Biodegradable Foam from Irradiated Sago Starch/Polyvinyl Alcohol Blend

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Introduction

Utilization of annually renewable agriculturally derived products such as starch as extenders and replacements for synthetic, petroleum-based polymer is currently an active area of research. Starch and its derivatives have been used as plastic materials for disposable items such as packaging loose-fills and picnic tableware. Use of starch in plastics not only reduces our dependence on petrochemical-derived monomers, but the starch portion will also biodegrade, causing the finished plastic article to lose its integrity and be reduced to small particles. Electron beam irradiation of polymer has been employed in the production of foam. High-energy irradiation typically produces free radicals that can readily interact with each other forming cross-linkages and thus strengthening the structure of the polymer. Cross-linking will also enhance the resistance of the cellular foam to thermal collapse. The objective of this study is, therefore, to produce biodegradable foam using sago starch. The starch has to be blended with polyvinyl alcohol for cross-linking to occur during irradiation. The blend is then irradiated and puffed up in a microwave oven for foam formation. The optimum ratio of sago starch to polyvinyl alcohol to be used in the blend, mixing temperature of the blend, and its irradiation dose are to be determined.

Materials and Methods

10/30/100, 15/25/100, 20/20/100, 25/15/100 and 30/10/100 of sago starch/polyvinyl alcohol/distilled water blends were prepared. Each blend had its polyvinyl alcohol solubilised in distilled water at 121 °C for 10 min and left to cool. After addition of sago starch to the aqueous polyvinyl alcohol and mixing at 60,70,80,90 or 100 °C, 30 ml of the blend was poured into a square petri dish (10 cm x 10 cm) and irradiated at 10,15,20,25 or 30 kGy. The conditions of the electron beam machine were as follows: acceleration voltage of 2.0 MeV, beam current of 10.0 mA, and speed of 0.94 m/min. The irradiated blend, in the form of a gel, was then puffed up in a microwave oven for 5 min.

The gel formed after irradiation of the blend was characterized by determining its gel content and gel strength while the foam produced from puffing up of the gel was examined based on its linear expansion capacity and surface morphology. The gel content was determined by weighing and placing the gel, with known moisture content, in between steel nets and autoclaving it at 121 °C for 1 h. The autoclaved gel was later washed with distilled water and dried in an oven at 60 °C overnight. The gel content was calculated as weight of dry gel after extraction divided by weight of the initial gel and reported in percentage. The gel strength was measured based on the force required to penetrate it with a Texture Analyzer (TAXT2). Pre-test speed of 10 mm/s, test speed of 1 mm/s, post-test speed of 10 mm/s, and penetration distance of 2 mm using a 15 mm in diameter cylindrical probe were employed. The percent linear expansion of the foam was calculated as length of the gel after foaming in a microwave oven minus length of the gel before foaming. The value obtained was then divided by the gel's original length and multiplied by 100. The surface morphology of the foam was examined by cutting a 5 mm cube of the foam and mounting it on an aluminium stub with silver conductive adhesive. The foam mounted stub was kept in a dessicator overnight and later coated with a gold film in a sputter coater and viewed under a scanning electron microscope (JEOL 6400, Japan) with an acceleration voltage of 15 kV.

Results and Discussion

A major practical use of high-energy radiation to modify materials has been in the cross-linking of polymers. Generally, the extent of radiation-induced cross-linking of polymers can be estimated from gel content determination. The gel content of irradiated sago starch/polyvinyl alcohol blend was increased when the irradiation dose was increased from 10 to 20 kGy. Thereafter, it reached a plateau indicating that maximum cross-linking of the polymers has occurred. The gel strength was also increased as a result of the increase in gel content. Optimum cross-linking is important for foam production. Cross-linking not only stabilizes bubbles during expansion of the foam but also enhances the resistance of the foam to thermal collapse. This enhanced resistance to thermal collapse is necessary for its applications.

The maximum linear expansion of all blends studied was obtained when they were irradiated at 15 kGy. When the irradiation dose was further increased to 30 kGy, the linear expansion of the foams decreased. This was due to the fact that excessive cross-linking that occurred at the high irradiation doses resulted in a decrease in the expansion of the foams. At 15 kGy of irradiation, an increment in the sago starch content of the blends enhanced the foam expansion.

The biggest foam's cell size was also obtained when the blends were irradiated at 15 kGy. The cell size, however, decreased when the irradiation dose was increased from 15 to 20 kGy. Further increment to 25 and 30 kGy resulted in a collapsed cell structure.

Conclusions

The optimum conditions for production of biodegradable foam from sago starch/polyvinyl alcohol blend were the usage of 20-30 parts of sago starch blended with 10-20 parts of polyvinyl alcohol in 100 parts of water, blend mixing temperature of 80 °C, and irradiation dose of 15 kGy. The weight loss of the foam was up to 39% in the first month of the burial period.

Benefits from the study

Procedure for producing biodegradable foam and increased utilization of a local starch

Patent(s), if applicable

Production of biodegradable foam from irradiated sago starch/polyvinyl alcohol blend

Stage of Commercialization, if applicable:

Nil

Project Publications in Refereed Journals

1. Wongsuban B, Muhammad K, Ghazali Z, Hashim K, and Hassan MA. 2003. Effects of electron beam irradiation on preparation of sago starch/polyvinyl alcohol foams. Nucl. Instr. and Meth. In Phys. Res. (Under review)

Project Publications in Conference Proceedings

1. Wongsuban B, Muhammad K, Ghazali Z, Hashim K, and Hassan MA. 2000. Biodegradable foams from electron beam irradiated polyvinyl pyrrolidone-sago starch blends: Effect of Irradiation Doses. In: Proceedings of the Conference on Sustainable Production and Optimum Utilization of Sago Starch, 21-22 August 2000, Kuching, Sarawak.

2. Ghazali Z, Idris S, Dahlan KZ, Wongsuban B and Muhammad K. 2001. Properties of electron beam cross-linked biodegradable sago starch foams. In: Proceedings of the International Seminar on K-Starch 2001, 16-18 October 2001, Kota Kinabalu, Sabah, p71-72.

3. Wongsuban B, Muhammad K, Ghazali Z, Hashim K, and Hassan MA. 2002. Microstructure of foams from electron beam irradiated sago starch-polyvinyl alcohol blends. In: Proceedings of the Seminar on Microscopy and Microanalysis, 7-8 May 2002, Selangor, p15-17.

Graduate Research

Name of Graduate	Research Topic	Field of Expertise	Degree Awarded	Graduation Year
Benchamaporn Wongsuban	Irradiation Modification of Sago Starch Blends for Production of Biodegradable Foams	Biopolymers for Food Packaging		

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