European Polymer Journal 49 (2013) 1215–1233

Contents lists available at SciVerse ScienceDirect

European Polymer Journal

journal homepage: www.elsevier.com/locate/europolj

Feature Article

Compatibilization in bio-based and biodegradable polymer blends

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ARTICLE INFO

Article history:
Received 6 August 2012
Received in revised form 12 January 2013
Accepted 23 January 2013
Available online 9 February 2013

Keywords:
Biopolymers
Degradation
Blends
Impact resistance
Compatibilization
Reactive processing

ABSTRACT

The production and use of biopolymers increases continuously with a very high rate thus all information on these materials is very important. This feature article first defines the terms used in the area then discusses the distinction between degradation and biodegradation as well as their importance for practice. Biopolymers often have inferior properties compared to commodity polymers. Modification is a way to improve properties and achieve property combinations required for specific applications. One technique is blending which allows considerable improvement in the impact resistance of brittle polymers. However, further study is needed on the miscibility–structure–property relationships of these materials to utilize all potentials of the approach. The chemical structure of biopolymers opens up possibilities to their reactive modification. Copolymerization, grafting, trans-esterification, the use of reactive coupling agents have all been utilized with success to achieve polymers and blends with improved properties. Several examples are shown for the various approaches and their outcome. Biopolymers and their blends are applied successfully in several areas from agriculture to consumer goods, packaging and automotive.

Contents

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http://dx.doi.org/10.1016/j.eurpolymj.2013.01.019

1. Introduction

Following a mild decline as a result of the 2008 financial crisis, the production of plastics increases continuously, and in 2010, it reached the value of 265 Mt worldwide and 57 Mt in Europe [1]. In the same year, European plastics converters processed 46.4 million tons into products, approximately 40% of these being short service life applications, mainly for packaging purposes, resulting in 24.7 Mt of post-consumer waste [1]. Not surprisingly, the related environmental concerns have also increased in recent decades strengthening efforts to reduce the ecological effect of polymeric materials. In 2009, for the first time in Europe, the amount of plastics waste utilized exceeded the amount going into landfills. This favorable tendency continued in the next year as well with 6 Mt being recycled into new products, 8.3 Mt converted into energy and 10.4 Mt deposited in landfills [1]. For the treatment of certain waste streams, however, composting proved to be the most advantageous method [2], thus biodegradable and compostable polymers have also found application in various fields.

Although the time-scale of the process is often disputed, a consensus has been reached regarding the prospective depletion of petrochemical feedstock [3,4]. Similarly to other areas, the plastics industry started looking for alternative sources of raw materials in the last few decades, and considerable interest is shown in natural, renewable solutions. Bio-based polymers, i.e. polymers produced from renewable feedstock, biomass in general, might replace fossil sources and also have considerable environmental benefits like decreased carbon-dioxide emission.

Although the term ''biopolymer'' is used in several different ways depending on the application area, the generally accepted definition covers polymers that belong to the abovementioned categories, i.e. are either renewable-based, biodegradable or both. The global production capacity of these materials shows dynamic growth [5,6]. Both environmental concerns and market trends stand behind this tendency, since with increasing oil prices, conventional polymers will become more and more expensive. Consumer expectations cannot be neglected either, since many customers take into consideration the environmental effect of the products they buy. The ratio of biodegradable polymers compared to non-degradable bio-based types has also increased recently [5]. One of the reasons leading to this trend might be the considerable changes in legislation related to compostable products in recent years. Long-term predictions, however, forecast the dominance of non-degradable biopolymers [5].

The relative importance of bio-based and biodegradable grades in polymer production might further increase in the future as production technology improves and becomes more cost-effective. According to various estimates, only less than 4% of world biomass is utilized by humanity, the majority for food-related, while only a fraction for chemical applications and plastics production [6] indicating that tremendous room exists for the further increase of capacity yet.

Biopolymers have much potential and several advantages, but they possess some drawbacks as well. In spite of increasing production capacity, they are still quite expensive compared to commodity polymers and their properties are also often inferior, or at least do not correspond to the expectation of converters or users. Although natural polymers are available in large quantities and are also cheap, their properties are even farther from those of commodity plastics. As a consequence, biopolymers must be often modified to meet the expectations of the market.

To utilize their potentials and penetrate new markets, the performance of biopolymers must be increased considerably. Consequently, the modification of these materials is in the focus of scientific research. In contrast to the development of novel polymeric materials and new polymerization routes, blending is a relatively cheap and fast method to tailor the properties of plastics. As a result, this approach may play a crucial role in increasing the competitiveness of biopolymers. In our present paper, we attempt to give a summary of recent trends and achievements in the field of biopolymer blends, with particular focus on miscibility–compatibility–property relationships.

2. Definitions, classification

As mentioned in the introductory part, the term ''biopolymer'' refers to polymers that are bio-based, biodegradable or both. Before discussing the various aspects of biopolymer blends, we define these categories in this section to help the understanding of subsequent discussion.

2.1. Biopolymers

Replacement of fossil feedstocks with renewable ones is one of the main endeavors of modern plastics industry. Natural polymers represent a specific class of materials among polymers based on natural resources. These occur in nature as macromolecules and we also include the physically or chemically modified natural polymers into this