Biopolymers – Sustainability for the Automotive Value-added Chain

© Röchling Automotive

AUTHORS

Fabrizio Barillari
is Product Manager of
Global Bio-Plastics and Battery
Solutions in the Propulsion Product
Group at Röchling Automotive
in Leifers (Italy).

Fabrizio Chini
is Manager Advanced
Development Propulsion at
Röchling Automotive
in Leifers (Italy).

Plastics are quintessential for the automotive industry as a readily available and easy-to-handle material, but consumers are increasingly confronted with images of mountains of rubbish and vast islands of floating plastic. Bioplastics could potentially be part of the solution to the problems associated with conventional plastic. Röchling Automotive has now developed the biopolymer Röchling-BioBoom and optimized it for use in the automotive industry.

MOTIVATION

The innovation pressure in the automotive industry has always been strong. But for some time now, the focus has no longer exclusively been on driving pleasure and safety. Concepts aimed at improving sustainability and carbon footprint are now, at least, as important to manufacturers and suppliers as traditional performance metrics and comfort features.

Plastics in particular are coming under scrutiny. Despite that plastic components in modern vehicles are subject to a clearly regulated material identification guidelines, distinctions among the different types of plastic are rarely discussed. Even when all the relevant recycling guidelines are observed, plastic's carbon footprint still leaves much to be desired. Vehicle manufacturers and suppliers are therefore required to intensively seek alternatives and new solutions.

The Coronavirus pandemic, which broke out in early 2020, has exposed further need for innovation. Governments and regulatory authorities have responded with numerous measures aimed at mitigating the economic impact on the automotive industry. But these aid packages have come with some clear demands: Any purchase incentives and state aid must go hand in hand with not only the promotion of electrification but also the continued reduction of emissions.

TRANSFORMING CELLULOSE INTO A MANUFACTURING MATERIAL

There are now numerous solutions available to reduce exhaust emissions. But the production processes behind these solutions rarely come in for scrutiny, even despite the fact that vehicle manufacture offers tremendous savings potential. For Röchling Automotive, bioplastics represent the next step toward resource-conserving production. The focus here is on CO₂ emissions generated during production. In collaboration with partners, a biopolymer that will help to cut emissions dramatically was developed. Compared with fossil-fuel-based polymers, bioplastics reduce production emissions by as much as 90 %. **FIGURE 1** shows the emissions generated during the production of different polymers.

The inspiration behind the development of the biopolymer Röchling-BioBoom was to use highly available, reasonably priced and, above all, renewable raw materials. It was also important that these materials could be processed as efficiently as possible to create a thermoplastic material. Finally,

a polymer derived from lactic acid and polylactides (PLA) [1] was chosen. Other monomers are more expensive to produce and the raw materials harder to obtain.

The lactic acid for biopolymers is obtained by fermenting sugar, a raw material that is readily available in huge quantities almost anywhere. Depending on the region, corn (USA), starch (Asia) or sugar cane (rest of the world) play a vital role. Sugar can also be converted to the finished material with a high degree of efficiency: For 1 kg of PLA, only around 1.6 kg of fermentable sugar as a raw material is required [2]. This means that PLA are biopolymers that can be produced in a highly energy- and resource-conserving process. **FIGURE 2** illustrates the process from the raw material to the finished PLA. The first step in the production process is to ferment the raw sugar or starch. The subsequent distillation process produces lactic acid (monomer), which is then converted to PLA (polymer).

COMPOUNDING AS A KEY PROCESSING STEP

PLA-based biopolymers are actually nothing new. Back in the 1930s, Wallace Hume Carothers developed a process for synthesizing lactic acid polymers. But despite being patented, the plastic never achieved commercial success – unlike nylon, his other invention. Today, PLA is mainly used as packaging for perishable foodstuffs and in the medical industry. While the thermoplasticity of the material makes it ideal for use in injection molding, polylactides by their very nature are comparatively sensitive to traditional polymers. This is one of

the reasons why the material has never gained a foothold in the automotive industry [3].

To make this plastic more appealing to automotive engineers, some of the shortcomings of standard PLA had to be resolved first [4]. This required intensive research, which initially focused on the further development of the polymer. The primary shortcomings were as follows:

- low softening temperature
- brittleness
- poor chemical resistance
- poor aging resistance at high temperatures
- poor workability [5].

