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Rice starch vs. rice flour: Differences in their properties when modified by heat–moisture treatment

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ABSTRACT

Starch and flour from the same rice grain source (with 20, 25 and 30% moisture content) were exposed to heat–moisture treatment (HMT) at 100 °C for 16 h in order to investigate whether there were differences in their susceptibility to modification by HMT and, if any, to determine the main causes of the differences. HMT had a far greater effect on paste viscosity of flour than of starch. A significant increase in paste viscosity after removal of proteins from HMT flour – as well as images of fast green-stained HMT flour gels – indicated that an important role was played by proteins in affecting properties of the modified samples. Greater effects of HMT on thermal parameters of gelatinization and gel hardness values of flours were observed – more so than those for starches. Following this observation, it was ascertained that components in rice flour other than rice starch granules also underwent alterations during HMT.

Heat–moisture treatment (HMT) is a physical modification technique applied to starches. It is considered to be natural and safe compared to chemical modification. Numerous studies have demonstrated the effects of such treatment on the structure and physicochemical properties of cereal, tuber and legume starches, including significant changes in X-ray diffraction pattern, crystallinity, starch chain interactions, granule swelling, amylose leaching, viscosity, gelatinization parameters, retrogradation, and acid and enzyme hydrolysis (Gunaratne & Hoover, 2002; Hoover & Vasanthan, 1994; Hormdok & Noomhorm, 2007; Jiranuntakul, Puttanlek, Rungsardthong, Puncha-arnon, & Uttapap, 2011; Juansang, Puttanlek, Rungsardthong, Puncha-arnon, & Uttapap, 2012; Watcharatewinkul, Puttanlek, Rungsardthong, & Uttapap, 2009; Watcharatewinkul, Uttapap, Puttanlek, & Rungsardthong, 2010). Changes in these properties would affect the versatility of starch in food products such as fried batter food, noodles, and other healthy food products.

Flours are fine, powdery materials obtained by grinding and sifting the starch-containing plant organelles, such as those from grains, seeds, roots, tubers, and fruits. Usually, flours contain almost the same components as the raw materials, except for moisture content. Components often found in flours include starch, non-starch polysaccharide, sugar, protein, lipid, and inorganic materials. Commercial rice flour is produced either by dry or wet milling of broken rice, whereas rice starch is generally obtained by the alkaline steeping method with multi-stage purification. Such a treatment results in a significant reduction of protein content as well as other components in rice starch. As reported by Singh, Okadome, Toyoshima, Isobe, and Ohtsubo (2000), the protein content of rice starch (0.2–0.9%) was much lower than that of rice flour (5.2–6.87%). It has been claimed that protein components account for the differences in thermal and pasting properties of rice starch and rice flour (Hamaker & Griffin, 1993; Lim, Lee, Shin, & Lim, 1999; Zhu, Liu, Sang, Gu, & Shi, 2010).

The effects of HMT on various aspects of rice starch properties have been reported by several researchers (Hormdok & Noomhorm, 2007; Khunae, Tran, & Sirivongpaisal, 2007; Shih, King, Daigle, An, & Ali, 2007; Zavareze, Storck, Suita de Castro, Schirmer, & Dias, 2010), whereas relatively little work has been done on properties of rice flour (Cham & Suwannaporn, 2010; Lorlowhakarn & Naivikul, 2006). None of the reviewed works involved comparison of starch and flour from the same source of rice kernels (the same variety, batch, etc.) in terms of susceptibility to modification by HMT. Therefore, in order to obtain information on properties of HMT rice starch compared to HMT rice flour, as well as to obtain a better understanding of the role of the components in flour (other than starch) on properties of HMT products, rice starch and rice flour from the same source – with moisture contents of 20, 25 and 30% – were subjected to HMT at 100 °C for 16 h. The treated products were then analyzed for their paste and gel properties as well as thermal properties. The magnitude of change in these attributes of starch

Abbreviations: HMT, heat–moisture treatment/heat–moisture treated; PB, protein body; T_o, onset temperature; T_p, peak temperature; T_c, conclusion temperature; ΔH, gelatinization enthalpy.

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and flour by HMT was compared and discussed in relation to the composition of rice kernels, especially the protein component.

1. Materials and methods

1.1. Materials

Rice grains (Prachinburi variety) were obtained from Prachinburi Rice Research Center, Prachinburi, Thailand. Porcine pancreatic α-amylase (EC 3.2.1.1, 28 U/mg solid) and amyloglucosidase (EC 3.2.1.3, 300 U/ml) were purchased from Sigma–Aldrich (St. Louis, MO, USA). A GLUCOSE liquicolor complete kit was purchased from Human Diagnostics (Wiesbaden, Germany). Protease (E-BSPRT) at a concentration of 50 mg/ml was purchased from Megazyme International Ireland (Bray, Ireland).

