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Physicochemical and thermal properties of gamma-irradiated sago (*Metroxylon sagu*) starch

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HIGHLIGHTS

- Properties of irradiated sago starch at doses 0, 6, 10 and 25 kGy were studied.
- Apparent amylose content and swelling power was reduced by irradiation
- Irradiation decreased relative crystallinity but did not alter the crystalline type.
- SEM of irradiated starch granules up to dose of 25 kGy showed no physical damage.
- Thermal properties of irradiated sago starch were slightly affected.

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ABSTRACT

Sago (*Metroxylon sagu*) starch was exposed to gamma-irradiation in air at doses 6, 10 and 25 kGy. Subsequent changes in the physicochemical and thermal properties were measured. The apparent amylose content and swelling power of irradiated sago starch was significantly reduced while reducing sugars and starch solubility were significantly increased due to degradation. X-ray diffraction studies showed that radiation did not affect the crystalline type but induced a decrease in the degree of crystallinity, indicating the destruction of the ordered distribution of neighboring polysaccharide chains in the starch granules, in particular of the amylopectin component, which is responsible for starch crystallinity. Differential scanning calorimetry (DSC) of irradiated sago starch showed a small but significant increase in the onset and peak transition temperatures at 10 and 25 kGy dose; the conclusion temperature and gelatinization enthalpy was not affected. SEM and particle size analysis produced no evidence of physical damage to sago starch up to 25 kGy dose radiation treatment since the granular appearance and size distribution was retained.

1. Introduction

Sago starch is obtained from the trunk of sago palm (*Metroxylon* spp.) through the process of extraction and purification. It is an important agricultural commodity of Malaysia, ranking fifth highest in terms of agricultural revenue after pepper, palm oil, cocoa and rubber (Abd–Aziz, 2002). Malaysia is the world's largest exporter, exporting about 44,000 t per year of sago products to countries including Japan, Europe, America and Singapore. Apart from its use in food, sago starch can also be utilized to produce adhesives for paper, textiles, and plywood; as stabilizer in pharmaceuticals and converted using acid/enzyme to produce glucose, high fructose syrup, monosodium glutamate, etc. New and potential applications of sago could be in the production of biodegradable plastics, bio-fuel and ethanol. However, application of sago starch in bioconversion is limited because of high paste viscosity and resistance of the raw granule to enzyme digestion.

Like other native starches, sago starch needs to be modified to obtain the required functional properties to meet industrial needs and extend its range of potential applications. Research on sago starch modification has been reviewed by Singhal et al. (2008). Chemical modification by hydroxypropylation cross-linking and acetylation loosen the granular structure, lower gelatinization enthalpy and increases the thermal stability of sago starch (Aziz et al., 2004). Zainal et al. (2005) synthesized carboxymethylated sago starch which exhibit excellent dispersibility and cold-water solubility. Enzyme-modified sago starch with a higher amount of linear long-chain dextrin suitable for use as coating for fresh fruits and vegetables, thereby inhibiting browning has also been studied

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by Wong et al. (2007). At present, limited studies have been reported on the ionizing irradiation of sago starch. Pimpa et al. (2007) observed changes in some of the physicochemical properties of electron beam irradiated sago starch while Mohd Adzahan et al. (2009) evaluated the pasting and leaching properties using different radiation techniques.

Ionizing radiation (gamma, X-ray or electron beam) is a physical treatment which has been used to modify starch through cross-linking (Nagasawa et al., 2004) and degradation (Sokhey and Hanna, 1993). Gamma radiation generates free radicals which can induce molecular changes and fragmentation of starch. Degradation of both the amylose and amylopectin occur by random cleavage of the glycosidic chains, to yield smaller fragments of dextrin that may either be electrically charged or uncharged (Ciesla et al., 1991).

The effect of gamma-irradiation on starch properties and food quality has been of interests to food processors. Research has been reported on irradiation of starches of rice (Yu and Wang, 2007), wheat (Ciesla and Eliasson, 2003), maize (De Kerf et al., 2001) and potato (Ciesla and Eliasson, 2002). The properties of irradiated starches have been reviewed by Tomasik and Zaranyika (1995) and Sokhey and Hanna (1993). The effect of irradiation varies with the botanical origin of starch. Crystallinity of irradiated starch increases with increasing radiation dose in wheat starches (MacArthur and D'Appolonia, 1984) and decreases in potato starch (Ciesla and Eliasson, 2002). Retrogradation tendency was lower in irradiated Lasco triticale but higher in Grana wheat starches at 2 kGy dose (Bachman et al., 1997).

