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Chitosan effects on physical properties, texture, and microstructure of flat rice noodles

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ABSTRACT

The use of chitosan as a natural preservative has increased for rice-based products, but little is known about chitosan effects on product quality. This work elucidated chitosan effects on the physical properties (moisture content, pH, and color), texture, and microstructure of flat rice noodles. Chitosan solutions (0.33 and 0.50 g chitosan/100 mL acetic acid) were added to rice flour noodles. Chitosan exhibited no effect on moisture contents, but it decreased the rice noodle pH and whiteness. Confocal laser scanning micrographs revealed that acetic acid caused protein network formation in rice noodles. Chitosan did not affect textural properties of rice flour gel because the acetic-acid-induced protein networks inhibited chitosan effects. During storage at 30 °C for 5 d, chitosan retarded increases in the hardness and gumminess and decreases in the cohesiveness and springiness of rice flour gel. Results show that chitosan is useful as a preservative in rice flour noodles without adversely affecting noodle quality.

1. Introduction

Flat rice noodles, made from high amylose content rice flour, are extremely popular noodles in Southeast Asia (Fu, 2008). However, fresh flat rice noodles spoil easily in a single day because of microorganism activity, so food preservatives, especially benzoic acid and sodium benzoate, are used widely to extend the shelf-life of rice noodles. Today demand for non-artificial food preservatives has increased, so natural preservatives are preferred. Chitosan, derived from chitin, has high potential as a natural preservative for rice noodles because it exhibits wide-spectrum antimicrobial activity against bacteria, yeast, and fungi (Juneja, Dwivedi, & Yan, 2012; No, Meyers, Prinyawiwatkul, & Xu, 2007). Chitosan inhibits spoilage microorganisms in cooked rice and rice cake with proven efficacy (Lee, Lee, & Rhim, 2000; Rachtanapun, Tantala, Klinmalai, & Ratanasumawong, 2015; Tsai, Tsai, Lee, & Zhong, 2006). Moreover, chitosan is an approved food additive in many countries including Korea, Japan, and the USA (Hayes, 2012; No & Meyers, 2004; Rachtanapun et al., 2015). Chitosan is applied in food by coating the food surface or by addition directly into food. Effects of chitosan coating on food quality have been well studied, but few reports describe direct effects of chitosan addition on food quality, especially for rice-based products. The effects of added chitosan on food quality depend on the target food type. No and Meyers (2004) reported that chitosan increases the brightness and yellowness of tofu (soy bean curd). In contrast, chitosan reportedly has no effect on the whiteness of cooked rice (Rachtanapun et al., 2015).

Food texture determines the consumer acceptance of noodles. Hardness of sweet potato starch noodles is increased by the addition of chitosan (Baek, Cha, & Lim, 2001), although chitosan shows no effects on the sensory attributes of amaranth pasta (Del Nobile, Benedetto, Suriano, Conte, Corbo, & Sinigaglia, 2009). Lee et al. (2000) reported no difference in sensory evaluation between the texture of wet noodles with chitosan and control noodles. Although numerous studies have examined chitosan effects on noodle texture, no clear explanation has been offered for how chitosan affects the texture of those noodles, especially from a microstructural viewpoint. Because the effects of chitosan on noodle texture depend strongly on the noodle type, chitosan effects on the target noodle texture must be elucidated before using chitosan as an additive. No report of the relevant literature describes a study of chitosan effects on the physical properties, texture, and microstructure of flat rice noodles.

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This work was undertaken to investigate the effects of chitosan on the physical properties (color, pH, and moisture content) and texture of flat rice noodles. The effects of acetic acid and chitosan on the flat rice noodle microstructure were first observed using confocal laser scanning microscopy (CLSM). The relation between the rice gel texture and changes in the noodle microstructure attributable to the presence of acetic acid and chitosan was examined in this work. Furthermore, chitosan effects on the moisture content, pH, color, and texture of flat rice noodles during storage were examined. The results presented herein are expected to be helpful as guidance for the widened application of chitosan in rice-based products.

2. Materials and methods

2.1. Materials

Flake crab chitosan (polymer type, MW 280,000 Da, 94.78% degree of deacetylation; Ta Ming Enterprises Co., Ltd., Samutsakhon, Thailand) was used for this study. Glacial acetic acid was purchased from Merck and Co. Inc., Germany.

2.2. Chitosan solution preparation

Crab chitosan flakes of 3.3 g and 5 g were dissolved in 1000 mL of 0.33 mL acetic acid/100 mL deionized water to achieve the final respective concentrations of 0.33 g and 0.50 g crab chitosan per 100 mL acetic acid. Crab chitosan solutions were prepared, sterilized, and stored according to the method described by Rachtanapun et al. (2015).

