Amorphous PHA:

The key to tuning the biodegradability speed of compostable polymers

Improved functionality and faster compostability

Bring a New Wave

PHACT

Hugo Vuurens

Nordic Bioplastic Conference

Copenhagen, 13 April 2022

Hugo.Vuurens@cj.net

TOPICS

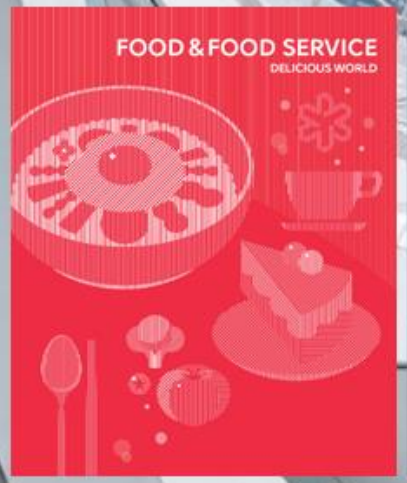
- Introductions to CJ Biomaterials
- PHA
- PHA Applications

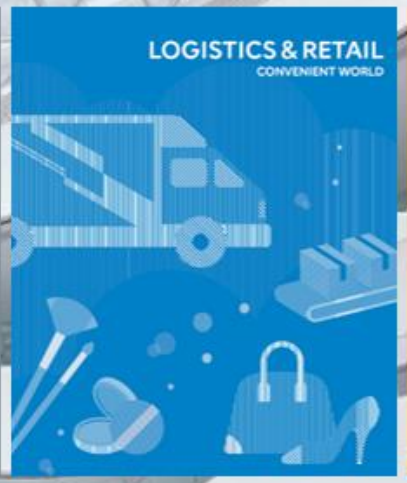
CJ Corporation

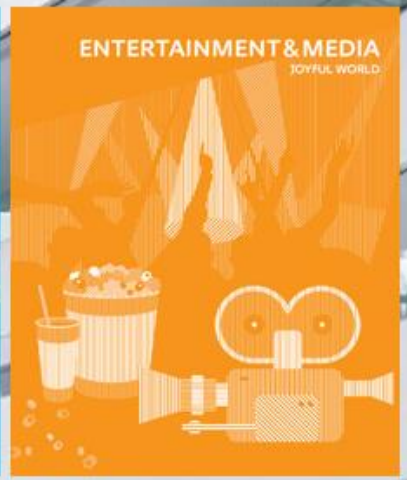
2021
Results

US$27.2 BN
₩34,484 BN

(1USD=1,268 KRW)







DELICIOUS WORLD

FOOD & FOOD SERVICE

Making it easy for everyone to enjoy delicious food while globalizing Korean cuisine.

CJ CHEILJEDANG (FOOD Div.)
CJ FOODVILLE
CJ FRESHWAY

HEALTHY WORLD

BIO

Improving health and wellness through biotech and pharmaceutical innovations.

CJ CHEILJEDANG (BIO Div.)
CJ FEED&CARE
CJ BIOSCIENCE
CJ BIOMATERIALS

CONVENIENT WORLD

LOGISTICS & RETAIL

Shaping the logistics and distribution industries in Korea. Innovating lifestyles and creating conveniences around the world with revolutionary logistics services.

CJ LOGISTICS
CJ LOGISTICS - E&C DIV.
CJ OLIVEYOUNG
CJ OLIVENETWORKS
CJ ENM - O SHOPPING DIV.

JOYFUL WORLD

ENTERTAINMENT & MEDIA

Creating and distributing Korean cultural content via media (TV and online), theaters, live events, and more.

CJ ENM - E&M DIV.
CJ CGV
CJ POWERCAST

OVER 700 KT FERMENTATION CAPACITY WORLDWIDE

13 Production sites in 7 countries, 2 R&D centers, and 137 Sales Networks in 18 countries across the globe

- **Indonesia:** 3 Plants, 2 for food & feed grade amino acids, 1 for PHACT PHA
- **Malaysia:** 1 Plant for L-Methionine
- **China:** 4 Plants for food & feed grade amino acids
- **USA:** 1 Plant for Lysine & Threonine
- **Brazil:** 2 Plants for Lysine & SPC
- **Korea:** 2 Pilot Plants
- **Vietnam:** 1 Plant for fermented soybean meal

PHACT HISTORY

Building our platform by combining world-scale biotech assets with a world-class technology portfolio to enable circular and sustainable solutions

2010

Launch of biomaterials activities as a new growth engine. Planning partnerships with global top-tier customers for production and sales of biobased chemicals.

2016

Acquisition of Metabolix technology and PHA Assets. PHA biopolymers and biochemicals manufacturing via microbiology. CJ assumed the USA based Metabolix research facility in (MA).

2020/21

Construction of PHA plant in Indonesia. 5,000 ton/year investment in Pasuruan, Indonesia.

2022

Plant Commissioning and Start-Up. First shipments Q1-2022. 5KT commercial capacity.

