TAPPI
INTERNATIONAL
FLEXIBLE
PACKAGING
& EXTRUSION
DIVISION

2024 FlexPack PLACE Conference
April 14-17, 2024 • San Diego, CA • Wyndham San Diego Bayside

Optimizing compostable Ingeo biopolymer extrusion coatings for improved performance and tailored degradability rates.

Andrea Auchter

Applications Development Manager / NatureWorks

952-562-3351 andrea.Auchter@natureworksllc.com

Andrea Auchter, Applications Development Engineer, CPP, CWSA, NATUREWORKS

Andrea Auchter is the technical lead for rigid packaging applications in the foodservice sector for NatureWorks – a global leader that invents and manufactures Ingeo™, a portfolio of high-performing biopolymers. During her time at NatureWorks, Auchter has launched a newly developed extrusion coating grade and created solutions for faster composting of packaging. Previously, Auchter was with General Mills for 15 years, as an associate principal engineer working primarily on sustainable innovation in global yogurt packaging.

She holds a degree in chemical engineering from the University of Wisconsin-Madison and is currently based in Minneapolis, Minn. with her family.

Nature builds things from CO_2 and so do we.

SUGARS

GREENHOUSE GASES → PLANTS → MANUFACTURE → ingeo BIOPOLYMERS → PRODUCTS

Our process starts with greenhouse gases

Nature looks at greenhouse gases, like atmospheric carbon, as a feedstock, a raw material.

Plants convert CO_2 into sugars

Sustainably grown, renewable agricultural feedstocks are used to convert CO_2 into starches.

Creating lactic acid, the building block of PLA

Plants are put through a milling process extracting the starch (glucose). Enzymes are added to convert the glucose to dextrose via a process called hydrolysis. Microorganisms then ferment this dextrose into lactic acid.

Transforming lactic acid into lactide

A proprietary two-step process transforms lactic acid molecules into rings of lactide, which is a valuable chemical on its own for use in many downstream markets.

Polymerizing lactide into PLA

The lactide ring is opened and linked together to form the long chain of polylactide polymer we call Ingeo. We form this long chain into pellets that are shipped around the world to our customers who transform them into a wide range of innovative products.

Resurgence in Paper-based Packaging

Thinking about Biobased

Plants are used to convert CO_2 into simple plant sugars, polymeric starch or cellulose, and more

PAPER + PACKAGING BOARD

60% see paper as part of the environmental solution while 53% see plastic as part of the problem (November 2021 Attitudes Survey)

PLA Coated Paper Products are Versatile

Fiber recovery if
paper-based and clean

Compostable packaging for
organics recycling if food soiled

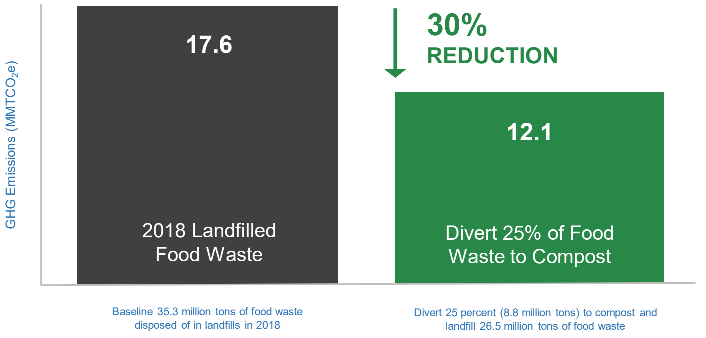
Biotechnology and Biomanufacturing R&D to

Further Climate Change Solutions

- Goal 2.2: Spur a Circular Economy for Materials
- Convert bio-based feedstocks into recyclable-by-design polymers that can displace >90% of today's plastics
- Goal 1.4: Reduce Methane Emissions
- By 2030, reduce methane emissions from food waste in landfills, to support the U.S. and global goals

EPA United States Environmental Protection Agency

Diverting another 25% of the food waste landfilled in 2019 to compost facilities would reduce the associated GHG emissions by approx. 30%.



Comparison of Life Cycle GHG Emissions for U.S. Food Waste Diversion from Landfills

Bold Goals for U.S. Biotechnology and Biomanufacturing

Harnessing Research and Development to Further Societal Goals

Per Executive Order 14081

Compiled by

The White House Office of Science and Technology Policy

Including se

U.S. Departmen

U.S. Department

U.S. Department

U.S. Department of Health

U.S. National Scier

March 2

Plastics Recycling Coverage PAGES 8-14

POLYMER POINTS WITH FRANK ESPOSITO PAGE 20

March 27, 2023 ▸ PlasticsNews.com $5

Plastics News

Biden sets US goal to replace 90% of plastics with biomaterials

By Steve Toloken
Plastics News Staff

President Joe Biden's administration is setting a goal of replacing 90 percent of fossil fuel-based plastics with bio-based alternatives over the next two decades.

In a report released March 22, the White House Office of Science and Technology Policy (OSTP) outlined what it called bold goals for helping the U.S. to be a leader in bioeconomy technology, produce low-carbon-intensity chemicals to fight climate change and shore up domestic supply chains.

"In 20 years, [the U.S. should] demonstrate and deploy cost-effective and sustainable routes to convert bio-based feedstocks into recyclable-by-design polymers that can displace more than 90 percent of today's plastics and other commercial polymers at scale," the report said.

According to the report,

See **Biden**, Page 19

> **"Accordingly, an urgent global need exists to rapidly enable a more circular economy for today's fossil carbon-based polymers production and to source chemical building blocks for tomorrow's recyclable-by-design plastics from bio-based and waste sources."**
>
> White House Office of Science and Technology Policy

Biden bioplastics goal seen as major signal

Industry analysts and bioplastic executives had a lot to say about the Biden administration's "bold goal" for the U.S. to replace 90 percent of fossil-based plastics with biopolymers in 20 years. Danimer Scientific photo

By Frank Esposito and Steve Toloken
Plastics News Staff

The White House's ambitious bioplastics goals announced March 22 face many hurdles but some in that nascent industry see it as a clear sign that President Joe Biden's administration wants to support more climate-friendly manufacturing.

