BIO Web of Conferences **124**, 01003 (2024) https://doi.org/10.1051/bioconf/202412401003
ICFSB 2024

Study on Biodegradation Technology for the Structural Change Reaction of Polymer Polylactic Acid

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Abstract: The wide application of chemical substances, although it brings great convenience to people's lives, but it is difficult to degrade in the natural environment of the chemical composition once the long-term retention of people's living space, it will seriously jeopardize the living and ecological environment. The use of biodegradation technology can effectively reduce the harm caused by chemical substances. The use of biodegradation technology can effectively reduce the harm caused by chemical substances. Based on the above background, the biodegradation technology for the structure change reaction of polymer polylactic acid (PLA) was studied. In the process of structure change reaction of polymer PLA, the cyclic degradation model is established and the thermal change reaction is analyzed, so as to find out the degradation weight loss rate and thermal properties, and complete the analysis of the thermal degradation behavior of polymer PLA. Clarify the basic concepts of polymer biodegradation, classify them, then prepare raw materials, simulate the biodegradation process, and analyze the specific implementation based on the degradation results.

1. Introduction

Biodegradation is one of the important processes of decomposing organic pollutants. The degradation ability of most organic compounds is directly affected by the degree of polymerization of compounds. Under normal circumstances, the longer the degradation time required, the longer the retention time of the substance in the ecological environment. In the evaluation of ecological risks, it can also be described in detail according to the transformation of compounds in the ecological environment [1]. At present, the research on biodegradation technology mainly involves the following aspects : (1) Research and development of biodegradable plastics-by finding new degradable materials to solve the problem of plastic pollution ; (2) Study on the role of microorganisms in the process of biodegradation-Analyze the decomposition behavior of microorganisms on organic matter, so as to determine the specific operation of microbial population in biological decomposition ; (3) Regulating the biodegradation process - by adding exogenous substances, changing environmental conditions, etc., to achieve the purpose of improving the efficiency and effectiveness of biodegradation ; (4) The application of biodegradable materials-the application of degraded materials in daily production and life, in order to achieve the sustainable development of natural ecology.

Zhang Lin et al.pointed out in their research that biodegradation has become an important alternative to traditional processes. At this stage, agriculture, textile industry, packaging industry, disposable goods processing and other industries have begun to apply biodegradation technology to treat waste and garbage generated in the production process. Due to the different material properties, the performance of degradation behavior and degradation mechanism will also be different, but the known conventional reaction conditions such as temperature, humidity, microorganism and oxygen content will still affect the implementation ability of biodegradation technology [2]. In order to further study the biodegradation, a biodegradation technology for the structural change reaction of polymer polylactic acid was proposed. Polylactic acid, also known as polylactide, is a polyester polymer obtained by multiple polymerization reactions with lactic acid as the main raw material. As a new type of biodegradable material, polylactic acid has strong thermal stability and can withstand high temperature processing at 170 ~ 230 °C.Moreover, this type of material has good solvent resistance and can be applied to a variety of different processing technologies. In addition, the products made from polylactic acid in addition to biodegradable, its overall biocompatibility and heat resistance is also significantly due to other materials.

2. Reaction Analysis of Structural Changes of Polymer Polylactic Acid During Degradation

2.1. Structural degradation cycle model of polymer polylactic acid

In recent years, related research institutions have mainly synthesized polylactic acid and its derivatives by condensing lactic acid monomers. Common condensation

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methods include solvent-free melt polymerization, solution polymerization and other forms, which can better solve the problem of difficult formation of polymer polylactic acid structure, and the practicability and economy of these methods are more in line with the actual demand standards. Polylactic acid degradation is a complex biological change phenomenon. In short, microorganisms with degradation ability first secrete a large number of extracellular depolymerases, then accelerate the degradation reaction under the stimulation of inducers, and finally generate a series of polymer degradation products [3]. The specific degradation reaction model of polymer polylactic acid structure is shown in Figure 1.

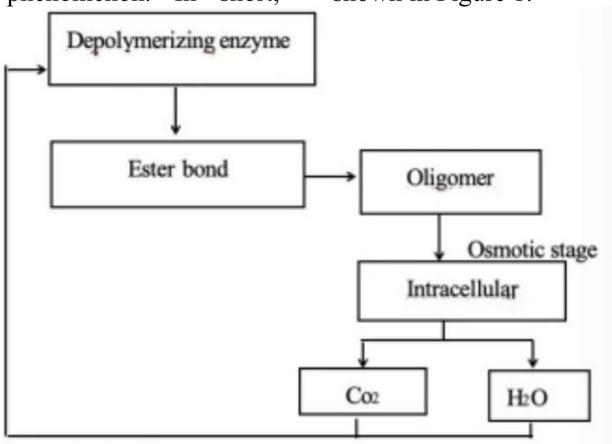

Figure 1. Structural degradation reaction model of polymer polylactic acid

Under the action of microbial corrosion, the depolymerase degrades the polymer polylactic acid, and the degradation product is metabolized into water and carbon dioxide in biological cells. After photosynthesis or fermentation of plants, it becomes the raw material for the production of polymer polylactic acid structure again, thus forming a complete polymer polylactic acid degradation cycle reaction model.