1.2. Starch and flour preparations

Rice starch was prepared by the alkaline steeping method (Ju, Hettiarachchy, & Rath, 2001), with some modifications. Dehulled rice grains were steeped in distilled water at 4 °C for 24 h. The supernatant was discarded and the steeped rice grains were ground with a blender, then passed through a 63 μm screen. The slurry was allowed to stand at 4 °C for 48 h. The supernatant was removed and the starch cake was re-suspended in 0.35% sodium hydroxide solution and kept at 4 °C for 48 h. The supernatant was decanted and the starch layer was re-slurried with water. The starch slurry was passed through a 63 μm sieve and allowed to stand at 4 °C for 24 h. The steps of washing with water were repeated three times. The starch cake was re-suspended in water, neutralized with 1 M hydrochloric acid to pH 7, and stored at 4 °C for 24 h. The supernatant was decanted, and the neutralized starch was re-suspended in water and placed at 4 °C for 24 h. Finally, the supernatant was removed and the starch cake was dried in an oven at 40 °C for 24 h. For rice flour, rice grains were ground with a blender, then passed through a 106 μm screen.

1.3. Chemical composition of starch and flour

Standard AOAC methods (1990) were used for the measurement of moisture, nitrogen, ash, and lipid. Protein was determined from estimation of total nitrogen using a conversion factor of 6.25. Phosphorus content was determined by a colorimetric chemical method (Smith & Caruso, 1964). Apparent amylose content was determined by a procedure described by Hoover and Ratnayake (2001). The amylose content was calculated from a standard curve prepared by using mixtures of pure amylose and amylopectin fractionated from rice starch (over a range of 0–100% amylose). Total starch was determined according to the method of McCleary, Gibson, and Mugford (1997).

1.4. Heat–moisture treatment

Rice starch and flour samples were adjusted to the desired moisture content (20, 25 or 30%) by soaking 200 g of starch in 600 ml of water overnight at 4 °C. The excess water in equilibrated slurry was then drawn out by vacuum suction to obtain a cake with moisture content around 40%. The cake was then air-dried to allow the moisture content to drop to the desired level. Moist samples (native and moistened rice starches and flours) in 250 ml screw-capped bottles were heated at 100 °C for 16 h. After HMT, the starches were dried at 40 °C overnight. Untreated rice starch and flour were used as controls.

1.5. Pasting properties

Pasting properties of starch slurry at a concentration of 8% (w/w) were determined by a Rapid Visco Analyzer (RVA-3D; Newport Scientific, Narrabeen, Australia) with a paddle rotated at a fixed speed of 160 rpm. The starch slurry was heated from 40 to 92.5 °C at a rate of 3 °C/min, maintained at 92.5 °C for 15 min, and then cooled to 40 °C at the same rate.

1.6. Light microscope

Samples were stained with fast green (0.1% for 20 min) and then rinsed with water, followed by iodine (0.2% iodine for 10 s), to observe the protein and starch in samples. The stained samples were examined under a light microscope at 200×.

1.7. Preparation of deproteinized rice flour

HMT rice flours were deproteinized by two methods: alkaline steeping and enzyme hydrolysis. Removal of protein by alkaline steeping was carried out according to the procedure described in Section 1.2. For enzyme hydrolysis, proteins in flour were hydrolyzed with protease as follows: a slurry of 2.24 g of HMT rice flour in 14.0 g of water was prepared in a Rapid Visco Analyzer (RVA) canister and its pH was adjusted to pH 7.8 with 0.1 N NaOH. Protease solution (0.1 ml) was then added, and the concentration of slurry was brought up to 8% before incubating at 37 °C for 30 min. Pasting properties of the deproteinized samples were then determined with an RVA. The control samples were done in parallel by using an equivalent amount of bovine serum albumin (BSA) instead of protease.

1.8. Texture analysis

After RVA testing, the canister containing starch/flour paste was covered with paraffin film and kept at 4 °C for 24 h. Texture of the gel was then determined using a Shimadzu EZ-S 50N Texture Analyzer (Shimadzu, Kyoto, Japan). Gel in the canister (with a dimension of 20 mm in height and 38 mm in diameter) was compressed at a speed of 2.0 mm/s to a distance of 15 mm with a cylindrical probe 20 mm in diameter. The obtained textural parameters were means of at least three measurements.

1.9. Differential scanning calorimetry

The thermal properties of starch/flour were determined by a differential scanning calorimeter (DSC 1; Mettler-Toledo, Schwerzenbach, Switzerland). The starch/flour (3 mg) was weighed in an aluminum pan (ME-00026763; Mettler-Toledo) and water (6 mg) was added. The pan was sealed and allowed to stand for 24 h at 4 °C. The scanning temperature range and heating rate were 25–100 °C and 5 °C/min, respectively. An empty pan was used as a reference. The transition temperatures reported were the onset temperature (T_o), peak temperature (T_p), and conclusion temperature (T_c). The enthalpy change on gelatinization (ΔH) was estimated by integrating the area between the thermograms and a baseline under the peak, and was expressed in terms of J/g of dry starch.

1.10. Statistical analysis

All analyses of starch and flour characteristics and properties were carried out with three replications. Experimental data were analyzed using one-way analysis of variance (ANOVA) and expressed as mean values ± standard deviations. A Duncan's test was conducted to examine significant differences among