The White House Office of Science and Technology Policy's new bioeconomy road map calls for replacing 90 percent of traditional plastics with bio-based materials in 20 years.

The 64-page report, which outlines what it acknowledges are "bold goals," is short on details of how to get there, saying the OSTP will work out research and development priorities and other actions in coming months.

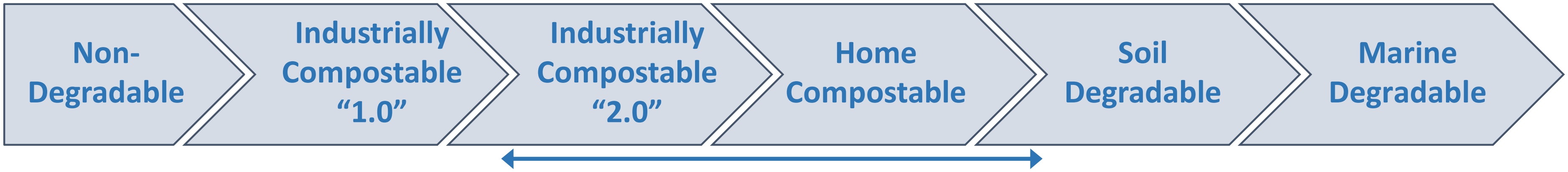
Industry analysts noted many challenges, from huge

See **Bioplastics**, Page 18

March 2023

Developing Accelerated Degradability / Compostability

Diverting more waste from landfills to compost facilities means there will be increased interest in processing the compost faster on existing acreage across the US.



Non-Degradable → Industrially Compostable "1.0" → Industrially Compostable "2.0" → Home Compostable → Soil Degradable → Marine Degradable

We look at degradability as a continuum

What does faster mean?

- Composts quickly in a broad range of environments
- We have seen capital investment in Aerated Static Piles (ASP) with ~40 days cycle time
- California seeking 60 days to biodegrade

And we're investing significantly in tailoring polymer grade design…

Solution– Equipment + Ingeo grade

Industrially compostable today, home compostable tomorrow

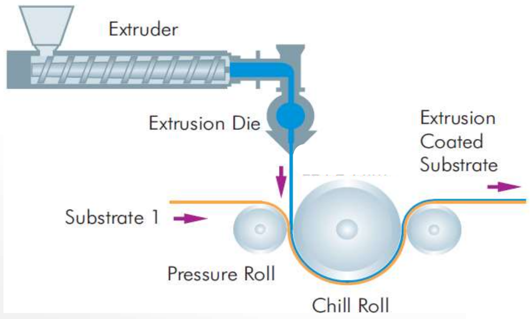
Safe Serviceware

recyclable
passes WMU standard
www.wmich.edu/pilotplants

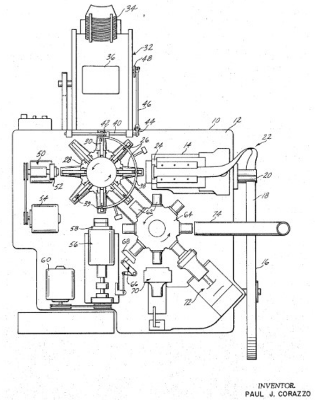
- Food safety compliances
- No taste or odor impact
- Certified compostable, repulpable and recyclable
- 90% biobased

Melt Processing

- Melt curtain strength and stability for high production rates and yields
- Low viscosity for adhesion at low coat weights

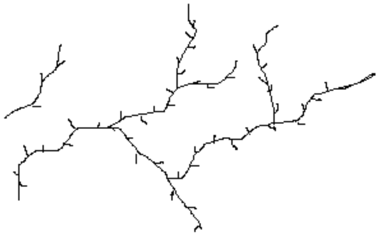


Cup Making



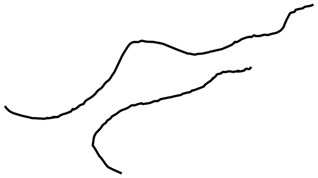
- Ductility to handle fastest production speeds
- Secure seals at seams and caulked pleats and folds preventing leaks
- Tight uniform lip rolls assure good lid fit

A Primer: Molecular Architecture that Forces Compromises



LDPE
Long and short chain branches
Broad molecular weight distribution
Tough at room temperature

- During processing, LDPE has high melt strength and low viscosity.
  - Low neck-in
  - No draw resonance
  - Increase adhesion through oxidation
- Linear PE blended with 10-20% LDPE becomes an extrusion coating grade.



PLA
No branching, all linear molecules
Narrow molecular weight distribution
Brittle at room temperature

During processing, PLA has
low melt strength and **high viscosity.**

- High neck-in
- Draw resonance limits line speeds
- Increase adhesion reducing heat loss

Legend	Experimental data
LDPE	Marlex 4517
PLA	Various
Ext Ctg PLA	Ingeo 1102
Next Gen Ext Ctg PLA	975-86-03

Expanding our Product Design “Toolbox”

Enhancing processability, functionality and end-of-life

Chemical:

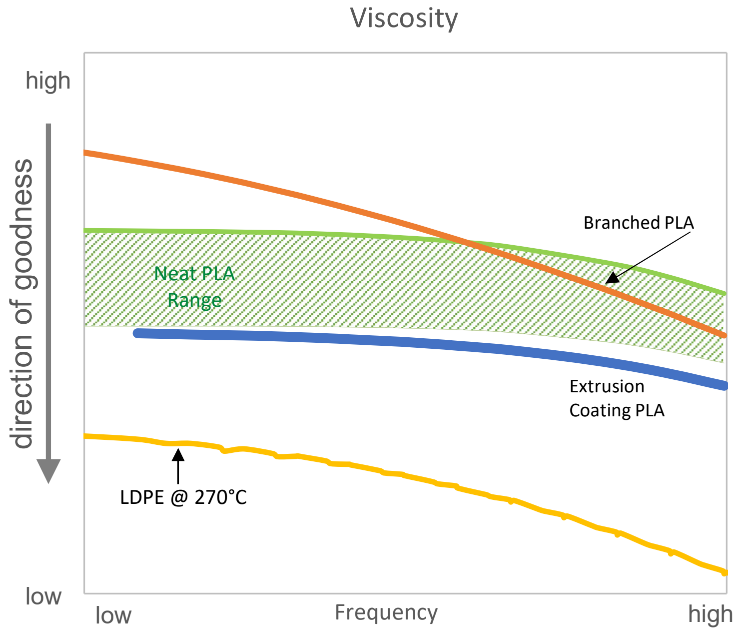
- Additive Content (e.g., prodegradant, enzyme, etc.)
- Polymer Chain Length (Molecular weight)
- Comonomer content
- Chain “end group” chemistry & reactivity
- Polymer Blends (PBS, PBSA, PCL, PBAT, PHA, etc.)
- Copolymers: block, random

