Processing biobased plastic

Solutions to three common challenges

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Processing biobased plastics: Solutions to three common challenges

At Wageningen University & Research (WUR) we are experts in biobased plastics and we have supported many businesses, start-ups as well as large and well-established organizations, in transitioning towards more sustainable plastic materials for their products. Biobased plastics are often a very good alternative to fossil-based plastics, but as is the case for any new material, they do come with their own processing challenges. These challenges can relate to material preparation, process optimization and property enhancement. In this whitepaper we explain the three most common challenges companies face when working with biobased plastics, and how to tackle them.

On the road towards a sustainable and circular future a special lane is reserved for plastics. Everyone knows that at present plastics contribute to climate change and pollution. We, therefore, need to move towards a more sustainable use of plastics. At the same time, the implications of this necessary transition for actual product design and manufacturing can be quite a journey.

Courses of action

There are a few routes to reduce the negative effects of our use of plastics, in which we elaborate in more detail in our 2024 position paper[1]. Let's look at the four main courses of action:

Reducing the amount of plastics

There are many applications where plastic products are used solely for convenience or where products are over dimensioned and include more plastic than necessary. Reducing the use or changing the design of these products will contribute to a reduction of the overall plastic impact.

Recycling

Effective recycling of products is essential to improve circularity and reduce the dependency on (fossil) feedstock. By designing products for optimal performance during use and end-of-life, more effective recycling with higher efficiencies can be realized.

Biobased plastics

Current fossil-based plastics make a large contribution to global CO_2 commissions and climate change. Replacing these plastics by biobased alternatives is an essential step if we want a fossil-free plastics industry in the future.

Biodegradable plastics

Both fossil-based and biobased plastics can be biodegradable, which means that they decompose and mineralize over a relatively short period in a specific environment, such as soil. Targeted application of biodegradable plastics can improve the circularity of compostable components (such as organic waste) and help mitigate plastic pollution.

1 www.wur.nl/position-paper-plastics-2024

Working with biobased plastics: what are the options?

Biobased plastics have a massive potential in replacing their fossil-based counterparts. We already see that toys and agricultural products are increasingly made of biobased plastics. But there are also hurdles to overcome when switching to biobased plastics. One of them can be mindset: companies want an exact copy of the original process and product. A little shift from product-thinking to usage-thinking often does the trick here. When redesigning from a sustainable usage point-of-view possibilities for biobased plastics will automatically pop up.

But, redesigning has its limits. Products need efficient manufacturing and fulfill the functionality for which they are designed, now and in the future. When working with biobased plastics such as PLA, there are a number of specific tricks to untap their full potential.

When collaborating with companies that make the switch to biobased plastics, we repeatedly see that they encounter hurdles that might seem insurmountable, but can be perfectly surpassed with just a few tweaks in the production process.
In this whitepaper we take you through the three stages of biobased plastic product manufacturing and we highlight which alterations you can make to make your process more successful:

1. **Material preparation**
   Biobased materials often attract and store more moisture. This can be an issue when processing at elevated temperatures and long residence times. Ensuring that the moisture level is sufficiently low by pre-drying the granulate before compounding or product processing can make all the difference.

2. **Process optimization**
   Each processing operation has its own set of requirements that a material needs to meet. Slight alterations in the material formulation (via polymer blending or additives) can have an enormous impact on the processability. Furthermore, it is important to realize that the guiding principles in fossil-based polymer processing do not always apply the same way to biobased plastics. As an example, the MFI listed on technical datasheets is considered to be the most important value to predict processability. However, a more detailed and realistic look into polymer flow will reveal that a one-on-one comparison based on MFI can lead to false conclusions, disappointment and unused opportunities for biobased plastics.

3. **Property enhancement**
   Biobased plastics are often considered unsuitable for use at high temperatures. However, various compounding and crystallization techniques exist to optimize their thermal performance and increase their application potential.

In this whitepaper we give tips and tricks to help engineers and R&D departments in their switch to biobased plastics. We focus on the most commonly used biobased polyester, PLA, and specific processing techniques (injection moulding and thermoforming). The knowledge presented here, however, can be translated to other materials and other conversion technologies. Of course we are always available to discuss with you the challenges you are facing. With the experience of our researchers combined with the availability of a wide array of lab and pilot equipment, characterization techniques and your own product and equipment knowledge, we are convinced that, together, we can make the switch and make biobased plastics work!

1. Material preparation

One of the most obvious differences between biobased and fossil-based plastics is that the majority of biobased plastics contain more oxygen atoms in their molecular structure. As a result biobased plastics (polyesters, starch and cellulose based plastics) are typically more sensitive to moisture (hygroscopic) than polyolefins (polypropylene and polyethylene). During processing, moisture can lead to unwanted side reactions like hydrolysis and degrade the plastic thereby severely reducing its functionality (for example strength, toughness, melt strength). Therefore it is of paramount importance to sufficiently dry biobased plastics and establish a sufficiently low moisture level before compounding or processing into products. This procedure aligns with the pre-drying of polyethylene terephthalate (PET) that is already an industrial custom. When this is taken into account, biobased plastics can be processed in similar manners as fossil-based polyolefins. In this section we show some experiments that demonstrate this concept.

