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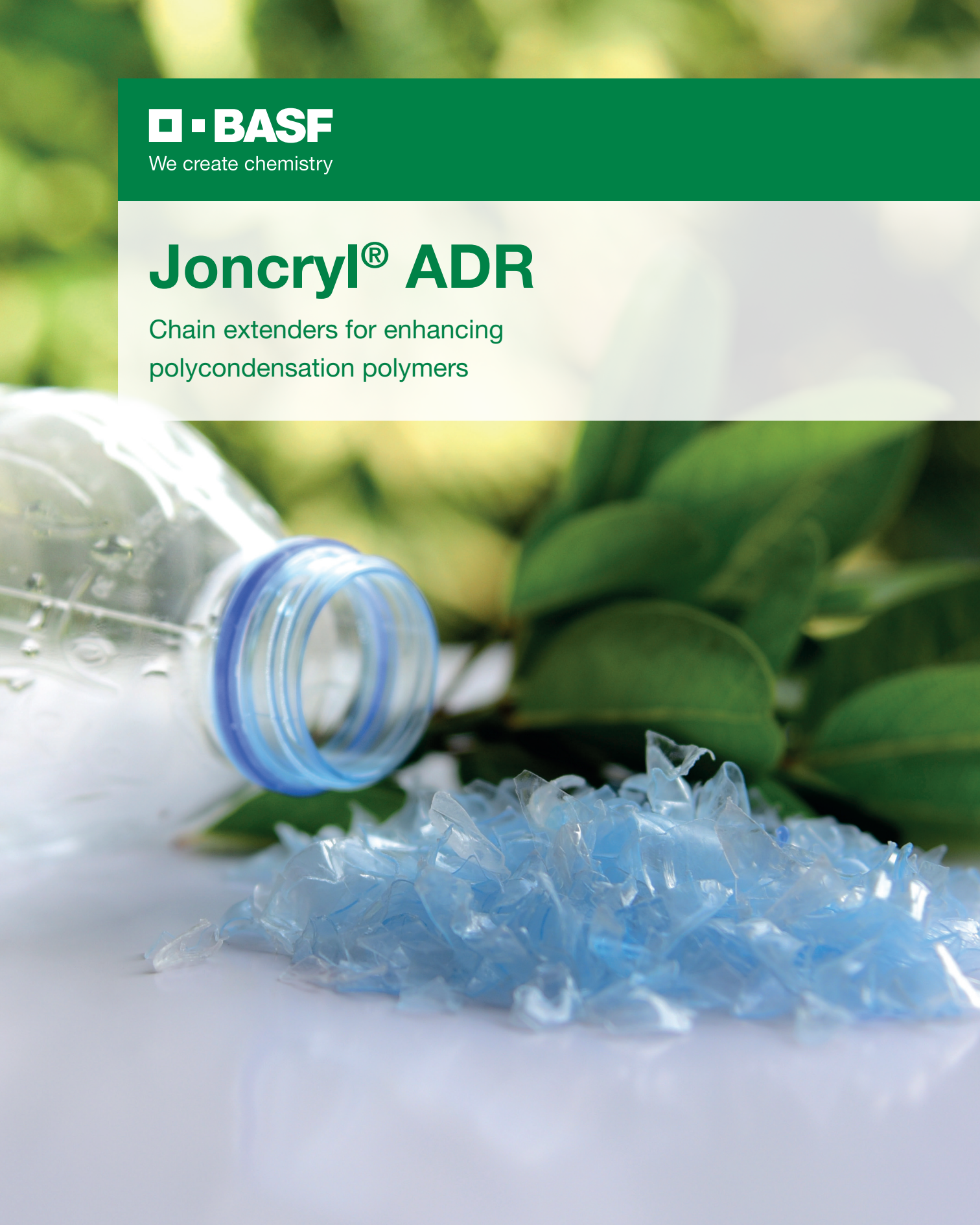
Joncryl® ADR

Chain extenders for enhancing polycondensation polymers



Joncryl® ADR

Joncryl® ADR at a glance

Joncryl® ADR chain extenders are multi-functional reactive polymers. The Joncryl® ADR portfolio includes different grades of Joncryl® ADR that react with the chain ends of polycondensation polymers like polyesters, polyamides or polycarbonates and biopolymers.