The present study was conducted to determine the effects of gamma-irradiation on sago starch that could possibly impart different functional properties for new applications. Here we report the physicochemical and thermal changes induced in sago starch by gamma-irradiation at doses of 6, 10 and 25 kGy.

2. Experimental

2.1. Materials

Sago (*Metroxylon sagu*) starch was purchased from commercial sago supplier in Sarawak (as fine white powder, food grade). The moisture content determined using oven-drying at 105 °C until constant weight was 13.14 ± 0.2 g/100 g which is within the typical range for commercial sago starch. The sample was used as received without further treatment.

2.2. Irradiation of sago starch

Sago starch (50 g) was sealed in polyethylene bags (13 cm × 13 cm) and gamma irradiated in air at Synergy Health plc radiation facility, Swindon, England. Radiation doses delivered were 6, 10 and 25 kGy at dose rate 8.3 kGy/h. Dosimetry was performed using red Perspex dosimeter. All the bags of sample were stored in a cabinet at room temperature (28.3 ± 0.3 °C) before analysis.

2.3. Characterization

2.3.1. Scanning electron microscopy (SEM)

Sago starch samples, sprinkled sparsely over aluminum stub, were metallized by depositing a thin layer of gold (20 nm thick) on the surface using a SEM Coating Unit (Biorad–Polaron Division). The granules were observed under a scanning electron microscope (FE1 Quanta Series).

2.3.2. Particle size analysis

Starch particle size was determined by a laser scattering technique, using particle size analyzer (Model Honeywell – Microtrac ASVR). About 1 g sample in 10 ml distilled water (dispersion liquid) was agitated using ultrasonic processor for 30 s before loading the sample into the dispersion unit. Each sample was measured three times and the mean values recorded using the software (Microtrac 9.1.6). The particle size measurement range was 0.02–700 μm.

2.3.3. Determination of apparent amylose and reducing sugars

The apparent amylose content was determined according to the colorimetric method of McGrane et al. (1998) using dimethyl sulphoxide (DMSO 90% in distilled water) as solubilizing agent. Reducing sugar was determined based on the dinitrosalicylic acid (DNS) method of Bruner (1964).

2.3.4. Swelling power and solubility

Swelling power and solubility of sago starch was determined at 95 °C according to the method of Schoch (1964) with minor modifications. Solubility was determined by drying 25 ml aliquot of the supernatant in an air oven at 130 °C overnight. Triplicate experiments were carried out for each sample.

2.3.5. X-ray diffraction and crystallinity

Monochromatic Cu K "alpha" I radiation (wavelength ¼ 1.542 A°) was produced by a Bruker AXS X-ray powder diffractometer Model D8 Advance under the following conditions: voltage 40 kV; current 30 mA; scanning from angle $2\theta = 4$–30°. To minimize the effects of different moisture contents on crystallinity, sago starch samples were equilibrated in a desiccator filled with water for 2 weeks. The degree of crystallinity (%) was quantitatively estimated from the ratio of the areas of the crystalline diffraction peaks to the area of whole diffraction pattern after baseline subtraction using a peak-fitting software (Origin Version 7.0, Microcal Inc., Northampton, MA, USA).

2.3.6. Differential scanning calorimetry

Thermal characteristics of sago starches were studied by using a Differential Scanning Calorimeter (Perkin Elmer Pyris 1). Starch (3.5 mg, dry weight) was loaded into a 40 μl capacity aluminum pan and distilled water was added to obtain a starch/water ratio of 1:3 by weight. The pan was hermetically sealed, equilibrated for 1 h at 27 °C, and heated from 35 °C to 160 °C at the rate of 10 °C/min. Characteristic temperatures of transitions were defined as T_o (onset), T_p (peak of gelatinization) and T_c (conclusion). Enthalpy of gelatinization (ΔH_G) was calculated on starch dry basis.

2.4. Statistical analysis

The data reported in the tables were subjected to one-way analysis of variance (ANOVA) using the statistical analysis software (SAS). Significant differences between means were further determined by Duncan's multiple-range test at 95% confidence level ($p < 0.05$).

3. Results and discussion

3.1. Effect of irradiation on granule morphology and size

SEM micrograph (Fig. 1) shows that native sago granules are predominantly ovoid with some having a spherical shape, but a significant property is the truncated end. Irradiation up to a dose of 25 kGy showed no evidence of physical damage since the smooth granular appearance is retained, with no splitting/fissures