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Functional properties of arrowroot starch in cassava and sweet potato composite starches

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ABSTRACT

Root and tuber composite flours and/or starches can meet industrial requirements of carbohydrate-based food products since they gelatinize at relative low temperatures with rapid and uniform swelling of granules, and they exhibit a high viscosity profile compared to cereal starches. Arrowroot starch (10, 20, 30, and 40%, respectively) was mixed in cassava and sweet potato starches and their resulting composite gels were investigated for their gelatinization enthalpies, pasting, and freeze-thaw properties. Peak viscosities of composite starches significantly increased ($P < 0.05$) from 224.45 to 360.25 RVU in cassava mix, to 306.65–580.25 RVU in sweet potato mix. The gelatinization enthalpies of sweet potato and cassava composite starches were significantly affected, which suggested that the thermal energy during gelatinization to break the structural element in starch granular packing was substantially altered with increasing increments of AS. This meant that granular intermolecular bond increased, whereas granule swelling decreased. The addition of AS minimized freeze-thaw damage by reducing the available water to form ice crystals in cassava and sweet potato gel pastes after the first freeze-thaw cycle. This confirmed that partial substitution of cassava and sweet potato starches with AS formed a paste with improved freeze-thaw stability. Addition of arrowroot starch to cassava and sweet potato starches apparently improved gel stability and may find use in modulating gelling properties of these starches in commercial products.

1. Introduction

Arrowroot refers to any plant of the genus *marantha*, but the term is most commonly used to describe the easily digested starch obtained from the rhizomes of *marantha arundinacae*. *Other* plants that produce similar starches include East Indian Arrowroot (*cucurma angustifolia*); Queensland arrowroot (*cannaceae* Family); Brazilian Arrowroot (*Euphorbiaceous* family) and Florida arrowroot (*Zamia pumila*). Arrowroot is a large perennial herb found in rainforest habitats. The plant is naturalized in Florida, but is chiefly grown in the West Indies (Jamaica and St. Vincent), Australia, South East Asia, and South and East Africa.

The few studies that exist on arrowroot starch include the carboxymethylation of arrowroot starch (Kooijman, Ganzeveld, Manurung, & Heeres, 2003), gelatinization profiles for arrowroot starch (Hoover, 2001), and Erdman (1986) compared some physical properties of St Vincent commercial starch to US-grown arrowroot starch. Since the volume of research on arrowroot starch is scarce, the objectives of this study were therefore, to study the behaviour of arrowroot starch in composite starches.

Root and tuber starches gelatinize at relatively low temperatures, with rapid and uniform swelling of granules. They also exhibit a high viscosity profile and high paste clarity compared to cereal starches, although they retrograde easily (Craig, Maningat, Seib, & Hoseney, 1989). These starches have unique physico-

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chemical properties, primarily, due to their amylose and amylopectin ratio, and (Hoover, 2001) reports that most root and tuber starches exhibit a typical B-type X-ray pattern. Wheat starch has higher phospholipids and produces a starch paste with lower transmittance than potato (Hoover, 2001). On the other hand, among all the commercial starches, potato starch exhibits the highest swelling power and gives the highest viscosity of pasting properties (Mitch, 1984). Phosphorus, a non-carbohydrate constituent, is found in potato starch with relatively high values and may affect the functional properties of the starch. However, one of the major problems to be solved using starches is their high solubility in water (Curvelo, Carvalho, & Agnelli, 2001; Guimarães, Wypych, Saul, Ramos, & Satyanarayana, 2010); thus, their composites will demonstrate high hydrophilicity. The uses of composite flours and or starches often alter their compositions, and may therefore change the functional and pasting characteristics of the final product (Osungbaro, Jimoh, & Osundeyi, 2010).

Gelatinization, manifested by irreversible changes such as swelling, crystallite melting, and starch solubilization is the disruption of molecular order within the starch granules when they are heated in water; whereas retrogradation defines the reassociation of gelatinized starch molecules resulting in more ordered structures. These ordered structures in turn influence starch physical properties such as viscosity of gels and pastes. Viscosity is largely influenced by granule shape and swelling power, amylopectin-amylose entanglement, and amylose and amylopectin granular interaction (Charles, Huang, & Chang, 2008; Hoover, 2001).

Studies on native starch have shown that different factors such as amylose leaching, starch processing conditions (e.g. pasting temperature, shearing, and heating rate) (Charles et al., 2008) influence the functional properties of starch suspensions and gels. Comparatively, composite starches offer the opportunity to create novel or enhanced hydrocolloidal functions in our foods. Hence, our objectives were to determine the pasting, gelatinization, and freeze stability properties of combinations of sweet potato, cassava, and industrially-prepared arrowroot starches.