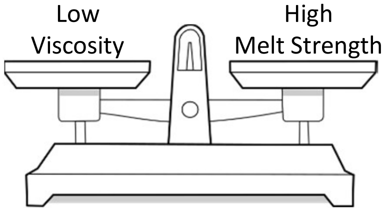
Physical:

- Thickness of the part
  - For films or sheet (gauge)
- Surface Area, Morphology

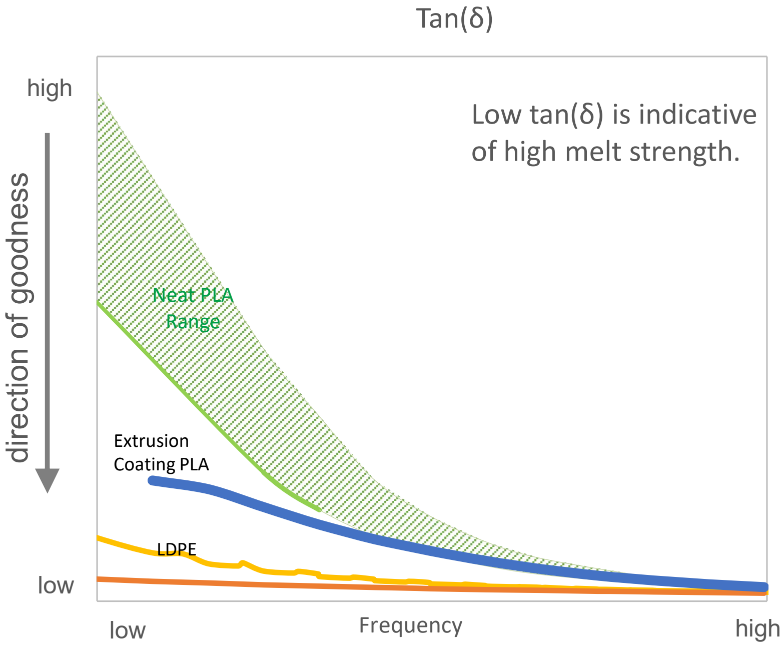
Comparing Extrusion Coating Melt Behavior

Want Low viscosity to penetrate easily into the paperboard





Want High melt strength to decrease neck-in and stabilize the web

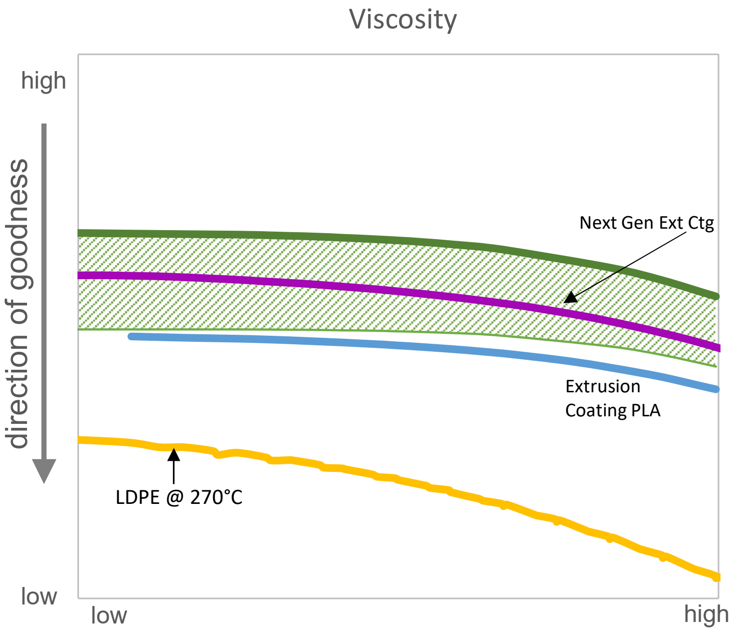


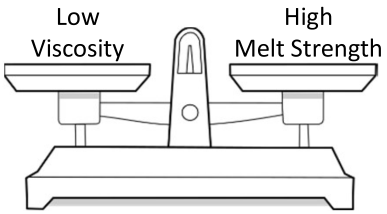
Low tan(δ) is indicative of high melt strength.

[DMA Rheological Data: Parallel Plate Rheometer @ 210°C]

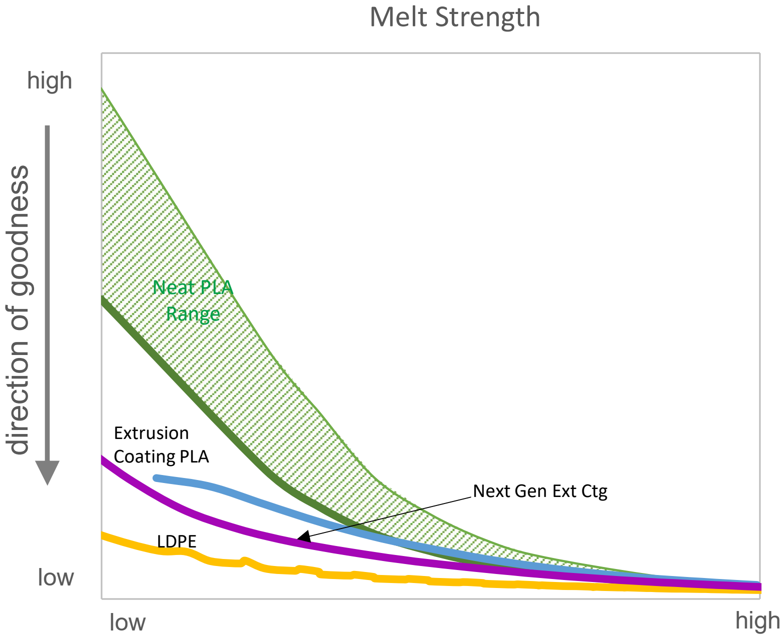
Comparing Extrusion Coating Melt Behavior

