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BIODEGRADATION OF STARCH-BASED MATERIALS

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ABSTRACT

The aim of this study was to compare three different test methods for assaying the biodegradability of starch-based materials. The materials tested included some commercial starch-based materials and thermoplastic starch film prepared by extrusion from native potato starch and glycerol. Enzymatic hydrolysis was performed using excess *Bacillus licheniformis* α-amylase and *Aspergillus niger* glucoamylase at 37°C. The degree of degradation was assayed by measuring the dissolved carbohydrates and the weight loss of the samples. The head-space test was based on carbon dioxide evolution using sewage sludge as an inoculum. The composting experiments were carried out in an insulated commercial composter bin. The degradation was evaluated visually at weekly intervals, and the weight loss of the samples was measured after composting. Good correlation was found among the three different test methods.

INTRODUCTION

The biodegradation of starch-based materials depends on the starch processing method used as well as on the biodegradability of other components. The main elements in biodegradability testing are incubation of the sample under conditions conducive to microbial attack and/or their enzymes, and evaluation of the degree of degradation [1]. Several studies have been carried out to evaluate biodegradation by incubating samples in a compost environment [2, 3] or measuring the carbon dioxide evolution in aquatic conditions [4, 5]. Using specific enzyme assays, the time needed to perform the biodegradation test can be reduced. According to some studies [6, 7], the ability of amylolytic enzymes to degrade starch composites can be rather limited.

We are currently studying the biodegradation of starch-based materials by several biodegradation test methods at VTT Biotechnology and Food Research. These tests include methods based on carbon dioxide evolution, composting, and enzymatic testing. Some preliminary results obtained are reported in this paper.

MATERIALS AND METHODS

Materials

Biopac was obtained from Austrian Biologische Verpackungssysteme GmbH (Sample 1) and Biopur from Biotec GmbH & Co. KG (Sample 2). Mater-Bi ZF02U film (Sample 3) was from Novamont North America. Thermoplastic starch film was prepared by extrusion from glycerol and native potato starch (Sample 4).

Test Methods

Enzymatic hydrolysis was performed at 37°C. A 100-mg sample was incubated with excess *Bacillus licheniformis* (Genencor International Europe Ltd., Finland), α-amylase, and *Aspergillus niger* glucoamylase (Boehringer Mannheim, Germany) in 10 mL of 0.1 M acetate buffer, pH 5.0. The degree of degradation during 24 hours was assayed by measuring the dissolved carbohydrates [8] and the weight loss of the samples.

The head-space test was based on carbon dioxide evolution using sewage sludge as an inoculum. A 30-mg sample was incubated with the sewage sludge microorganisms at 25°C in 50 mL mineral nutrient solution (ASTM D5247-92), and carbon dioxide evolution was measured at weekly intervals.

The composting experiments were carried out in an insulated commercial composter bin (Sepe, Suomen kompostointipalvelu Ky, Finland) filled with biowaste. The composting test was based on naturally occurring composting reactions, and no external heating and ventilation was employed. Square sheets of tested materials were attached to the steel frame which was buried in the biomass. The degradation was evaluated visually at weekly intervals, and the weight loss was measured after composting. To ensure that the composting proceeded as expected, temperature, pH, moisture, and oxygen and carbon dioxide concentrations inside the composter bin were measured.

RESULTS

During the enzymatic hydrolysis the materials tested were hydrolyzed extensively with the exception of Sample 3, in which starch was blended with other polymers (Fig. 1). The weight loss of the samples was larger than the amount of solubilized carbohydrates, indicating the solubility of other components besides starch. The enzymatic method used represents a rapid means of obtaining preliminary information about the biodegradability of starch-based materials.

