Production technology of biodegradable polymer composites containing carbon nanotubes and graphene with increased strength

ABSTRACT

The increased in recent years interest on environmentally friendly technologies has prompted industry and scientists to replace traditional polymers obtained from petroleum with their equivalents derived from renewable sources. Biopolymers currently are only a small part of the market. The most common biopolymer, with a wide range of uses, is polylactide. However, further expansion of the applications of this polymer requires its properties modification.

Carbon nanomaterials such as graphene and carbon nanotubes, thanks to their excellent thermal and electrical properties and, in particular, strength unmatched among other available materials, can be used as a filler for polymer nanocomposites.

One of the methods of obtaining composites is mixing nanocarbon additives with the polymer in the melt phase. This method is environmentally friendly, economically justified and commonly used in industry. It uses internal mixers or extruders. Obtaining high-quality products containing graphene or carbon nanotubes using this method requires solving problems related to the properties of nanocarbons (low bulk density, high agglomeration capacity) and inappropriate processing equipment for materials with nanometric dimensions.

The development of composites based on polylactide with fillers in the form of graphene or carbon nanotubes, characterized by improved mechanical properties compared to unmodified polylactide, using the melt mixing method was the aim of the research and analyses presented in the dissertation.

The solution proposed in this work is to divide the production process into two stages: obtaining a highly filled polylactide masterbatches with carbon nanofiller, characterized by good filler dispersion and solving the problem of dosing nanocarbons to processing devices, and then obtaining the target composites containing up to 2 wt.% of graphene or carbon nanotubes.

Using a internal mixer, the influence of the mixing parameters, filler grain size and the type of polylactide used on the properties of the obtained concentrates, was investigated. Graphite flakes of various sizes were used as carbon filler. The knowledge and experience gained during this work allowed attempts to obtain masterbatches with carbon nanomaterials. The obtained masterbatches containing 25% by weight of graphene, multi- or single-walled carbon nanotubes were characterized by very good dispersion, without visible agglomerates of the filler.

After successfully completing the work using the internal mixer, steps were taken to develop a method for continuous production of nanocomposites. The use of extruders required the selection of the best configuration of the plasticizing system allowing for obtaining masterbatches and then composites with the best possible distribution

of nanocarbons. Three screw configuration of the co-rotating twin-screw extruder were tested, differing in their ability to mix and grind raw materials and the risk of polylactide degradation. The single-screw and twin-screw extrusion processes were compared and the effect of multiple extrusion on the properties of composites, including filler dispersion, was examined.

Presented research and analyses allowed the development a technology for obtaining composites characterized by an increase in tensile strength and Young's modulus by 10 and 15%, respectively, in the case of a material containing multi-walled carbon nanotubes in the amount of 1% by weight and 10 and 19% in the case of using 0.5% by weight of graphene additive. Without compromising the other properties of composite materials.

An additional benefit of the activities carried out is the expansion of knowledge on the effect of processing parameters and the geometry of the extruder's plasticizing system on the properties of carbon nanocomposites.