The Degradation of Polylactic Acid Aiber

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Abstract: Polylactic acid (PLA) fiber, also known as corn fiber, is made of corn and other grains through fermentation, polymerization and spinning. Thus it is biodegradable and environmentally friendly. Three kinds of buffer solutions with PH values of 4, 7.2 and 11 were made for the investigation of the degradation properties of PLA. The experimental results showed that the degradation of polylactic acid fiber was degraded rapidly in the buffer solution. After 10 days, significant degradation was observed from the fiber in the buffer solution of PH 11. However, little change occurred for the fibers in the other two solutions, which evidently revealed that alkali level was the dominate factor for the degradation of PLA fibers.

Keywords: Polylactic acid fiber; Degradation; Buffer solution; PH value

1. Introduction

Synthetic fibers have been accounted for a large proportion of textile fibers in recent decades. Their advantages have been mainly demonstrated in high performance applications, rather than the products used in our daily life. The waste synthetic fibrous assemblies may not decompose in natural conditions, which are regarded as a kind of pollution to the environment. Biodegradable fiber is thus desirable as a replacement for the daily applications.

Polylactic acid (PLA) fiber, or corn fiber, is a synthetic fiber made of polylactic acid or polylactic acid ester extracted from natural sugar of cereals (mainly corns) and beets through solution spinning or melt spinning, which has the desired merits of biodegradable and environmental friendly [1-3]. The waste PLA fiber can be completely decomposed into carbon dioxide and water. The molecule chains of PLA fibers may degrade into oligomers and monomers. From the perspective of polylactic acid material, such degradation may be divided into simple hydrolytic degradation and enzymatic hydrolysis degradation [4, 5]. The simple hydrolytic degradation is the inverse of esterification reaction, in which the ester bond is attacked by water molecules and break down to carboxylic acid and alcohols. This hydrolysis reaction is mainly affected by ambient temperature, humidity, acidity and other factors, which includes water absorption, ester bond breaking, and proliferation of soluble oligomers and dissolution of fragments. The enzyme degradation of polylactic acid ester is an indirect reaction. The PLA fiber is first hydrolyzed in the natural environment, instead of the polylactic acid ester directly attacked by enzyme. After the hydrolysis is developed to a critical level, enzyme works and results in degradation.

At present，the degradation of PLA fiber has been evaluated by soil burial test. During the burial test, the PLA fiber or its assemblies are buried in soil for a period of time, and then the samples are taken out to observe its appearance and change of performance. Burial test normally takes a fairly long time, usually a couple of months, which is quite inconvenient for practical users. In this study, a method was developed to accelerate the degradation process of PLA fibers, by applying buffer solutions with different PH values.

2. Materials and methods

2.1 Experimental materials and instruments

Materials: spunbonded PLA fiber, potassium dihydrogen phosphate (KH2PO4), hydrochloric acid (HCl), anhydrous sodium carbonate (Na2CO3), borax (Na2B4O7.10H2O), sodium hydroxide solution (NaOH) and distilled water.

Instruments: electronic balance, oven, beaker and glass rod.

2.2 The preparation of buffer

The preparation methods of three different PH values of buffer were as follows:

(1) Borax - sodium carbonate buffer (pH11): taking anhydrous sodium carbonate 5.30 g，adding distilled water to make the 1000ml of sodium carbonate solution; taking another borax 1.91g, adding distilled water to make 100ml of borax solution. The borax - sodium carbonate buffer was the mixture of 973ml sodium carbonate solution and 27ml borax solution.

(2) Phosphate buffer (pH4): taking potassium dihydrogen phosphate 50g, adding distilled water to make 400ml potassium dihydrogen phosphate solution, and then adjusting pH to 4 with hydrochloric acid.

(3) Phosphate buffer (pH7.2): mixing 0.2mol/L (0.27218g/L) potassium dihydrogen phosphate solution 100ml and 0.2mol/L (0.08g/L) sodium hydroxide solution 70ml, then adding distilled water dilute to 400ml.

2.3 Experimental Methods

Three groups of 4g dried PLA fibers were put into three kinds of buffer solution whose PH are 4, 7.2 and 11, respectively. The samples were stirred with glass rod until all saturated and degraded under the constant temperature 37℃.20 hours later, the treated fibers, which were removed from the buffer solution and cleaned by distilled water, were oven dried at 50℃ until all moisture was removed. The dry fibers were weighed using electronic balance. The operation should be repeated every 20 hours for ten days. Finally the residual weight percentage was employed to evaluate the degradation level.

The weight change of PLA fiber was measured by the percentage of residual weight. The Original fibers weight and the treated fibers weight were denoted as W_0 and Wn (n represents the days of degradation). The residual weight percentage (%) = Wn / W_0 × 100%.

3. Results and discussion

3.1 The overall appearance changes of PLA fiber

Treated with different PH values of buffer solution for 10 days, the overall appearance changes of PLA fiber are shown in Figure 1. Fibers in the buffer solutions with PH value 4.0 and 7.2 had no obvious change, so the solutions are clear and transparent. However, in buffer with PH value of 11, the filament became short bundles. Fibers have been degraded and a large number of small fiber segment appeared in solution.

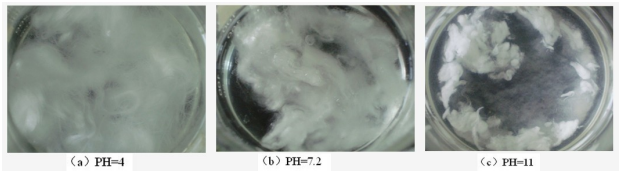

Figure 1 the overall appearance photo of PLA fiber

3.2 The weight change of PLA fiber

The weight changes of polylactic acid fiber degraded in the number of days are shown in Figure 2. Figure 2 shows that the residual weight of polylactic acid fiber percentage was 100% in the buffer solution with PH value of 7.2. And in buffer with PH value of 4, a slight weight change occurred from the eighth day. However, a very significant change can be seen in the curve named PH=11. There was almost no change in the first two days, but the fibers eventually degraded over time. The residual weight of polylactic acid fibers gradually decreased from the 5th day and the rate of degradation accelerated.

4. Conclusion

Polylactic acid fibers may degrade under alkaline conditions and the degradation occurs faster than in the neutral and acidic conditions. It is feasible to accelerate the degradation of polylactic acid fibers by applying alkali buffers. Compared with the enzyme degradation method, the developed method in this study is more powerful in terms of shortening the burial test time.

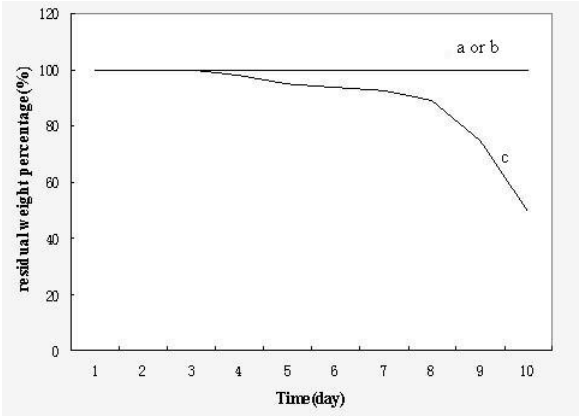

Figure 2 The residual weight as a percentage of the original weight vs processing days: (a)PH=4,(b)PH=7.2,(c)PH=11

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