SPECIAL:
Bioplastics

Teamwork for Better Performance

Additive Combination Improves Properties and Processability of Biodegradable Polymers

Biodegradable polyesters are difficult to process. However, the right additive can enhance their processing and material properties. Even better results are likely to be obtained by a combination of two such additives: blending a pair of them into polyesters leads to much stronger effects.

The additive Vinnex 2525 increases the melt strength of PLA, helping to produce a robust blown film extrusion process and constant film thickness

The ever-growing problem of plastic waste is boosting interest in biodegradable polymers. After all, biodegradation as an end-of-life option can make a meaningful contribution to a circular economy for plastics [1, 2]. European Bioplastics, an industry association, expects global production capacity for such polymers, and especially biodegradable polyesters, to expand markedly over the next several years [3]. Unfortunately, biodegradable polyesters are still limited in their potential applications. The reason is often a failure to deliver the property profile that compounders, plastics converters and end users have come to expect from conventional thermoplastics. In addition, they are difficult to process. The task of compounding is to offset both these weaknesses.

Polymeric organic additives based on polyvinyl acetate have a proven track record when it comes to modifying biodegradable polyesters. The company

Wacker, for example, supplies these under the Vinnex brand, with polarities tuned precisely to biodegradable polyesters. The resulting compatibility makes them highly effective [4]. Also well-known within the plastics industry is Genioplast Pellet, a universal range of silicone-based additives for thermoplastics compounding that is also supplied by the chemical group [5]. These act as processing aids by reducing friction and thereby enhancing the polymer's end properties.

Tests on PLA and PBS Biodegradable Polyesters

Applications engineers from Wacker set out to study how a combination of both additive systems might affect the processing and material properties of biodegradable polyesters. The study focused on polylactic acid (PLA) and chalk-filled polybutylene succinate (PBS) which made it possible to look into the additives' effects on filled and unfilled polymer systems.

Two commercial standard grades of the two polyesters served as polymer matrixes, namely Ingeo Biopolymer 4043 D (PLA) from Nature Works and BioPBS FZ 91 PM (PBS) from PTT MCC Biochem. Both are semi-crystalline, made from renewable raw materials and have been optimized by the manufacturers for the production of plastic film. PLA is known to be a rigid, high-tensile material which is extremely brittle and fragile and has poor thermal stability [6–8]. Its high melt viscosity and low melt strength make melt processing difficult. It also suffers from a low rate of crystallization [9], with post-crystallization being the reason that PLA articles typically become progressively more brittle.

By contrast, PBS has mechanical properties akin to those of polyolefins [10]. Unlike PLA, it is a flexible, tough material of high tensile strength. By virtue of its comparatively high degree of crystallinity [10], PBS has high heat resistance [11, 12]. However, it also has a tendency to post-crystallize on account of its low rate of crystallization [10, 13, 14].

The Four Additives Studied

The study was conducted on the additives Vinnex 2504, Vinnex 2525, Genioplast Pellet S and Genioplast Pellet P Plus. Vinnex 2504, a vinyl acetate-ethylene copolymer, was chosen to represent the powder grades from the Vinnex range. It is primarily used by compounders to incorporate soft segments into a polymer matrix. Vinnex 2525, a resin available in pellet form, is a polyvinyl acetate homopolymer. When used as a processing aid, it improves flowability, increases the melt strength and reduces post-crystallization by semi-crystalline polyesters. Genioplast Pellet P plus is approved for food contact. Genioplast Pellet S is primarily aimed at technical applications. There are no significant differences in the properties of these two grades. Therefore, no further distinction will be made between them in the following.

The biopolyesters used in the screening were compounded on a Berstorff ZE-25 twin-screw extruder from Krauss-Maffei. The compounds were then pelletized and processed into test specimens – injection-molded test panels, flow spirals, blown film and compression molded panels – which were tested and assessed in accordance with industry standards. The non-additive biodegradable polyesters served as references. They were processed in the same way as the others. The modified compounds were produced »

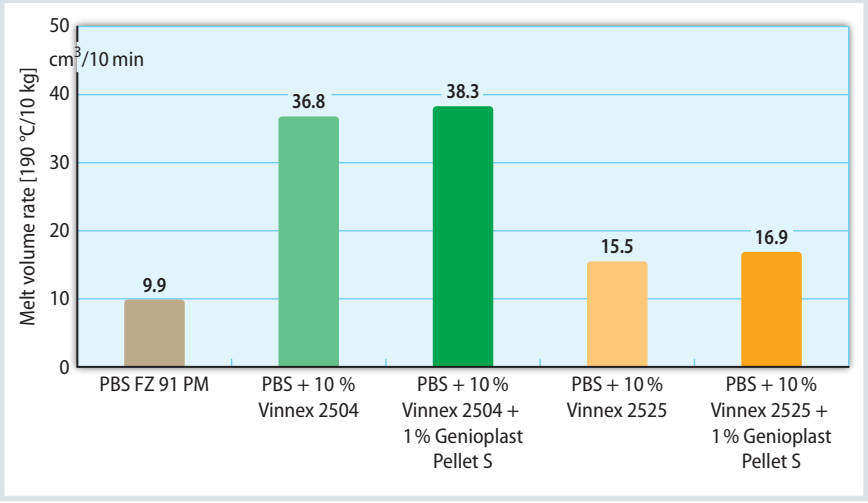

Fig. 1. The combination of Vinnex and Genioplast Pellet increases the melt volume-flow rate of filled PBS in particular Source: Wacker; graphic: © Hanser

