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Physicochemical properties of hydrothermally treated glutinous rice flour and xanthan gum mixture and its application in gluten-free noodles

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A B S T R A C T

This study reported a quality improver of gluten-free food formulated using hydrothermally treated polysaccharide mixtures (HTT-PSM) of glutinous rice flour and xanthan gum at different concentrations. The pasting and viscoelastic properties were determined by rapid visco analyser and rheometer respectively. The results showed that HTT-PSM had a lower gelatinisation temperature, higher peak viscosity and weaker gel strength than native glutinous rice flour. The incorporation of HTT-PSM into rice dough decreased the dough development time and stability significantly; and increased its extensibility from 2.8 mm to 11.9 mm. Its high extensibility attribute enabled the dough to make gluten-free noodles with higher tensile strength and similar texture profile as compared to wheat noodles. Sensory evaluation showed that the overall texture of the gluten-free noodles was acceptable, but not as comparable to wheat noodles. Positive correlations were observed between xanthan gum content and peak viscosity, gel strength, noodle tensile strength, hardness and chewiness.

1. Introduction

The prevalence of coeliac patients and consumers' perceptions of gluten-free products as healthier alternatives have resulted in an increasing demand for a wider range of gluten-free products. Gluten confers elasticity and extensibility to the dough, and contributes to the retention of shapes of many food products such as noodles and baked confectioneries. The lack of gluten leads to a fragile and crumbly dough with poor processibility, and therefore, poses a big problem to the food industry. Moreover, gluten-free products often lack resilience and other textural attributes which are desirable to consumers.

Pregelatinised starch-based flour has been widely used as a texture improver in many food products. Cham and Suwannaporn (2010) and Hormdok and Noomborm (2007) used pregelatinised rice flour to improve the textural properties of rice noodles. Hydrothermal treatment, one of the most common methods to produce pregelatinised starch-based flour, has been widely studied. It was reported that hydrothermal treatment changed the X-ray pattern, swelling factor, crystallinity, starch chain associations, acid and enzymatic hydrolysis of various starches (Hoover and Manuel, 1996; Ozcan and Jackson, 2003). These changes affect the granular rigidity, gelatinisation and retrogradation, as well as gel structure, stability and hardness of starch (Takaya et al., 2000).

Several studies had conducted to prove that non-starch polysaccharides (NSP) can be incorporated into gluten-free flours to improve the textural properties of food products. Inglett et al. (2005) used an oat hydrocolloidal fibre to improve the binding qualities of noodles made with rice flour. Modified starch, xanthan gum (XG) and locust bean gum had also been used to improve texture and reduce changes of flavour in pasta made from pea flour (Gallagher et al., 2004). Lazaridou et al. (2007) used NSP such as pectin, carboxymethylcellulose (CMC), agarose, XG and oat β-glucan to improve the storage modulus and elasticity of rice flour dough for gluten-free bread.

Different types of NSP and starch-based flours are mixed to improve the characteristics of starch-based products. Lim et al. (2002) found that dry heating with sodium alginate, CMC or XG changed the paste viscosity of waxy maize and potato starches. XG provided the most substantial changes among these three gums.

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Chung et al. (2007) claimed a continuous increase in pasting viscosity of waxy rice starch when heated with phosphate salts and XG. Li et al. (2013) reported that crosslinking between starch granules was formed by xanthan polymers when XG and waxy rice starch were mixed and dry-heated.

Starches with varying amylose/amylopectin ratios and from different sources bring about different physical, textural and pasting properties during and after cooking (Champagne, 1996). According to a comprehensive review written by BeMiller (2011), many works have been done on the mixtures of hydrocolloids and starch-based flours from different sources including corn, wheat, potato, sweet potato, rice and etc. However, glutinous rice, with its unique sticky texture upon gelatinisation (due to high amylopectin content), has not been widely reported. The aim of this study was to manipulate the physicochemical properties of hydrothermally treated polysaccharide mixtures (i.e. glutinous rice flour and XG) in order to improve the textural and sensory quality of gluten-free food. XG was incorporated at different concentrations to study the effect of XG on the properties of HTT-PSM.

2. Materials and methods

2.1. Materials

Glutinous rice flour and rice flour (White Elephant Brand, Thailand) used in this experiment was provided by D'Cake Pte Ltd, Singapore. Xanthan gum (XG) (Versagum 200, Cargill) was obtained from a local distributor, Tosu Supplies Trading, Singapore.

