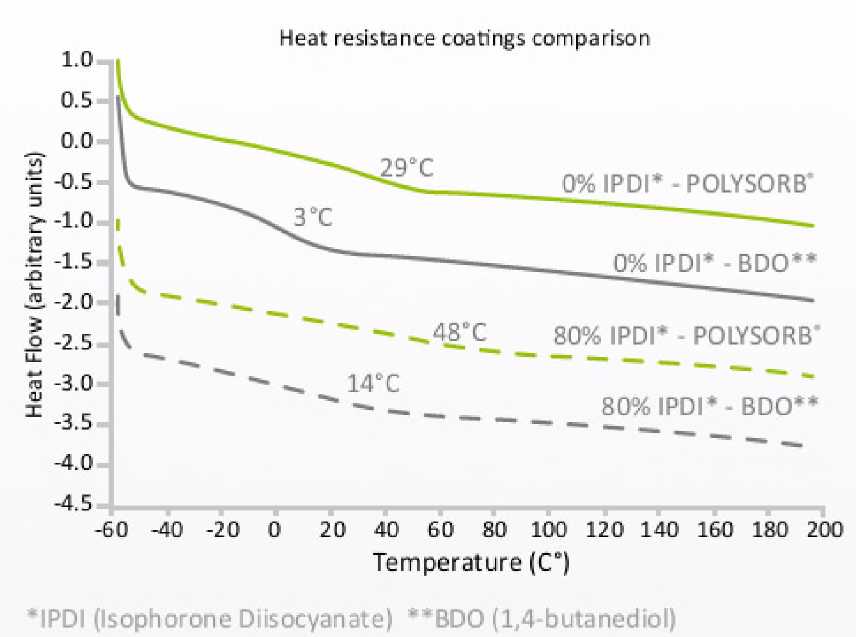


PEIT trays holding Bolognese sauce show no distortion or discoloration after 30 seconds in the microwave at 900W, unlike PET trays which are perform poorly in this application.

These benefits of PEIT for elevated temperature food and drink applications are already being commercially exploited. For example, Morning Recovery (More Labs, Los Angeles, USA), a blend of electrolytes and other ingredients for rehydration and replenishment, is now supplied in PEIT-based polymer packaging in place of glass for export applications. Produced in an established injection molding line this packaging is lightweight and hot filled at 85°C to confer good shelf-life.

PU coatings with improved heat resistance

PUs are made by reacting alcohols with two or more reactive hydroxyl groups per molecule i.e. diols, triols or polyols, with a diisocyanate. With this system too there are consequently opportunities to substitute with isosorbide to improve the property slate. For example, 1,4 butanediol (BDO) is routinely used as a chain extender, to increase the molecular weight of PUs. Substituting BDO with isosorbide creates coatings with a higher Tg and correspondingly higher heat resistance. Furthermore, the inclusion of isosorbide can enhance adhesion and improve impact and abrasion resistance, deliver a PU coating with substantially superior performance for a range of applications.



In conclusion

The availability of high purity isosorbide in industrial quantities presents opportunities to address key limitations with established polymers, such as the thermal stability of PET, and more generally to tailor thermal properties to more closely match specific applications. The examples presented here illustrate the potential for POLYSORB® isosorbide to deliver polymers that answer more effectively to industrial requirements while at the same time reducing environmental impacts.

For more information on high purity POLYSORB® isosorbide from Roquette, click here.

[1] FEA Standard 647: Plastic Aerosol Dispensers – Technical Requirements. Available to download at: https://www.aerosol.org/mediaroom/fea-647-and-fea-650-are-now-available/

[2] "How we do a Recycling Evaluation!" https://www.epbp.org/page/5/layout-link-2-test-procedures

[3] ASTM D7611/D7611M – 20 Standard Practice for Coding Plastic Manufactured Articles for Resin Identification. Details and available to purchase: https://www.astm.org/Standards/D7611.htm

[4] Add in SK Chemicals article