CJ Blossom Park R&D Centre

CJ Blossom Park is the largest food and BIO convergence research institute of its kind in Korea. Home to all the core food and bio research institutes in one location and exuding powerful synergy.

A 1.2 million sq. foot (112,000 sq. meters) R&D center represents the onset of CJ's acceleration into becoming a global company, and creating a sense of newness through open communication.

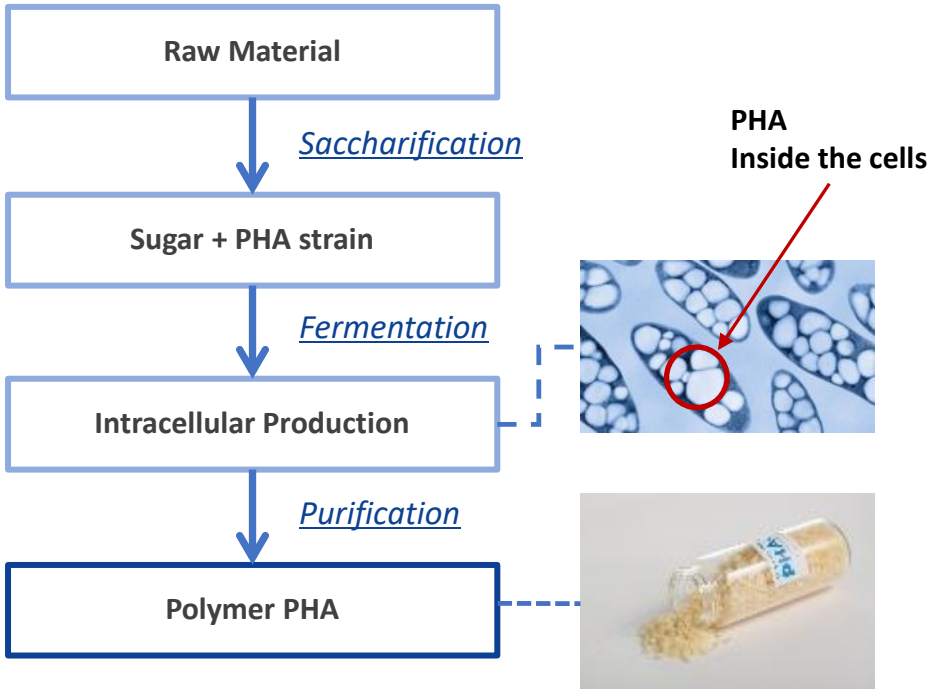
CJ Biomaterials: PHA

PHA's (PolyHydroxyAlkanoate) are produced in Nature by bacterial fermentation

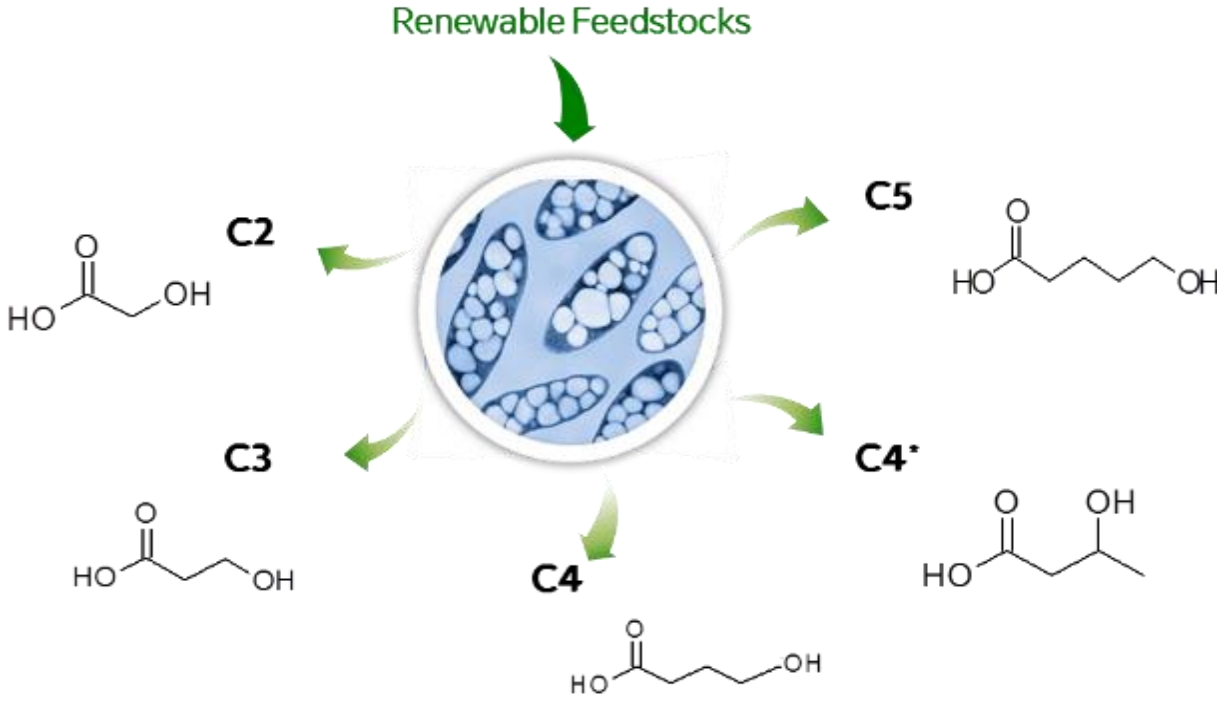
Many bacteria produce and use PHA as an energy storage material in nature
Theoretically more than 150 types of PHA can be created.