2.2. Preparation of hydrothermally treated glutinous rice flour and polysaccharides mixtures

Hydrothermally treated glutinous rice flour (HTT-GRF) was prepared according to Bielskis et al. (1989) with modifications. Native glutinous rice flour (NGRF) and water were mixed in a cooking mixer (UM-SK5, Stephan, Germany) at powder to water ratio of 3:7 (% w/w). The mixture was mechanically-stirred at a constant speed of 510 rpm, heated to 90 °C, and held for 30 min. The cooked paste was then dried using a food dehydrator (Ultra FD 1000, Ezidri, Australia) at 60 °C for 24 h. The dried paste was pulverized into smaller pieces using a food processor (R 201, Ultra E, Robot Coupe, USA). The coarse powder was then further ground into fine powder using a knife miller (Drindomix GM 200, Retsch, Germany) at 10,000 rpm for 1 min. The grinded samples were separated to its respective particle sizes using a sieve shaker (EML Digital Plus, Haver & Boecker, Germany) with mesh apertures of 63 μm, 125 μm and 250 μm. For hydrothermally treated polysaccharide mixtures (HTT-PSM), XG was mixed with NGRF with respective ratio of 1:99, 3:97, 5:95 and 7:93 on dry weight basis before hydrothermal treatment (HTT). The particle size of each sample was standardised by mixing particle size of 125–250 μm, 63–125 μm and below 63 μm in the proportion of 70%, 20% and 10% respectively. The sample names and its descriptions used in this study are listed in Table 1.

Table 1
Denotations of samples.

Sample name	Description
RF	Native rice flour
WF	Native wheat flour
NGRF	Native glutinous rice flour
NGRF_1	Native glutinous rice flour dry-mixed with 1% XG
NGRF_3	Native glutinous rice flour dry-mixed with 3% XG
NGRF_5	Native glutinous rice flour dry-mixed with 5% XG
NGRF_7	Native glutinous rice flour dry-mixed with 7% XG
HTT-GRF	Hydrothermally-treated glutinous rice flour
HTT-PSM_1	Glutinous rice flour hydrothermally-treated with 1% XG
HTT-PSM_3	Glutinous rice flour hydrothermally-treated with 3% XG
HTT-PSM_5	Glutinous rice flour hydrothermally-treated with 5% XG
HTT-PSM_7	Glutinous rice flour hydrothermally-treated with 7% XG

2.3. Pasting properties

Pasting properties for each sample were analysed using a Rapid Visco Analyser (RVA-4, Newport Scientific, Australia) based on AACC method with modifications (AACC, 1995). Sample (3 g, 14% moisture basis) was weighed into an RVA aluminium canister and 25 mL of chilled deionised water was added. The sample was dispersed at a shear rate of 960 rpm for 10 s followed by a constant shear rate at 160 rpm. Sample was held at 15 °C for 2 min to study the cold-water viscosity, heated to 95 °C at 13.9 °C min^{-1} and held at 95 °C for 2.5 min before cooling to 45 °C at 12.7 °C min^{-1}. The sample was eventually held at 45 °C for 6.4 min. The values obtained were peak viscosity (maximum apparent viscosity during heating), breakdown viscosity (difference between the peak viscosity and the lowest apparent viscosity after heating ramp), setback viscosity (difference between the maximum apparent viscosity during cooling and the lowest apparent viscosity after the heating ramp) and final viscosity (apparent viscosity at the end of the test). The experiments were performed in triplicates, and the results were expressed as an average value.

2.4. Viscoelastic properties

Viscoelastic properties for each samples were analysed using a Physica controlled-stress Rheometer (MCR 301, Anton Paar, Austria) based on method from Lazaridou et al. (2007) with slight modifications. Samples (3 g, corrected to 14% moisture content) were dispersed in 50 mL of deionised water. The suspension was placed in a 90 °C water bath and stirred at 250 rpm for 30 min. The paste was allowed to equilibrate to room temperature for 1 h prior to analysis. A parallel plate geometry was used with a gap of 1 mm at constant temperature of 25 °C. Frequency sweep test was conducted at 0.1–10 Hz with a constant strain of 1% as determined to be within the linear viscoelastic region (LVR) by amplitude sweep. Storage modulus (G'), loss modulus (G'') and loss tangent ($\tan \delta = G''/G'$) were determined. Shear stress vs. strain data was monitored to evaluate the slippage of the sample. The experiments were performed in triplicates, and the results were expressed as an average value.

2.5. Dough development characteristics

Characteristics of dough development include the analysis of a number of parameters such as water absorption (WA), development time (DT), stability and softening. Each sample was analysed using a DoughLab equipment (Perten Instruments, Hägersten, Sweden) based on method from Gomez et al. (2009) with slight modifications. In the mixing bowl of equipment, the dough was formed by rotary action of two sigma-arm mixing blades at 63 rpm, 30 °C with a sample size of 50 g (14% moisture basis), and its resistance to kneading as a torque value was obtained. To obtain NGRF, HTT-GRF and HTT-PSM_1 to 7 dough types, 10 g of sample powder and 40 g of RF (14% moisture basis) were premixed for 1 min in the mixing bowl before the addition of water and kneading. For RF and WF samples, 50 g sample (14% moisture basis) were used. The experiments were performed in triplicates and the results were expressed as an average value.