What is Ingeo?

Ingeo biopolymer is the world's first performance material whose manufacture shows a significant reduction in greenhouse gas emissions. Made from plants, not oil, Ingeo is derived from abundant 100% annually renewable plant resources.

How is Ingeo made?

Carbon is captured in these plant resources, sequestered from the atmosphere during plant photosynthesis and stored as plant starches. NatureWorks LLC uses dextrose derived from these starches as the starting point for Ingeo. Through a process of fermentation, separation and polymerization, the carbon and other elements in these natural sugars are transformed into the family of Ingeo grades captured in this resin guide.

Where is Ingeo used?

Ingeo is used uniquely to create a full and diverse range of finished consumer goods marketed under the Ingeo brand. Bridging both plastics and fiber categories, Ingeo is fueling innovation and spearheading a whole raft of creativity across a wide range of products from packaging, foodservice, automotive, electronic, and durable goods, to personal care products, clothing, and homewares.

Ingeo Benefits

Environmental Benefits

- Fewer greenhouse gas emissions
- Less fossil fuel used
- Made from plants - not oil
- Peer reviewed and 3rd party validated eco-profile
- Multiple end of life options after use
- Cradle-to-cradle options

Performance Benefits

Ingeo plastics

- Excellent gloss, transparency, and clarity
- Excellent form and stiffness
- UV A and B Stable
- Non-allergenic
- Exceptional flavor and aroma barrier properties
- Easy to blend, mold, shape, emboss, and print
- Ability to lightweight

Ingeo fibers

- Outstanding moisture management properties
- Outperforms polyester for breathability, comfort and insulation
- Low odor retention
- High UV light resistance
- Hypoallergenic, easy care, and quick drying

Ingeo Regulation Information and Scope/Specifications

Food Packaging Materials Compliance¤ø

Ingeo products have food contact compliance in many regions of the world including the US (FDA) and EU. For conditions or limitations and information on other regions of the world please refer to the Regulatory Affairs Compliance Information (RACI) document* or contact us directly.

Chemical Control Law Compliance

Ingeo products are compliant with chemical control laws in many regions of the world including the US, EU (REACH), Japan, China, etc. For more details or other regions of the world please refer to our RACI document* or contact us directly.

Biobased Content

NatureWorks carries the "OK biobased" certification from Vinçotte and the USDA BioPreferred label. Certification is based on the biobased content of Ingeo which can be determined through radiocarbon dating according to ASTM D6866-5. Both certifications require that the raw materials and the final articles carry certification in order to claim compliance.

Industrial Composting according to ASTM D6400 and EN13432

Composting is a method of waste disposal that allows organic materials to be recycled into a product that can be used as a valuable soil amendment. Ingeo is a compostable material in municipal and industrial composting facilities where available. Ingeo carries certification through various organizations including BPI (US) and DIN CERTCO (EU). For further information refer to RACI document or contact us directly.

Certification Notes:

BPI and DIN CERTCO certification programs require both plastic articles and polymer products be certified. Therefore, NatureWorks' certifications cannot be automatically leveraged by downstream customers.

BPI - ASTM D6400:

- 3001D, 4032D, 4043D, 4060D, 7001D, in parts up to 2.0 mm thickness
- 2003D, 3052D, 3251D, in parts up to 3.2 mm thickness

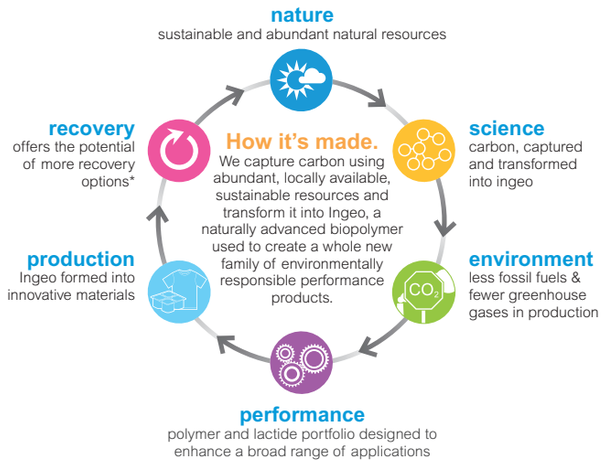
DIN CERTCO EN 13432:

- 2003D, 3001D, 3052D, 4032D, 4043D, 4060D, 7001D in parts up to 2.0 mm thickness

¤ US and EU are shown as an example, if you need data for other geographic regions please contact NatureWorks LLC.

ø It is the responsibility of both the manufacturers of finished food contact articles as well as the industrial food packers to make sure that these articles in their actual use are in compliance with the imposed specific and overall migration requirements.

* RACI document is located at: www.natureworksllc.com/RACI



*Check out the complete Ingeo eco-profile and read about our improved carbon footprint potentials in The Ingeo Journey at www.natureworksllc.com

Where can you learn more about Ingeo resin?
visit www.natureworksllc.com

Follow **@NatureWorks** on Twitter!

