

# Processing Guide

## Sheet and film extrusion of (high heat) PLA

Revision date 23 Aug 2018  
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 Date previous version 21 Apr 2016  
 Version & language 2 - EN

**PROCESSING GUIDE**  
**SHEET AND FILM EXTRUSION OF (HIGH HEAT) PLA**  
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### INTRODUCTION

This processing guide describes the handling and extrusion of PLA film and sheet. Total Corbion PLA has developed PLA resins for the production of sheet and (oriented) films. Typical applications include roll stock for thermoforming, fresh food packaging, candy twists, bank and gift cards, and label film. Processing of these PLA resins can usually be done on existing, conventional extrusion equipment.

Sheet/film extrusion is a general processing technology with a lot of possibilities in terms of dimensions and formulations, the information that is given in this processing guide only serves as a starting point. Optimization of the process is recommended to find the optimal process conditions for the formulation that is used. To validate the product against customer requirements, testing of produced PLA is recommended.

### STORAGE CONDITIONS

It is recommended to store PLA polymers and compounds in its closed, original moisture-barrier packaging at temperatures below 50°C. Storage in direct sunlight should be avoided. The supplied PLA pellets are typically semi-crystalline.

### TYPICAL PLA RESIN PROPERTIES

Property	Unit	Typical value					
		Luminy® LX175	Luminy® LX575	Luminy® L175	Compound D <sup>1</sup>	Compound E	Compound K
Application examples		Biaxially oriented films, cold cups	Biaxially oriented films	Biaxially oriented films, cold cups	Hot fill, coffee cups, MW trays	Hot fill, coffee cups, MW trays	Hot fill, coffee cups, MW trays
Density	g/cm <sup>3</sup>	1.24	1.24	1.24	1.39	1.34	1.29
Optical purity	%L-isomer	96%	98%	>99%	N/A	N/A	N/A
MFI (210°C/2.16kg)	g/10 min	8	8	8	6	5	8
Melting temperature	°C	155	165	175	N/A	N/A	N/A
Glass transition temperature	°C	55-60	55-60	55-60	N/A	N/A	N/A
Tensile modulus	MPa	3500	3500	3500	5500	5400	3600
Tensile strength	MPa	45	50	50	60	60	50
Elongation at break	%	<5	<5	<5	<5	<5	8
Impact (Charpy notched, 23°C)	kJ/m <sup>2</sup>	<5	<5	<5	2	2	8
HDT-B (amorphous) <sup>2</sup>	°C	55-60	55-60	55-60			
HDT-B (semi-crystalline) <sup>2</sup>	°C			100-110	120	120	80

<sup>1</sup> Can be used as stand-alone compound or as part of a mixture with, for example, PLA/PDLA homopolymers. Compounds for evaluation only – Total Corbion PLA does not commercially sell compounds.

<sup>2</sup> HDT B, 0.45MPa, flatwise using injection molded test bars. HDT depends on processing conditions. For crystalline resins, formulation included 3 - 7% nucleating agent (D070) and molded at 90 - 100°C tool temperature.

Table 1: Typical properties of Luminy PLA grades and PLA compounds suitable for extrusion

### DRYING PLA

Luminy PLA resins are supplied in sealed aluminum-lined barrier packaging with a maximum moisture content of 400 ppm. It is recommended to reduce the moisture content before melt processing to a level less than 250 ppm and preferably to 100 ppm. Moisture causes hydrolysis of the PLA homopolymer during melt processing, resulting in reduced mechanical performance in the final part.



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Luminy PLA Resins can be dried using most conventional drying systems. The preferred method to dry PLA is by using a desiccant hot air dryer system. Another option is to use a vacuum drying oven. It is highly recommended to check the actual moisture content after drying, for which the Karl-Fischer or Brabender Aquatrac methods can be used. In case additives are used, it is also necessary to check the moisture content of the additives and dry them if necessary.

The dried PLA should be processed as soon as possible after drying and preferably under an inert (Nitrogen) atmosphere to prevent moisture uptake. Starting at 100ppm moisture content, the critical level of 250ppm is already reached after 15 minutes of exposure to atmospheric conditions (Figure 1).