The main commercial types are PHB, PHBV, PHBH, P3HB4HB, P3HP

[PHA Production]



[PHA ; Polyhydroxyalkanoate]



Product properties of PHA

Various physical properties with different PHA resin types

Sort	Unit	Test Method	PHA Types		
			cPHA (crystalline)	scPHA (semi crystalline)	aPHA (amorphous)
Specific gravity	g/cc	ISO 1183	1.23	1.23	1.23
T_g (glass transition temp.)	℃	DSC	0 ~ 5	-15 ~ -5	-15 ~ -20
T_m (melting temp.)	℃	DSC	180	130	N/A
Flexural Strength	MPa	ISO 178	< 1400	< 800	< 4
Charpy Impact strength	KJ/M^2	ISO 179	3	5	N/A
Tensile strength	MPa	ISO 527	30 ~ 40	1 ~ 30	< 1
HDT (heat deflection temp.)	℃	ISO 75-2	100	90 ~ 100	-
Representative manufacturer	-	-	Company D, K, **CJ BIO**	Company D, K, T, **CJ BIO**	**CJ BIO**

Biodegradability of Biopolymers

✓= yes / X = no

Product[1)]	Biodegradability			
	Industrial	Home	Soil	Marine
PLA	✓	X	X	X
PBS	✓	X	X	X
PBAT	✓	X	X	X
TPS	✓	✓	✓	X
aPHA	✓	✓	✓	✓
scPHA	✓	✓	✓	✓

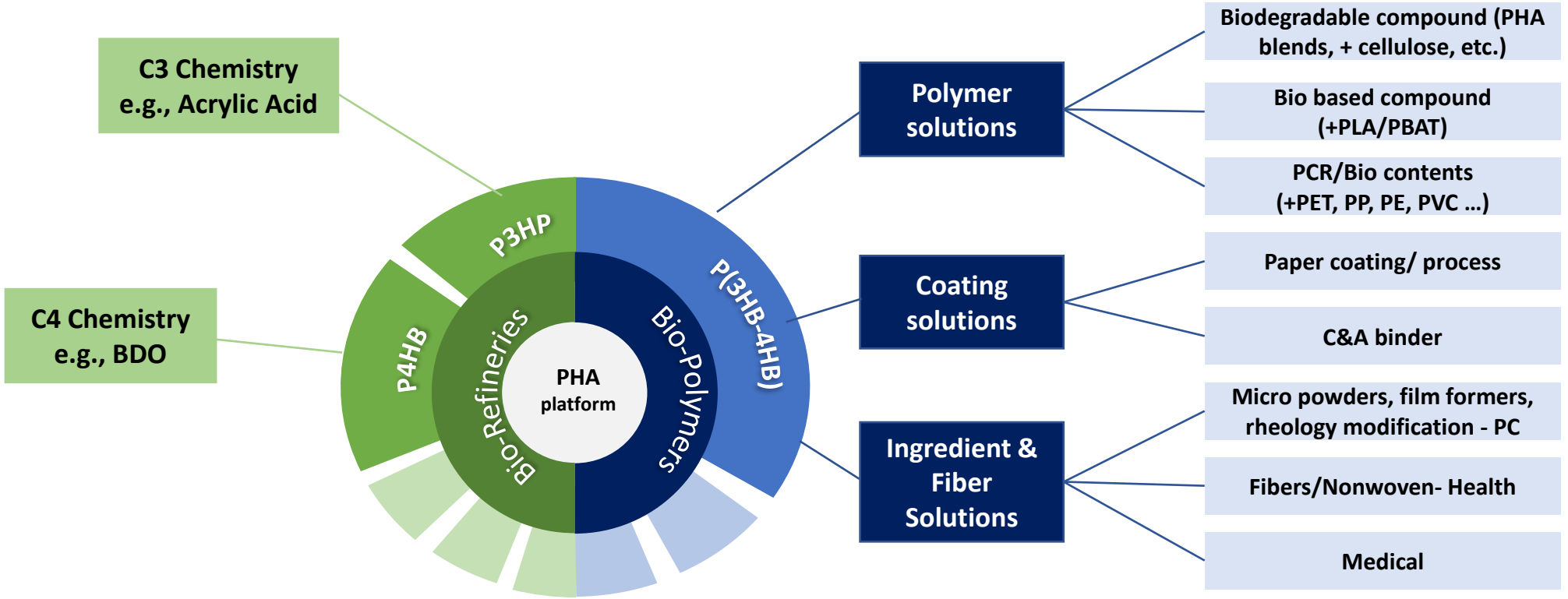
Conditions of Biodegradability

TYPE	CONDITIONS
Industrial	Composting facilities, Microbe, Oxygen at 58°C
Home	Backyard(Home) landfill, at 28°C
Soil	Field, forest, soil at 25°C
Marine	Sea at 30°C