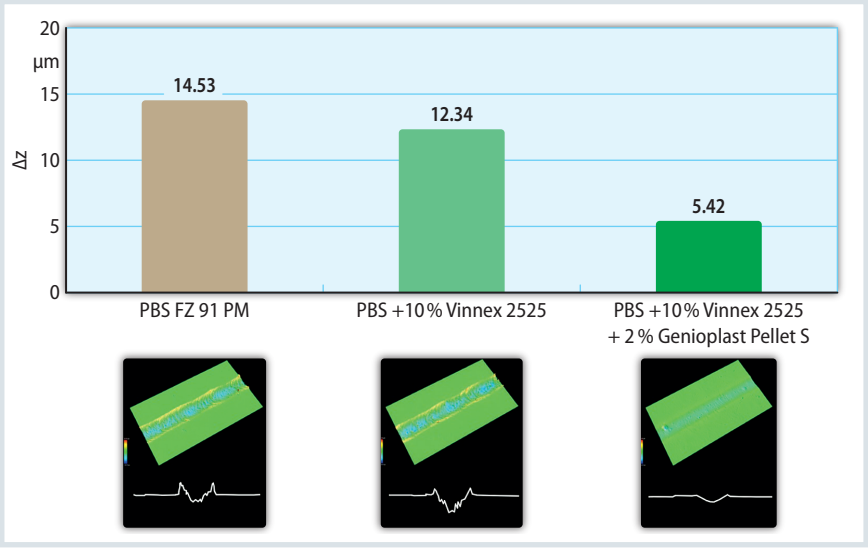

Fig. 2. Examination of scratches in test panels of chalk-filled PBS (scratch depth Δz in the chart; scratch profiles in the photos): in the compound containing added Vinnex and Genioplast (right), the scratch turns out to be much shallower and less rough than in the compound containing no added Vinnex 2525 (left) and the compound containing added Vinnex 2525 only (center)

Source: Wacker; graphic: © Hanser

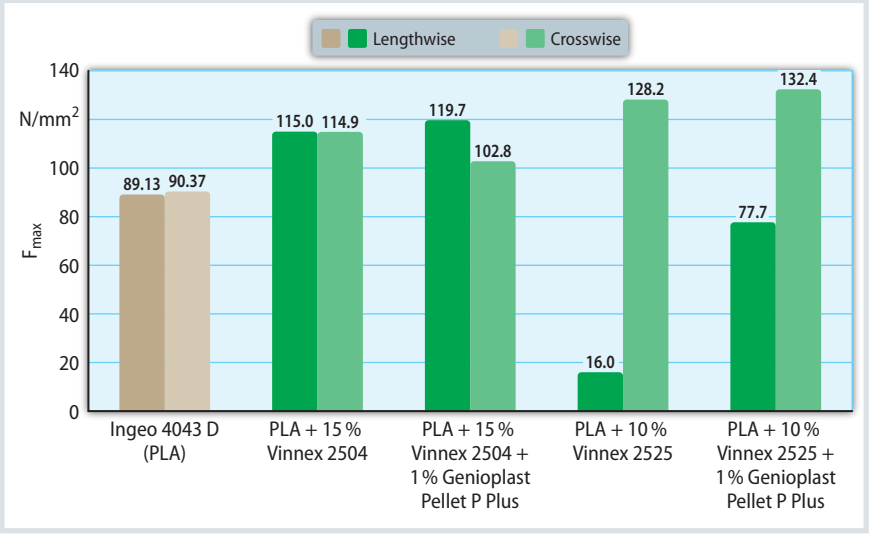

Fig. 3. The combination of Vinnex 2504 and Genioplast Pellet increases the tear strength of PLA blown film in both the longitudinal and transverse directions. The combination of Vinnex 2525 and Genioplast Pellet only increases the transverse direction of the film Source: Wacker; graphic: © Hanser

by incorporating either a Vinnex grade on its own or a combination of a Vinnex grade and Genioplast Pellet into the polyesters. The PLA-based compounds were always unfilled, whereas the PBS-based counterparts contained 15 % chalk.

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Silicone Additives Lower Electricity Costs in Processing

In the compounding of filled PBS, addition of friction-lowering silicone pellets reduces the torque demand on the extruder during production of the compounds and leads to lower power consumption. The observed effects may be small, but they can yield appreciable cost savings in large lines.

The flow behavior of the melted compounds was tested using the melt volume-flow rate specified in ISO 1133 and a spiral flow test. In the latter test, the combination of the additive systems makes for a longer flow path. The additive combination generally leads to a substantial increase in the melt volume-flow rate, with combinations with Vinnex 2504 proving especially beneficial to the melt flow (**Fig. 1**).

