Biopolymers modification with natural rosin resins

Company introduction

Synthomer

- → A **leading global supplier** of water-based and differentiated polymers; Headquartered in London (UK)
- → **+4000** employees across **31** manufacturing sites in c.**20** countries
- → **5** global innovation centres of excellence, in UK, China, Germany, Malaysia and Ohio, USA
- → **3** end-market focused divisions
- → **£2bn** in revenue in 2025 from **6,000+** customers
- → **£138m** EBITDA in 2024
- → **60%+** of new products have defined sustainability products
- → **45%** reduction in Scope 1 and 2 GHG emissions since 2019

SILVER | Top 15% ecovadis Sustainability Rating

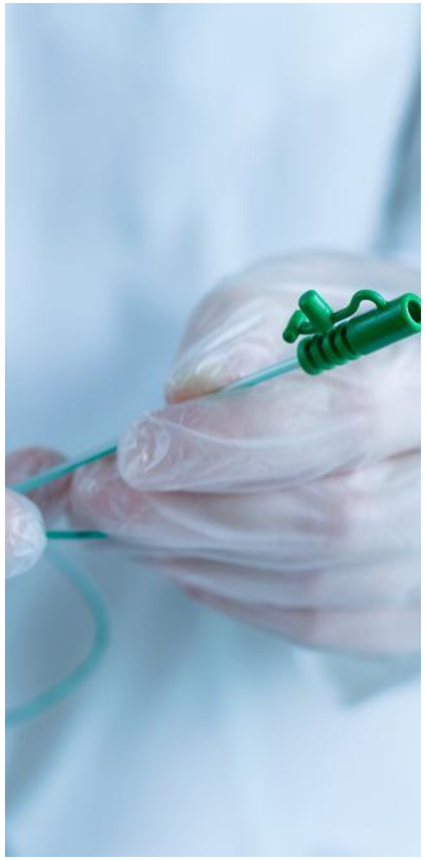
SCIENCE BASED TARGETS
DRIVING AMBITIOUS CORPORATE CLIMATE ACTION

ISCC
International Sustainability & Carbon Certification

Adhesive Solutions

Coatings and Construction Solutions

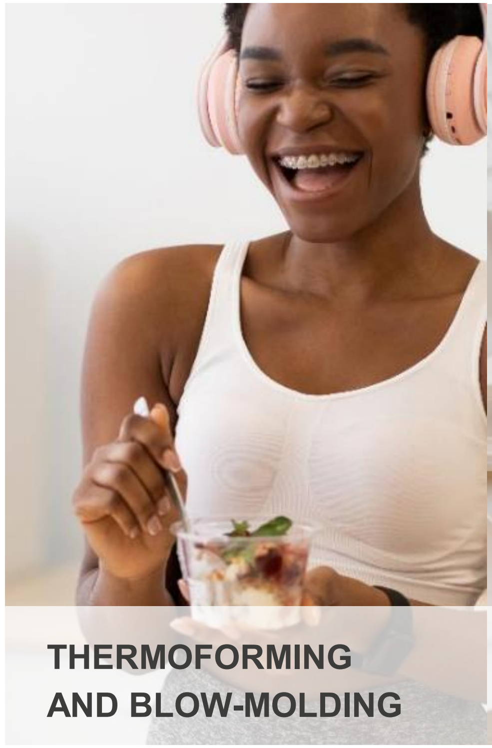
Health, Protection & Performance Materials