2.2. Thermal analysis of polylactic acid structure

In order to accurately grasp the heat release of the structural change reaction of polymer polylactic acid in the process of biodegradation, the whole reaction process was tested by differential scanning calorimeter under nitrogen protection. Firstly, 5-8mg film samples were heated from 0 °C to 200 °C at a heating rate of 10 °C / min. Then, it was kept at 200 °C for about 3 min to completely eliminate the thermal history of the polymer polylactic acid film. Then, the temperature of the film sample was reduced to-60 °C at a cooling rate of 10 °C / min. Finally, at the heating rate of 10 °C / min, the temperature of the polymer polylactic acid film was increased to 200 °C again. The complete thermal change reaction expression of polylactic acid structure is as follows:

$$C = \frac{|\Delta H_2|}{\chi \cdot |\Delta H_1|} \cdot 100\% \quad (1)$$

χ represents the mass fraction of the polymer polylactic acid film, ΔH_2 represents the total amount of heat released during the biodegradation process, and ΔH_1 represents the standard enthalpy of heat release. During the degradation process, the structural change reaction of polymer polylactic acid is an irreversible biological change behavior, so the thermal change effect has a one-time characteristic. In the process of biodegradation, the conversion efficiency of polymer polylactic acid structure change reaction to organic matter cannot reach 100 %. Therefore, when analyzing the effect of thermal change, the heat release measured by differential scanning calorimeter cannot maintain an infinitely increasing trend. When the actual heat release reaches a certain numerical level (that is, the instantaneous heat release of biodegradation can support the smooth progress of subsequent hydrolysis reaction), the heat value measured by differential scanning calorimeter always remains stable. From a macro perspective, the biodegradation of polymer polylactic acid structure has the characteristics of non-sustainable exothermic reaction.

2.3. Degradation weight loss rate and thermal properties

For the solution of the weight loss rate and thermal properties of polymer polylactic acid, it is necessary to grasp the quality changes of polylactic acid samples before and after degradation. Firstly, a certain mass of high molecular polylactic acid sample was selected as the reactant, and it was placed at room temperature for natural biodegradation. Then, a part of the polylactic acid sample was taken out at regular intervals to observe its damage ; Then, the polylactic acid sample was cleaned with deionized water, and then placed in a constant temperature oven at 40 °C for drying operation until its quality level no longer changed. Finally, the above steps are repeated many times, and the weight loss rate of the polymer polylactic acid sample film is solved according to the obtained weighing results. For the solution of the degradation weight loss rate, the following expression is used:

$$Z = \left(\frac{M - M'}{M}\right) \times 100\% \qquad (2)$$

M represents the quality of the polymer polylactic acid sample before the degradation reaction, and M' represents the quality of the polylactic acid sample after drying. The determination of the thermal degradation properties of polymer polylactic acid can continue to use the differential scanning calorimeter. First, the polymer polylactic acid sample is cut into pieces and completely dried ; then, 5 mg of the sample was weighed and placed in the crucible ; Finally, the sample was pressed in a closed environment. The entire determination process must be completed in a nitrogen environment, with room temperature as the initial temperature, maintaining a rate of 20 °C / min to 200 °C ; in the experimental environment of 200 °C, the constant temperature state of 2min was maintained to achieve the purpose of completely eliminating the thermal history. Cooling to 40 °C at a rate of 15 °C / min ; the temperature was raised again to 200 °C at a rate of 20 °C / min. According to the specific numerical records, the degradation thermal properties of polymer polylactic acid were analyzed.

2.4. Thermal degradation behavior of high molecular polylactic acid

Compared with other types of organic matter, polylactic acid can be degraded in many different ways, such as photodegradation, thermal degradation and so on. In the degradation process, adding sufficient amount of biocatalyst, the polymer polylactic acid can be directly converted into polylactic acid oligomers. If the temperature is raised to 220℃ again, the polylactic acid oligomer will undergo secondary degradation to form lactide. Under the action of biocatalyst, lactide can undergo ring-opening polymerization, and when the polymerization strength is large enough, it will form polymer polylactic acid again [4]. As the intermediate product of the biodegradation of polymer polylactic acid, polylactic acid oligomers and lactide have strong endothermic properties, but their stability at high temperature is relatively weak. Therefore, the requirements of the external temperature for the whole reaction are not very harsh. Because the whole reaction process is always accompanied by obvious exothermic and endothermic behavior, the biodegradation of polymer polylactic acid is also called thermal degradation. This reaction is an important component of the structural change reaction of polymer polylactic acid.