Superior Surface Finish for Biodegradable Polyesters

When used in tandem with Vinnex, the chief role of Genioplast Pellet is to influence the material properties. It exerts a particularly great influence on the surface finish of the plastics. The surface roughness of the polyesters is not enhanced by Vinnex on its own, for example. Genioplast needs to be added to lessen the effects of friction. As a result, a coefficient of sliding friction of less than 0.3 can be achieved in the case of both PLA and chalk-filled PBS – this level is required by plastics converters for many applications. In the case of PLA, this level is achieved with a combination of Vinnex 2504 and Genioplast Pellet. In the case of filled PBS, it can be achieved with a blend of Vinnex 2525 and Genioplast.

The reduced surface friction imbues the biopolyesters with greater scratch and abrasion resistance. This is confirmed by visual assessment of abrasion resistance in the Crockmeter test and gravimetric determination of abrasion by the abrasive disk method according to DIN 53754. The friction-reducing effect is especially clear from a confocal microscopic examination of scratch marks produced on smooth injection-molded test panels using a scratch hardness tester (model: 530 P-I; manufacturer: Erichsen): with Genioplast Pellet, the scratches are shallower, the scratch profile becomes flatter and the surface inside the scratch is less rough. This effect is very pronounced at an additive application rate of 2 % (**Fig. 2**).

Improvements in Longitudinal or Transverse Direction

With regard to the mechanical properties, the study revealed a mixed picture. Combinations of the two additive types yielded improvements in a number of cases but not in others. The effects depend on the grade of Vinnex employed and vary with the polyester matrix. For example, the combination of the two additives produces a higher elongation at break in the case of chalk-filled PBS, but leaves unfilled PLA virtually unchanged.

As expected, Vinnex 2504 acts as an impact modifier for PLA, whereas Vinnex 2525 does not. A combination of Vinnex 2504 and Genioplast Pellet increases the tear strength of PLA blown film in both longitudinal and transverse directions. Combination with Vinnex 2525, on the other hand, leads to a marked improvement in the transverse direction (**Fig. 3**). The tear strength of the films was determined in the Graves angle test (DIN 53515). The mechanical properties improve, without any impairment of heat resistance. This was confirmed by a determination of the Vicat softening points (**Fig. 4**) as per ISO 306 (methods A and B).

Summary

The studies show that Vinnex and Genioplast Pellet are complementary in their effects and exert a greater influence when employed in combination rather than separately. Both the processing properties and the material properties of the biodegradable polyesters benefit substantially from the additive combination. Such a combination proves especially advantageous in the production of blown film. Here, Vinnex enhances the flowability and melt strength, while Genioplast Pellet increases the take-off and winding speed by lowering surface friction.

In general, the role played by Vinnex in the additive combination is chiefly to influence the behavior of the polymer melt and thus the processing properties, with the choice of grade in many cases exerting a major influence on the resultant effect. When used alongside Vinnex, Genioplast Pellet mainly modifies the material properties. It enhances the surface properties of biodegradable polyesters, without coating the surface in a liquid lubricant film. In general, this additive has a more pronounced effect on filled than on unfilled polymer systems.

Combining both additive systems can help unlock further applications for biodegradable polyesters. The combination greatly mitigates those processing and performance disadvantages – relative to conventional thermoplastics – which have limited the use of these polymers to date. In the usual application quantities and, depending on the system in question, the two additives do not lead to any impairment of degradability, for example, of PBS, PLA or thermoplastic starch and combinations of these biodegradable polymers. ■

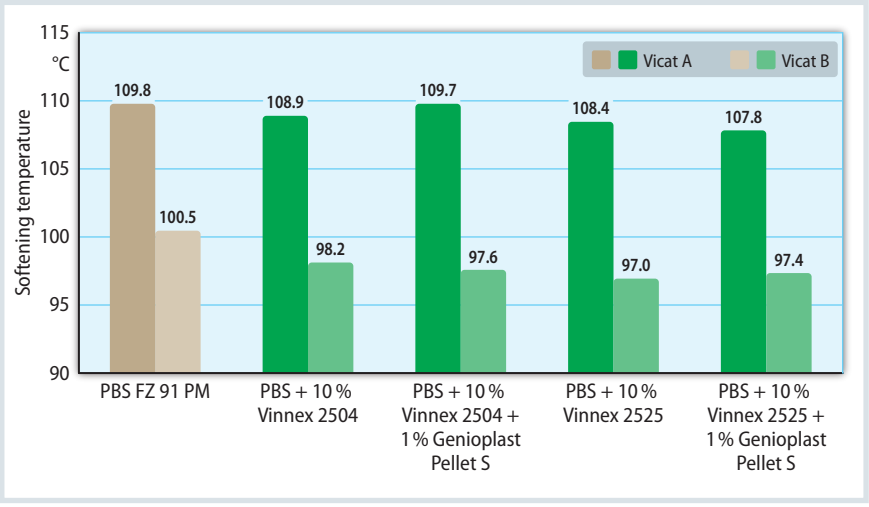

Fig. 4. The additive combinations lower the softening temperature of chalk-filled PBS only marginally Source: Wacker; graphic: © Hanser