Want Low viscosity to penetrate easily into the paperboard





Want High melt strength to decrease neck-in and stabilize the web

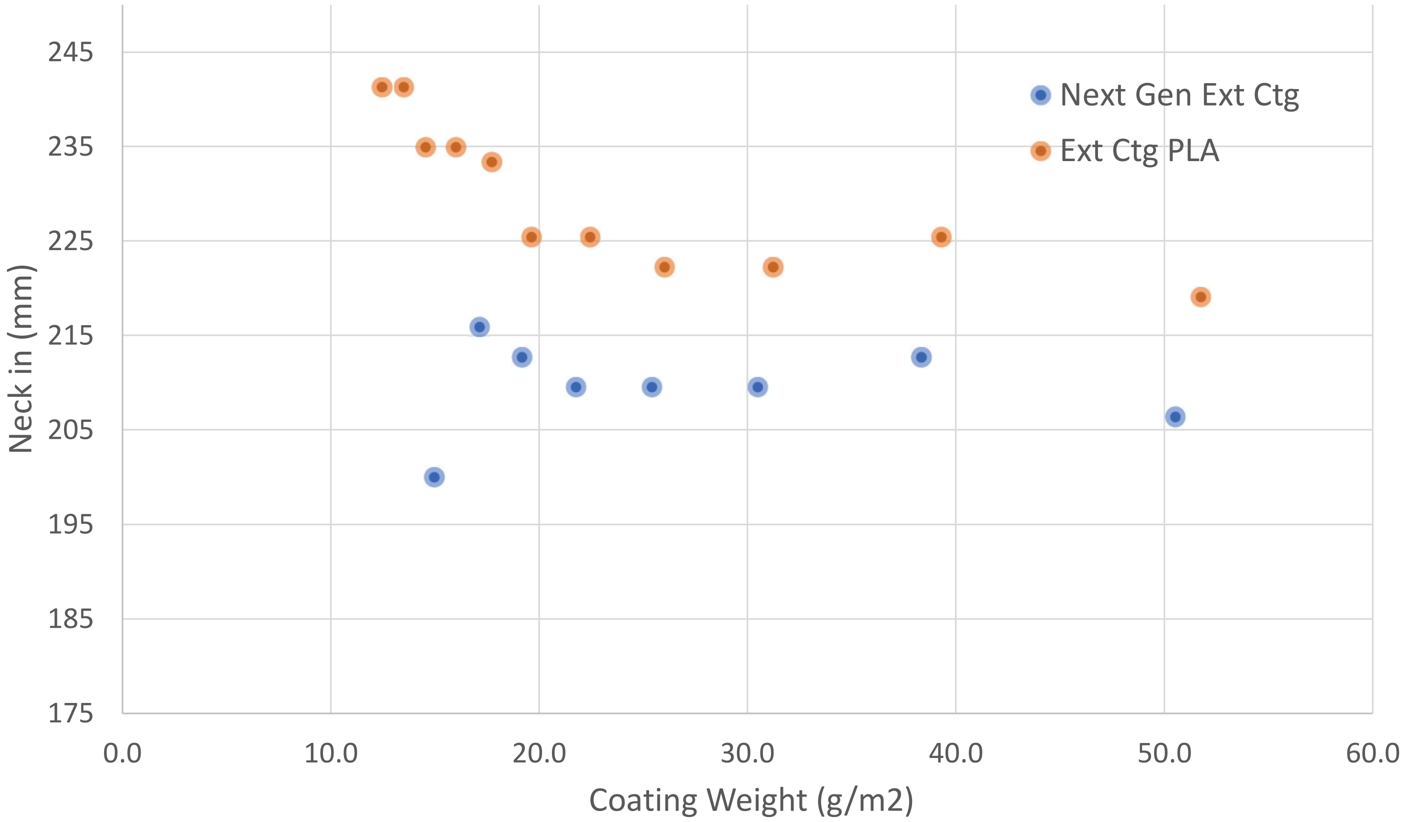


[DMA Rheological Data: Parallel Plate Rheometer @ 210°C]

