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Viscoelastic properties of starches and flours from two novel rice mutants induced by gamma irradiation

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ABSTRACT

Storage and loss moduli (G' and G'') of rice starch and flour pastes dependent on temperature and frequency were characterized from two starch mutants (waxy mutant GM077 and white-core mutant GM645) and their parent Guangluai 4 (GLA4). The values of G' and G'' for rice starch and flour pastes decreased with the increase in temperature during heating. GLA4 contained the highest amylose content and exhibited the highest values in both G' and G'', while the waxy mutant GM077 that had the lowest amylose content showed the lowest values in G' and G''. During the cooling process, GLA4 and GM645, with higher amylose content, presented more significant increase in values of G' and G'', indicating that amylose played an important role in intermolecular entanglement and gel network formation. G'' showed sharper increase than G' as a function of frequency for both starch and flour pastes. Results observed in the current study will be of use to rice breeders and allied industries to meet the diversified demands for quality improvement of food products.

1. Introduction

Rice is the staple food crop for half of the world population, and has been consumed by humans for at least 5000 years. According to the International Grain Council (IGC), the global rice production is forecast to rise to nearly 467 million tons for 2012–2013 from 462 million tons in 2011–2012. Around 90% of the world's rice is produced and consumed in Asia. China, India, Thailand and Vietnam are among the major rice producers with China being the largest one, where the rice production accounts for around one-third of the total global production. Rice is primarily consumed as milled rice, but is also added as an ingredient to a number of products in order to confer creaminess, crunchiness, and firmness (Rosell & Gómez, 2006).

Although the proximate composition of rice grain is affected by cultivar, growth environment, and grain processing, the major component in rice flour is starch, which constitutes over 80% of the dry material (Lin, Singh, Chang, & Chang, 2011; Patindol, Guraya, Champagne, & McClung, 2010). Characterization of native starch from rice mutants or other novel sources is required for identifying desirable functional properties with the potential to replacing chemically modified starches.

The rheological characteristics of rice starch or flour determine their usage in food and non-food applications, so it is necessary to have them well documented. Noosuk, Hill, Farhat, Mitchell, and Pradipasena (2005) showed that the storage modulus (G') from oscillation, the instantaneous elastic modulus, and the Newtonian viscosity from creep testing strongly increased as both starch and amylose concentration increased for Thai rice starch gels. They also observed that samples whose amylopectin had a higher proportion of chains of DP 3–10 and a lower portion of chains with DP 11–22 showed no retrogradation on storage (Noosuk et al., 2005). Rice starches with the highest amylose content and with amylopectin with the lowest content of short side-chains had the highest maximum storage modulus (Singh, Nakaura, Inouchi, & Nishinari, 2007). The percentage of short chains (DP 6–11) was positively correlated to both storage and loss muduli, while the percentage of longer chains (DP 18–23) had a negative correlation with both moduli (Wang et al., 2010).

Water mobility was observed to be significantly correlated with rheological or textural parameters. It was mainly controlled by starch concentration, amylose content, and granule structure, with amylose content playing the major role (Lu et al., 2011). It is well-known that the textural properties of rice flours are mainly attributed to starch due to pasting and subsequent retrogradation, which is affected by the ratio of short-to-long amylopectin chains (Singh, Lin, Huang, & Chang, 2012). However, information about the concerted

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influences of starch structure, protein and amylose contents on the rheological properties of rice starch and rice flour is still scarce.

In our previous report, two starch mutants were identified from a high-amylose *indica* rice, Guangluai 4, following gamma ray irradiation mutation breeding. The structural and physical properties of the flour and starch were characterized (Kong et al., 2014). It should be noted that the mutant isolated from mutation breeding is regarded as an isogenic line of its parent, which means that all background fingerprints are the same except for the defective gene being responsible for the observed trait. The objective of the present study was to characterize the rheological properties of starch and flour from the two rice mutants.

2. Materials and methods

2.1. Materials

Two starch mutants, waxy mutant (GM077) and white-core mutant (GM645) were isolated from Guangluai 4 (GLA4) at a mutation breeding program in which the GLA4 was treated with ^{60}Co gamma irradiation at the dose of 350 Gy (Kong et al. 2014). The parent and two mutants were planted on the campus farm at Zhejiang University in June and the seeds were harvested in late September. The preparation of rice flour and starch were referred to Kong et al. (2014).

2.2. Rheological properties of starch and flour pastes

Rice starch and flour pastes (5% solids on a dry weight basis) were prepared by adding the powder to distilled water in a beaker with constant stirring in a water bath at 90 °C for 30 min; aluminium foil was applied to minimize water loss. The pastes were immediately transferred to the platen of a rheometer (AR1000-N, TA Instruments, New Castle, Delaware, USA), which was equipped with a smooth parallel plate measuring geometry of 40 mm diameter. The gap size, strain and frequency were set at 1000 μm, 2% (within the linear viscoelastic region of these preparations) and 1 Hz, respectively.

