UNIVERSITI PUTRA MALAYSIA

MODIFICATION OF SAGO STARCH AND POLYVINYL ALCOHOL BLENDS BY IRRADIATION FOR THE PRODUCTION OF BIODEGRADABLE FOAMS AND FOAM TRAYS

BENCHAMAPORN WONGSUBAN

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Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfilment of the Requirement for the Degree of Doctor of Philosophy

February 2007

Dedicated to my mother, my late father, brother and sister, my husband and my wonderful daughters for their love, patience and understanding.

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Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the degree of Doctor of Philosophy

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February 2007

Chairman: **Associate Professor Sharifah Kharidah Syed Muhammad, PhD**

Faculty: **Food Science and Technology**

Electron beam irradiation induced cross-linking in aqueous PVA and PVP but caused degradation in aqueous sago starch. Sago starch/PVP blends were more readily cross-linked than sago starch/PVA blends. The gel strength of both blends was increased when the irradiation dose was increased due to the cross-linking. Sago starch was found to enhance the gel strength of the blends. An enhancement in storage modulus and tan δ with increment in irradiation dose further indicated the formation of irradiation-induced cross-linking. This confirmed that there was molecular interaction occurring in the sago starch/PVA and sago starch/PVP blends. Grafting might have also occurred in the irradiated sago starch/PVA and sago starch/PVP blends as can be observed from the shifting of the thermogravimetric analysis spectrum. The findings of electron microscopic studies on the fracture surface morphology of the blends gave further evidence on the occurrence of irradiation induced cross-linking in them.

The effects of the type and concentration of polymers, mixing temperature and electron beam irradiation dose on properties of foam were investigated. Blends of sago starch/polyvinyl alcohol (PVA) and sago starch/polyvinyl pyrrolidone (PVP) were mixed at 25°C and 80°C. They were then electron beam irradiated with doses ranging from 10 to

30 kGy. Foams were subsequently produced by puffing the irradiated blends in a microwave for 5 to 8 min. High linear expansion foams can be produced from 25:15 of sago starch:PVA, 30:10 of sago starch:PVA, 20:20 of sago starch:PVP and 25:15 of sago starch:PVP blends mixed at 80°C. Irradiation dose of 15 kGy was found to be suitable in the production of the sago starch/PVA foams with maximum linear expansion of the foams obtained while 10 kGy was suitable for the production of the sago starch/PVP foams. An increment of sago starch in the blends enhanced the linear expansion of the foams. Changes in blend morphology were observed when the blends were exposed to higher irradiation doses. Sago starch/PVA blend was suitable for foam production because it produced a flexible and glossy foam as compared to sago starch/PVP blend that produced a very rigid foam. The linear expansion ratio of foam from sago starch/PVA blend was higher than that of foams from tapioca starch/PVA, wheat starch/PVA and corn starch/PVA blends.

The irradiated sago starch/PVA blend was moulded into trays by a hot and cold press machine. The physical characteristics of the trays such as tear resistance, water absorption capacity and moisture absorption isotherm were then determined. Irradiation or cross-linking of the sago starch/PVA blend increased the tear and moisture resistances of the foam trays produced from it. Results of the soil burial test showed that the sago starch/PVA foam trays were biodegradable with up to 40% of weight loss occurring in the first month of the burial period. This was accompanied by the growth of microbes, presumably fungi, which were observed on the foam trays under the scanning electron microscope.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Doktor Falsafah

PENGUBAHSUAIAN CAMPURAN KANJI SAGU DAN ALKOHOL POLIVINIL MELALUI IRRIDIASI UNTUK PENGHASILAN BUSA DAN DULANG BUSA MUDAH TERURAI

Oleh

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Pengerusi: **Profesor Madya Sharifah Kharidah Syed Muhammad, PhD**

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Irridiasi pancaran elektron menjana ikatan silang didalam akueus PVA dan PVP tetapi menyebabkan degradasi dalam akueus kanji sagu. Campuran kanji sagu/PVP lebih sedia diikat- silang daripada campuran kanji sagu/PVA. Kekuatan gel kedua-dua campuran meningkat apabila dos irradiasi ditingkatkan kerana ikatan silang tersebut. Kanji sagu didapati meningkatkan kekuatan gel campuran tersebut. Peningkatan modulus penyimpanan dan tan δ seiring dengan peningkatan dos irridiasi menujukkan pembentukan ikatan silang hasilan irridiasi. Ini mengesahkan bahawa interaksi molekul berlaku di dalam campuran kanji sagu/PVA dan kanji sagu/PVP. Percambahan mungkin berlaku dalam campuran kanji sagu/PVA dan kanji sagu/PVP seperti yang diperhatikan dalam pergerakan spektra analisis termogravimetrik. Penemuan hasil kajian mikroskopik elektron ke atas morfologi permukaan retak campuran telah membuktikan kewujudan ikatan silang hasil irridiasi.