1) PLA (Poly Lactic acid), TPS (Thermoplastic Starch), PBAT (Polybutylene co-adipate co-terephthalate), PBS (Polybutylene Succinate), PHA (Polyhydroxy alkanoate, aPHA: amorphous / scPHA: semi crystalline)

CJ Biomaterials Technology Platform

CJ PHA Platform



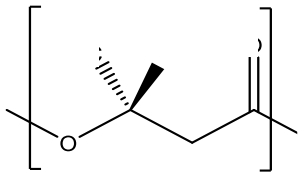
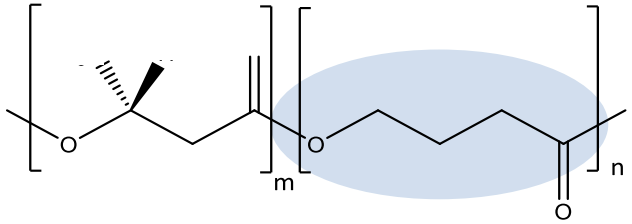
Bio Polymers	PHA-enabled solutions to provide **functional biodegradability**, improve biobased **polymers performance**, increase **bio-content**
Bio Refineries	Leverage PHA's unique bio-chemistry to create **renewable and sustainable solutions** to chemically derived **monomers and molecules**

* Polyhydroxyalkanoate

CJ PHA - PHACT

CJ PHACT technology platform is broad and differentiated

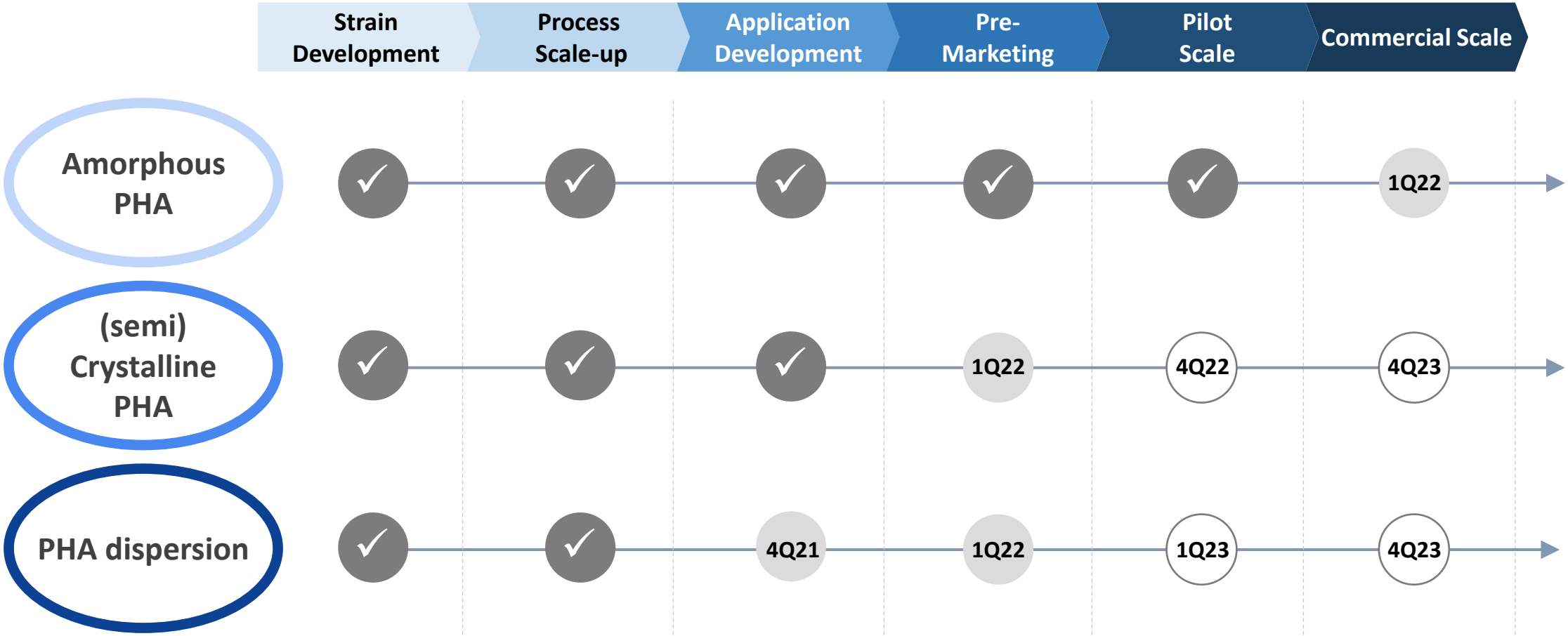
PHACT: PHA with Molecular structure of P(3HB-co-4HB)

