Development of Marine-degradable Bionylon from Biomass Wastes-derived Itaconic acid

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[Abstract]

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Itaconic acid (IA) is commercially produced from edible starch and glucose, and future competition with food is a concern. Therefore, a new IA production technology using recombinant microorganisms capable of utilizing nonedible waste biomass as alternative resource is being studied. In this project, amino acid-producing *Corynebacterium glutamicum* is metabolically engineered, and is used for IA production from Kraft pulp as a model nonedible lignocellulosic biomass. Approximately 4.6 million tons of Kraft pulp remains unused; it is widely used as feedstock in the paper industry and has been considered as an attractive renewable substrate for the production of biofuels and biochemicals. IA is extracted from culture using purification process, and the purified bio-based IA is then used to synthesize a unique bio-based nylon. A series of environmentally adaptable bio-nylons with high thermomechanical properties and degradability are developed from the IA derived from nonedible biomass. The following results are obtained. (1) Bionylons are produced on a scale of 5 kg, and the technology is transferred to a company; (2) synthesized bionylons with various carbon numbers and their composites exhibit a glass transition temperature of 50 °C or higher and water content of 2.7% or lower; (3) produced composite samples exhibit high toughness (207 MJ/m^3) by combining with additives such as montmorillonite; (4) produced bionylons with high bio-derivation degree exhibit mechanical strength of up to 400 MPa and marine degradability; (5) bionylons are produced from nonedible biomass-derived IA. Similar to above, bionylon fibers are developed.

The biodegradability and biotoxicity of bionylon derived from IA and hexamethylenediamine (nylon-6i) are investigated. Nylon-6i is soluble in pure water under intense ultraviolet irradiation and solubilizes in seawater under natural sunlight irradiation. The biodegradability of the solubilized nylon-6i is confirmed by BOD tests using seawater and marine sediments. Three nylon-6i consuming microorganisms are isolated from the supernatant of the BOD test, and genomic and transcriptomic analyses reveals that these microorganisms possess several nylon-degrading enzymes and express these genes when cultured with nylon-6i. Furthermore, molecular genetic testing using simulated seafloor cultures and the deep-sea sediment genome database reveal that genes for nylon-degrading enzymes are widely distributed in the deep-sea environment. In addition, biotoxicity tests using freshwater fish, marine microalgae, and marine crustaceans reveal that the toxicity of the solubilized polymer and monomer is extremely low. According to these findings, nylon-6i is an environmentally-friendly material with high biodegradability and low biotoxicity.

[References]

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