Like **NatureWorks LLC** on Facebook!

USDA CERTIFIED BIOBASED PRODUCT PRODUCT 100%

OK biobased S149 VINÇOTTE

ingeo™

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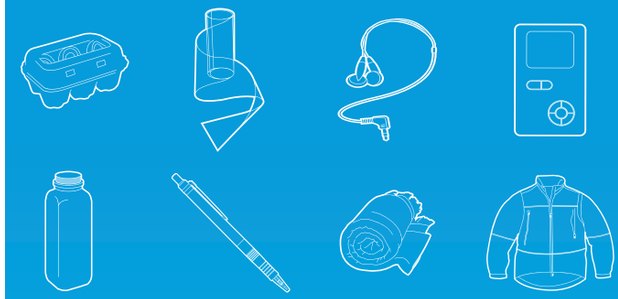

Ingeo resin product guide

Naturally Advanced Materials

This Ingeo Resin Product Guide is intended to provide a collection of the physical, mechanical and thermal properties for the Ingeo grade family. In addition, regulatory approvals / specifications, grade characteristics, and typical applications are provided on each product line and its uses.

Please refer to individual technical data sheets on each grade for the most up-to-date data and information at www.natureworksllc.com

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Ingeo Grade Overview

2000 Series – Extrusion/Thermoforming

General purpose transparent extrusion grade.

2003D Used as is or as part of a formulated blend on conventional extrusion equipment

2500HP High viscosity & designed to crystallize during processing

3000 Series – Injection Molding

Designed for injection molding applications.

3001D Unlubricated, medium-flow grade

3052D Lubricated, medium-flow grade

3100HP Medium viscosity & designed for medium-flow injection molding applications

3251D Lubricated, ultra high flow grade

3260HP Designed to crystallize during processing for higher heat deflection temps in opaque applications

4000 Series – Films & Sheet

Designed for use in the production of oriented films, cardstock and graphic arts.

4032D High heat film

4043D General purpose film

4044D Reactive extrusion grade

4060D Heat seal layer for film

6000 Series – Fibers/Nonwovens

Designed for fiber processes from mono to multifilament as well as spunbond & meltblown products. Melting point ranges from 130°C to 170°C with amorphous to crystalline grades.

6060D Amorphous low melt for staple fiber/bico fiber sheath layer 3.5rv

6100D For when lower fiber shrinkage and higher dimensional stability is required

6201D Continuous filament/staple for dyed fiber applications

6202D Staple fiber/spunbond for nonwovens, non-dyed fiber applications

6204D Designed for fiber processes where deeper disperse dying in the final product is desired: partially orientated yarn (POY), fully drawn yarn (FDY), staple fibers, and continuous filament

6252D Meltblown

6260D Designed for meltblown fiber processing or extrusion into mechanically drawn staple fibers

6302D Amorphous low melt for staple fiber/bico fiber sheath layer 3.0rv

Ingeo Properties

Extrusion/Thermoforming and Injection Molding

Physical Properties	ASTM Test Method	Grade						
		2003D	2500HP#	3001D	3052D	3100HP#	3251D	3260HP#
Specific Gravity	D792	1.24	1.24	1.24	1.24	1.24	1.24	1.24
MFR (g/10min*)	D1238	6	8	22	14	24	80	65
(g/10min**)	D1238						35	
Clarity		Transparent	Opaque	Transparent		Opaque	Transparent	Opaque
Relative Viscosity^	D5225	4.0		3.1	3.3	3.1	2.5	
Peak Melt Temp (°C)	D3418	145-160	165-180	155-170	145-160	165-180	155-170	165-180
Glass Transition Temp (°C)	D3418	55-60	55-60	55-60	55-60	55-60	55-60	55-60
Mechanical Properties								
Tensile Yield Strength [psi (Mpa)]		8,700 (60)[7]	9,500 (65.5)[8]	9,000 (62)[8]	9,000 (62)[8]	9,300 (64)[8]	9,000 (62)[8]	9,200 (63)
Tensile Strength at Break [psi (Mpa)]		7,700 (53)[7]	8,300 (57)	7,800 (54)[8]	8,300 (57)[8]	8,900 (61)[8]	8,000 (55)[8]	6,500 (45)[8]
Tensile Modulus [kpsi (Gpa)]		524 (3.6)[7]	680 (4.7)	540 (3.7)[8]	530 (3.7)[8]	625 (4.3)[8]	545 (3.8)[8]	650 (4.5)[8]
Tensile Elongation (%)		6[7]	4.3[8]	3.5[8]	3.5[8]	2.2[8]	3.5[8]	1.3[8]
Notched Izod Impact [ft-lb/in (J/m)]	D256	0.3 (16)	0.75 (40)	0.3 (16)	0.3 (16)	0.6 (32)	0.3 (16)	0.3 (16)
Flexural Strength [psi (Mpa)]	D790	12,000 (83)	18,300 (126)	15,700 (108)	15,700 (108)	15,700 (108)	15,700 (108)	15,700 (108)
Flexural Modulus [kpsi (Gpa)]	D790	555 (3.8)	646 (4.36)	515 (3.6)	515 (3.6)	632 (4.36)	540 (3.7)	623 (4.3)
Heat Distortion Temp. at 66 psi (°C)	E2092	55	144	55	55	149	55	151

