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Architectural changes of heated mungbean, rice and cassava starch granules: Effects of hydrocolloids and protein-containing envelope

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Abstract

Architectural changes of starch granules induced by heat were demonstrated using light microscopy and confocal laser scanning microscopy. Heat treatment (80 °C, 30 min) on mungbean starch, cassava starch and rice flour suspensions resulted in the rearrangement of amylose and granule-associated proteins within the deformed granules. The presence of alginate and carrageenan influenced the RVA pasting characteristics of starch/flour-hydrocolloid mixed suspensions by maintaining the granular structure of amylose-rich swollen granules or inducing the aggregation of the swollen ones. Generally, the addition of hydrocolloid increased peak viscosity, lowered breakdown and reduced setback of the flour-hydrocolloid mixed paste. This study demonstrated that the heat treatment in excess water generated the protein-containing granule envelope encasing the mungbean and cassava starch content within the deformed granules.

Keywords: Architecture; Cassava; Granule; Mungbean; Rice; Starch

1. Introduction

Rice (*Oryzae sativa*, L.), cassava (*Manihot esculenta* Crantz) and mungbean (*Vigna radiata* (L) Wilczec) are major starch crops in Asia. The native starches have been used extensively in traditional starchy foods such as noodles, snacks and desserts in the Orient. In addition, it is a common practice to use mixed flour in creating different textures and appearances. The textural properties of starch pastes and gels can range from firm and chewy mungbean starch vermicelli to soft and sticky cassava-based desserts. These starches/flours have different physicochemical properties; i.e., granular size distribution, swelling power, pasting, gelatinization and retrogradation characteristics (Hongsprabhas, 2006; Kasemsuwan, Bailey, & Jane, 1998; Xu & Seib, 1993).

Although the benefits of hydrocolloid addition to starch functionalities are apparent, the influences of hydrocolloids appear to vary due to the botanical origins of starch. The molecular interactions between starch and gum, extensively investigated during the past ten years, are critical to the overall functionalities of starch-hydrocolloid composites (Alloncle, Lefebvre, Llamas, & Doublier, 1989; Christianson, Hodge, Osborne, & Detroy, 1981; Funami et al., 2005a, 2005b, 2005c; Sae-kang & Suphantharika, 2006; Shi & BeMiller, 2002). However, little attention has been emphasized on the roles of starch granular structure and starch ghosts, which also impart the overall starch functionalities in food products.

The importance of starch ghosts has been underestimated in many of the physically analytical techniques, which treated gelatinized starch as a uniform amylopectin, amylose and non-starch constituents. The starch granule ghosts have been classified as starch granule surface, the granule envelope and the starch granule ghost (Atkin, Abeysekera,

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& Robards, 1998). The starch granule surface is the outermost layer of the granule; while the swollen surface surrounding most of the starch during gelatinization is called the granule envelope. The granule ghost is the remnants of the envelope after the structural collapse, where most of the starch has been liberated. The ghost remnants have been shown to be composed of amylopectin (Atkin et al., 1998). The large structure of starch ghosts, which possesses elastic properties (Atkin et al., 1998), could affect molecular progression after gelatinization, such as phase separation, re-crystallisation and retrogradation of amylose and amylopectin, which contribute to the overall functional properties of starch. Sae-kang and Suphantharika (2006) have demonstrated that the granular ghost structure of cassava starch still exists after gelatinization under shear.

The effects of botanical origins of starch and the architecture of starch granules, before and after heating, were emphasized in this study. The research strategies were to use the anionic hydrocolloids; namely alginate and carrageenan, to alter pasting characteristics and subsequent molecular interactions between hydrocolloids and starch constituents. We hypothesized that the existence of the swollen starch granules in the cooked starch paste, as well as the characteristics of the granule envelope, have played an important role in determining the overall pasting characteristics. The insights in the characteristics of the swollen starch granules, at microscopic scale, could help understanding the contributions of the excluded volume of swollen granules during and after starch/flour pasting.