PHA	**P3HB (crystalline, cPHA)**	**P3HB-4HB (semi-crystalline, scPHA)**	**P3HB-4HB (Amorphous, aPHA)**
Structure			 [CJ aPHA Pellet]
4HB content	**5~15%**		**>33%**
Features	• 1st generation PHA • Crystalline polymer • Brittle and narrow process window	• General PHA • Semi-crystalline polymer • Versatile properties	• 2nd generation PHA • Amorphous polymer • Flexible, modifier

Increase in 4HB content promotes "rubber-like" properties (Low Tg)

* **P3HB:** Poly(3-hydroxybutyrate) ** **P4HB:** Poly(4-hydroxybutyrate)

CJ PHA – Product range PHACT



faster composting is attractive for composters

Compostable packaging needs to create value for composters

Input

75% ~ 85% of total revenue

1 The greatest focus is to increase incoming volume and the incoming tipping fee.

Screening

Grinding

2 Accelerated processing frees up more space for incoming volume and improves working capital.

- Operating Expense
- Administrative Expense

55%

- Screened out material for landfill

5%

Resulting in EBITDA: ~40%

Screening

Compost sale

15% - 25% of total revenue

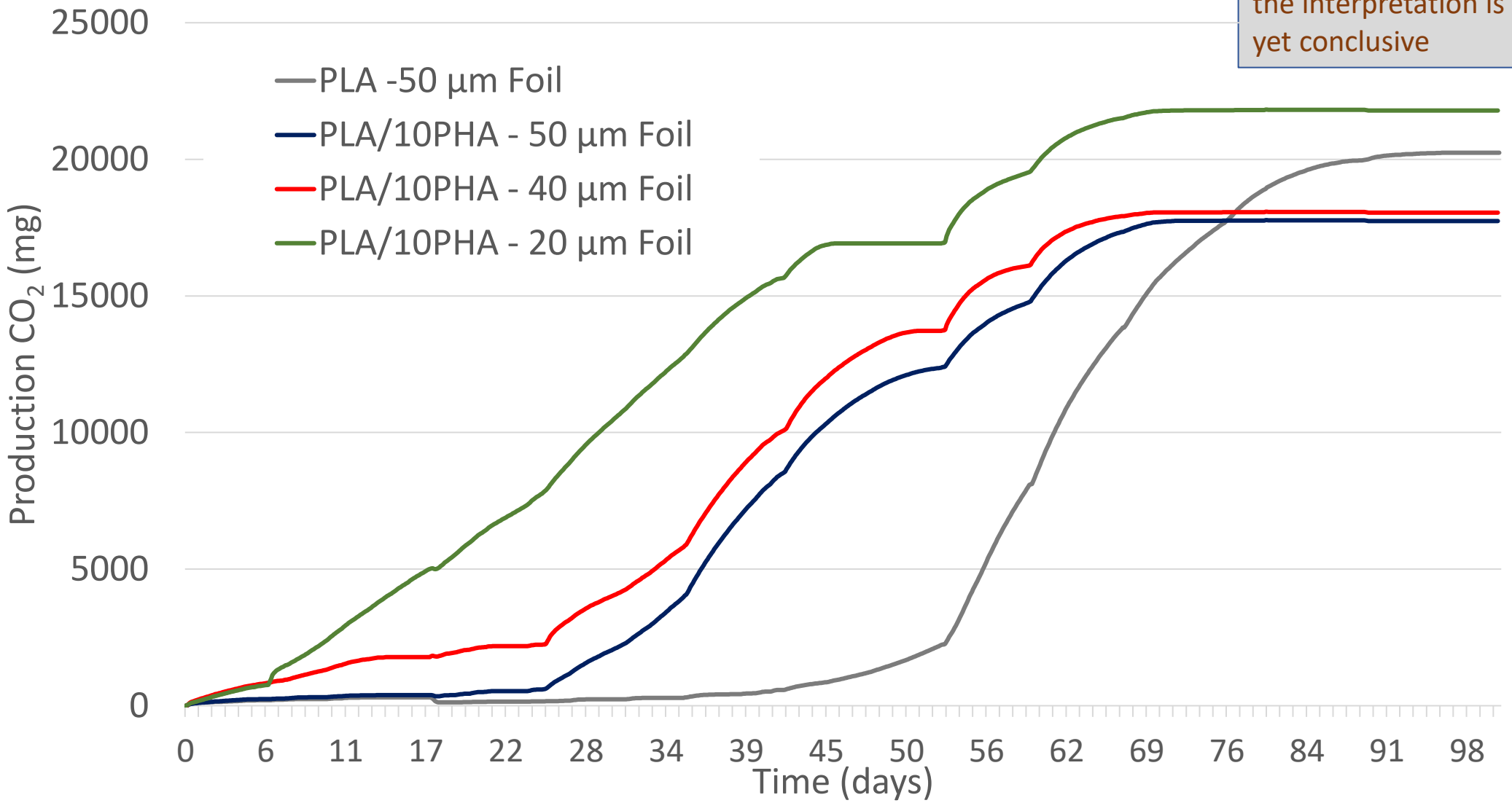
3 Composters try to value add here through quality and special soil blends.