2.3. Preparation of rice flour and rice starch

Rice grains (Leung 11 cultivar) were purchased from a rice mill in Kalasin, Thailand. The rice grains were wet milled according to Sangpring, Fukuoka, and Ratanasumawong (2015). The rice flour consisted of 10.69 g moisture/100 g dry sample, 6.02 g protein/100 g, 0.23 g ash/100 g, and 0.11 g fat/100 g. The amylose content of rice flour analyzed using the method described by Juliano (1971) was 36.51 g/100 g. This value agrees with the amylose contents of six Thai rice cultivars, which were 32–36 g/100 g (Yoenyongbuddhagal & Noomhorm, 2002).

Rice starch was prepared from rice flour by following a modified method of Lumdubwong and Seib (2000). To extract the protein from the rice flour, 0.05 mol/L NaOH solution was added to the rice flour in the ratio 5:2. After extraction, the rice starch was washed with deionized water, dried at 40 °C, milled, screened through a 0.150 mm sieve, packed in plastic bags, and stored at 10 °C until use. The rice starch consisted of 10.44 g moisture/100 g dry sample, 0.10 g protein/100 g, 0.17 g ash/100 g, and 0.01 g fat/100 g. The amylose content of the rice starch, as analyzed using the method described by Juliano (1971), was 38.80 g/100 g.

2.4. Rice noodle preparation

Fresh rice flour noodles were prepared according to the method described by Sangpring et al. (2015). Rice flour slurry was prepared by mixing 40 g of rice flour with 60 g of either deionized water, 0.33 mL acetic acid/100 mL deionized water, 0.33 g chitosan/100 mL acetic acid, or 0.50 g chitosan/100 mL acetic acid. Sixty grams of each slurry were poured evenly on a stainless tray and were steamed at 100 °C for 3 min. The rice noodle sheet was removed from the tray and cut into 20 cm × 1.5 cm strands.

Rice starch noodles with either deionized water, 0.33 mL acetic acid/100 mL deionized water, 0.33 g chitosan/100 mL acetic acid, or 0.50 g chitosan/100 mL acetic acid were prepared using the method used for the preparation of the rice flour noodles described above.

2.5. Moisture content and pH of rice noodles

The moisture contents of the rice starch or rice flour noodle samples were measured according to AOAC method 935.29 (AOAC, 2000). The pH of each rice noodle sample was measured according to AOAC method 943.02 (AOAC, 2000).

2.6. Color of rice noodles

After steaming, the rice flour noodle sheets were cut into 5 cm × 5 cm sheets. The color of each type of rice noodle sheet was measured using a colorimeter (Miniscan XE; Hunter Associates Laboratory Inc., USA) based on the CIE system with color values of L^*, a^* and b^*. The whiteness index (WI) of each sample was calculated using Eq. (1) (Rachtanapun et al., 2015).

$$WI = 100 - \left[(100 - L^*)^2 + a^{*2} + b^{*2}\right]^{1/2} \quad (1)$$

The whiteness of each type of rice noodle was averaged from at least 10 noodle sheets. All measurements were conducted in triplicate.

2.7. Texture profile analysis of rice gels

Texture profile analysis (TPA) method is usually applied to measure the noodle texture using a texture analyzer because this method collects large amounts of information related to the noodle texture at one time. To acquire accurate data, a machine load cell should match well with the magnitude of acquired force from sample. Cham and Suwannaporn (2010) reported that fresh flat noodle hardness was only 0.13 kg. Therefore, to increase the force to match with the load cell, the sample thickness was increased and prepared in the form of rice gels according to the method described by Huang, Kennedy, Li, Xu, and Xie (2007), with some modifications. The ratio between rice flour or rice starch to solutions was equal to the ratio used in preparing noodles. Rice flour or rice starch slurry was prepared by mixing 40 g of rice flour or rice starch with 60 g of either deionized water, 0.33 mL acetic acid/100 mL deionized water, 0.33 g chitosan/100 mL acetic acid, or 0.50 g chitosan/100 mL acetic acid. Sixty grams of either slurry of rice flour or rice starch was poured evenly in a 7.3 cm × 5.4 cm × 1 cm deep aluminum tray, after which it was steamed for 15 min. Rice gel of both types was cut into cubes 1 cm × 1 cm × 1 cm. Texture profile analysis (TPA) of both rice gels was conducted using a texture analyzer (TA-XT PLUS; Stable Micro Systems, Ltd., Surrey, UK) with a 50 kg load cell according to the modified method of Baek et al. (2001) and Huang et al. (2007). Compression was repeated at 1.0 mm/s with a flat-faced 100-mm-diameter cylinder probe at 50% strain. The pause between the first and second compressions was 60 s. Hardness, cohesiveness, springiness, and gumminess were analyzed from the measured profile. At least 10 samples were measured for each treatment. Each measurement was taken in triplicate.

2.8. Confocal laser scanning microscopy (CLSM)

The respective microstructural features of the rice flour and rice starch noodles prepared with deionized water, 0.33 mL acetic acid/100 mL deionized water, or 0.50 g chitosan/100 mL acetic acid were observed using a confocal laser scanning microscope (LSM5 PASCAL; Carl Zeiss Inc., Göttingen, Germany). Sample preparation