To test the influence of moisture on the stability of polymers at elevated temperatures, thermal stability tests were performed at WUR. A polymer extrusion process was mimicked by a capillary rheometer (see page 14) applying constant pressure and temperature.

These tests allow for recording of the minimal pressure that is required to compress the polymer through a die. During the tests, the shear on the material was kept at a minimum level so that degradation effects of the material can solely be attributed to thermal degradation. Three different polymers were tested; one polyolefin which is polyethylene (PE), and two polyesters, more specifically, polylactic acid (PLA) and polybutylene succinate adipate (PBSA). Two tests were performed on each polymer, an experiment on the non-dried polymer, subjected to ambient conditions for at least 8 hours and an experiment on a polymer that was dried for at least 8 hours in a two-chamber dry-air desiccant dryer to achieve moisture contents below 250 ppm (which equals to 0.025 wt.% of the total mass). All polymers were exposed to an isothermal treatment at 190°C for 30 minutes. The materials were pre-heated for 5 minutes before the recording started. Results are normalized to the starting pressure of the dried samples. Results of both the undried and dried polymers are shown in Figure 1 and Figure 2 respectively.

Figure 1 shows that the initial moisture levels differ almost two orders of magnitude clearly demonstrating the difference in moisture absorption between polyolefins and polyesters, and how rapidly polyesters attract moisture. More importantly, the figure also clearly shows that the pressure of undried PE remains constant throughout the whole test which is an indication of its insensitivity to moisture under processing conditions. PLA and PBSA on the other hand start at a lower normalized pressure than PE which then gradually decreases over time. This demonstrates that hydrolysis already takes place during the 5 minute pre-heating step and that this degradation process continues as the test progresses. Figure 2 shows a near constant normalized pressure level for all polymers that were dried prior to thermal exposure. As all other conditions are kept constant, this shows that lowering the moisture concentration to levels below 250 ppm allows for prolonged thermal treatments for biobased polymers during processing operations such as compounding and injection moulding which will be covered in the upcoming sections.

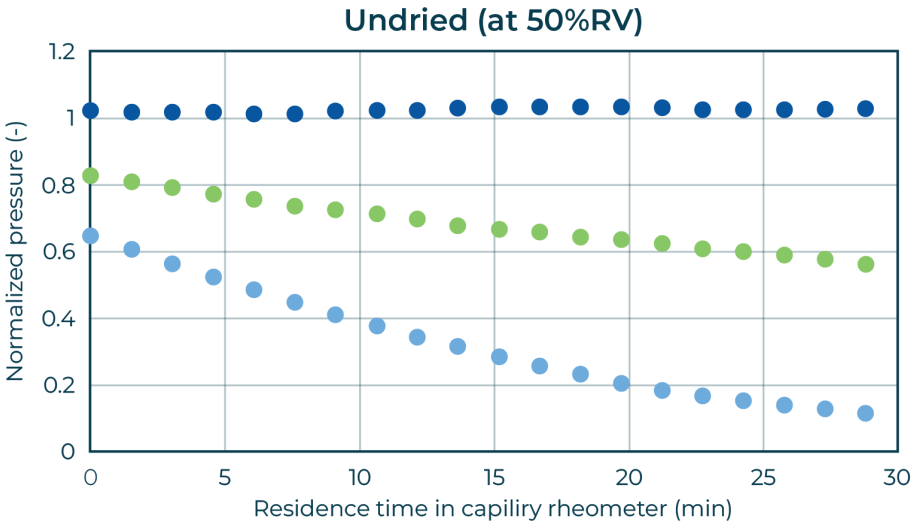

Figure 1: Normalized pressure over time measured by capillary rheometry of 3 non-dried polymers (PE, PLA and PBSA). Moisture content before testing in between brackets.

PE (70 ppm)

PLA (1227 ppm)

PBSA (1775 ppm)

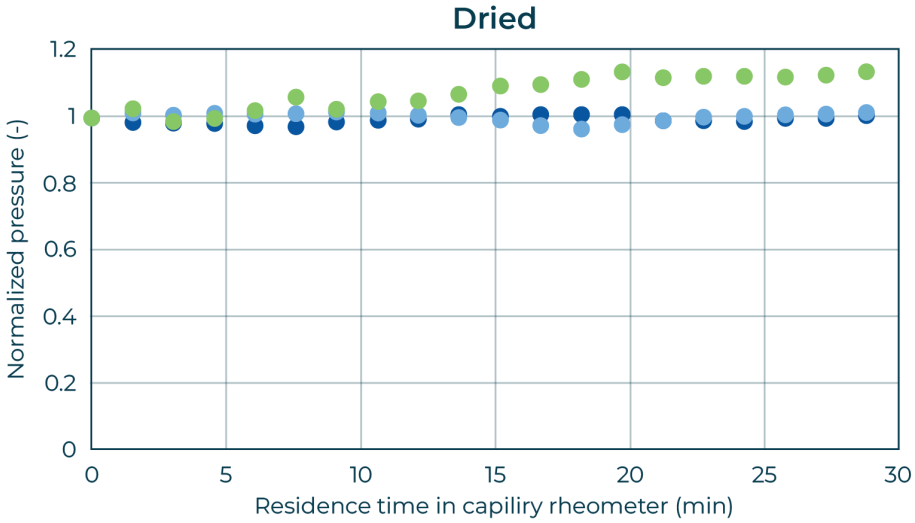

Figure 2: Normalized pressure over time measured by capillary rheometry of 3 dried polymers (PE, PLA and PBSA). Moisture content before testing in between brackets.

