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"Influence of polymer extrusion conditions
on mechanical properties and gaseous thermal degradation products"

This study covers the processing of low-density polyethylene (LDPE), the most popular and still one of the cheapest synthetic materials, and polylactide (PLA), which is currently the most common biodegradable material.

The aim of the study was to optimize extrusion conditions for LDPE and PLA, which will in the future, reduce the generation of large amounts of production waste during processing processes. The study assessed the influence of the parameters of the extrusion process in a co-rotating twin-screw extruder, including the extrusion temperature, the rotational speed of the screws and the screw configuration of the extruder's plasticizing system, on the structure and properties of both polymer materials.

To assess processing parameters and thermo-oxidative-mechanical degradation, mechanical analyzes were used: Charpy impact strength, static stretching and three-point bending. Thermal measurements were performed using the differential scanning calorimetry (DSC) technique. The effect of processing parameters on rheological properties was assessed using mass melt flow rate (MFR) and by molecular weight estimation determined by gel permeation chromatography (GPC).

So far, there are few reports on gas products generated during processing processes. Meanwhile, they are a valuable source of information about the processes occurring in the material inside the device, which may provide, among others, details about material degradation. The study attempted to examine the gaseous products released during the extrusion process. The analysis was performed using a gas chromatograph with a mass spectrometer (GC/MS).

The performed analyses of mechanical properties did not show the influence of the applied variable extrusion process parameters on the obtained LDPE results, the exception was the screw configuration of the plasticizing system. There was no influence of extrusion parameters on thermal properties. The analysis of the mass melt flow rate (MFR) was of great importance, as it turned out to be crucial in the analyses of the solid extrusion product of LDPE samples. An increase in this parameter was observed, mainly due to the screw configuration of the plasticizing system, but also the extrusion temperature and rotational speed of the screws.

In turn, in the case of tests carried out on the solid extrusion product of PLA, the influence of mainly the screw configuration on the obtained values of mechanical properties was also observed. No changes were observed during thermal analysis of PLA samples. Most samples had a narrow range of values, only for melting enthalpy measurements significant differences up to 21 J/g were observed. Similarly to the LDPE samples, the most reliable results were observed for rheological analyses. A significant increase in the mass melt flow rate (MFR) was observed, while the average molecular weight (Mw) decreased. Both parameters were influenced by all applied extrusion process variables.

As a result of the analysis of gaseous products formed during the extrusion of LDPE and PLA using GC/MS, alkanes, alkenes, ketones, alcohols, polyhydric alcohols, carboxylic acids and cyclic compounds were identified. Hydrocarbons above C_{10} dominated. A characteristic compound during extrusion of PLA was 3,6-dimethyl-1,4-dioxane-2,5-dione, i.e. lactide. The analysis provided information about the influence of the applied extrusion process parameters on the complexity of the obtained compounds. Characteristic compounds for LDPE that indicate degradation during extrusion are alcohols with a single hydroxyl group and, to a lesser extent, diols, branched compounds, as well as alkanes with a chain length above C_{13}. However, for PLA samples, 1,3-dioxane, 1,3-dioxolane, 2,2-dimethyl-1,3-dioxolane were observed, which indicated degradation during extrusion. In both materials, a greater number of signals were observed in the chromatograms as the extrusion parameters increased.

The obtained data verified the influence of individual extrusion process parameters on the properties of LDPE and PLA. It has been shown that the causes of large amounts of post-production waste and degradation of polymer materials are most often poorly selected extrusion conditions. In order to avoid or minimize material degradation during processing, first of all, attention should be paid to the configuration of the extruder's plasticizing system and the extrusion temperature. With rising prices of raw materials, it is particularly important to ensure that the amount of post-production waste, which cannot always be reused, is kept to a minimum, especially in the case of biodegradable plastics.

10.06.2024 r.

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