Approved for external use

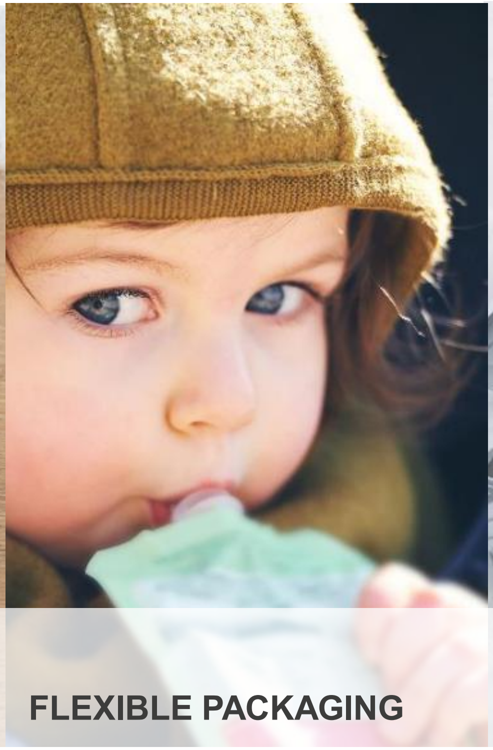
Manufacturing of rigid and flexible packaging items

Plastic modification additives that enhance material properties to:



THERMOFORMING AND BLOW-MOLDING

BIOPOLYMERS



FLEXIBLE PACKAGING

MECHANICAL RECYCLING

- → Reduce virgin plastics by downgauging
- → Reduce carbon footprint
- → Reduce electricity consumption
- → Improve recyclability
- → Increase PCR content
- → Improve processability
- → Replace unwanted materials without machine change

Approved for external use

Biopolymers: Derived from natural sources to help address concerns around plastic pollution and fossil resource depletion

MOST COMMON RAW MATERIALS

→ Starch
→ Cellulose
→ Polylactic acid (PLA)
→ Polyhydroxyalkanoates (PHA)

APPLICATIONS

→ Packaging (films, containers, bags)
→ Agriculture (mulch films, seed coatings)
→ Medical (implants, drug delivery systems)
→ Textiles
→ 3D printing

To reduce costs, reactor-based biopolymers are often blended with low-cost starch or fillers made from organic waste sources

PLA + STARCH

- Cost-effective
- Improved biodegradability
- Renewable sources

PHA + CELLULOSE

- Enhanced mechanical properties
- Fully biodegradable
- Biocompatible

However, a ‘**YES**’ in this case comes with a ‘**BUT**’:

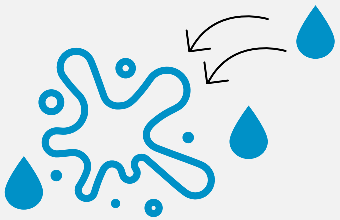
- Reduced mechanical strength
- Moisture sensitivity
- Brittleness
- Higher production cost
- Processing complexity

PLA – Polylactic Acid PHA – Polyhydroxyalkanoates

Why do starch-PLA blends need improvement?

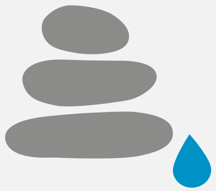
Many biopolymer blends have poor performance and are difficult to process due to incompatibility of their components.

STARCH



Hydrophilic
water-loving

PLA



Hydrophobic
water-repelling

See next:

5 reasons why Synthomer solutions matters

Processing challenges

Biopolymers must be compatible with existing processing equipment (e.g., extrusion, injection moulding, thermoforming).

Most biopolymer blends have issues with:

→ High viscosity and limited melt flow leads to:

- Difficult extrusion and moulding
- Long pre-drying time
- Warpage and uneven shrinkage
- Discoloration and burn marks

Here is why it matters (2 of 5)

Material performance

Mechanical limitations of organic filled biopolymer blends:

→ PLA is brittle and starch is weak. This can lead to brittle and low toughness biopolymers

→ Biopolymers filled with finely milled organic waste have phase compatibility issues that can result in low toughness and brittleness

2

Here is why it matters (3 of 5)

Phase incompatibility

Biopolymers are often based on high starch or organic filler loading to keep cost down, but this often leads to phase incompatibility

→ Hydrophilic starch vs. hydrophobic PLA can cause poor adhesion and phase separation

→ Organic fillers that are not compatible enough with the biopolymer can cause poor adhesion and even phase separation during moulding

Barrier weakness of starch-based biopolymer blends

Even if the starch-based biopolymer processes, it might end up with:

→ High water vapor permeability in starch that gives poor moisture resistance

→ Incompatible polymer matrix leading to poor gas barrier

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Migration risks

PLA and starch blends often use glycerol as a plasticizer:

→ Glycerol plasticizer can leach out over time

- Can lead to property loss (e.g., increased stiffness)
- Can lead to increased migration through the matrix into the (food) packaging

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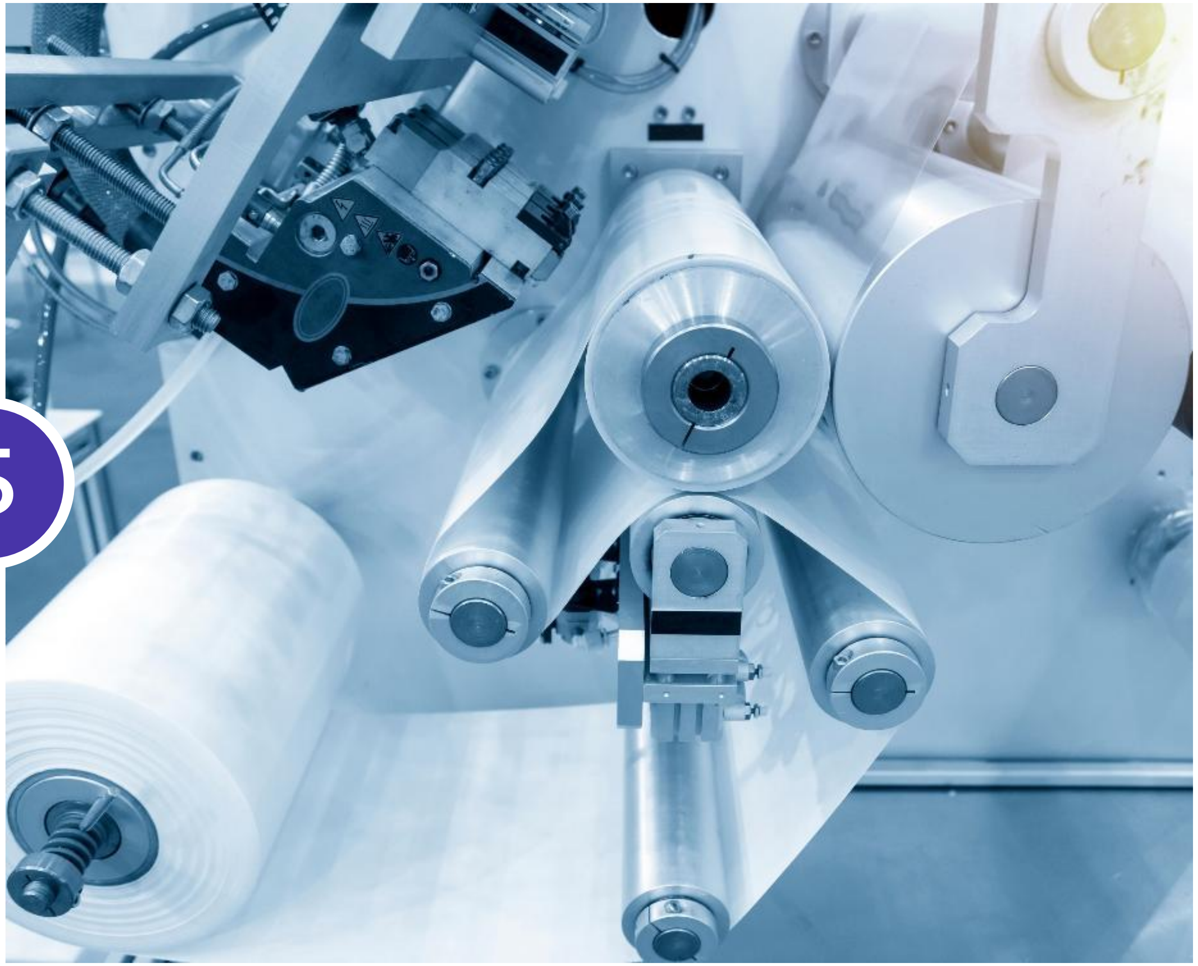
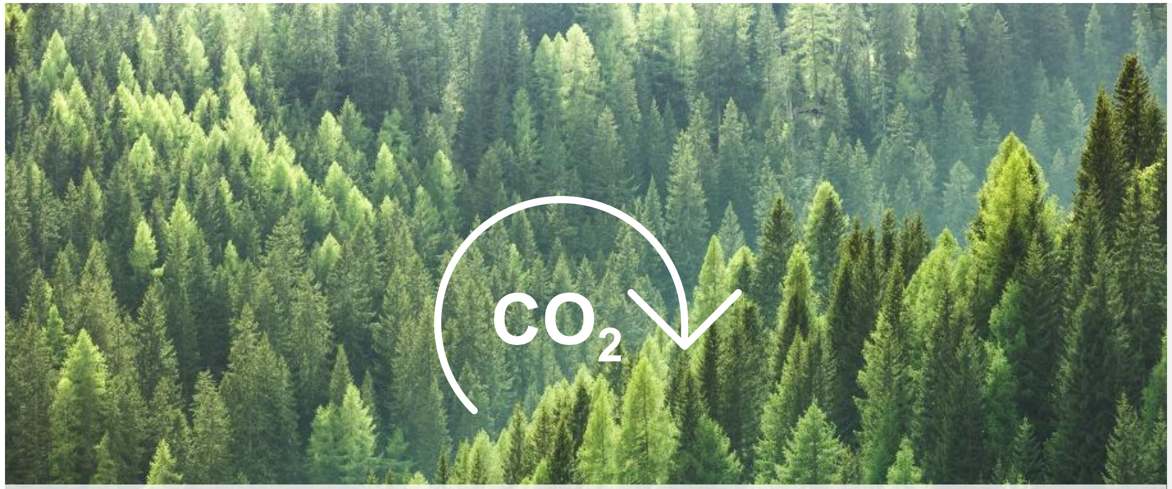