Main levers are incoming volume & tipping fees, accelerating composting, and product quality

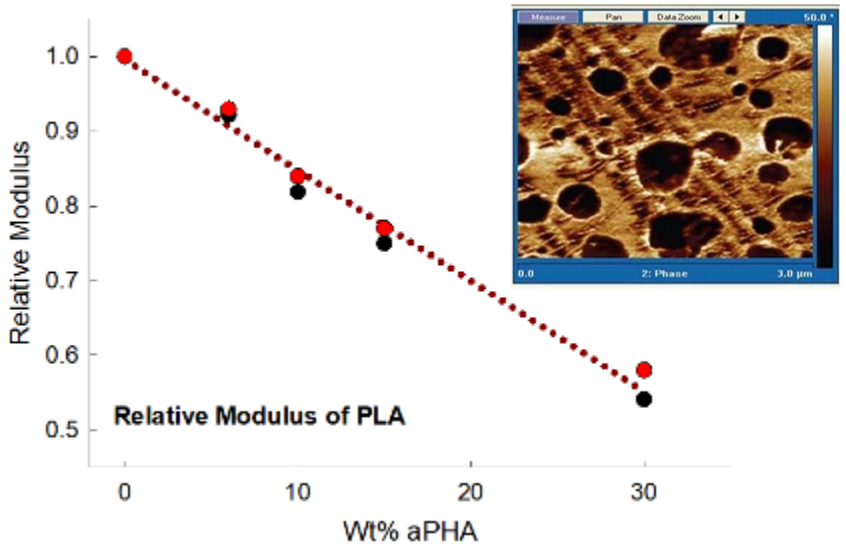
Dr. Mounir Izallalen mizallalen@eastman.com Eastman.com/brand/Aventa EASTMAN

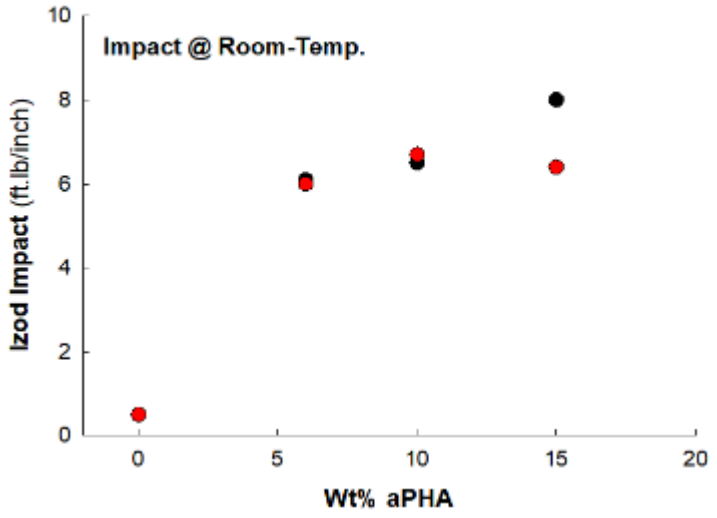
PLA Biodegradation – *Faster Industrial Composting*

Indicative
Tests are still ongoing and the interpretation is not yet conclusive



PLA Modification





Value Proposition of Amorphous PHA (PHACT A1000P) with PLA

- Faster industrial composting of PLA
- Improves flexibility and film handling capability of PLA
- Considerable impact toughening of PLA; 5-20% of aPHA will make PLA much more ductile in fibers, film and 3D filaments
- Enhanced tear propagation resistance of PLA films
- Improved ease of edge trimming in sheet and thermoforming
- Maintains the bio-based carbon content of PLA @ 100%

Blends of PLA and other compostable polymers with amorphous PHA are patent protected by CJ

