

Reprocessing of Ingeo™ Biopolymer Edge and Skeleton Trim

Like most commodity thermoplastics used in the packaging industry, edge trim and process reclaim from Ingeo biopolymer sheet or film can be reprocessed into prime sheet and film provided that certain handling and process guidelines are followed.

1.0 Regrind or Flake Handling

In most extrusion operations, Ingeo biopolymer edge trim and process reclaim will be in the amorphous form, due to lack of a heated (100+°C) annealing step or a semi-solid orientation step in the extrusion operation. It is imperative to handle the reclaim properly to minimize issues during drying, conveying and extrusion. It is possible to recrystallize the regrind to minimize potential processing issues.

The two methods for treating reclaim are described below.

2.0 Amorphous regrind

Small amounts of amorphous reclaim can be fed directly back into the extrusion process provided the total percentage is less than 50% and certain precautions are taken during extrusion. Amorphous reclaim must be dried at temperatures less than 45°C (113°F) to prevent agglomeration of the reclaim flake and subsequent blocking of discharge chutes and feed throats. When blending amorphous reclaim with warm pellets from a second dryer stream the pellets must be less than 50°C (122°F). This is to prevent agglomeration and sticking of the flake which could cause further material transport problems.

The extruder screw used for processing amorphous flake should be equipped with screw cooling. Screw cooling prevents sticking of the amorphous flake to the screw root in the feed section of the extruder. If sticking happens, the extruder will begin surging and eventually a result in a complete loss of conveying. Screw cooling should penetrate two diameters in length into the compression section of the screw. Cooling the feed section of the screw only is not sufficient to prevent screw sticking.

3.0 Crystalline regrind

Ingeo biopolymer regrind can also be recrystallized. This is the preferred method as it increases the regrind melting temperature to that of the incumbent feed material. NOTE: See the "Ingeo Biopolymer Crystallization and Drying" technical bulletin for details.

If the reclaim flake is crystalline, there are typically no concerns with drying and extrusion. Some customers have reported excellent processing of up to 100% reclaim flake without issues.

The screw design should be optimized to handle the low bulk density of reground sheet or film.

4.0 Property Changes

A second concern when processing reclaim material is the effect on properties. Thermal degradation occurs in all polymers when they are exposed to heat for extended periods of time. The degradation results in either crosslinking or a loss of molecular weight, and formation of color bodies that adversely affect the optical properties of the polymer. If the regrind is properly dried and processed, Ingeo biopolymer has the same stability as many other commonly used thermoplastics. The primary degradation mechanism Ingeo biopolymer is molecular weight loss due to hydrolysis, which is mitigated by properly drying the resin and regrind prior to extrusion. Figure 1 shows the percent loss in molecular weight as a function of time for an Ingeo biopolymer (approximately 6 melt flow rate at 210°C, 2.16 kg) and a commercial grade of high heat resistance, general purpose polystyrene of 1.5 melt flow rate (200°C, 5 kg) at a typical processing temperature of 220°C (430°F).

