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Biodegradation in Landfilled of Biodegradable Micro-braided Yarn

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Abstract

Biodegradable polymer yarns of polymer blends of poly(lactic acid) (PLA) and poly(butylene succinate-co-adipate) (PBSA) reinforced with natural fiber were prepared by a micro braiding technique. The biodegradation of the micro-braid yarn was studied by field tests. The yarn are prepared from polymer blends of PLA:PBSA with ratios of 100:0, 90:10, and 85:15 (wt%) by a single screw extruder. Braided samples were prepared using jute as a braided core fiber. The mechanical property analysis showed tensile strength of polymer yarn with jute fiber higher than polymer yarn without jute. Biodegradation of micro-braiding yarn with and without jute fiber was studied by buried under controlled conditions compared with cellulose. The field biodegradation test was carried out for 28 days with period of 7 days sampling. It was found that humidity and soil temperature affected the biodegradability of polymers. Analysis of samples confirmed that buried at low temperature position showed higher degradation than at high temperature. High humidity enhanced the degradability due to hydrolysis reaction. Micro-braided polymer yarns of PLA:PBSA (85:15) and PLA:PBSA (85:15)/jute showed similar biodegradability confirmed that the mechanism of biodegradation from surface of the yarn was priority.

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Keywords: biodegradable polymer; poly(lactic acid); poly(butylene succinate-*co*-adipate); jute fiber

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1. Introduction

Composite materials produced from bio-based and biodegradable polymers are important due to they are friendly to environment from their origin of starting materials and the post-consumer products. Poly(lactic acid) (PLA) is one of the well-known bio-based materials. Lactic acid is first produced from various starches, sugars, and other biomass materials through biological fermentation, and then is chemically converted to poly(lactic acid) [1,2]. PLA has high transparency and elastic modulus, can be thermoplastically processed like conventional plastics, and has been widely used in the development of disposable products, such as disposable cutlery, cups, and films [3–5].

However, since PLA is quite brittle (low strain at break and high modulus) at room temperature and easily hydrolyzable, its applicability has been somewhat limited [6]. Thus, blending of PLA with various soft and tough polymers can enhance mechanical properties and biodegradability [7,8].

On the other hand, poly(butylene succinate-*co*-adipate) (PBSA) is commercially available aliphatic polyester synthesized from diacids and diols with high flexibility, excellent impact strength, melt processability, thermal, chemical resistance and low melting point of 90ºC, which is more readily biodegraded than PLA [9]. They have excellent processability and can be moulded into a variety of products using conventional equipment applicable to polyolefins [10]. Weraporn Pivsa-Art, *et al*. reported the preparation of polymer blends of PLA and PBSA using a twin screw extruder. The blends were fabricated into compression molded parts and melt-spunfiber. The impact strength of the compression molded parts was improved by the addition of soft PBSA. Crystallinity of the blend fibers was affected by the post drawing condition as well as the PBSA content [11]. Yun-Xuan Weng, *et al*. reported a biodegradation behavior of P(3HB,4HB)/PLA blends in real soil environments. Their blends have different degradation rates in different depths of soil [12]. Yun-Xuan Weng, *et al*. studied a biodegradation behavior of poly(butylene adipate-*co*-terephthalate)(PBAT), poly(lactic acid) (PLA), and their blends under soil conditions. The carbon atom content in the molecular structure of the PBAT, PLA, and PBAT/PLA samples decreased, while the oxygen atom content increased, indicating that the samples indeed degraded [13]. Sommai Pivsa-Art, *et al*. reported the effect of additive on crystallization and mechanical properties of poly(lactic acid) (PLA) and poly(butylene succinate-*co*-adipate) (PBSA) blends. PLA and PBSA were blended in a twin screw extruder, which incorporated poly(butylene adipate-*co*-terephthalate) (PBAT) as an additive in PLA/PBSA blend. The ratio of PLA/PBSA was 80/20. The contents of PBAT were varied from 0 to 50 wt%. The addition of 20 wt% PBAT showed the maximum impact performance of the PLA/PBSA blends [14].

It is known that PLA degradation in compost takes place in two main and consecutive stages, *i.e.* the hydrolytic and enzymatic degradation [15]. PLA disintegration starts by surface hydrolysis [16] leading to polymer random decomposition [17]. The degradation process is related to the molecular weight, degree of crystallinity, purity, stabilizers, whether there is blocking or not, and so on [18]. The biodegradation of PLA under soil conditions is a complex process, and the degradation rate is relatively slow [19–21]. However, under composting conditions, PLA undergoes biological decomposition into carbon dioxide and water [22–24]. Toshinori *et al.* studied the biodegradation behavior of PLA under composting conditions. The results demonstrated that the PLA film samples degraded in three weeks, while PLA rope samples degraded in six weeks [25].

PLA and PBSA are both biodegradable polymers, and jute is the natural product. The composite yarn of biodegradable polymer reinforced with natural fiber is expected to show excellent biodegradability. This research reports the study of biodegradation of micro-braiding yarn prepared from polymer blend of PLA/PBSA fiber reinforced with jute fiber under soil landfilled conditions.

2. Experimental

2.1 Materials

Poly(lactic acid), PLA (2002D, Natureworks LLC, USA) was used in this study. Poly(butylene succinate-*co*-adipate), PBSA (Bionelle®) was supplied by Showa High Polymer Co., Ltd., Japan.). Jute was supplied by Kyoto Institute of Technology which was purchased from Bangladesh.

2.2 Fiber preparation process