To tackle these issues without negatively impacting costs, Synthomer brings its **ROSIN RESINS** to the table

BIO-SOURCED, CONSISTENT QUALITY, SUSTAINABLE TECHNOLOGY



FEEDSTOCK: Pine trees

Living pine trees pull CO_2 from the air, which poses a favorable carbon footprint to rosin products compared to products from non-renewable feedstocks

RCI* >90%

GUM ROSINS:** ABALYN™, ABITOL™, FORAL™, FORALYN™, PENTALYN™, PERMALYN™, STAYBELITE™

The majority of Synthomer rosin-based products contain **more than 90% bio-based content**

*RCI: Renewable Carbon Index
Versions of these trademarks are available upon request with ISCC PLUS certification, and they are receiving BIO as a suffix (e.g., FORAL™ AX-E **BIO)

With our gum **rosin**, the starch can have a molecular interaction with the PLA biopolymer

GUM ROSIN AND STARCH

→ **Hydrogen bonding:** The carbonyl groups of gum rosin esters can form hydrogen bonds with the hydroxyl groups of starch, enhancing interfacial adhesion and reducing water affinity

→ **Hydrophobic modification:** Esterified gum rosin increases the hydrophobicity of starch, improving water resistance and potentially barrier properties

With our gum **rosin**, the starch can have a molecular interaction with the PLA biopolymer

GUM ROSIN AND GLYCEROL

→ **Esterification:** Glycerol (three hydroxyl groups) reacts with rosin acids to form tri-esterified products, which act as plasticizers and compatibilizers within the matrix

→ **Plasticization:** The presence of rosin esters can modulate the plasticizing effect of glycerol, balancing flexibility and strength

With our gum **rosin**, the starch can have a molecular interaction with the PLA biopolymer

GUM ROSIN AND PLA

→ **Ester–ester compatibility:** Both PLA and gum rosin esters contain ester groups, facilitating miscibility and interfacial adhesion via dipole–dipole and hydrogen bonding interactions

→ **Lubrication and chain mobility:** Gum rosin esters, especially those with lower molecular weight, can act as external lubricants, increasing melt flow and processability

Lab trials, analysis and conclusions

Laboratory trials at Synthomer Middelburg, NL

Scope of work

GOAL

Measure Melt Flow Index (MFI) of typical biopolymer formulations and compare it to modified formulas containing Synthomer rosin resins or their blends.