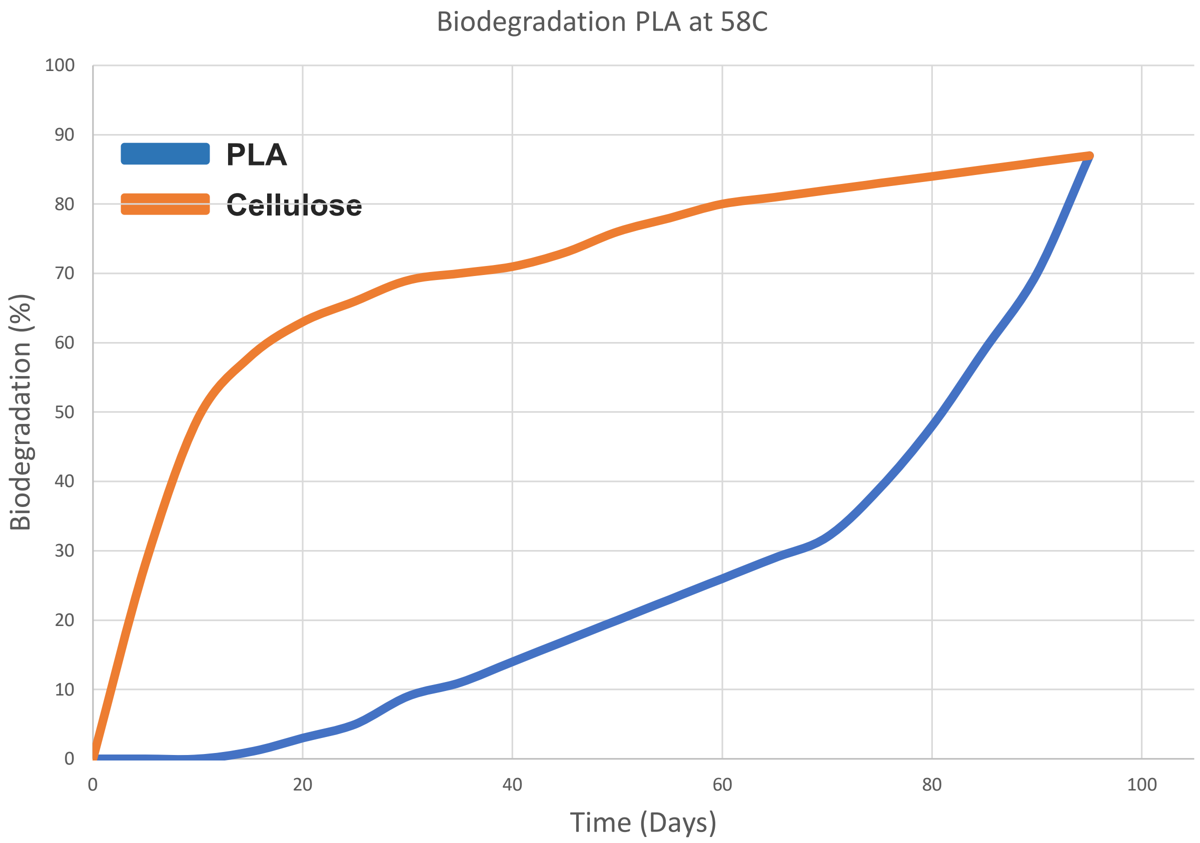
Improved Toughness

Material Property	Testing standard	Ext Ctg PLA	Next Gen Ext Ctg
Gardner Impact MFE (in*lb)	ASTM D5420	8.7	10.2
Elongation at Break	ASTM D-638	4.82	15.92
HDT	ASTM D-648	49.9	49.51
Vicat	ASTM D-1525	55.8	56.6