Joncryl® ADR chain extenders are used for recycling of polycondensates and as high-value additives for biopolymers. The addition of Joncryl® ADR allows for improved processing and higher productivity, thus increasing sustainability and saving costs.

Key benefits of Joncryl® ADR chain extenders:

- Chain extension: increase melt strength → improve processing (including extrusion, blow molding, thermoforming, foams and fiber extrusion) of polycondensation polymers and biopolymers
- Compatibilization: stabilize polycondensates and biopolymer blends → enhanced mechanical properties of the material
- Hydrolytic stabilization: ensure stability of polycondensates during manufacturing and protect against hydrolytic degradation and loss of properties

Joncryl® ADR chain extenders increase the molecular weight of polycondensation polymers via reactive processing, providing higher melt strength and allowing for:

- Improved mechanical properties of recycled polycondensates such as PET, PC or PA
- Improved mechanical properties of biopolymers such as PLA
- Increased recycled polymer utilization
- Upgrading lower molecular weight polycondensation polymers and recycled polymers to be used in higher value applications
- Compatibilization of compounds and blends
- Improved hydrolytic stability
- Increased flexibility to process bio(degradable) polymers, enabling better replacement of traditional polymers even in more demanding applications

Hydrolysis

Fig. 1: Joncryl® ADR chain extension mechanism

Linear chain extension and chain branching

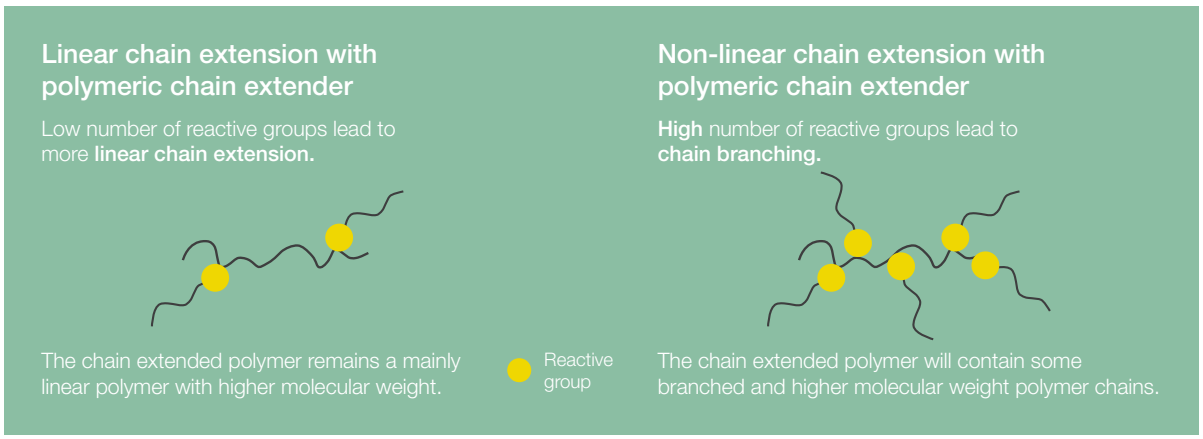


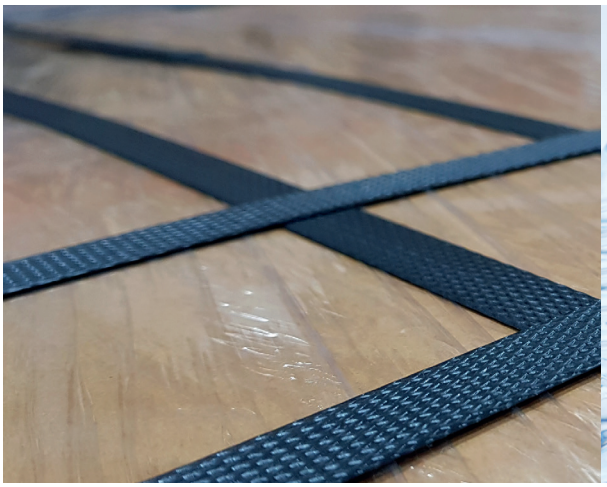
Fig. 2: Linear chain extension and chain branching with Joncryl® ADR

Key application: recycling of polycondensates

Joncryl® ADR chain extenders can be used to re-couple polymer chains in recycled polycondensation polymers. The addition of Joncryl® ADR enhances the recycling abilities of polycondensates, enabling more uses and recycle counts. Joncryl® ADR works in-reactor, shortens condensation and improves SSP (solid state polymerization) for rPET. Increasing the melt strength and the molecular weight of the polymers enables stable processing and improves the mechanical properties of the polymers for end-use applications. In addition, Joncryl® ADR improves the hydrolytic stability of polymers like rPET.

Ideal for recycling applications:

- PET sheet and films:
  Joncryl® ADR chain extenders can be used to rebuild molecular weight of PET sheet trims and recycled PET bottle flakes, recycling them into extruded PET sheets.
- Strapping:
  Joncryl® ADR chain extenders can be used to improve tensile strength and elongation in strapping applications. It allows straps to be made of up to 100 % recycled PET.
- Fibers:
  Joncryl® ADR chain extenders can be used to improve the tensile properties of recycled PET e. g. for high-tenacity fiber.
- Reactive compatibilization:
  Joncryl® ADR chain extenders can be used to compatibilize different types of polycondensation polymers into a useful compound, widening the engineering design freedom for creating new materials that meet challenging requirements.
- rPET bottle recycling:
  A low dosage of Joncryl® ADR chain extenders restores properties and increases the intrinsic viscosity of bottle grade rPET, providing the potential for more recycling rounds, better processing, and productivity for recycling plants, resulting in increased sustainability and costs savings.



Key application: high-value additives for biopolymers

Biopolymer processibility improvement:
Joncryl® ADR chain extenders can enable manufacturing of chain-extended biopolymers (e. g. PLA) with higher molecular weight, broader molecular weight distribution and higher degree of branching. Thus, chain-extended biopolymers (e. g. PLA) have higher melt strength, enabling to be processed with greater stability and to better replace traditional polymers in more demanding applications.

Examples for biopolymer applications:

- PLA blown film:
  Adding a low dosage of Joncryl® ADR to PLA stabilizes the blown film process, resulting in a more regular shape, higher melt strength, improved speed line, thickness and blow-up ratio.
- PLA foam:
  Joncryl® ADR chain extenders enable the branching of PLA which results in higher molecular weight and lower density foams with closed cell structures.
- Biopolymer dry blends:
  Biopolymers are often deployed as a blend of two immiscible polymers, e. g. a stiff, brittle biopolymer (e. g. PLA) with a soft component. These blends need compatibilization to produce a stable polymer blend.
- Biopolymer compatibility and compounding:
  Chain extenders can act as a reactive compatibilizer for biopolymers and enable them to be blended or compounded with different blend components. This ability allows biopolymers to be designed for a much wider range of applications.