METHODOLOGIES

→ MFI determination according to ISO1133

ROSIN ACID, ROSIN ESTERS AND BLENDS USED

→ FORAL™ AX-E rosin acid, hydrogenated
→ FORAL™ 85-E glycerol ester of gum rosin, hydrogenated
→ FORAL™ 105-E pentaerythritol ester of gum rosin, hydrogenated
→ Blend A: 30% FORAL™ AX-E + 70% FORALYN™ 110
→ Blend B: 40% FORAL™ AX-E + 60% FORALYN™ 110
→ Blend C: 60% FORAL™ AX-E + 40% FORALYN™ 110
→ Blend D: 50% FORAL™ AX-E + 50% FORALYN™ 110
→ FORALYN™ 110 pentaerythritol ester of gum rosin, partially hydrogenated

MODEL FORMULATIONS TESTED

→ 80% TPS / 20% PLA
→ 70% TPS / 30% PLA
→ 90% PBAT C1200 + 10% PLA LX975

TPS = Thermoplastic starch (corn starch)
PLA = Polylactic acid
PBAT = Polybutylene adipate terephthalate
PLA LX975 = PLA with high flow (high MFI)

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Compounding protocol

PREMIXING

- → **Dry Blend:** starch, PLA pellets, and gum rosin ester (pre-dried at 50°C for 12 h to <1% moisture)
- → **Glycerol:** is added as a liquid, during premixing with a Henschel mixer with the starch to ensure homogenous compound