Next Gen Ext Ctg Shows Less Neck in



PLA Biodegrades Under Industrial Conditions



COMPOSTABLE

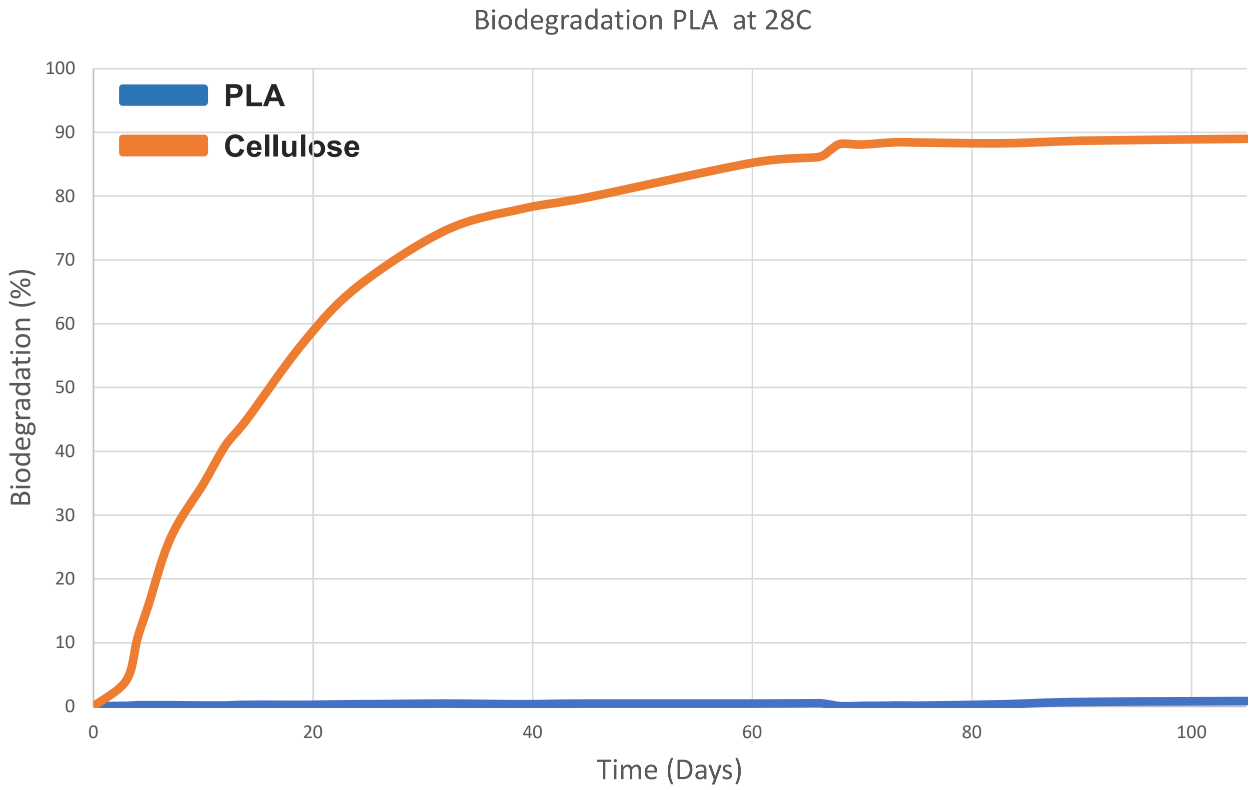
COMMERCIALLY COMPOSTABLE ONLY

BPI COMPOSTABLE

FACILITIES MAY NOT EXIST IN YOUR AREA

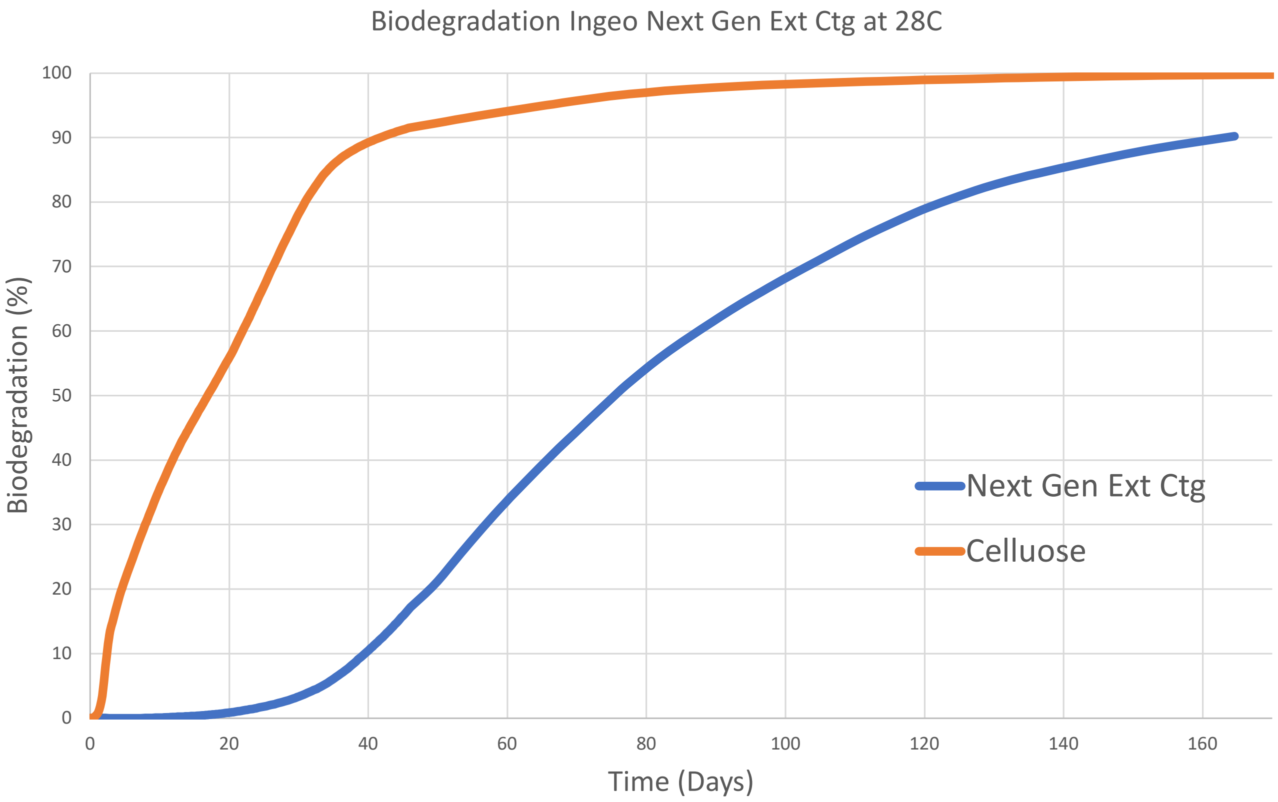
- **Biodegradation of PLA under ASTM 5338 (58°C)**
- External labs will test biodegradation
- They test how long microorganisms take to convert the material to CO2
- Composting requires biodegradation and disintegration

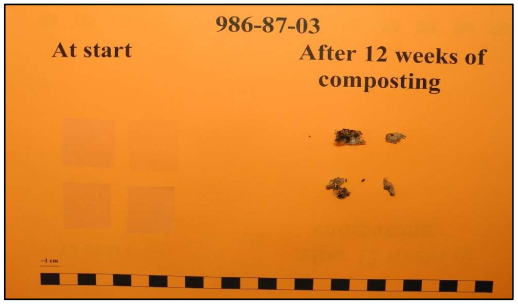
Biodegradation of PLA Under Home Composting Conditions (28°C)



No measurable biodegradation after 195 days of testing.

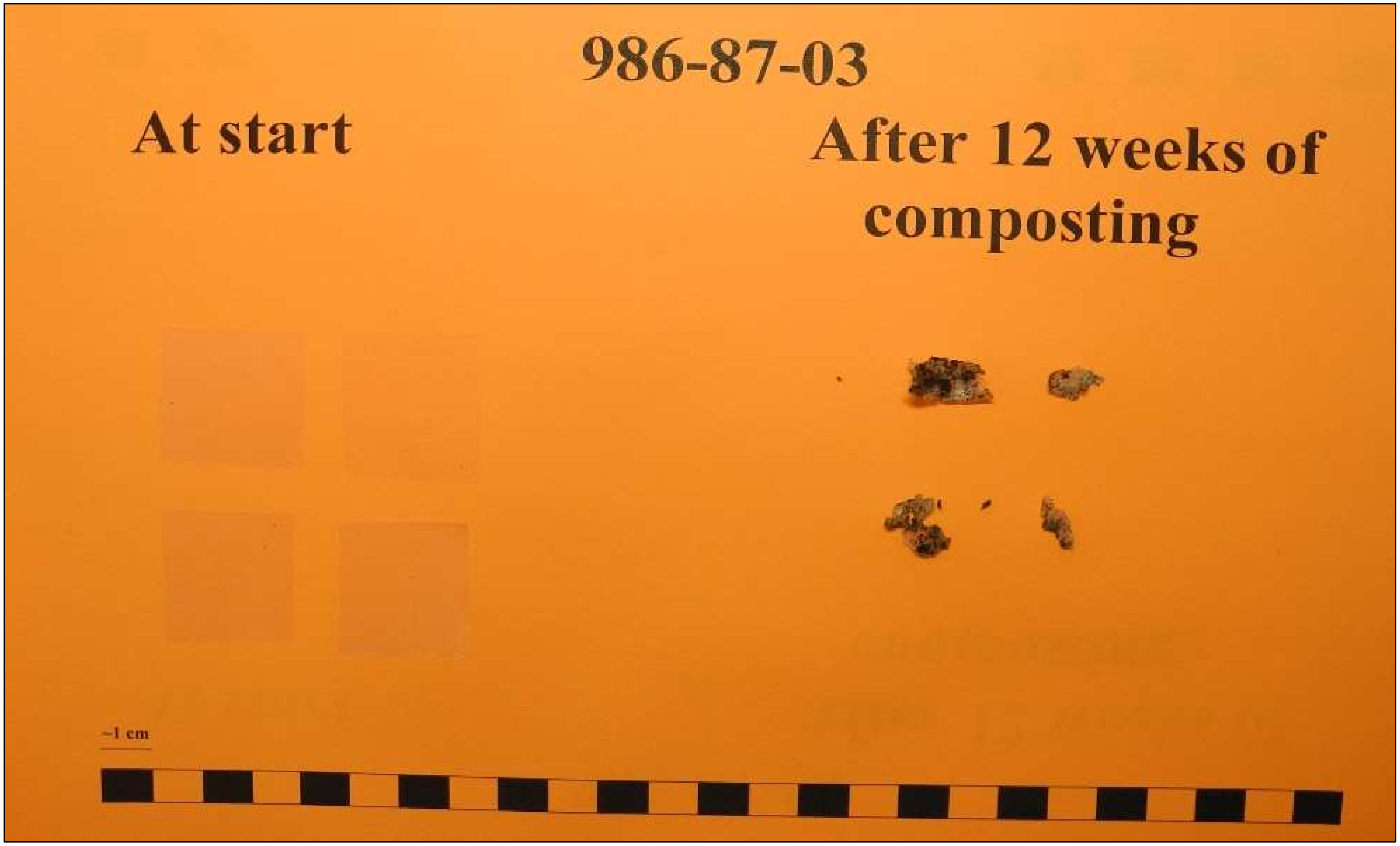
Next Generation Extrusion Coating PLA at 28°C





