



Complex modification effect of linseed cake as an agricultural waste filler used in high density polyethylene composites

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Abstract

Linseed cake (LC) is a by-product of agricultural industry which does not have any large-scale industrial applications. The possibilities of its utilization as filler with plasticizing ability for high density polyethylene (HDPE)-based composites have been investigated. Composites containing 5, 10, 20 and 30 wt% of the waste filler have been prepared using a melt mixing method. The influence of the LC on the mechanical and thermomechanical properties of the composites, as well as their water absorption and morphology, have been evaluated by the following methods: static tensile test, impact strength assessment using Dynstat method, hardness measurements, differential scanning calorimetry, dynamic mechanical thermal analysis, scanning electron microscopy observations, measurements of Vicat's softening temperature and water uptake test. Application of different measuring techniques allows for describing complex modification effects of the composites' properties changes induced by the presence of lignocellulosic filler with high oil content. The results of the study proved a pronounced influence of LC on high density polyethylene-based composites, especially a plasticizing effect of crude linseed oil contained by the waste filler particles. LC also has been assumed to affect the polymeric matrix crystallization process. It was found that complex modification of polyethylene results from simultaneously occurring different phenomena including: plasticization of the HDPE by linseed oil, improved crystallinity of the semicrystalline matrix, presence of the rigid lignocellulosic particles dispersed in polymer and accumulation of the oil in the interfacial regions.

Keywords Polyethylene · Natural composites · Waste management · Natural filler · Mechanical properties

Introduction

At the beginning of the XXI century, in the era of global warming and rapidly growing world's population, terms of circular economy and sustainability became crucial concerns for business, governments and researchers alike. The idea of circular economy, which embraces the balance between environment and economy, can be defined as “a system in which resource input and waste, emission, and energy

leakage are minimized by slowing, closing and narrowing material and energy loops” [1]. One of the ways to achieve this goal is to treat waste products coming from one process as valuable resources for the industry.

Another highly appreciated method to decrease the environmental impact of manufactured goods is to substitute conventional, non-renewable materials with their sustainable counterparts [2]. In the polymer processing industry, natural-based fillers are a frequently used alternative for conventional reinforcing and modifying agents because of their low carbon footprint, environmental friendliness and satisfactory properties [3, 4]. Nevertheless, planting and processing plants to obtain fillers for polymeric composites is also energy, water and resources-consuming [5]. Ecologically wise, it can be more advantageous to incorporate a plant-based waste product into a polymeric matrix and thus create an environmentally friendly composite.

Linseed (*Linum usitatissimum*) is a versatile plant cultivated around the world, mostly for fibers and oil-rich seeds. Linseed cake (LC) is a by-product of the linseed oil

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