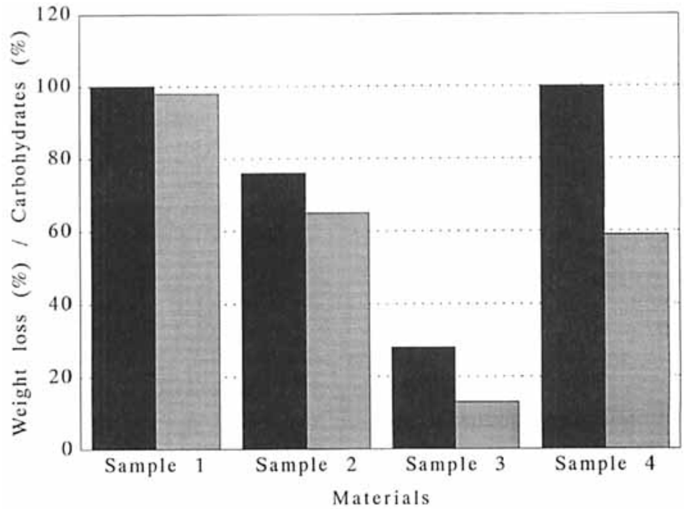

FIG. 1. Weight loss and dissolved carbohydrates after 24 hours in enzymatic hydrolysis. ■: weight loss (%); ▧: dissolved carbohydrates (% dry weight).

In the head-space test the highest carbon dioxide evolution was measured during the first 2 weeks of incubation (Fig. 2). The largest CO_2 evolution (% theoretical) was obtained when Samples 1 and 4 were tested. The advantages of the head-space test are evident: it is easy to perform and a large number of samples can easily be tested.

Samples 1 and 4 were degraded completely after 49 days of composting (Table 1). The weight loss of Sample 2 was 65%, and its thickness was reduced but no

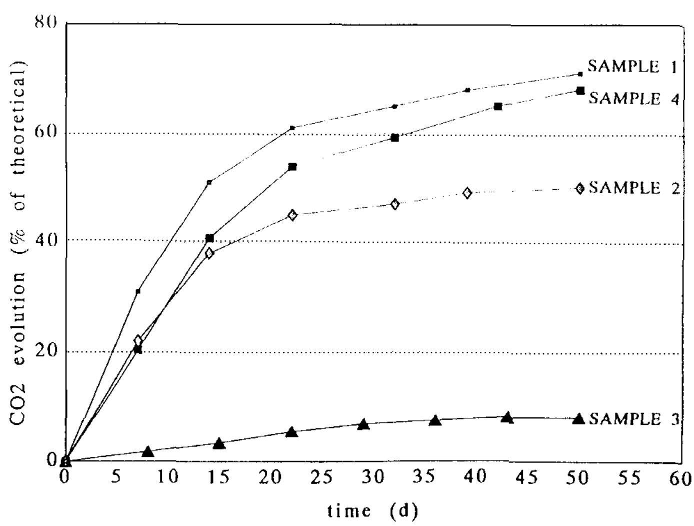

FIG. 2. Carbon dioxide evolution (% theoretical) in the head-space test.

TABLE 1. Biodegradation of the Samples by the Three Different Test Methods

Material	Enzymatic test, 24 hours, weight loss, %	Head-space test, 50 days, CO_2 evolution,[a] %	Compost test, 49 days, weight loss, %
Sample 1	100	100	100
Sample 2	75	73	65
Sample 3	28	14	45
Sample 4	100	100	100

[a]CO_2 evolution of the sample (% theoretical)/CO_2 evolution of the native starch (% theoretical).

holes were formed during composting. Sample 3 became very brittle and the weight loss was 45%. The disadvantage of the composting test is that it is time consuming. It is also difficult to control the composting parameters, and the reproducibility of the results is poorer than with the two other methods.

CONCLUSION

Good correlation was found among the three different test methods. In the case of blended polymers such as Sample 3, the most excessive degradation was obtained by the composting test. The conditions in the compost environment are ideal for degradation mainly because of the mixed microbial population, the broad diversity of the enzymes secreted, and the high temperature during the thermophilic phase of composting.

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