PE (0 ppm)

PLA (9 ppm)

PBSA (156 ppm)

2. Process optimization

Plastic processing is performed by applying temperature and shear to melt a thermoplastic polymer which allows for compounding (mixing with other polymers, additives or fillers) and product processing (moulding into specific shapes and geometries). To identify how biobased polymers can be optimally processed and which processes are suitable, thermal analysis is crucial (see page 14). Some thermal properties are intrinsic to the polymeric chain and therefore are automatically chosen when the polymer is selected. The good news: many properties can be improved by properly compounding the material by means of additives, fillers and nucleating agents. In addition, accurate knowledge of material transition temperatures enables targeted process modification to achieve optimized polymer processing. Two properties that highly influence the processing possibilities of polymers and plastics are crystallization behaviour and melt flow. For optimal processing of biobased polymers it is important to understand the basic theoretical aspects of both properties and how to use them to your advantage, which is covered in this section.

Nucleation agents widen processing window for thermoforming of biobased polymers

PLA, a semicrystalline polymer, starts melting at 145°C and can be subsequently melt-processed at temperatures within the range of 190°C to 210°C, provided an adequate drying process was employed prior to processing. In addition to the melting behaviour of a polymer, crystallization behaviour is another crucial thermal property that needs to be understood for optimal polymer processing in product development processes such as thermoforming or injection moulding. These properties can be measured by differential scanning calorimetry (DSC) (see box). By using the right combination of processing temperature and additives, the processing window of these processes can be modified and enlarged.

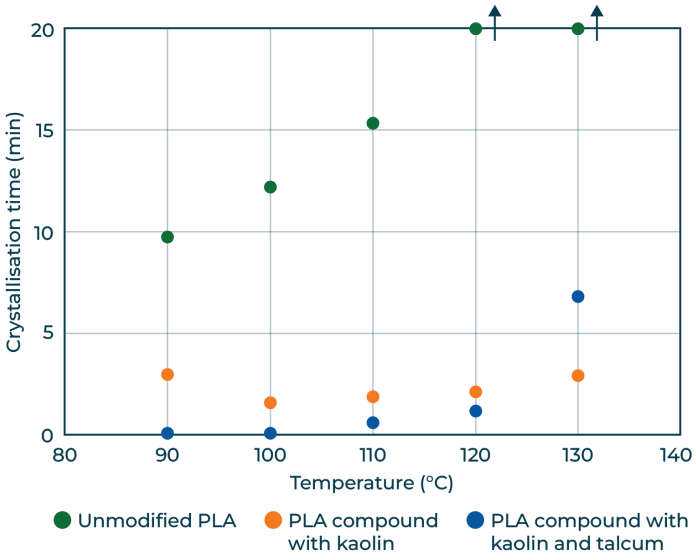

Figure 3: Crystallization times of unmodified PLA and two compounds with different levels of kaolin and/or talcum via isothermal differential scanning calorimetry. Crystallization temperatures of PLA at 120°C and 130°C are above 20 minutes.

Figure 3 shows the effect of the addition of nucleating agents such as kaolin and talcum particles on the crystallisation speed of PLA. These measurements are performed by applying a constant temperature and recording the energy that is required for this process in time. When crystals start forming, energy is released and therefore less energy is required to keep the polymer at its set temperature. The time that is required for this process to be completed is called the polymer crystallization time. This information can be used for the thermoforming of heat stable products such as coffee cups, which is usually performed between 90°C up to 130°C. In this process, timing of crystallisation is essential to obtain a stable process and a well-formed cup. A compound that needs more than a minute to start its crystallization process will not be suitable for thermoforming at commercial scale, since the moulding times will be too long. In addition, too fast crystallisation also poses risks for thermoforming processes as if the material is crystallised before stretching in the mould has taken place, which may result in rupturing of the walls and unstable processing. For thermoforming of PLA, the crystallization should not start during the pre-heating step and needs to be completed once your process is finalized.

Figure 3 shows how combinations of kaolin and talcum can help to reduce and optimize the crystallization time of PLA at different processing temperatures. While the optimum crystallization temperature of neat PLA typically lies around 90°C, the use of additives allows for both a shift of the optimal crystallisation temperature as well as a reduction of the overall crystallization time at all temperatures. For most (biobased) polymers, a delicate equilibrium needs to be found between the processing temperatures, the amount of additive needed and the resulting crystallisation behaviour. Ideally, crystallisation time is independent of the temperature as this will create a broad processing window which facilitates more facile processing. Furthermore it is noteworthy to address that crystallization can also be induced by mechanical forces. In thermoforming processes this can be observed during stretching of the material in the moulding process and this is called strain induced crystallization. In practice this can lead to even faster crystallization times than those recorded via DSC and this therefore needs to be taken into account when developing compounds.