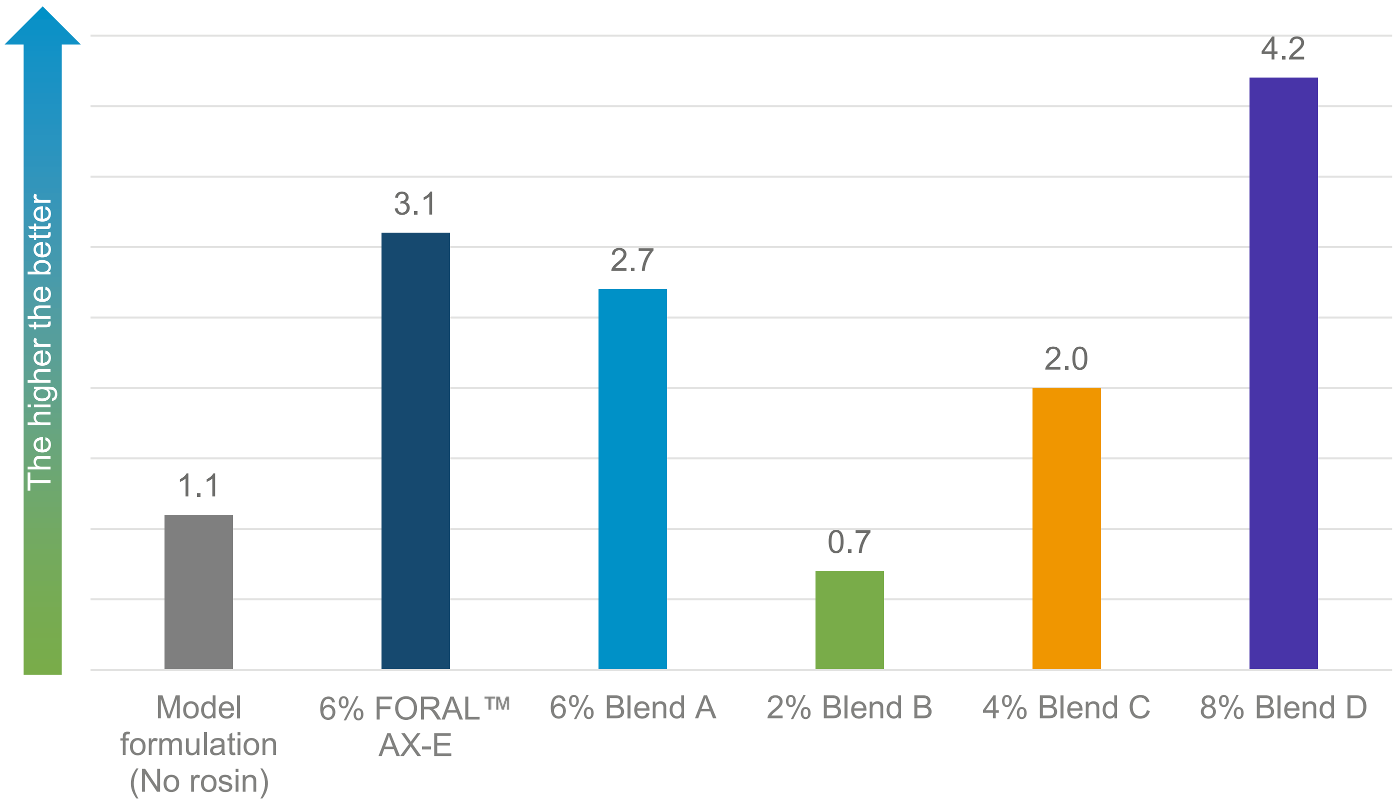
MIXING SEQUENCE

- → Feed starch and glycerol (and water if needed for starch gelatinization) into the Henschel mixer; allow gelatinization and plasticization. Leave for 12h prior to compounding
- → Ensure thorough mixing and dispersion; monitor torque and temperature for process control on Brabender kneader

Model formulation based on 80% TPS / 20% PLA

Shaping viscosity according to your needs

MFI in g/10min. (160°C / 5 kg)



CONCLUSIONS

Melt flow index (MFI): Increases by 100–380% with 2–6% gum rosin ester in PLA-starch-glycerol blends, indicating improved processability and lower viscosity.