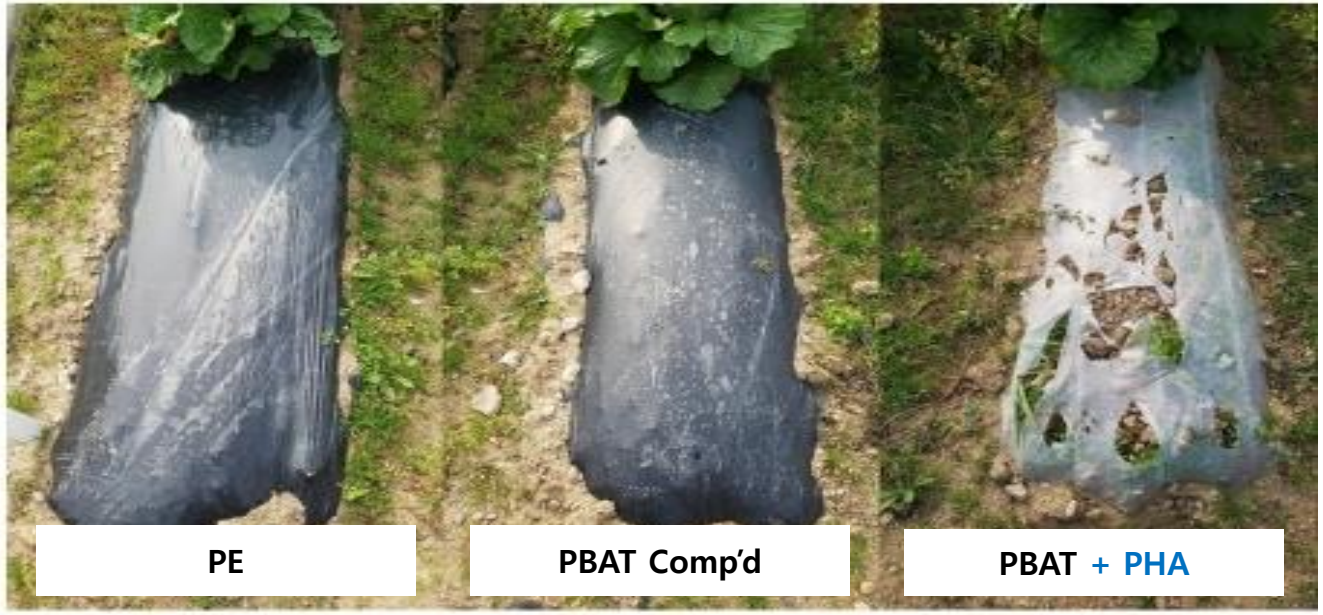
CJ Biomaterials and NatureWorks Celebrate a New Alliance!

Announced to the press in November 2022 that the two organizations have signed a Master Collaboration Agreement (MCA) that calls for joint collaboration on the development of sustainable materials solutions based on CJ Biomaterials' PHACT™ Biodegradable Polymers and NatureWorks' Ingeo™ biopolymers. The two companies will develop high-performance biopolymer solutions that will replace fossil-fuel based plastics in applications ranging from compostable food packaging and food serviceware to personal care, films, and others.