Spiral Flow tests better suited than MFI to compare polymer flow for injection moulding

Traditionally, transparent thin-walled injection moulded products for (mainly) food packaging, are made of polypropylene (PP). Wall thicknesses of approximately 0.5 mm are easily achievable with such a material and there are few restrictions on the design (flow length, corners, transparency and/or colour). PP is a tough, flexible and strong material with a very favourable water barrier that prevents food products from either losing moisture or becoming soggy.

PLA is an interesting biobased alternative for injection moulded products as it combines a good mechanical performance with transparency. A clear disadvantage when processing PLA (or other transparent biobased plastics such as cellulose acetates) into thin-walled products via injection moulding, is that the flow properties during polymer processing follow a different trend than those of polyolefins. In the industry, the Melt Flow Index (MFI) is generally used as a benchmark to compare the flow behaviour of plastic grades. The rule of thumb for PP is that an MFI of 20 g/10 min or higher is suitable for thin-walled injection moulding applications. However, using this rule of thumb directly for PLA and other biobased polyesters would be comparing apples and pears. This is best illustrated by the relationship between viscosity (η) and shear rate (ẏ), which is as follows:

$$\eta = m\dot{y}^{n-1}$$

Here, m is the consistency constant and n is the power law coefficient. The value of n is material dependent and has a direct effect on the flow behaviour at different shear rates. This effect has been modelled for various polymers with different n-values and is shown in Figure 4a.

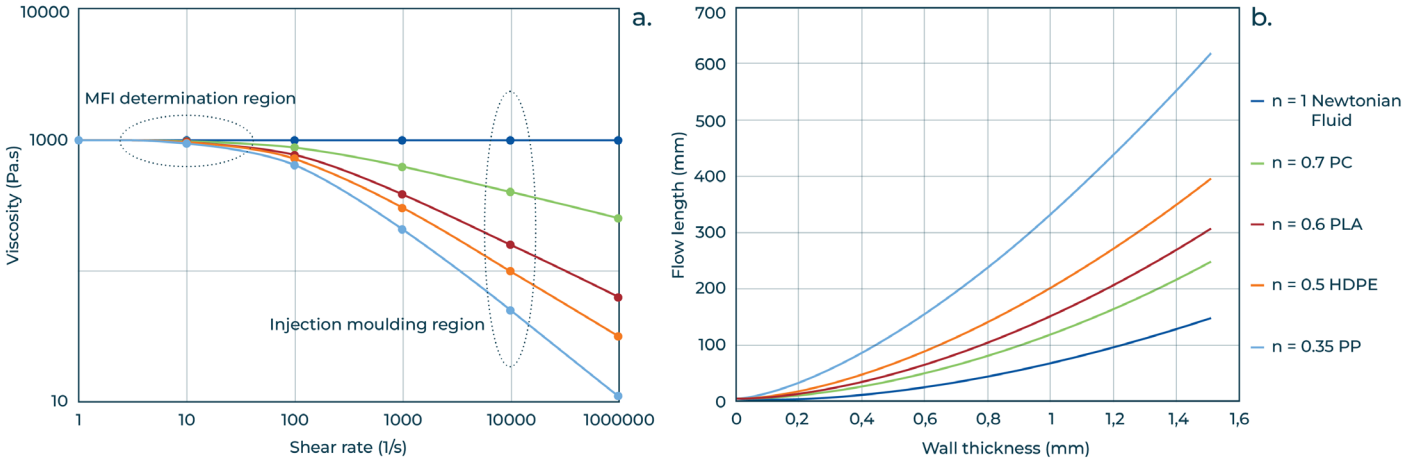

Figure 4: Modelled relation between viscosity and shear rate (a) and flow length and wall-thickness (b) for different polymers

This figure shows that the viscosity at the shear rate at which the MFI is determined (around 10 s-1 in Figure 4) is the same for PP and PLA, resulting in comparable MFI values. However, the shear rate during an injection moulding process is two to three orders of magnitude higher (around 10000 s-1). Figure 4a also shows that the viscosity-shear rate dependence of PP as compared to PLA is very different . This means that the viscous flow of a PP with a comparable MFI as PLA during the injection moulding process is much higher and can therefore more easily fill the mould of a thin-walled product. This is further illustrated by the relationship between the flow length (L) and the wall thickness (h):

$$L = Ch\left[\frac{h^2}{\alpha}\left(\frac{\Delta P}{k}\right)^{1/n}\right]^{n/1(1+n)}$$

Here α is the thermal diffusivity, P is the pressure drop and C and k are constants. This relationship is modelled in Figure 4b. This figure shows that, for a product with a wall thickness of 1 mm, PP has a flow length that is twice as high as PLA. The same mould can therefore be filled much more easily with PP than with PLA, while the MFI is comparable. It can be concluded from these calculations that instead of MFI measurements a different characterization method is necessary for an application oriented comparison of the flow behaviour of polyolefins and (biobased) polyesters. A suitable measuring method for this is using a Spiral Flow injection mould (shown in Figure 5a). With this equipment, a polymer is injected by an injection moulding machine into a spiral-shaped mould with an open end. The distance that the polymer covers in this mould can therefore be taken as a measure for the flow length. Because the polymer is exposed to (for injection moulding) relevant shear stresses via this method, the values obtained are more representative for the comparison of the flow ability of individual polymers under processing conditions than MFI values.