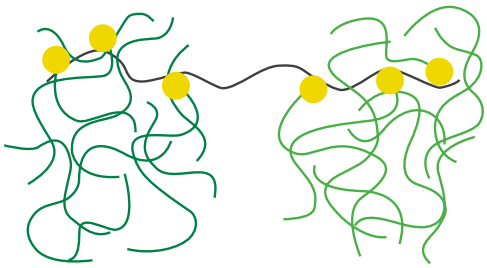


Fig. 3: Compatibilization of a biopolymer blend by use of Joncryl® ADR (schematic illustration)

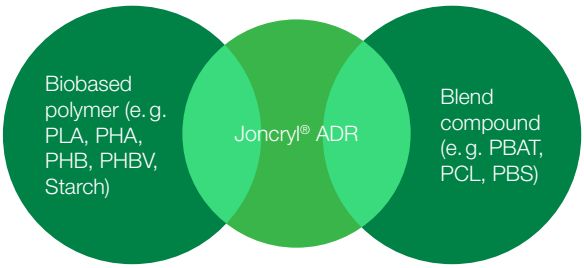


Fig. 4: Joncryl® ADR as enabler for blending and compounding of biopolymers

Joncryl® ADR portfolio overview

Product family	Joncryl® ADR 4385[1)]	Joncryl® ADR 4400	Joncryl® ADR 4468
Description chain extension	linear to medium branched	linear to medium branched	medium to highly branched
Morphology	liquid	solid flakes	solid flakes
Molecular weight (Mw)	6000	6700	7300
Glass transition Tg (°C)	-37	62	59
Epoxy equivalent weight (g/mol)	450	485	310
Non-volatile (% by GC)	> 99	> 99	> 99
Viscosity at 23 °C (Ps)	500 - 700	n/a	n/a
Food contact compliance	limited[2)]	yes[2)]	yes[2)]
Typical dosage (%)	0.1 - 1.5	0.1 - 1.0	0.1 - 1.0
Temperature range (°C)	< 300	< 320	< 320

[1)] Available in North America

[2)] Please request a Food Contact Declaration for complete information including any restrictions or limitations.
Detailed product information available on request

Processing of Joncryl® ADR

Recommended dosage

Every chain extension problem is unique and depends on the target requirements in different applications and for different resin types. In general, the recommended initial Joncryl® ADR trial dosage should be approx. 0.1 - 0.3 %. Dosage can be increased or decreased depending on the outcome and the target requirements.

Hygroscopicity and drying

Joncryl® ADR flakes are quite hydrophobic, and pick-up only trace moisture over time, especially when properly stored. Coupled with its low use level, there is generally no need to dry the resin before use. Moreover, elevated temperatures (T > 50 °C) will lead to sintering of the flakes.

Masterbatches (MB) should not be dried above 110 °C to prevent pre-reaction within the masterbatch from happening, or MB agglomeration depending on the carrier. For pre-dying of the base polymer please refer to manufacturer's recommended conditions.

Feeding

Dry-blending is possible for all Joncryl® ADR flakes and masterbatches, e. g. with pre-dried and cold plastic pellets or flakes in a low shear mixer or with other materials in a high shear mixer. Again, to avoid sintering or agglomeration avoid temperatures higher than 50 °C of the mixture.

Joncryl® ADR can be volumetrically, gravimetrically or flood fed directly into the feeding or mixing zone of a single-screw/twin-screw extruder or fed via side feed systems. For further recommendations (residence time, temperatures, extruder settings etc.) please refer to the Product Information of the respective Joncryl® ADR grade.

Extrusion temperature profile and residence time

When feeding solid Joncryl® ADR into the 1st zone of the extruder, it is recommended to operate this zone at lower temperatures than normal. This will prevent early melting and agglomeration of the additive. In case chain extender masterbatches are used, please refer to masterbatch suppliers' directions for additional information and instructions.

All other extrusion zones should employ normal processing conditions as recommended by the plastic manufacturer.

