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Molecular properties of cassava starch modified with different UV irradiations to enhance baking expansion

N. Vatanasuchart[a], O. Naivikul[b], S. Charoenrein[b], K. Sriroth[b,*]

[a]*Institute of Food Research and Product Development, Kasetsart University, 50 Paholyothin Road, Jatujak, Bangkok 10900, Thailand*
[b]*Faculty of Agro-Industry, Kasetsart University, 50 Paholyothin Road, Jatujak, Bangkok 10900, Thailand*

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Abstract

Commercial cassava starch was modified with 1% (w/w) lactic acid solution and irradiated with ultraviolet radiation: UVBA (280–420 nm), UVB (310–330 nm) and UVC (254 nm) for 7–15 h. Thermal properties and molecular size distributions of the cassava starch molecules were investigated to explain structural changes responsible for baking expansion ability. The acidified starches irradiated with UVB or UVC for 7 and 9 h achieved the desired baking expansion ability and showed a significant increase in the peak temperatures determined with the differential scanning calorimeter (DSC). The results indicated formation of stable network structures suitable for the expansion. However, the transition enthalpy of these starches did not significantly decrease from that of the commercial starch. Using high performance size exclusion chromatography (HPSEC), it was found that the amylose content of the commercial starch (DPn 2173 ± 163) was decreased to DPn 1551 ± 62 and 1427 ± 54 by UVB, and to DPn 1216 ± 28 and 1096 ± 30 by UVC irradiated for 7 and 9 h, respectively. Profiles of the molecular distributions showed that it was mainly amylose molecules that was degraded by UVB whereas both amylose and amylopectin molecules were degraded by UVC in the amorphous regions.

Keywords: Cassava starch; Baking expansion; UV irradiation; Thermal properties; Molecular size distributions

1. Introduction

Solar ultraviolet (UV) radiation can be classified into UVA (315–400 nm), UVB (280–315 nm) and UVC (100–280 nm), the short wavelengths of less than 290 nm undergoing significant absorption by the atmosphere at the ozone layer (Nee, 1996; World Health Organization, 1994). Most research works on starch modification by UV irradiation have employed an artificial UVC source (Bertolini, Mestres, Colonna, Lerner, & Della Valle, 1998; Fiedorowicz, Tomasik, Sangguan, & Seung, 1999).

Several researchers have stated that sunlight, particularly certain UV wavelengths, as well as lactic acid fermentation are essential for the baking expansion ability of cassava starch (Bertolini, Mestres, Lourdin, Della Valle, & Colonna, 2001; Cardenas & de Buckle, 1980; Dufour, Larsonneur, Alarcon, Braset, & Chuzel, 1996). In a study on the oxidative modification of cassava starch with lactic acid together with sun drying, baking behavior with an increase in specific volumes of tested biscuits was obtained, but this did not occur when the starch was oven dried (Mestres & Rouau, 1997; Plata-Oviedo & Camargo, 1998). Moreover, it was found that the lactic acidified cassava starch exposed to UV irradiation from a broad band mercury vapor lamp of 250–600 nm produced marked expansion ability (Bertolini, Mestres, & Colonna, 2000).

Recently, the effects of different frequencies and durations of UV irradiation on pasting properties of cassava starch in relation to biscuit expansion were observed by Vatanasuchart, Naivikul, Charoenrein, and Sriroth (2003). The peak viscosities of the starches irradiated with UVB for 7 and 9 h were 196.55 ± 2.41 and 195.67 ± 0.83 RVU, those of starches irradiated with UVC were 176.55 ± 1.83 and 169.54 ± 3.24 RVU, and those of starches dried with hot air were 121.07 ± 0.97 and 116.92 ± 1.89 RVU, respectively. This study found that the UVB irradiated starches possessing the desired expansion ability showed less change in the peak viscosity from that of commercial starch

* Corresponding author. Fax: +66 29 40 56 34.
E-mail address: ifrnpv@ku.ac.th (K. Sriroth).

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(235.84 ± 1.65 RVU). Lactic acidification together with sufficient UV energy resulted in partial depolymerization of the cassava starch molecules. Thus, when the starch paste was heated, the modified starch molecules more readily took up water molecules, resulting in a higher peak viscosity of the UVB irradiated samples than those treated with the UVC irradiation or hot air drying which provided too much starch depolymerization. Fiedorowicz et al. (1999) found that after UV irradiation of corn starches, there was evidence of the formation of crosslinkages between starch molecules at sufficient energy uptake.