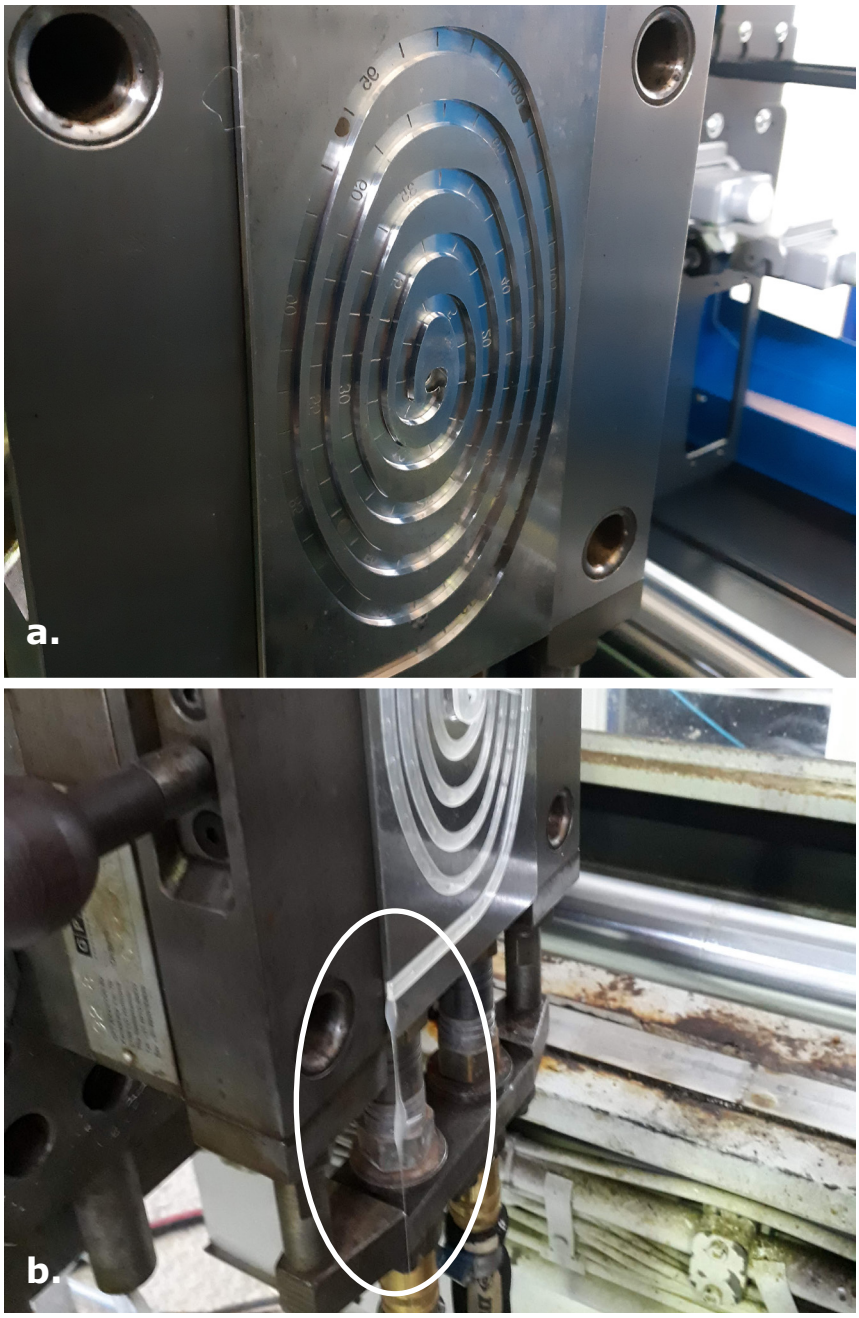

Figure 5: Spiral flow experimental mould setup at WFBR that is used for determination of flow length injection moulding processes (a) and experimental results that demonstrates the improved flow length of a modified PLA formulation (b)

To illustrate the difference between the determination of the MFI and the Spiral Flow length, Figure 7 shows both values for PP and a range of modified and unmodified biobased polyester materials. It shows that the unmodified biobased polyester materials all have very different MFI values, but that the Spiral Flow length for all these materials is approximately between 40 and 50 cm. The tested PP grade, on the other hand, has an MFI that lies within the same range while the spiral flow length is more than twice as long. This thus shows that the determination of the MFI is not sufficient to give a judgment on the applicability of a polymer in (thin-walled) injection moulding applications.