2. Materials and methods

2.1. Materials

Food grade mungbean starch (MB, Pine Brand, SithiNan, Thailand), rice flour (RF) and cassava starch (CS) (Jade Leaf Brand, Bangkok Interfood, Thailand) were obtained from a local supermarket. MB had 12.01% moisture content and 0.17% protein while RF contained 10.28% moisture and 7.59% protein. The CS contained 12.17% moisture but there was no protein detected by the Kjeldahl method (AOAC, 2000). Commercial grade sodium alginate (Algogel 6021) and sugar standardized carrageenan (Satiagel ME10) were obtained from Degussa Texturant Systems (Thailand). Potassium iodide (APS Finechem, Australia) and Rhodamine B (Invitrogen, USA) were used to stain amylose and protein, respectively.

2.2. Microstructure of starch granules before and after heating

One milliliter of MB, CS or RF suspensions were prepared in distilled water (unless specified) at a concentration of 0.67% (w/v), shaken vigorously and allowed to stand for 10 min at room temperature to absorb water. The suspension was heated in a water-bath at 80 °C for 30 min in a quiescent condition. The sample was cooled down at room temperature (27 °C) for 1 min and centrifuged at 14,000 rpm for 5 min (Spectrafuge 16M, USA) as described by Hongsprabhas (2006). The supernatant liquid was discarded. The sediment obtained after centrifugation was suspended in a 0.5 mL of distilled water and stained with 10% Lugol's iodine solution (Autio & Salmenkallio-Marttila, 2001). The microstructure was examined before and after heating at 80 °C for 30 min under the Leica DME Light Microscope (USA).

A solution of Rhodamine B (0.01% in 95% ethanol) was added to the unheated and heated starch suspensions prepared as described above. After incubation for 5 min, each sample was loaded into a slide well and observed for a location of fluorescent-labelled protein using the Confocal Laser Scanning Microscopy or CLSM (Axio Imager MI, Carl Zeiss PTe Ltd, Germany). An HeNe laser with an excitation wavelength of 543 nm was used. CLSM digital image were acquired using the LSM 5 PASCAL program.

2.3. Viscosity of commercial hydrocolloid gums

The commercial alginate (0.1–1.0% w/v) and carrageenan (0.1–0.3% w/v) were prepared in distilled water, boiled until clear solutions were obtained, cooled down at room temperature for 1 h and equilibrated at 25 °C for 2 h. The viscosity was measured at a shear rate of 12.2–122 s^{-1} using a Brookfield Rheometer (DV III+, USA) equipped with a small sample cell adaptor (UL-adapter, spindle no. 0). The cell was maintained at 25 °C throughout measurement. Reading was taken in triplicates.

2.4. Pasting characteristics

Rapid Visco Analyzer (RVA, Newport Scientific, Warriwood, Australia) was used to characterize pasting properties of mixed flour suspensions containing hydrocolloid gums at specified concentration. The flours were dispersed in the hydrocolloid suspension and incubated at 8 °C overnight to ensure that both starch and hydrocolloid were hydrated prior to heating. Twenty-five milliliters of mixed flour-hydrocolloid suspension containing 12% (w/v) of flour and different concentration of hydrocolloid was heated from 50 to 95 °C at the rate of 12 °C/min, held at 95 °C for 2.50 min, cooled to 50 °C at the rate of 12 °C/min and finally kept at 50 °C at 160 rpm. Amylogram describing pasting characteristics included pasting temperature (temperature where viscosity first increased), peak time (minutes at which the peak viscosity occurred), peak viscosity (the maximum viscosity developed soon after the heating cycle ended), holding strength (viscosity after holding at 95 °C for 2.5 min), breakdown (the viscosity difference between peak viscosity and holding strength), final viscosity (viscosity after cooling at 50 °C for 2 min) and setback viscosity (the viscosity difference between final viscosity and peak viscosity).