Reprocessing of Ingeo Biopolymer Edge and Skeleton Trim

Relative Molecular Weight Loss at 220°C Melt Temperature

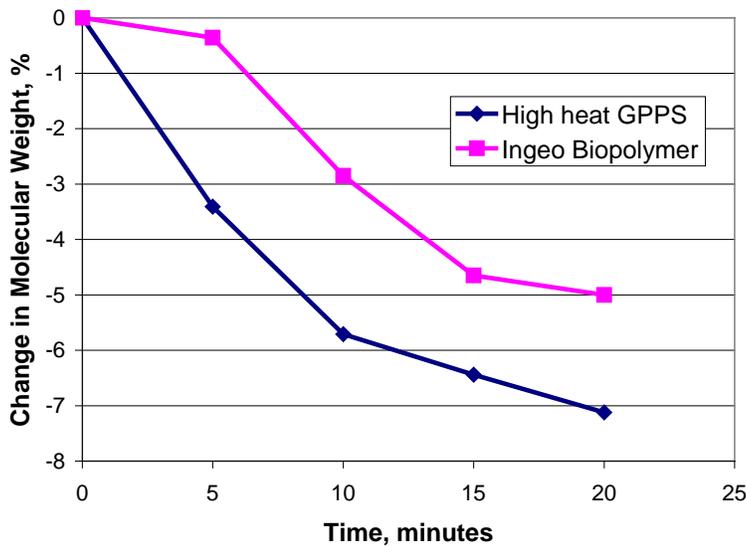


Figure 1: Loss in weight average molecular weight from initial starting molecular weight as function of time at 220°C (430°F) for two different polymers.

It can be seen that the loss in molecular weight for Ingeo biopolymer is comparable to that of the commercial grade polystyrene.

Finally, residence time and temperature during extrusion is very important. Melt temperature has a significant affect on polymer viscosity. It is important to keep the melt temperature under control. Excessive melt temperature results in sag and thermal degradation. Figure 2 shows the change in shear viscosity as a function of time for dried polymer.

Viscosity Stability of Ingeo™ biopolymer dried to <20 ppm Water (constant shear rate of 10 sec-1)

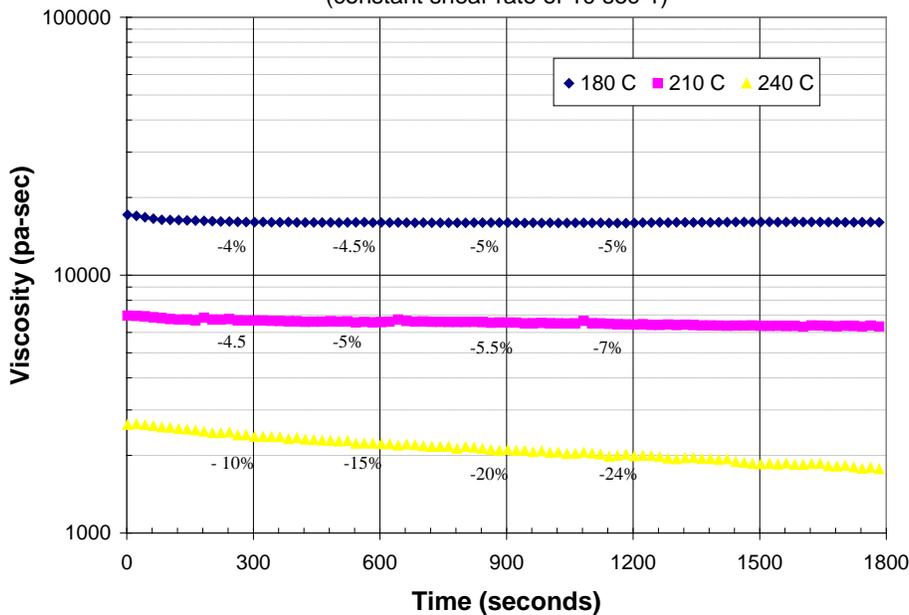


Figure 2: Change in shear viscosity for 2002D as a function of time at three processing temperatures. Numbers indicate the % loss in viscosity from the initial value.

It can be seen that the viscosity change is small for lower melt temperatures, resulting in optimum processing conditions and increased melt strength. At a melt temperature of 240°C the loss in viscosity is significant. It is critical the melt temperature remain less than 230°C (445°F) for optimum use of reclaim material.

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Reprocessing of Ingeo Biopolymer Edge and Skeleton Trim

Safety and Handling Considerations

Safety Data Sheets (SDS) for Ingeo biopolymers are available from NatureWorks. SDS's are provided to help customers satisfy their own handling, safety, and disposal needs, and those that may be required by locally applicable health and safety regulations. SDS's are updated regularly; therefore, please request and review the most current SDS's before handling or using any product.

The following comments apply only to Ingeo biopolymers; additives and processing aids used in fabrication and other materials used in finishing steps have their own safe-use profile and must be investigated separately.