To resolve these issues, the monomers and the polymerization process were improved. In this process, compounding also plays a key role. Through the careful selection of various additives, it is possible to enhance the many positive qualities of the raw plastic in order to make PLA appealing for the automotive industry. This can be done using varying quantities of talc, glass and wood fibers.

The material properties can thus be matched exactly to the respective application. The rigidity was improved (Young's modulus of elasticity of 3400 MPa in the variant containing 10 % talc), which helps to reduce the wall thickness of certain components. In subsequent development stages, it has been possible to prevent moisture absorption by the PLA and reduce shrinkage. This results in less deformation overall and improved dimensional stability. When it comes to dimensional stability under heat, PLA from Röchling Automotive performs much better at 100 °C than standard PLA at 54 °C (Heat Deflection Temperature HDT A

FIGURE 1 CO₂ footprint of various raw materials (© European Bioplastics | nova Institute)

with 1.80 MPa). With a cold impact resistance of 4.5 to 10 kJ/m², the PLA material offers much better performance when compared to PA6 GF30, for example. Due to the natural color of the PLA material it is also easy to dye for mold-in-color applications.

REDUCTION OF CO₂

TABLE 1 shows a model calculation using the example of a mid-range vehicle. When all the necessary plastics such as Polyphthalamides (PP), Polyamides (PA), Acrylonitrile Butadiene Styrene (ABS) and ABS Polycarbonates (ABS-PC) are replaced by their equivalent bio-variants, this reduces emissions of CO₂ in production by an average of around 480 kg [6]. This highlights the potential of PLA in the automotive industry.

The emissions generated during production are rarely analyzed in detail at individual component level. **FIGURE 3** shows the materials used in a modern sedan, with plastics accounting for around 11 % of the materials. In **FIGURE 3**, those materials are highlighted that can be replaced by biopolymers. The amount of plastic may appear low at first glance. But given a total of 67.1 million cars and 24.6 million commercial vehicles manu-

factured globally in 2019 [7], it is clear that even much smaller savings would have a huge impact. And besides, the trend toward replacing more and more metallic parts with plastic parts shows no signs of slowing. Not only can this help to reduce weight, but the design freedom afforded by plastic helps to make engines even more efficient [8].

TABLE 2 shows the three currently available bioplastic variants. These enable numerous application areas to be covered, each with very different requirements. **TABLE 3** shows an air filter box that meets all the necessary technical requirements but has been optimized for Röchling's biopolymer. All biopolymer products can be used in the engine compartment and are resistant to coolant, cleaning agents, battery acid, engine oil and fuel. They even have the same surface finishes as conventional plastics – even in the interior.

The components for the material are subject to continuous quality control, from raw material production to the finished product. Continuous testing is also performed by a number of independent organizations. The PLA is, among other things, Reach-compliant and has successfully completed a Life Cycle Assessment (LCA).

FUTURE OF BIOPLASTICS

Modern-day PLA may already be very robust and have a wide range of applications, but ongoing research and optimization are vital. For example, it is around 20 % denser than PP and 3 to 5 % denser than PA. Production costs, too, are still higher than those for comparable standard grades, even if they are much lower than for any other bio-based polymer.

In the future, PLA will be developed into a high-performance material and potentially part of a whole family of polymers. Since it is a polyester, it can be modified, refined and mixed with a whole range of different substances and materials. This means that it will be possible in the future to replace even plastic components exposed to very high temperatures inside vehicles by biovariants. What makes PLA from Röchling special is that the raw materials are not sourced from the food industry. Sugar is used that is suitable only for industrial processing. The same material is used in the paper and construction industry, for example. This rules out any negative impact on global food supply [1]. In addition, technology for producing the required monomer from waste products is already being developed. This will provide yet another way of drastically reducing environmental impact.