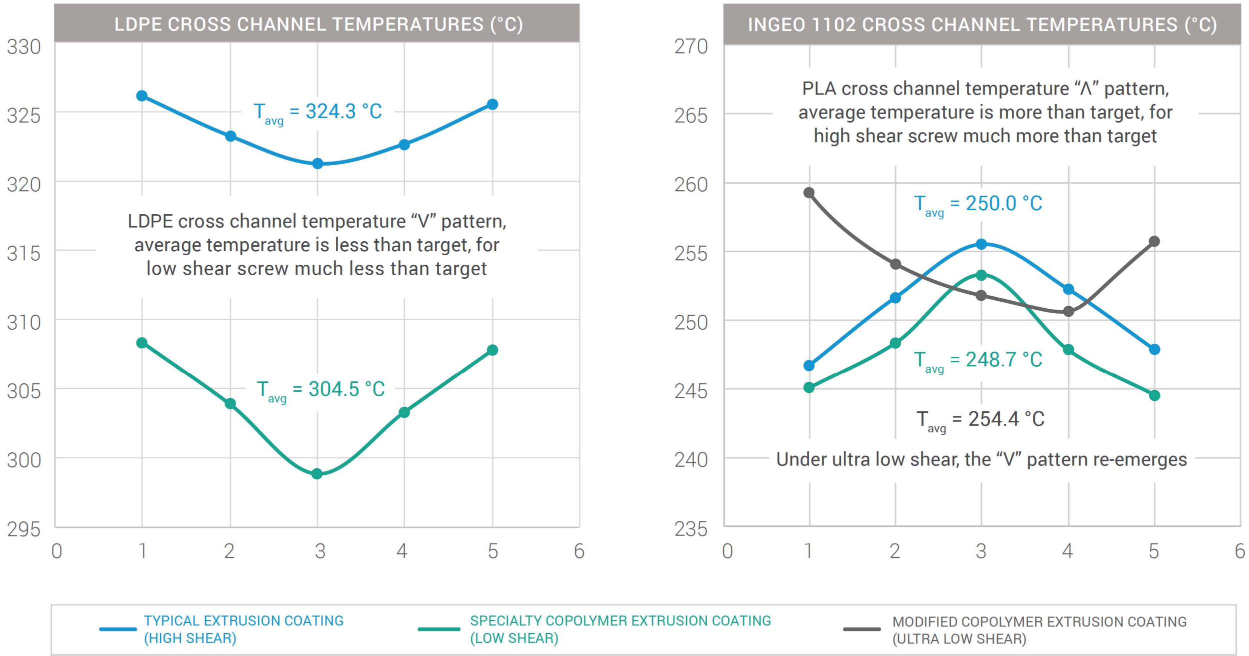
Very small and very fragile pieces

Passing biodegradation in 365 days, and disintegration in 26 weeks


986-87-03
At start
After 12 weeks of composting
~1 cm

Differing melt temperature profiles should drive design changes that can increase extruder output at acceptable temperatures.

- What is good for a low viscosity thermally stable polymer (LDPE) is not good for a high viscosity thermally sensitive polymer (PLA)
- Measuring temperature only at channel edge does not accurately reflect mid-channel melt temperatures. With Ingeo, the true melt temperature is likely hotter than edge measurements indicate.