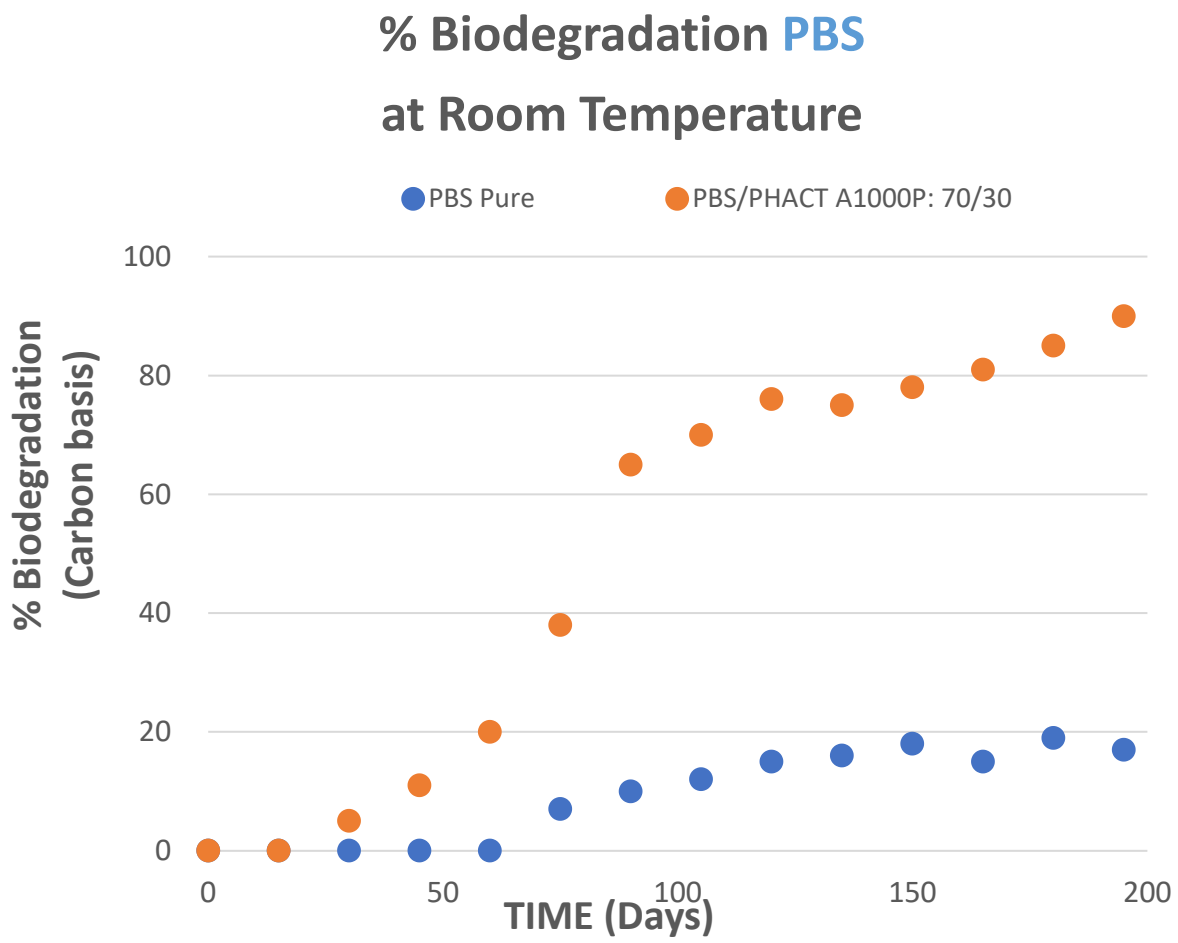
PBAT Modification

Agriculture Mulch Films

- Enhancing Soil Degradable
- Biobased content



PBS Modification



Value Proposition of Amorphous PHA (PHACT A1000P) with PBS

- Enable home composting of PBS
- Enhanced tear propagation resistance of PBS films
- Increase in bio-based carbon content
- Excellent blown and cast film processing and performance

Blends of PBS and other compostable polymers with amorphous PHA are patent protected by CJ

Applications: all PHA

All PHA Applications

3-D Printing

Marine compostable bottles

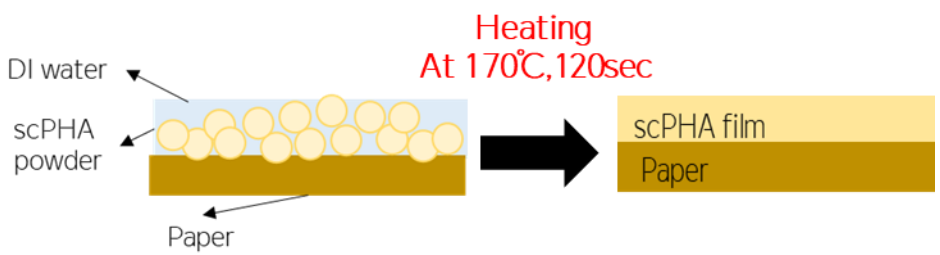
California legislation against microplastics puts focus on faster compostable products:
“A new water bottle from a startup called Cove looks like it’s made from ordinary plastic. But it’s the first of its kind to be made from a blend of PHA, a type of bio-based plastic that’s designed to break down when it’s composted”

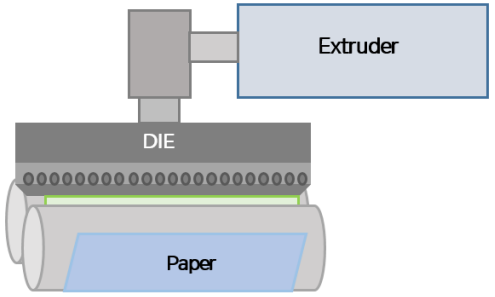
Source: https://www.prnewswire.com/news-releases/cove-the-worlds-first-biodegradable-water-bottle-is-hitting-shelves-on-dec-1st-301678530.html

Paper Barrier Coating

Coating Process	Dispersion coating	Extrusion coating
Appearance	scPHA dispersion (Latex)	Pellet aPHA with PLA/scPHA
Standard grade	**S2500E** (scPHA in emulsion); **FS7550E** (50% scPHA with acylic binder)	**e.g. CA1570P** (compounded 30%aPHA with 70% PLA)
Application	**Popcorn, fast food, drinks** Coating weight: 25g/m^2 or less	**noodle soup cup** Coating weight: 25g/m^2 or more

- Compostable
- Repulpable
- Biobased
- Dispersion coating





Technology & Applications

- ✓ **Monolayer film extrusion (blown or cast)**
- ✓ **Multilayer film co-extrusion (blown or cast)**
- ✓ **Sheet extrusion - Thermoforming**
- ✓ **Injection/Blow molding**
- ✓ **Fibres & NonWovens**
- ✓ **Paper coating (extrusion or dispersion)**

01
FLEXIBLE PACKAGING
(SHOPPING, COMPOSTING BAGS)

02
RIGID PACKAGING
(FOOD CONTAINER, COFFEE CAPSULE, STRAW)

03
PAPER COATING
(CARDBOARD, PAPER CUPS COATING)

04
AGRICULTURE
(NURTURE POTS, MULCHING FILM, SHADES,, CLIPS, HOOKS
CROP PROTECTION and GEOTEXTILES

05
3D FILAMENT, OTHER FILAMENT
(FISHING NET, POLYMER MODIFIERS)

GO!PHA

Global Organization for PHA

Members

Academic Members

THANK YOU!

Amorphous PHA:
Biobased, Improved functionality
and faster compostability

CJ BIOMATERIALS

Bring a New Wave
PHACT

PHACT - improved functionality and biodegradation

Biodegradable
- Soil (Ambient)
- Home Compost
- Industrial Compost
- Fresh Water
- Marine Water
- Anaerobic

Biobased
Sugar used as feedstock
Other sources demonstrated

Products and Applications
PHAs can be compounded and processed using conventional plastics processing equipment.

Fermentation
Microbial engineering enables high polymer (PHA) accumulation in microbes.

Recovery
High Purity polymer is recovered and converted into usable form for downstream processing