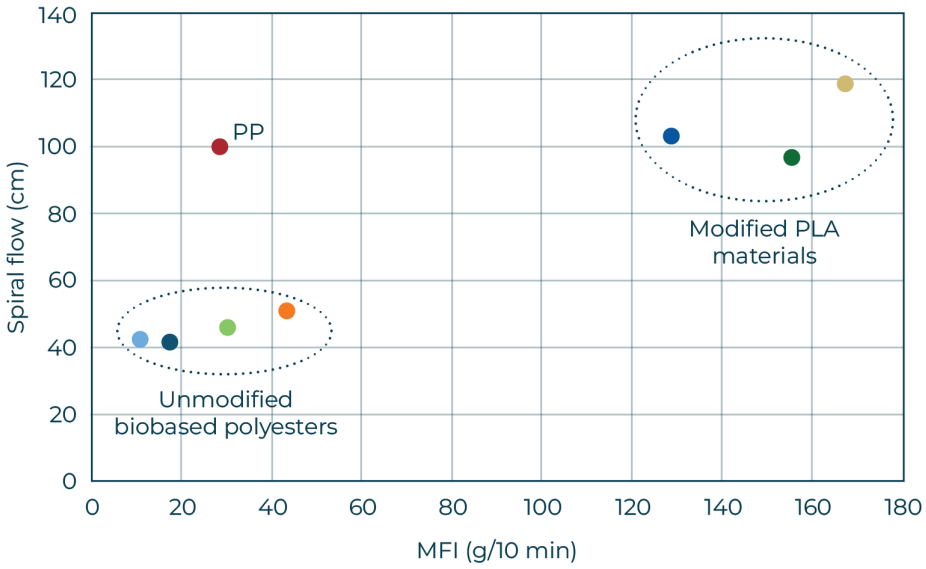

Figure 6: Overview of the melt flow index and spiral flow values for PP, unmodified biobased polyesters and a number of PLA materials modified through research at WFBR.

As part of a recently finished public private partnership research project in which we collaborated with injection moulding companies and biopolymer producers, WUR aimed to increase the flow performance of PLA polymers to make it suitable for the injection moulding of thin-walled transparent products. Using the compounding facilities at WUR, new PLA based formulations were prepared that were subsequently characterized via MFI and spiral flow. Figure 6 shows that these new formulations have higher MFI values and spiral flow lengths that in some cases even exceed the values measured for PP. For some formulations it is even expected to find higher values as the spiral flow mould reached its maximum capacity, as can be seen in Figure 5b.

In conclusion, these results demonstrate that when one wants to start with the injection moulding (or other plastic processing operations) of biobased plastics, a biobased polymer should not be evaluated on the MFI value alone. It is always recommended to perform additional characterization in order to better understand the material characteristics at the shear rate regime at which your process is taking place. Measuring the spiral flow value is a facile approach to obtain this information for injection moulding processes. For other processing methods (e.g. cast extrusion, thermoforming or film blowing) capillary rheometry can give even more valuable insights.

Better understanding of the flow characteristics of biobased polymers, and not blindly following MFI specifications and measurements, will open the door to development of biobased plastic products that were originally deemed impossible to produce.

3. Property enhancement

A common complaint when using biobased plastics such as PLA is their dimensional stability and mechanical properties at high temperatures (above 60°C). This is often the case when biobased plastics are intended to replace fossil-based plastics without any alterations to the processing. However, via targeted material formulation it is possible to enhance the high temperature performance of biobased plastics (such as the heat stable PLA based coffee cups that were addressed earlier). The most important polymer property in this respect is the heat deflection temperature (HDT) (see box).

A well-known method to enhance the shape stability of polymers at high temperatures (and therefore obtain higher HDT values) is the use of mineral fillers. Commonly used mineral fillers are kaolin, chalk, talcum and other minerals. They can be found in different particle sizes and shapes and can also have a huge impact on the stiffness, strength and toughness of biobased plastic and at the same time can enhance crystallization.

An example of PLA compounds enhanced by the use of mineral fillers is shown from the DMTA (see box) results in Figure 7. This graph provides insight into the stiffness (=E modulus) of a material at a certain temperature. From this figure it can be observed that mineral fillers have induced crystallization and stiffness which is reflected by the elevated plateau modulus at temperatures above 90°C and results in a higher heat deflection temperatures of the material. By adding mineral fillers, HDT values of more than 100°C can easily be obtained for PLA compounds.

Another way of improving the thermal performance of biobased polymers such as PLA, is via miscible polymer blends. The creation of a miscible blend implies that the polymer chains are effectively mixed with each other (like two different types of spaghetti that are cooked together in the same pot) creating a polymer material with modified thermal properties. These blends show different thermal properties to that of an immiscible polymer blend which will be governed by the polymer that has the lowest thermal stability. Figure 7 shows the DMTA graphs of neat PLA and two miscible blends. The miscible PLA blends show a drop in E-modulus at a higher temperature (enhanced Tg and recrystallization temperature) which is a result of the modified thermal behaviour of these materials. In addition, blending contributes to increase other properties such as melt strength and, to improve flexibility and impact performance. By combining polymer crystallization, blending and functional fillers, polymer products can be developed that function in the same way as their fossil-based counterparts.

