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Reprocessed polylactide: Studies of thermo-oxidative decomposition

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ABSTRACT

The combustion process of virgin and reprocessed polylactide (PLA) was simulated by multi-rate linear non-isothermal thermogravimetric experiments under O_2. A complete methodology that accounted on the thermal stability and emission of gases was thoroughly developed. A new model, Thermal Decomposition Behavior, and novel parameters, the Zero-Decomposition Temperatures, were used to test the thermal stability of the materials under any linear heating rate. The release of gases was monitored by Evolved Gas Analysis with in-line FT-IR analysis. In addition, a kinetic analysis methodology that accounted for variable activation parameters showed that the decomposition process could be driven by the formation of bubbles in the melt. It was found that the combustion technologies for virgin PLA could be transferred for the energetic valorization of its recyclates. Combustion was pointed out as appropriate for the energetic valorization of PLA submitted to more than three successive reprocessing cycles.

1. Introduction

The research in the packaging industry within a framework of sustainable development is focused on the use of bio-based materials which accomplish the benefit of coming from renewable resources, and being biodegradable once discarded, within a rational time. In this sense, polylactide (PLA) is an aliphatic polyester that can be obtained from agricultural resources, and reintroduced into the carbon cycle after being used. The increasing know-how in the technology of production of PLA (Gupta and Kumar, 2007) enhances its performance as suitable candidate for replacing commodities at the packaging sector.

Despite the potential of PLA for being treated by biological valorization in composting facilities, the foreseeable high amount of plastic waste invites to diversify and combine the available technologies of valorization. Among current procedures, material valorization by mechanical recycling is widely established (Vilaplana and Karlsson, 2008). It mainly consists in recovery, washing, drying, shredding and processing by means of extrusion or injection. The inherent thermo–mechanical degradation may modify the polymeric structure (Badia et al., 2009, 2011a) and consequently affect the thermal, rheological and mechanical properties (Strömberg and Karlsson, 2009; Badia et al., 2012a), thus reducing the performance rates of recycled goods.

A viable solution to manage bio-based recycled plastics waste, when no better performance can be guaranteed, could be the application of thermally-induced valorization technologies, such as pyrolysis and combustion (Al-Salem et al., 2009).

The application of these thermal operations must be carefully handled by technologists during the design of energetic valorization facilities, taking into account the knowledge of the thermal stability and the detection of emitted gases. As well, the characterization of the decomposition kinetics should be considered.

Thermogravimetric analysis (TGA) is a widely used technique to assess the thermal stability and reaction kinetics of biomass (Barneto et al., 2010) and bio-based polymers (Carrasco et al., 2010). On the other hand, detection techniques such as Fourier transform-infrared spectroscopy (FT-IR) are widely used hyphenated to TGA for gas detection (Materazzi and Vecchio, 2010).

The majority of current studies on the combustion behavior of PLA are reported from the point of view of the flame retardancy (Bourbigot and Fontaine, 2010), but not approached from the point of view of the management of their wastes. The aim of this work was thus to assess the behavior of mechanically-recycled polylactide submitted to a combustion process, with the purpose of assuring the performance of energetic valorization processes as a contribution for further plastic waste management solutions.

2. Experimental procedure

2.1. Reprocessing simulation and sample preparation

Polylactide (PLA) 2002D is a thermo-forming grade PLA obtained from NatureWorks LLC (Minnetonka, MN) in the form of pellets. Prior to processing, virgin PLA (VPLA) pellets were dried during 2 h at 80 °C in a dehumidifier Conair Micro-D FCO 1500/3

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