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ORIGINAL PAPER

Improvements in morphology, mechanical and thermal properties of films produced by reactive blending of poly(lactic acid)/natural rubber latex with dicumyl peroxide

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Abstract The effect of dicumyl peroxide (DCP) as a free-radical cross-linking agent on the morphology, thermal and mechanical properties, and gas permeation of blown films prepared by reactive blending of poly(lactic acid) (PLA) and natural rubber latex was investigated. In comparison to the blown films without DCP, SEM micrographs revealed that the amount of debonded rubber domains from the cryo-fractured surface reduced considerably. This was when DCP at 0.003 phr was incorporated and the free radicals from thermally decomposed DCP reacted with PLA and NR chains, generating PLA–NR copolymers and cross-linked NR as confirmed by FTIR spectra. These PLA–NR copolymers acted as compatibilizers, which increased the strength at the PLA/NR interfaces, leading to the improvement in tensile strength, elongation at break, tensile toughness, impact strength, and tear strength. Although DCP did not influence the cold crystallization of PLA, TGA thermograms showed that thermal stability slightly increased owing to the enhanced interfacial adhesion. However, the addition of DCP at 0.005 and 0.010 phr resulted in a high content of cross-linked NR gel, by consuming the free radicals instead in copolymer formation. Therefore, the compatibilization efficiency was significantly reduced and the mechanical properties of reactive PLA/NR blown films finally dropped. Also, this poor interfacial adhesion facilitated the micro-void formation at the polymer–rubber interface as a result of mechanical stretching upon the film blowing process, increasing the permeation of water vapor and oxygen molecules. According to our study, it can be summarized that to optimize the morphology, mechanical properties, and gas permeation property of the free radical-assisted reactive blends, it is of great concern to carefully balance reactive compatibilizer formation and gel formation by adjusting the DCP content.

Keywords Poly(lactic acid) · Natural rubber · Reactive blend · Dicumyl peroxide · Mechanical properties

Introduction

Over recent years, biodegradable biopolymers have gained much interest as eco-friendly materials in replacement of conventional petrochemical-based plastics because they are produced by fermentation/polymerization of the renewable agricultural sources (sugarcane, tapioca, corn, etc.) and can decompose into carbon dioxide, water, and biomass in a short time as a result of enzymatic action of microorganisms [1]. Among them, poly(lactic acid) (PLA) is a commercially available aliphatic semicrystalline polyester with many promising properties including high optical appearance, high tensile strength, biodegradability, and biocompatibility [2–4]. Therefore, PLA has been continuously used for diverse applications such as green food packaging [5, 6] and in the tissue engineering field [7, 8]. Unfortunately, neat PLA shows brittle fracture behavior (elongation at break less than 4% [2]); this could restrict its applications.

Numerous methods have been conducted to toughen PLA. Manipulation of the content of stereoisomers and degree of crystallinity in the PLA structure can alter the mechanical properties and biodegradability of PLA; however, toughened PLA using this technique still has poor properties, which is not enough for some advanced applications [9,

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