Kesan jenis dan kepekatan polimer, suhu pencampuran, dos irridiasi pancaran elektron ke atas ciri busa telah diselidik. Campuran kanji sagu/alkohol polivinil (PVA) dan kanji sagu/pirolidon polivinil (PVP) dicampur pada suhu 25°C dan 80°C. Campuran tersebut kemudian diirradiasi dengan pancaran elektron berdos 10 hingga 30 kGy. Busa kemudian dihasilkan dengan mengembangkan campuran terirridiasi tadi didalam ketuhar gelombang mikro 5 hinnga 8 minit. Busa dengan pengembangan linear yang tinggi boleh dihasilkan daripada campuran 25:15 kanji sagu:PVA, 30:10 kanji sagu:PVA, 20:20 kanji sagu:PVP dan 25:15 kanji sagu:PVP yang dicampur pada 80°C. Dos irridiasi 15 kGy didapati sesuai untuk menghasilkan busa kanji sagu/PVA dengan pengembangan linear yang maksima, manakala 10 kGy pula sesuai untuk busa daripada kanji sagu/PVP. Penambahan kanji sagu dalam campuran meningkatkan pengembangan linear busa. Perubahan dalam morfologi campuran didapati apabila campuran dikenakan dos irridiasi yang lebih tinggi. Campuran kanji sagu/PVA sesuai untuk pengeluaran busa kerana ia menghasilkan busa yang fleksibel, licin dan berkilat jika dibandingkan dengan campuran kanji sagu/PVP yang menghasilkan busa yang lebih tegar. Nisbah pengembangan linear busa daripada campuran kanji sagu/PVA adalah lebih tinggi daripada yang diperolehi dengan campuran kanji ubi kayu/PVA, kanji gandum/PVA dan kanji jagung/PVA.

Campuran kanji sagu/PVA yang diirridiasi dibentuk menjadi dulang dengan mesin tekanan sejuk panas. Ciri fizikal dulang seperti ketahanan koyakan, kapasiti penyerapan air dan isoterma penyerapan kelembapan ditentukan. Irridiasi atau pengikatan silang campuran kanji sagu/PVA meningkatkan ketahanan koyakan dan

kelembapan dulang busa yang dihasilkan. Keputusan ujian penanaman dalam tanah menunjukkan dulang busa daripada kanji sagu/PVA boleh dibiodegradasi sehingga 40% daripada kehilangan berat berlaku pada bulan pertama tempoh penanaman. Ini diikuti dengan pertumbuhan mikrob, berkemungkinan kulat, yang dapat diperhatikan pada dulang busa dibawah mikroskop elektron imbasan.

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I certify that an Examination Committee has met on 9th February, 2007 to conduct the final examination of Benchamaporn Wongsuban@Benchamaporn Pimpa on her Doctor of Philosophy thesis entitled "*Irradiation modification of sago starch and polyvinyl alcohol blends for production of biodegradable foams and foam trays*" in accordance with Universiti Pertanian Malaysia (Higher degree) Regulations 1981. The committee recommends that the candidate be awarded the relevant degree. Members of the Examination Committee are as follows:

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DECLARATION

I hereby declare that the thesis is based on my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at UPM or other institutions.

_____

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Date: 27 MARCH 2007

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LIST OF ABBREVIATIONS

ATR	Attenuated total reflectance
CA	Cellulose acetate
CFC	Chlorofluorocarbon
DMA	Dynamic mechanical analyser
DP	Degree of polymerisation
EPS	Extruded polystyrene
M	Molarity
FTIR	Fourier transform infrared spectroscopy
MW	Molecular weight
PB	Paperboard
PCL	Polycaprolactone
PHBV	Polyhydroxybutyrate-co-valerate
PHEE	polyhydroxyesterether
PLC	Polylactic acid
PVA	Polyvinyl alcohol
PVP	Polyvinyl pyrrolidone
R^2	Coefficient of determination
SCFs	Starch-based composite foams
T_m	Melting temperature
TGA	Thermogravimetric analyser
USA	The United States of America