The pastes were cooled down to 50 °C in order to start the experimental temperature sweep. The sample edges were covered throughout with a thin layer of low-density silicon oil (dimethylpolysiloxane; 50 cPs viscosity) to minimize evaporation, starch and flour pastes were heated from 50 to 90 °C at a scan rate of 2 °C/min and then cooled from 90 to 25 °C at the same rate. The parameters of storage modulus (G'; solid component of the network), loss modulus (G''; liquid component) were recorded as a function of temperature. Following the temperature sweeps, materials were held undisturbed for 5 min at 25 °C to achieve a state of equilibrium and then subjected to a frequency sweep at 25 °C over the range of 0.628–125 rad/s to once more monitor the viscoelastic functions.

2.3. Statistical analyses

The results of the rheological analyses are illustrated as the means and the standard deviation of three independent measurements. The data analyses were performed with the SAS System for Windows version 8 (SAS Institute Inc., Cary, NC, USA), The Tukey's studentized range test was conducted for comparison of mean of individual accessions at $p < 0.05$.

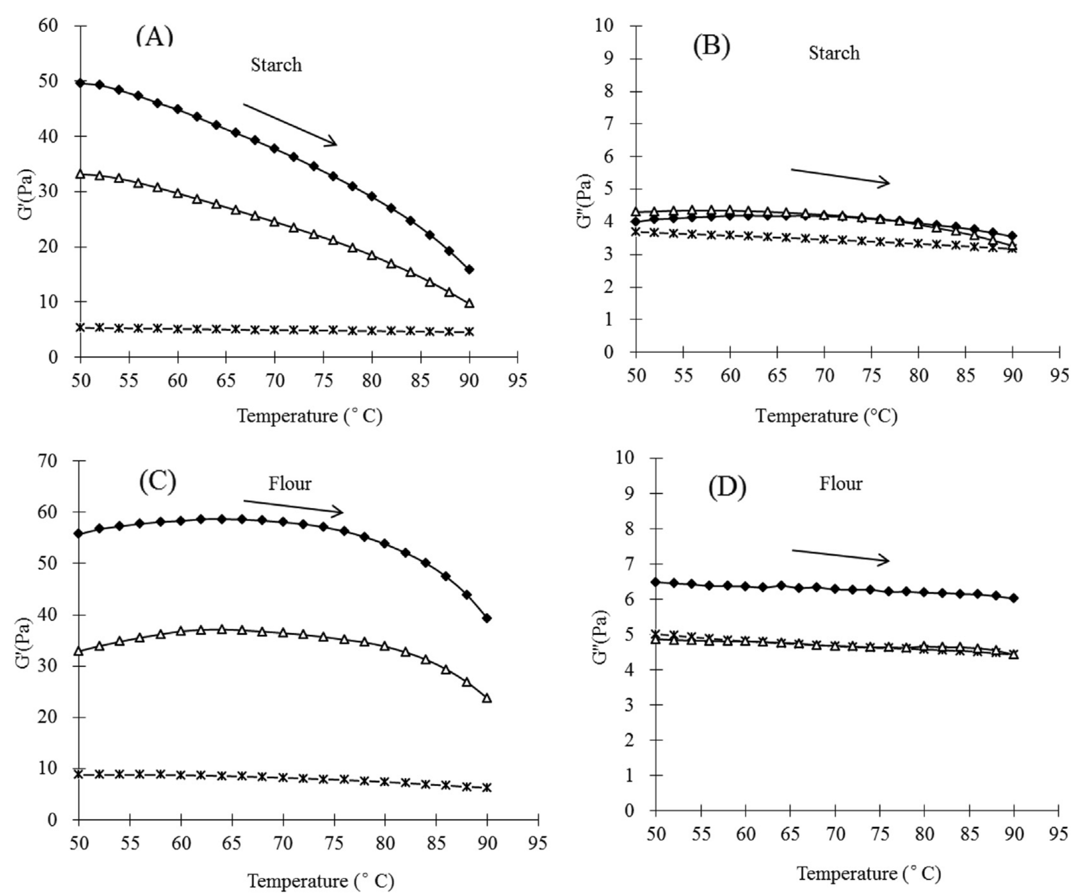

Fig. 1. Changes in storage (G') and loss (G'') moduli of 5% rice starch and flour pastes during heating (heating rate, 2 °C/min; strain, 2%; frequency, 1 Hz). —◆—: GLA4; —✳—: GM077; —△—: GM645.