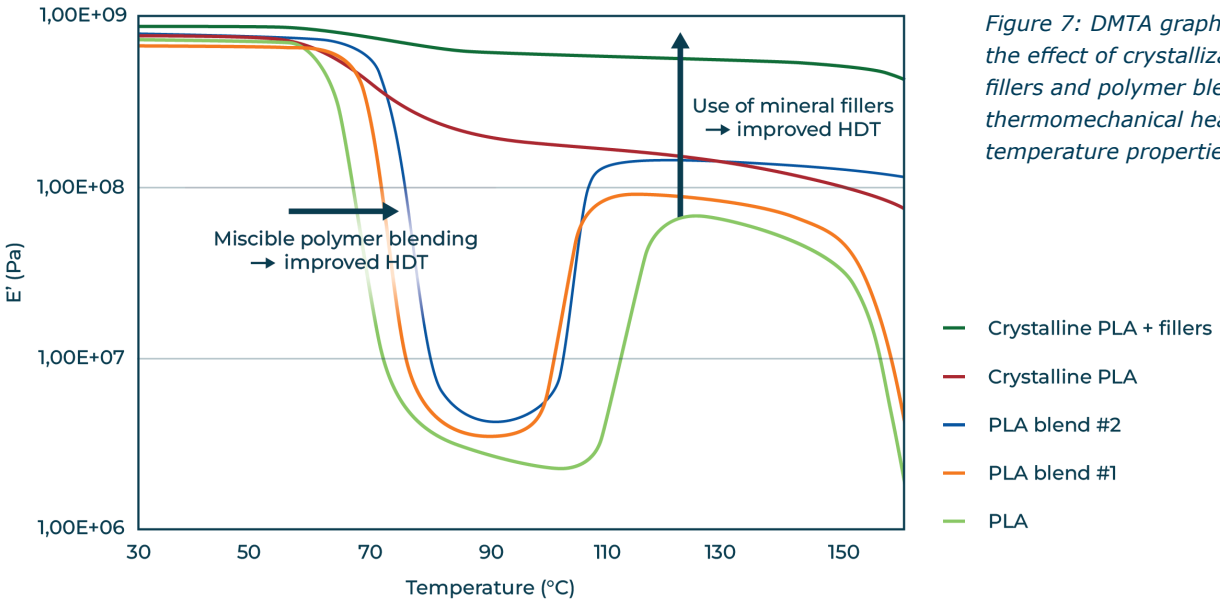

Figure 7: DMTA graphs that show the effect of crystallization, mineral fillers and polymer blending on the thermomechanical heat deflection temperature properties of PLA

Evaluating thermomechanical properties of biobased polymers

Questions such as "What is the processing window of this polymer? What is the thermal stability of these materials during processing? Can I use biobased plastics at high temperatures and what do I need to do to achieve this?" can be answered by measuring different thermomechanical properties. Flow and thermal analysis of polymers (available in data sheets and processing guides) give us information about the processing and performing properties of the materials. Here we explain the basics of five of the most frequently employed thermomechanical characterization techniques for (biobased) polymers.



Figure 9: pictures of different thermal analytical techniques. From left to right: DSC, DMTA and HDT.

Differential Scanning Calorimetry

Differential Scanning Calorimetry (DSC) is a thermal characterization technique that measures the difference in heat flow between a polymer sample and a reference as a function of temperature. This allows for the determination of various material properties such as melting (Tm), crystallization (Tc) and glass transition temperatures (Tg). These values give a first estimation of the processing conditions and the potential use temperatures of the polymers.

A DSC measurement only requires a small amount of material (~10-20 mg) in the form of powder or pellet which is placed in a sealed metal cup prior for placement in the DSC apparatus. Based on the information one wants to obtain from the experiment a heating program is selected. This can either be heating of the sample under a constant rate (e.g. heating from -50°C to 200°C at a rate of 10°C per minute) which is useful for determination of melting and glass transition temperatures. Alternatively, a constant temperature can be applied for a set amount of time (e.g. a constant temperature of 180°C for 2 hours). This is called an isothermal treatment and is useful to gain insight in crystallization behavior during specific processing operations.

Heat Deflection Temperature

The Heat Deflection Temperature (HDT), also known as Deflection Temperature Under Load (DTUL), measures the temperature at which a material deforms a specific amount (typically 0.25 mm) under a given load. This test indicates how well a material resists deformation at elevated temperatures. Essentially, it's a measure of a material's stiffness at high temperatures. HDT is measured according to ISO-75 or ASTM D648.

Samples are placed in a liquid medium with a good heat conductivity (e.g. an oil bath). Under application of the fixed stress, the temperature is gradually increased until the targeted deformation is obtained. The temperature at which this occurs is defined at the HDT of the polymer. Different variations of the method exist which depend on the selected stress. Polymers and plastics are most often tested via HDT-A (stiff polymers, applied stress of 1.80 MPa) and HDT-B (flexible polymers, applied stress of 0.45 MPa). Specimens subjected to HDT tests are prepared according to specific guidelines, for example via injection- or compression moulding. It is important to note that sample preparation may influence the outcome of the HDT measurement, for example via crystallization.