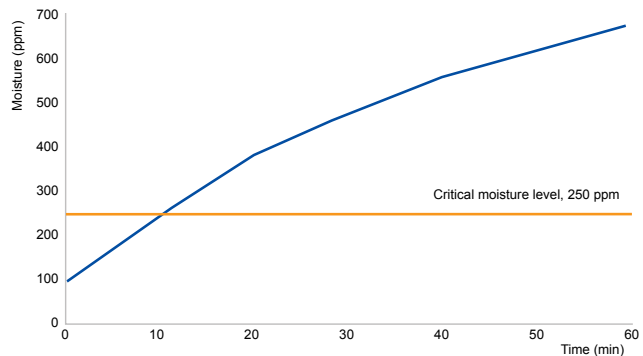


Figure 1: Moisture take-up curve PLA homopolymer

The packaging should be kept sealed before usage and any unused material should be resealed immediately. It is recommended to have a closed system from the dryer into the feeder, a dryer installed on top of the feeder, or to apply a dry nitrogen blanket in the feeder and throat of the extruder to prevent moisture uptake. Typical PLA drying conditions using a desiccant hot air dryer are shown in table 2.

Parameter	Amorphous PLA	Pre-crystallized standard PLA (Luminy® LX175)	Crystalline PLA homopolymers (Luminy® L105, L130, L175)
Drying time	24 hours	4-6 hours	4-6 hours
Air temperature	40°C	85°C	100°C
Air dew point	< -40°C	< -40°C	< -40°C

Table 2: Typical PLA drying conditions

### START-UP AND SHUTDOWN

Before introducing Luminy PLA, the extrusion equipment needs to be well cleaned and purged to prevent cross contamination. Also, make sure that the feeding and blending equipment in the material preparation steps (before the materials and additives enter the extruder) is extensively cleaned and that they are free of dust and contamination. The purging procedures below are recommended for removing other polymers when processing PLA.

1. Check if other polymers from previous runs are present in the barrel of the machine. To prevent starting up the machine with non-molten material, the temperature range of the machine should be set to the processing temperature of the previously used polymer or the PLA, whichever has the highest processing temperature.
2. Purge the system with a polyolefin with similar MFI to PLA, or a purging compound (e.g. ASAClean, Dyna-Purge, etc.) followed by purging with the PLA homopolymer.
3. Change the temperature of the barrel to the required temperature for PLA.
4. Check that the processed material is free of contamination before starting production.
5. At completion of the run, it is recommended to purge the system again by using a purging compound to clean the machine from remaining PLA material for 5 times the average residence time. Check the recommendations of the supplier of the purging material for the right conditions.

After completion of the run, PLA must be removed from the whole system. PLA can degrade over time into lactic acid causing corrosion of the equipment.

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### EXTRUDER SETUP AND TEMPERATURE PROFILE

The resins or compounds are ready to use, however if specific functionality is required, additives (e.g. anti-static, anti-block, color concentrates, impact modifier, etc.) can be added as masterbatches. Masterbatches are preferably PLA based and can be dry blended with the polymer resin or compound or gravimetrically fed.

Luminy PLA can be processed on conventional extrusion equipment. A general purpose single screw extruder with L/D ratios between 24 and 32. Typical extruder conditions for PLA sheet/film extrusion are shown in the table below.

Parameter	Unit	Luminy LX175	Luminy LX575	Luminy L175	Compound D	Compound E	Compound K
Feed zone	°C	20-40	20-40	20-40	20-40	20-40	20-40
Melt zone	°C	170-190	180-190	180-190	180-210	180-210	180-210
Mixing & conveying	°C	190-210	190-210	190-210	190-210	190-210	190-210
Die head temperature	°C	190-210	190-210	190-210	190-210	190-210	190-210

Table 3: Typical extruder temperature conditions for processing PLA.

### CAST SHEET EXTRUSION

Sheet extrusion can be done on conventional extrusion equipment. To avoid cross contamination the extruder and auxiliary equipment need to be purged and cleaned before and after PLA extrusion. Both horizontal and vertical roll stacks have been used successfully. The temperatures of the rolls need to be set in the range of 25-50°C. Too high temperature results in sticking of the film onto the chill roll, leading to poor sheet quality. Air entrapment between the sheet and chill roll will result in poor sheet quality and should therefore be avoided. Electrostatic pinning or vacuum can be applied to reduce the risk of air entrapment. PLA has a similar stiffness to Polystyrene. Edge trim is preferably slit with rotary shear knives.

### BLOWN FILM EXTRUSION

Blown film extrusion is a well-known production technology to make thin films. The low melt strength of PLA requires the use of additives, like melt strength enhancers to be able to process neat PLA. Often PLA is part of a compound to make biodegradable film for use in for example shopping bags or as mulch film. In these cases PLA is often part of the formulation and we recommend contacting the supplier of the compound for the processing recommendations. In case PLA homopolymer is used in these formulations, we recommend processing temperatures to be set 20°C higher than when standard PLA is used in these formulations.

### REGRIND

Edge trim or skeleton waste can be ground, crystallized and dried. The dried re-grind can be blended with virgin resin before feeding back to the extruder. The maximum loading of regrind depends on the application and needs to be carefully validated, but typically 20-40% of ground material can be added back in.

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