2.5. Hydrolysis mechanism of structural change reaction

Hydrolysis is the most common structural change reaction of polymer polylactic acid. As a form of biodegradation, it refers to the decomposition of polymer polylactic acid structure in aqueous solution. In the physiological environment, the hydrolysis reaction behavior consists of two stages (figure 2):

First, During the hydrolysis reaction, the water molecules in the aqueous solution directly penetrate into the structure of the polymer polylactic acid, resulting in the rapid relaxation of the polylactic acid chain, and the ester bonds that play a connecting role are initially hydrolyzed. The average molecular weight of the polymer begins to decrease, and the long chain is hydrolyzed into a water-soluble oligomer, and the entire reaction process does not require any biological enzyme catalysis. It is also believed that the carboxyl terminal group has a direct effect on the reaction intensity when the polymer polylactic acid is hydrolyzed, so the whole reaction behavior satisfies the autocatalytic degradation mechanism.

Second, The active metabolic ability of the structural change reaction of polylactic acid is strong, and the hydrolysate can be hydrolyzed again into monomeric lactic acid under the catalysis of biological enzymes. In the process of biodegradation, the substance can be metabolized into carbon dioxide and water. In general, the structural change reaction of polymer polylactic acid is obviously affected by the catalysis of biological enzymes, which can only be carried out under the action of specific biological enzymes. Although the weight of the obtained hydrolysate is relatively small, these substances can be directly used for biodegradation behavior.

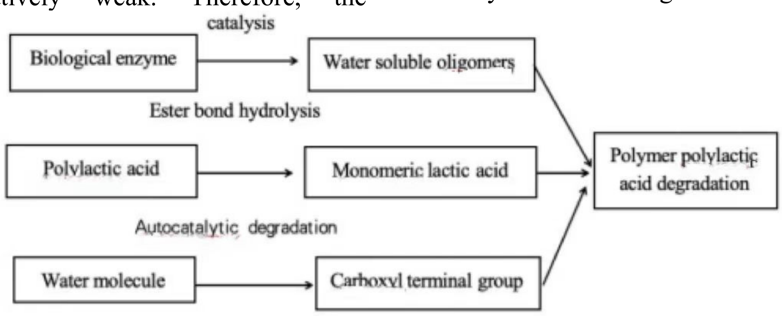

Figure 2. Hydrolysis mechanism of structural change reaction of polymer polylactic acid

If the chemical properties of the monomer lactic acid formed after the breaking of the polymer polylactic acid ester bond are relatively stable during the hydrolysis process, it means that the water molecule content is relatively abundant in the initial stage of biodegradation, and the biological enzyme can be completely dissolved in the mixed water molecule solution. After degradation, the water-soluble oligomer can be directly used by other microorganisms.

3. Basic concept of biodegradation technology

3.1. Biodegradation of polymers

Biodegradation refers to the decomposition of organic matter by microorganisms, which may be manifested as aerobic respiration of microorganisms or anaerobic respiration of microorganisms. The difficulty of degradation behavior is not only related to the ecological characteristics of organic matter itself, but also has an inseparable relationship with its structural characteristics [5]. In general, the simpler the structure is, the higher the possibility of polymer biodegradation is. Some organic compounds with complex structures may even be difficult to biodegrade in the natural environment. In addition, biodegradation is not necessarily caused by changes in the chemical substances or structures of organisms. It may also be because polymer compounds are mineralized and converted into inorganic compounds containing nitrogen, phosphorus, hydrogen, oxygen and other elements. In the natural environment, the degradation of organic matter is one of the main forms of chemical conversion, and most of the polymer organic matter can be fully degraded under the condition of changing the external conditions.

3.2. Classification of degradation techniques

As far as the existing research is concerned, biodegradation technology includes four forms : inherent biodegradation, primary biodegradation, rapid biodegradation and final biodegradation. Among them, the inherent biodegradation has relatively strict requirements on the environment. Only when the inoculum and chemical substances can maintain a long-term contact state, can the full decomposition of organic matter be achieved [6]. Primary biodegradation means that under the action of biology, the simplest chemical structure of chemical substances has changed, and the original materials have become other substances after decomposition. The reaction rate of rapid biodegradation is faster, and the complete decomposition of organic matter can be achieved within a fixed time. The final biodegradation reaction process consumes a large amount of oxygen. After decomposition, the organic matter is converted into water, carbon dioxide, microbial cells and new mineral salts.