SUMMARY

Röchling Automotive is launching a PLA that is suitable for use in the automotive industry. The raw material for this plastic is cellulose. Not only is this raw material readily available, but the

Vehicle mass	1700 kg
Total mass: PP, PA, ABS-PC, ABS	135 kg
CO ₂ emission using petrochemical plastic	535 kg
CO ₂ emission using PLA	65 kg
Benefit	87 %

TABLE 1 CO₂ savings potential when suitable plastics are replaced by biopolymers
(© Röchling Automotive)

- Plastics → ABS
- Plastics → ABS-PC
- Plastics → PA
- Plastics → PP
- Plastics → PUR
- Elastomers → EPDM
- Fluids → Fluids
- Glass → Glass
- Insulation → Carpets/sound dampening
- Metal/other → Metal/elastomers
- Metal/other → Metal/plastic
- Metal → Alloy
- Metal → Steel
- Metal → Steel/alloy
- Other → Electric motor
- Other → Electric components
- Other → Several components
- Other → Wire harness

FIGURE 3 Material composition in a mid-range car (those materials are highlighted which can be replaced by biopolymers (© Röchling Automotive I A2Mac1)

production process is comparatively climate-friendly. Production emissions can be improved significantly. The production of biopolymers reduces CO₂ emissions by up to 90 % in comparison to the production of conventional plastics. So for a mid-range car, this equates to savings of around 480 kg of CO₂.

The biopolymer Röchling-BioBoom is currently available in three variants: talc-filled, glass-fiber-reinforced, and in a combination of the previous two variants. Customized compounding processes open up a broad range of applications for the bioplastic in the automotive industry. Components made from this material have no limitations in terms of resistance and aesthetics. Numerous certificates validate its benefits over other types of plastic – especially when it comes to environmental sustainability. In the near future, Röchling Automotive's entire product portfolio will be available in a bioplastic variant.

REFERENCES

[1] Vink, E. T. H.; Davies, S.; Kolstad, J. J.: The eco-profile for current Ingeo polylactide production. In: Industrial Biotechnology 6 (2010), No. 4, pp. 212–224

[2] Lovett, J.; de Bie, F.; Visser, D.: Sustainable sourcing of feedstocks for bioplastics. Clarifying sustainability aspects around feedstock use for the production of bioplastics. Total Corbion PLA, Whitepaper (Version 1.2), 2017

[3] Koltzenburg, S.; Maskos, M.; Nuyken, O.: Polymere: Synthese, Eigenschaften und Anwendungen. Berlin: Springer, 2014

[4] Maier, R.-D.; Schiller, M.: Handbuch Kunststoff Additive. München: Carl Hanser Verlag, 2016

[5] Notta-Cuvier, D.; Odent, J.; Delille, R.; Murariu, M.; Lauro, F.; Raquez, J. M.; Bennani, B.; Dubois, P.: Tailoring polylactide (PLA) properties for auto-

motive applications: Effect of addition of designed additives on main mechanical properties. In: Polymer Testing 36 (June 2014), pp. 1–9

[6] Morão, A.; de Bie, F.: Life Cycle Impact Assessment of Polylactic Acid (PLA) Produced from Sugar-cane in Thailand. In: Journal of Polymers and the Environment 27 (2019), pp. 2523–2539

[7] N. N.: OICA: Production Statistics. Online: <http://www.oica.net/category/production-statistics>, access: July 22, 2020

[8] Ratiu, S. A.; Zgaverdea, A. C.: The Potential of Using Bio Plastic Materials in Automotive Applications. In: Materiale Plastice 56 (2019), No. 4, pp. 901–909

Name	PLA 67C1	PLA 80VT4	PLA 71FV6
Modulus of bending	3500 MPa	5300 MPa	6100 MPa
Young's modulus	3200 MPa	5200 MPa	6200 MPa
Tensile strength at break	40 MPa	60 MPa	60 MPa
Elongation at yield	3 %	2 %	2.4 %
Elongation at break	> 20 %	2 %	2.4 %
Charpy notches at 23 °C	23 kJ/m ²	7 kJ/m ²	10 kJ/m ²
Charpy notches at -30 °C	7.5 kJ/m ²	6.2 kJ/m ²	10 kJ/m ²
HDT/A 1.80 MPa	65 °C	92 °C	125 °C
Density	1.26 g/cm ³	1.37 g/cm ³	1.43 g/cm ³

TABLE 2 The biopolymer Röchling-BioBoom is currently available in three variants (© Röchling Automotive)

Material	Young's modulus [MPa]	Density [g/cm ³]	CO ₂ [g/granulate g]	CO ₂ [g/injection]	CO ₂ [g/part]
PA6 GF30	7500	1.37	9.1	450	8097
RA PLA GF30	7380	1.43	0.5	390	852
					– 90 %

TABLE 3 CO₂ savings potential of around 90% when PLA is used for an air filter box (© Röchling Automotive)

Air filter box
V = 921.9 cm³
Injection molding