* 210˚C/2.16kg **190˚C/2.16kg [7] ASTM D882 [8] ASTM D638 ^ 1.0 g/dL in chloroform at 30˚C # nucleated, crystallized properties. non-impact modified

Fibers/Nonwovens

Physical Properties	ASTM Test Method	Grade									
		6060D	6100D	6201D	6202D	6204D	6252D	6260D	6302D	6362D	6400D	6752D
Specific Gravity	D792	1.24										
Relative Viscosity*	D5225	3.3	3.1	3.1	3.1	3.1	2.5	2.5	3.0	2.5	4.0	3.3
MFR g/10 min (210°C, 2.16kg)	D1238	8	24	15-30	15-30	15-30	70-85	65	15-20	70-85	6	15
Melt Density (230°C)		1.08										
Crystalline Melt Temp (°C)	D3418	125-135	165-180	155-170	155-170	155-170	155-170	165-180	125-135	125-135	160-170	145-160
Glass Transition Temp (°C)	D3417	55-60										

* 1.0 g/dL in chloroform at 30˚C

Ingeo Grade Overview (cont.)

6000 Series – (cont.)

6362D Designed for specialty fiber products where an amorphous structure is desired

6400D Monofilament/BCF/Industrial multifilament products

6752D Sheath polymer for spunbond applications

7000 – Injection Stretch Blow Molding

Designed for use in injection stretch blow molded (ISBM) bottle applications.

7001D General purpose ISBM bottle grade

7032D Heat-set ISBM bottle grade

8000 – Foam

Designed for expanded foam sheet.

8052D Expanded foam sheet

10000 – Binders & Adhesives

Multi-purpose thermoplastic binder grades for applications from electrophotographic printing to adhesives to building/construction.

10361D Amorphous/low-melting, high-flow resin

Films & Sheet

Physical Properties	ASTM Test Method	Grade			
		4032D	4043D	4044D	4060D
Specific Gravity	D792	1.24			
Melt Density (g/cc)		1.08 @ 230 ˚C			
Glass Transition Temp.	D3418	55 -60 ˚C			
MFR* (g/10 min)	D1238	7	6	6	10
Relative Viscosity*	D5225	4.0			3.4
Morphology		Semi-crystalline			Amorphous
Peak Melt Temp (˚C)	D3418	155-170°C	145-160°C	145-160°C	NA
Oxygen	D3985	650 - 700 cc-mil/m2-24-hr-atm			
Carbon Dioxide	Internal	2700 - 3000 cc-mil/m2-24-hr-atm			
Water Vapor	F1249	350 - 400 g-mil/m2-24-hr			

* 210˚C/2.16kg ^ 1.0 g/dL in chloroform at 30˚C

Injection Stretch Blow Molding

Physical Properties	ASTM Test Method	Grade	
		7001D	7032D
Specific Gravity	D792	1.24	
Clarity	D1746	Transparent	
Relative Viscosity*	D5225	4.0	
Peak Melt Temp (°C)	D3418	145-160	155-170
Glass Transition Temp (°C)	D3418	55-60	
Oxygen	D3985	650 - 700 cc-mil/m2-24-hr-atm	
Carbon Dioxide	Internal	2700 - 3000 cc-mil/m2-24-hr-atm	
Water Vapor	F1249	350 - 400 g-mil/m2-24-hr	

* 1.0 g/dL in chloroform at 30˚C

Foam and Binders & Adhesives

Physical Properties	ASTM Test Method	Grade	
		8052D	10361D
Specific Gravity	D792	1.24	1.24
Melt Density (g/cc)			1.08 @ 230˚C
Glass Transition Temp (°C)	D3418	55-60	55-60
MFR^ (g/10 min)	D1238	14	70-85
Relative Viscosity^		3.3	2.5
Mechanical Properties			
Tensile Yard Strength [psi (Mpa)]	D638	9,000 (62)	
Tensile Elongation (%)	D638	3.5	
Notched Izod Impact [ft-lb (J/m)]	D256	.3 (16)	
Flexural Strength [psi (Mpa)]	D790	15,700 (108)	
Flexural Modulus [kpsi (Gpa)]	D790	515 (3.6)	

* 210˚C/2.16kg ^ NTR Internal Viscotek Method

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