2. Material and methods

Industrial arrowroot starch was received as a gift from the St. Vincent Arrowroot Association. Sweet potato and cassava starches were bought from the local food market in Pingtung, Taiwan. Starch samples were stored in desiccators at room temperature.

2.1. Rapid Visco Analyser measurements of starch

The pasting properties of all composite starches were analyzed in triplicates with a Rapid Visco Analyser (RVA 4) controlled by Thermocline for Windows (version 2.2, Newport Scientific Pty Ltd., Warriewood, Australia). Samples for RVA tests contained 3 g of starch and 25 g of water. The RVA pasting curve was analyzed to determine a series of characteristic parameters of: initial viscosity (viscosity during 50 °C holding period); pasting temperature (temperature at which viscosity starts to increase); peak viscosity (maximum viscosity during heating to or hold at 95 °C); trough viscosity or holding strength (minimum viscosity after peak viscosity has been reached); and final viscosity (viscosity at end of run) (Tan, Torley, & Halley, 2008).

2.2. Differential scanning calorimetry of composite starches

A TA 2920 Modulated Temperature DSC (MTDSC; TA Instruments Inc., New Castle, Delaware, USA) was used to investigate the gelatinization process and thermal properties of the composite starches. Starch-solution concentrations of 10% (0.3 g of starch in 2.5 g of water or hydrocolloid solution) of known moisture content were selected for modulated temperature differential scanning calorimetry (MTDSC) studies to correspond to the concentrations used for RVA studies. The starches were mixed with the required amount of solvents and left to equilibrate overnight at room temperature. Test samples were carefully weighed (<20 mg) into aluminium pans and hermetically sealed. The scan intervals were 10–100 °C for all starches. A heating rate of 5 °C/min was chosen and the modulation was set at ±1 °C for every 60 s. These conditions were selected to minimize error that may result from incomplete modulation of the sample volume. At least duplicate analyses were conducted for each starch–solution combination. The Universal Analysis software was used to analyze the DSC to determine the onset (T_o), peak (T_p), end temperatures (T_e), and enthalpy of the starch gelatinization transition. In MTDSC, the sample experiences a sinusoidal modulation (oscillation) overlaid on the conventional linear heating or cooling ramp, which provides the benefits of separating the total heat flow signal into its heat capacity (reversible thermal event) and kinetic components (irreversible event, in this case the gelatinization process) (Tan et al., 2008).

2.3. Freeze-thaw stability of arrowroot starch

Freeze-thaw stability of composite starch samples was investigated by submitting the gelatinized starch pastes to alternate freezing and thawing cycles (freezing for 24 h at −18 °C and thawing for 1.5 h at 30 ± 2 °C) (White, Abbas, & Johnson, 1989). Five percent starch pastes was prepared by heating a starch sample in the required amount of water at 95 °C water bath for 30min and pouring in a previously weighed 10 mL centrifuge tube. Weights of the centrifuge tubes were recorded and subsequently frozen. Tubes were subjected to freeze-thaw cycles, followed by centrifugation at 6000 rpm for 30 min, then the percentage of water separated after each freeze-thaw cycle was measured. The weight of water was measured and the extent of syneresis was expressed as the percentage of water separated (Jayati, Singha, & Kulkarni, 2002). The following equation was used to calculate syneresis.

$$\text{Syneresis (\%)} = [\text{Water separated (g)} / \text{Total weight of sample (g)}] \times 100$$

2.4. Statistical analysis

All samples were analyzed in triplicate. The general linear model and multiple regression analysis (SAS Institute, Cary, NC) were used to analyze the data. Correlation analysis between two sets of data were performed using the CORREL analysis tool of Microsoft Excel, which calculates the covariance of the data sets divided by the product of their standard deviations.

3. Results and discussion

3.1. Granule morphology of arrowroot starch

Starch granules of *M. arundacecae* ranged in size from 9.47 to 22.47 μm. Most of the arrowroot starch granules showed a wide distribution range, which included a mixture of large (elliptical to oval), intermediate (oval), and small (oval to elliptical) granules (Fig. 1). The granular surfaces of all starch granules appeared to be smooth and showed no evidence of fissures. All of the large granules were regularly shaped, although a few broken granules indicated that very little fragmentation occurred during industrial

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