This present study was undertaken to examine effects of irradiation of lactic acidified cassava starch with different UV wavelengths on changes in molecular properties responsible for baking expansion behavior. Thermal characteristics and profiles of apparent amylose and amylopectin size distributions of the modified starch samples were determined and compared.

2. Experimental

2.1. Materials

A total of 100 kg from the same batch of commercial cassava starch donated by Taiwa Public Co. Ltd. (Thailand) was used in this study. DL-Lactic acid, 85% syrup (Sigma No. L-1250) and amylose standard (Sigma No. A-0512), were purchased from Sigma Chemical Co. (Japan). Other chemical agents were of analytical grade from Merck (Germany).

2.2. Modification of the cassava starches by lactic acid hydrolysis and different UV irradiations

The cassava starch (200 g, dried starch basis) was dispersed in 600 g of 1% (w/w) lactic acid solution, and a hydrolysis period of 15 min at 25 °C was allowed, using the method adapted from Plata-Oviedo et al. (1998). The acidified starches were drained with a Buchner funnel using a vacuum pump and the 150 g samples with a final moisture content of approximately 42% were transferred to a stainless steel tray. Then, the samples were placed in three different UV cabinets, which were lined with highly polished aluminum and supplied with air circulator. There were (i) four UVBA lamps (Philips, TL 20W/12) emitting radiation of 280–420 nm, which was 64% UVB and 36% UVA; (ii) four UVB lamps (Philips, TL 100W/01) emitting energy from 310–330 nm, which was 90% UVB and 10% UVA and (iii) five UVC lamps emitting energy at 254 nm (Sylvania, 30W), as well as different exposure periods of 7, 9, 11 and 15 h used for modification (Nee, 1996). The UV irradiated acidified starches were compared to the acidified starches dried in a conventional hot air oven at 40 °C for the same periods and to the commercial cassava starch used without any treatment. The dried starch sample was sieved through a 100 mesh sifter to obtain fine and homogenous powder. The final moisture content of the treated starches for 7, 9, 11 and 15 h were 15.14 ± 0.50, 14.51 ± 0.28, 13.52 ± 0.46 and 12.79 ± 0.16%, respectively; that of the commercial starch was 11.71 ± 0.13%.

2.3. Baking test

The test for the baking expansion ability was performed by baking cassava rolls prepared using a procedure adapted from a recipe for *pao de queiji* (Maria's Cookbook, 2002). Cassava rolls were made with 45 g (dried starch basis) of the cassava starch, 45 g whole milk, 10 g soybean oil, 0.5 g salt, 5 g egg and water. A 14 g portion of dough was weighed on baking paper and baked at 210 °C for 20 min. After baking, the volumes of six cassava rolls were determined by the sesame seed displacement method and their weights were measured. Calculation for specific volume (cm^3/g) was done by dividing the obtained volume of the baked roll by its weight (Plata-Oviedo et al., 1998).

2.4. Thermal properties

Thermal properties of UV irradiated acidified cassava starch, hot-air dried acidified starch and the commercial starch were examined by using a differential scanning calorimeter (DSC) (Perkin-Elmer Pyris I, USA), equipped with a cooling system according to the method adapted from Sriroth et al. (1999). A starch sample (3.4 mg, dried starch basis) was weighed in the aluminum DSC pan and deionized water was added to obtain a 30% starch suspension. The cover was carefully put on and sealed hermetically using sealing tools. Weights of the sealed pans before and after determination were recorded to check for water leakage due to improper sealing. The pans were kept overnight before determination. The sample pan was placed carefully in the DSC and was heated at 10 °C/min from a temperature of 30–95 °C. An empty pan was used as reference and the instrument was calibrated using indium standard. Endothermal curves exhibiting onset, peak and end temperatures (°C) and transition enthalpy (J/g of the sample weight) of the starch sample were recorded.

2.5. Molecular size distribution of the UV irradiated acidified cassava starches

Molecular size distribution of amylose and amylopectin were characterized with high performance size exclusion chromatography (HPSEC) according to the method of Govindasamy, Oates, and Wang (1992). The system consisted of a pump (LC-10AT, Shimazu, Japan), auto-injector (SIL-10A, Shimazu, Japan) and three SEC columns (Ultrahydrogel Linear, Ultrahydrogel 120 and Ultrahydrogel 120, serially placed in a column oven (CTO-10AS, Shimazu, Japan) maintained at 40 °C. A differential