FORAL™ AX-E rosin acid, hydrogenated

FORALYN™ 110 pentaerythritol ester of gum rosin, partially hydrogenated

Blend A: 30% FORAL™ AX-E + 70% FORALYN™ 110

Blend B: 40% FORAL™ AX-E + 60% FORALYN™ 110

Blend C: 60% FORAL™ AX-E + 40% FORALYN™ 110

Blend D: 50% FORAL™ AX-E + 50% FORALYN™ 110

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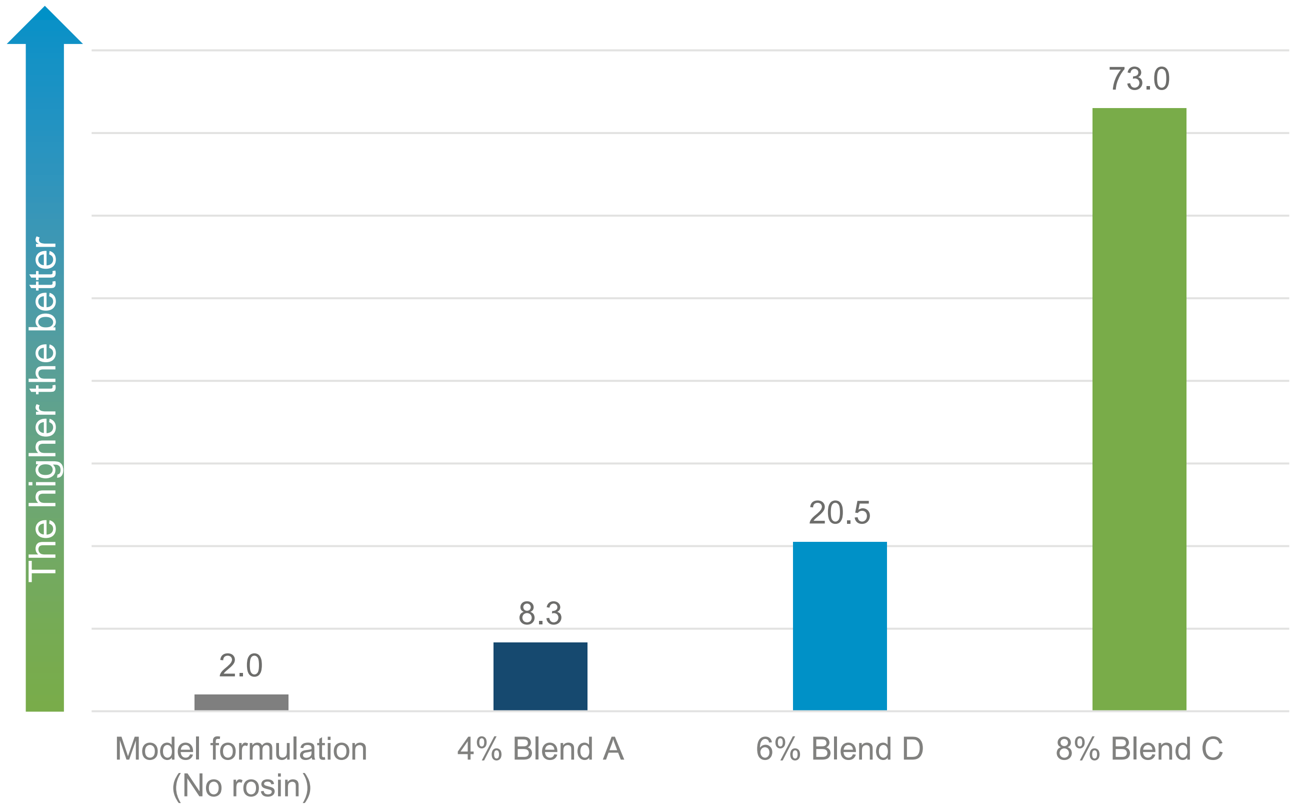
Finding the right balance for the best value for money formulation

MFI in g/10min. (160°C / 5 kg)



CONCLUSIONS

→ The matrix TPS and PLA (70/30) unmodified, would result in a highly biodegradable biopolymer formulation that maximizes low-cost starch; however, it will be difficult to process due to its low MFI

→ The MFI can be tailored by adding different percentages of Synthomer rosin resins and rosin esters while maximizing high levels of low-cost starch