Process recommendations

In addition to drying resin

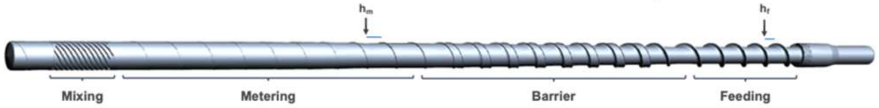
Low shear high output screw design

Minimize Die Lip Gap

Keep melt temperature <250°C or <482°F

Consider edge encapsulation extruder

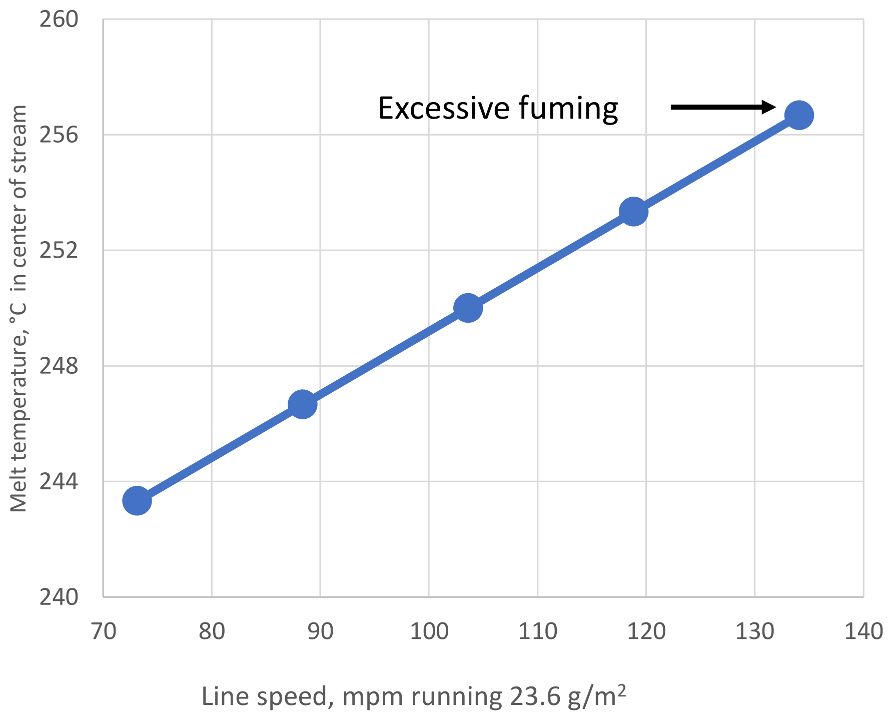
Low Shear Design for PLA



SAM NORTH AMERICA, LLC

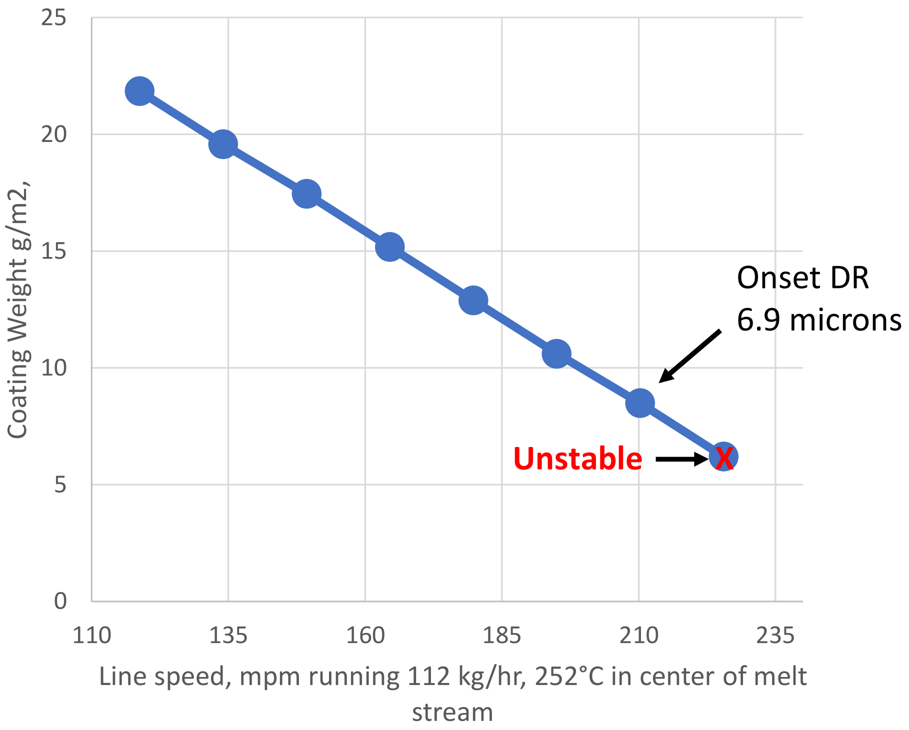
Optimized processing further demonstrates stable melt curtain and low coat weight potentials

Center of melt stream °C; testing max screw speed (output)



Excessive fuming

Coating weight potential; testing max draw down (reduced, 0.508 mm die gap)



Onset DR
6.9 microns

Unstable

SAM NORTH AMERICA, LLC

Optimizing the extrusion coating process could double output and triple line speed

	OUTPUT AT 75 RPM			LINE SPEED		
	LDPE	**Extrusion Coating PLA**		**Extrusion Coating PLA**		
SCREW DESIGN	Output (kg/hr) Temp. °C	Output (kg/hr) Temp. °C	Increase over typical screw design	Increase over typical screw design	Increase by reducing die lip gap	Increase by edge encapsulation and no change in die lip gap
Single Flight Double Mixer High Sheer Design Typical Extrusion Coating Design	50 (324)	78 (252)			**30%**	
Melt Barrier Flight Single Mixer Moderate Shear Design Compromise Extrusion Coating Design	66 (314)	107 (253)	37%	31%		
Melt Barrier Flight Single Mixer Low Shear Specialty Copolymer Extrusion Coating Design	64 (304)	119 (249)	53%	43%	86%	102%
Melt Barrier Flight Single Mixer Ultra Low Shear Design Modified Copolymer Extrusion Coating Design		**145* (252)**	**86%**		**197%**	

**Increased screw speed to 100RPM due to low temperatures found with ultra low shear screw*

Process recommendations
in addition to drying resin

- Low shear high output screw design
- Minimize die lip gap
- Keep melt temperature <250°C or <482°F
- Include edge encapsulation extruder

For more information see

Nicole Whiteman et all (2021) Rethinking the paper cup – beginning with extrusion process optimization for compostability and recyclability *Tappi Journal Vol. 20* (No. 6) page 353-362

TAPPI JOURNAL
WWW.TAPPI.ORG

THE PAPER AND PACKAGING INDUSTRIES' TECHNICAL RESOURCE
JUNE 2021 | VOL. 20 NO. 6

RECYCLING 353
Rethinking the paper cup — beginning with extrusion process optimization for compostability and recyclability
Nicole Whiteman, Andrea Auchter, Andrew Christie, and Michael Prue

PAPERMAKING 365
A guide to eliminating baggy webs
Frédéric Parent, Jean Hamel, and David McDonald

Thank You

Andrea Auchter
NatureWorks
Applications Development Manager
Andrea_Auchter@natureworksllc.com