4. Biodegradation simulation based on structural change reaction of polymeric polylactic acid

4.1. Preliminary preparation

Biodegradation simulation study based on the structure change reaction of polymer polylactic acid needs to prepare acetonitrile, pure water, standard test sieve, glass bottle, solid phase extraction column, microcomputer acidity meter, centrifugal separator, constant temperature oscillation culture and liquid chromatography, in which acetonitrile and pure water must be distilled more than twice. The inoculants, reactants and chemicals were placed in the reactor at the same time, and the reactor was placed in a temperature-adjustable oscillator. The experimental device was rotated back and forth to simulate the flow effect of natural water, so that the reactant particles floated on the surface of the experimental solution [7-10]. In the process of simulation experiment, it is necessary to collect water samples and sediment samples on the surface of the reaction solution as the test objects, and screen the reactants obtained from the sampling to ensure that the samples are completely dried and placed in a closed container for biodegradation. After the experiment is completed, the PH test paper should also be used to measure the acidity and alkalinity of the reaction solution(figure 3).

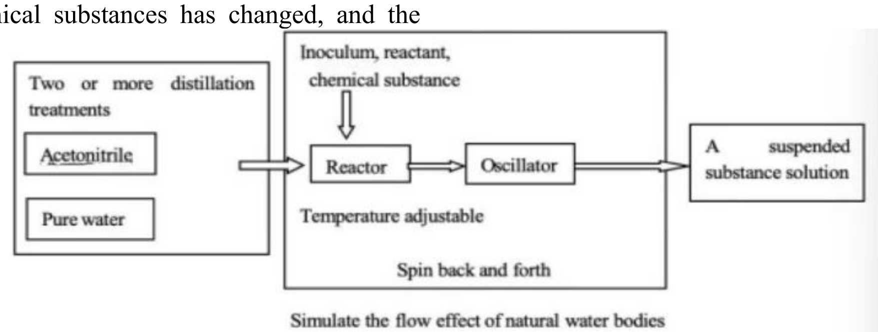

Figure3. Process of biodegradation simulation experiment

4.2. Simulation Analysis of Biodegradation

After a period of degradation reaction, the remaining samples were re-sampled and the suspended small particles were removed by centrifugation. The hue degree of the samples was analyzed by liquid chromatograph, and the biodegradation degree of polymer organic matter was calculated according to the half-life formula. If there are still a large number of sediments in the remaining mixed solution, it means that the current degree of biodegradation is low, and the polymer organic matter still has a strong residual degradability value ; if there are deposits in the remaining mixed solution but relatively few, it means that the remaining mixed solution is higher, and the polymer organic matter has residual degradable value, but after re-biodegradation, more carbon dioxide, water, microbial cells and other substances cannot be obtained. If there is no sediment in the remaining mixed solution, it means that the current degree of biodegradation is extremely high, and the polymer organic matter does not have the remaining degradable value. In order to ensure the full progress of the biodegradation reaction, it is necessary to ensure that the selected sample will not be completely consumed by microorganisms during the degradation process before starting the simulation reaction.

5. Conclusion

According to the above analysis, it can be seen that in the study of biodegradation technology of structural change reaction of polymer polylactic acid (PLA), different degradation products can be obtained by changing the numerical level of degradation cycle model, degradation weight loss rate and other parameters. In the field of organic degradation, making full use of the heat released by the structural change reaction of polymer polylactic acid (PLA) can not only promote the rapid progress of biodegradation, but also bring the following effects :

First, In the biological environment, as the main degradation material, the chemical properties and structural characteristics of polylactic acid will affect the intensity of the reaction, especially in the case of chemical substances, water, biological enzymes and other factors do not change, to ensure that the hydrolysis, enzymatic hydrolysis and other reactions at the same time, in order to obtain more sustainable use of biodegradable resources.

Second, The structural change reaction of polylactic acid (PLA) can be completed only under the promotion of catalyst, and this catalyst often exists directly in the natural environment, which means that in the case of non-human control, as long as the suitability of temperature is ensured, microorganisms can spontaneously degrade organic matter.

Third, The rate and temperature of biodegradation reaction are controllable factors, but the reaction products are only affected by the composition of organic elements. To some extent, the reaction from organic matter to inorganic products conforms to the artificial control conditions, but the reaction from inorganic products to organic matter is difficult to achieve.

In the future, further research can be carried out in promoting the development of polymer polylactic acid biodegradation technology, so as to implement the rectification and protection of the natural environment while realizing the sustainable development of the ecological environment.

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