The Joncryl® ADR reaction profile is dependent on temperature and the concentration of available co-reacting species in the plastic matrix. The reaction is generally mixing limited for T > 230 °C, e. g. high temperatures; in other words, the reaction will be dictated by stoichiometry even for a short residence time in a well-mixed system. For mid-range temperatures (210 °C) the extent of reaction can vary with the extruder residence time. At lower temperatures (T < 190 °C), the additive will still work but can become increasingly sluggish. Regardless, Joncryl® ADR should not be processed at temperatures higher than a maximum processing temperature of 300 - 320 °C. For specific limits please see grade specific Product Information.

Extruder pressure effects

The use of Joncryl® ADR in reactive extrusion operations produces significant increases in molecular weight of the plastic being modified. This increase in molecular weight raises the melt-viscosity and can substantially raise the pressure observed in the equipment. Operation variables should be adjusted to accommodate these normal and expected pressure increases.

Additionally, at constant temperature, pressure changes can occur from inconsistent feed rates and/or poor mixing. Fluctuations in the feed rate of Joncryl® ADR larger than 10 % of the target value may cause large instantaneous extruder pressure spikes. To attain steady and consistent pressure, homogenous dry blends and robust co-feed systems are essential.

The selection of the screen pack can influence the pressure. Finer screen mesh will produce even higher pressures during the chain extension process.

Masterbatch compounding

Joncryl® ADR can be compounded into a masterbatch to improve it's dispersibility.

- Before compounding, the carrier resin should be dried to low moisture according to manufacturer's recommendations. Joncryl® ADR does not need to be dried.
- If the carrier resin pellets are held at a temperature above 60 °C due to pre-drying, Joncryl® ADR should be separately fed into the compounder from the carrier resin.
- For masterbatch compounding, the use of twin screw extruders is recommended with a L/D ratio of 36 - 42. The screw design needs sufficient mixing elements to ensure proper homogenization.

- Higher screw speed should be used to minimize risk of chain extension reaction (~200 - 300 rpm) but slow enough to ensure enough mixing.
- A loading of ~20 - 30 % Joncryl® ADR in the carrier is recommended.
- Vacuum degassing is recommended (100 mbar) to reduce volatiles.
- Process temperature range to be used should be referred to carrier resin supplier recommendations.
- Motor current or screw torque should be carefully monitored during extrusion. A sudden increase due to chain extension reaction might be prevented from happening by increasing screw speed or decreasing temperature.
- Quality Control Measurement: When done properly, a Joncryl® ADR masterbatch should enable property improvement on par as to when a similar absolute loading of neat chain extender is fed in with the resin. Comparison can be made by benchmarking the torque of the masterbatch against that of the neat chain-extender system.
- A Certificate of Analysis of a Joncryl® ADR masterbatch typically documents density, moisture content and MVR or MFR specification.

Mixing ratio	**PET**	**PLA**	**PC**
Base polymer	75 %	75 %	70 %
Joncryl® ADR 4400 or 4468	25 %	25 %	30 %
Typical temperature profile twin screw extruder			
Feeding zone (°C)	20 - 40	25 - 120	150
Melting zone (°C)	200 - 240	200 - 220	250
Mixing zone (°C)	260 - 280	210 - 220	270
Venting zone (°C)	250 - 275	210 - 220	270
Discharge zone (°C)	250 - 270	200 - 220	280
Screw speed (rpm)*)	200 - 300	200 - 300	200 - 300
Recommended melt temperature (°C)	240 - 280	215 - 230	250

*) depending on extruder setting and shear rate

Processing conditions (exemplary for Joncryl® ADR 4400 or 4468) for PET, PLA and PC masterbatch compounding

Note

The data contained in this publication are based on our current knowledge and experience. In view of the many factors that may affect processing and application of our product, these data do not relieve processors from carrying out own investigations and tests; neither do these data imply any guarantee of certain properties, nor the suitability of the product for a specific purpose. Any descriptions, drawings, photographs, data, proportions, weights etc. given herein may change without prior information and do not constitute the agreed contractual quality of the product. It is the responsibility of the recipient of our products to ensure that any proprietary rights and existing laws and legislation are observed.
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