Melt Flow Index

The Melt Flow Index (MFI)—also called Melt Flow Rate (MFR)—is a measure of the ease of flow of a thermoplastic polymer in the molten state. It gives a quick idea of a plastic's melt viscosity under specified conditions and is important to select a specific grade based for a specific processing method. The MFI is measured under Standardized Conditions (ASTM D1238 or ISO 1133) and typically listed in material datasheets.

In a melt flow indexer, a sample of polymer (in pellet or powder form) is loaded into a barrel. The chamber is then heated to a specific temperature (commonly between 190 and 230 °C) and a piston with a standard weight (commonly 2.16 kg but also other weights are reported) is placed on top of the molten plastic. The exact test conditions vary depending on the polymer type and are commonly chosen to reflect the processing temperature of the specific polymer. Under the pressure of the weight, the polymer melt will flow through a small die and once a steady-state flow is achieved, the extrudate is collected. The amount (by mass, in grams) of polymer that flows out in 10 minutes is weighed. For example if 8 grams of PLA flows through the die in 10 minutes the MFI is 8 g/10 min. Determining the MFI allows for a rough estimation of the viscosity under process conditions and is suitable to compare different grades of the same polymer. However, comparing the MFI of different types of polymers (for example PLA with PP) might lead to large misconceptions as is further explained in this whitepaper.

Dynamic Mechanical Thermal Analysis

Dynamic Mechanical Thermal Analysis (DTMA) is a technique used to characterize the viscoelastic properties of materials, particularly polymers, as they are subjected to oscillating stress or strain. It essentially measures how materials respond to periodic forces, providing insights into their stiffness (denoted as storage modulus, E' or G'), damping characteristics (denoted as loss modulus, E'' or G''), and how these properties change with temperature, time, or frequency. Analysis via DMTA can broaden the understanding of a given HDT value and contribute to successful product development.

A DMTA experiment is performed by placing a polymer sample between two clamps which are then placed in a heating chamber. The sample is then subjected to a specific oscillation program (displacement and frequency) and temperature program (either fixed heating rate or isothermal treatment). The DMTA will then measure both the storage modulus and the loss modulus over time which results in material specific DMTA curves. For both amorphous and semi-crystalline materials, a decrease of the modulus is observed when the material softens, around the Tg. Semi-crystalline polymers also show a second more profound decrease of storage modulus at the melting point. Furthermore, crystallization can be observed in a DMTA curve by an increase in the storage modulus after reaching the Tg. The shape and dimensions of the curve can be used to derive an indication of the crystallization speed. Semicrystalline materials with a low crystallization rate, such as PLA, are often amorphous after processing and can recover part of its original modulus after reaching their crystallization temperature. The speed of crystallization can be influenced by the types of additives used and the selected PLA grade.

Capillary rheometry

Capillary rheometry is a technique to characterize the flow behavior of polymers under high shear rates, mimicking processing conditions like extrusion and injection moulding. Capillary rheometry and Melt Flow Index (MFI) are both methods for assessing the flow behavior of polymer melts, but they differ significantly in their approach and the information they provide. MFI is a simpler, single-point measurement, while capillary rheometry offers a more comprehensive analysis across a range of shear rates and temperatures. As such, the latter offers a more elaborate method to compare the processing behaviour of different types of polymers. A capillary rheometry measurement involves forcing a molten polymer through a capillary (a small tube) under controlled pressure and measuring the resulting flow rate or pressure drop. This data provides insights into the material's viscosity and other rheological properties, and allows for the construction of viscosity-shear rate relations (see Figure 4) which are crucial for understanding how it will behave during manufacturing processes.

Small adjustments lead to a wide array of biobased possibilities

Biobased plastics, just as every other material, have their own unique functional and processing properties. Biobased plastics can give rise to unique properties of its own such as biodegradability during industrial composting (for PLA) and even natural environments such as soil and water (polyhydroxy alkanoates (PHA) being a prime example). However, things that work for fossil-based plastics cannot always be copied directly to biobased plastics.

In this whitepaper we've shown that with just a few adjustments a whole world of opportunities opens up. Whether it's for packaging, agriculture or even the building and automotive industry, biobased plastics can play a leading role in the transition to more sustainable production, use and end-of-life of products. At WUR we have already helped many companies making this transition by designing new materials and implement these into industrial processes enabling the development of more sustainable plastic products. A selection of these products, all with their own unique challenges, is shown in Figure 8.

Figure 8: Selection of biobased plastic products developed by WFBR in collaboration with industrial partners. From left to right, bottom to top: foamed eggbox, thin-walled injection moulded cup, dog chew products, grass turf netting, biobased foamed box, biodegradable plant pots and thermally stable coffee cups.

Not all biobased plastics will require all adjustments and processing tricks addressed in this paper. To fulfill the specific need for your product, often only one modification will already solve most of the issues. Whatever works best for your product and processing equipment is dependent on a thorough analysis of the final product requirements, desired processing route and the preferred feedstock process. With our processing expertise combined with our thermal and mechanical characterization methods, we are able to support you in finding the most (cost)effective route to using biobased plastic for your products. Of course we already have a lot of knowledge that we can apply to your specific case, but as researchers we also like a good challenge. Therefore, please feel free to reach out with your biobased plastics question, we'd love to help out.

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