Hazards and Handling Precautions

Ingeo biopolymers have a very low degree of toxicity and, under normal conditions of use, should pose no unusual problems from incidental ingestion or eye and skin contact. However, caution is advised when handling, storing, using, or disposing of these resins, and good housekeeping and controlling of dusts are necessary for safe handling of product. Pellets or beads may present a slipping hazard.

No other precautions other than clean, body-covering clothing should be needed for handling Ingeo biopolymers. Use gloves with insulation for thermal protection when exposure to the melt is localized. Workers should be protected from the possibility of contact with molten resin during fabrication.

Handling and fabrication of resins can result in the generation of vapors and dusts that may cause irritation to eyes and the upper respiratory tract. In dusty atmospheres, use an approved dust respirator.

Good general ventilation of the polymer processing area is recommended. At temperatures exceeding the polymer melt temperature (typically 175°C), polymer can release fumes, which may contain fragments of the polymer, creating a potential to irritate eyes and mucous membranes. Good general ventilation should be sufficient for most conditions. Local exhaust ventilation is recommended for melt operations. Use safety glasses (or goggles) to prevent exposure to particles, which could cause mechanical injury to the eye. If vapor exposure causes eye discomfort, improve localized fume exhausting methods or use a full-face respirator.

The primary thermal decomposition product of PLA is acetaldehyde, a material also produced during the thermal degradation of PET. Thermal decomposition products also include carbon monoxide and hexanal, all of which exist as gases at normal room conditions. These species are

highly flammable, easily ignited by spark or flame, and can also auto ignite. For polyesters such as PLA, thermal decomposition producing flammable vapors containing acetaldehyde and carbon monoxide can occur in almost any process equipment maintaining PLA at high temperature over longer residence times than typically experienced in extruders, fiber spinning lines, injection molding machines, accumulators, pipe lines and adapters. As a rough guideline based upon some practical experience, significant decomposition of PLA will occur if polymer residues are held at temperatures above the melting point for prolonged periods, e.g., in excess of 24 hours at 175°C, although this will vary significantly with temperature.

Combustibility

Ingeo biopolymers will burn. Clear to white smoke is produced when product burns. Toxic fumes are released under conditions of incomplete combustion. Do not permit dust to accumulate. Dust layers can be ignited by spontaneous combustion or other ignition sources. When suspended in air, dust can pose an explosion hazard. Firefighters should wear positive-pressure, self-contained breathing apparatuses and full protective equipment. Water or water fog is the preferred extinguishing medium. Foam, alcohol-resistant foam, carbon dioxide or dry chemicals may also be used. Soak thoroughly with water to cool and prevent re-ignition.

Disposal

DO NOT DUMP INTO ANY SEWERS, ON THE GROUND, OR INTO ANY BODY OF WATER. For unused or uncontaminated material, the preferred option is to recycle into the process otherwise, send to an incinerator or other thermal destruction device. For used or contaminated material, the disposal options remain the same, although additional evaluation is required. Disposal must be in compliance with Federal, State/Provincial, and local laws and regulations.

Environmental Concerns

Generally speaking, lost pellets, while undesirable, are benign in terms of their physical environmental impact, but if ingested by wildlife, they may mechanically cause adverse effects. Spills should be minimized, and they should be cleaned up when they happen. Plastics should not be discarded into the environment.

Product Stewardship

NatureWorks has a fundamental duty to all those that use our products, and for the environment in which we live. This duty is the basis for our Product Stewardship philosophy, by which we assess the health and

Reprocessing of Ingeo Biopolymer Edge and Skeleton Trim

environmental information on our products and their intended use, and then take appropriate steps to protect the environment and the health of our employees and the public.

Customer Notice

NatureWorks encourages its customers and potential users of its products to review their applications from the

standpoint of human health and environmental quality. To help ensure our products are not used in ways for which they were not intended or tested, our personnel will assist customers in dealing with ecological and product safety considerations. Your sales representative can arrange the proper contacts. NatureWorks literature should be consulted prior to the use of the company's products.

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