FORAL™ AX-E rosin acid, hydrogenated

FORALYN™ 110 pentaerythritol ester of gum rosin, partially hydrogenated

Blend A: 30% FORAL™ AX-E + 70% FORALYN™ 110

Blend C: 60% FORAL™ AX-E + 40% FORALYN™ 110

Blend D: 50% FORAL™ AX-E + 50% FORALYN™ 110

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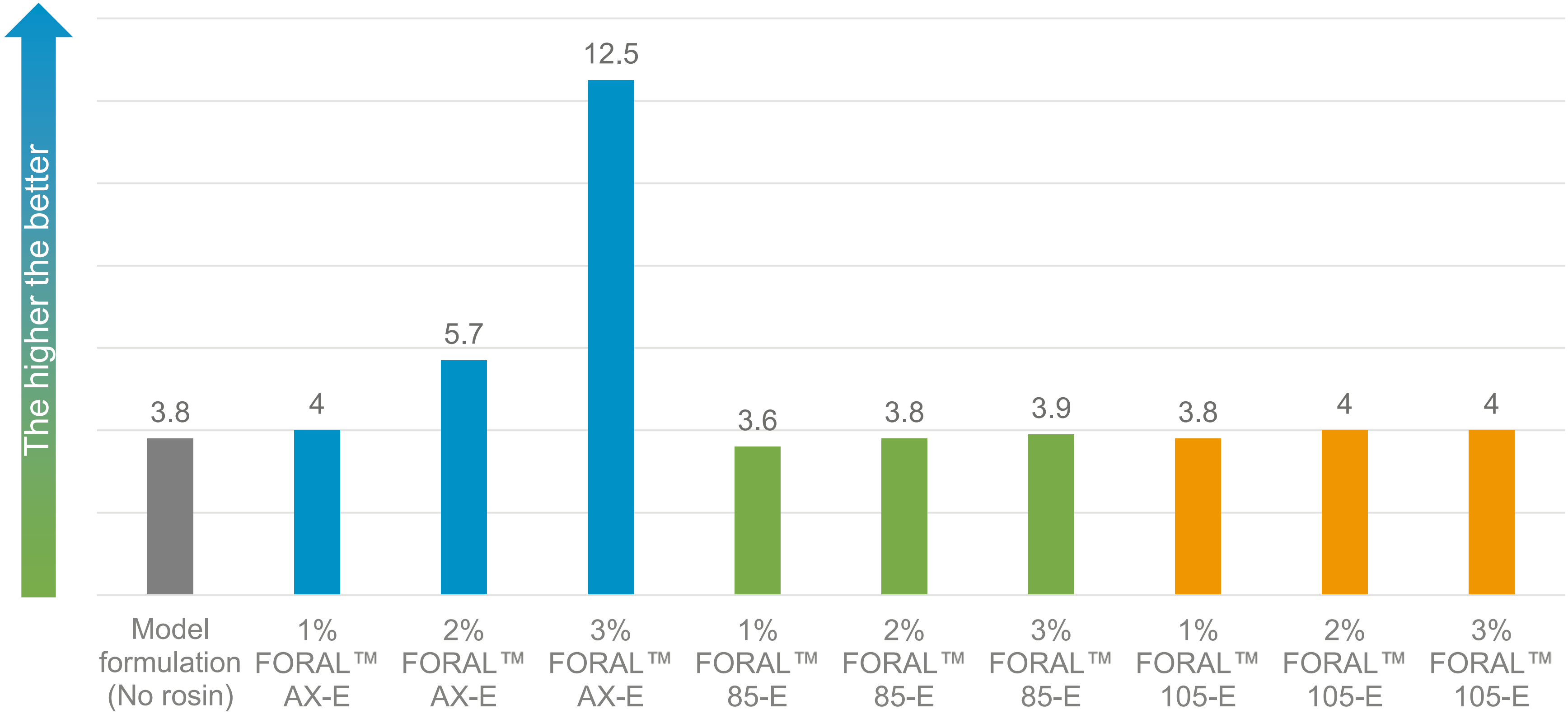
Finding the right balance for the best value for money formulation

MFI in g/10min. (180°C / 2.16 kg)

Courtesy of the University of Hof



CONCLUSIONS

→ This low MFI biopolymer compound is typically used for more flexible materials

→ FORAL™ AX-E rosin acid is more effective at increasing MFI in this matrix in comparison to the rosin esters

→ The choice of rosin resin and loading level in each matrix is important

FORAL™ AX-E rosin acid, hydrogenated
FORAL™ 85-E glycerol ester of gum rosin, hydrogenated
FORAL™ 105-E pentaerythritol ester of gum rosin, hydrogenated

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In a nutshell

Synthomer rosin resins for better processability

Based on Synthomer rosin resins‘ molecular characteristics and observed behaviours, they can be used to:

TACKLE PROCESSING CHALLENGES

IMPROVE MATERIAL PERFORMANCE

INCREASE PHASES COMPATIBILITY

IMPROVE BARRIER WEAKNESS*

*OF STARCH-BASED BIOPOLYMER BLENDS

REDUCES MIGRATION RISKS

For further questions please contact:

Adhesive.technologies@synthomer.com

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