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The effect of sodium chloride on microstructure, water migration, and texture of rice noodle

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ABSTRACT

It is believed that salt can reduce the hardness and increase the elasticity of dried rice noodle. However, there is no scientific evidence on the role of salt on the quality of the dried rice noodle. This work aimed to investigate the effect of NaCl on the microstructure of dried rice noodle, water migration in rice noodle during cooking, and the texture of cooked rice noodle. The level of NaCl used in this study was 0, 3, and 5 g NaCl/100 g rice flour. Confocal Laser Scanning micrographs revealed that NaCl enhanced the development of the protein network but it reduced the packing of starch lumps in the dried rice noodle. Water distribution inside the rice noodle during rehydration was revealed for the first time using MRI. Water migrated more slowly into the rice noodle with NaCl than the control (without NaCl) because the amount, size, and the depth of pores of the dried rice noodle with NaCl were reduced due to the formation of the protein network. It was found that NaCl increased the extensibility and decreased the tensile strength of the cooked rice noodle. The cooking loss increased with the increase in the NaCl concentration.

1. Introduction

Rice noodle is one of the most popular noodles in Asia. Rice noodle is made by mixing rice flour with a high amylose content (amylose content > 25%) with water (Hormdok & Noomhorm, 2007). Then, the rice flour slurry is steamed to obtain the fresh rice noodle sheet. The fresh noodle sheet is cut into strips. Fresh rice noodle has a high moisture content, so it is easily perishable. In order to extend its shelf-life, fresh rice noodle is dried to the final moisture content at 10–12%. The process of drying rice noodle is divided into three steps: pre-drying, ageing, and final-drying. In the pre-drying step, some water is removed, so the moisture content of noodle is about 34%. Then, the noodle sheet is aged at room temperature for 12–24 h. Finally, the noodle sheets are cut into strips and dried to the final moisture content at 10–12%. The consumption of rice noodle, which is a gluten-free product, has increased recently due to the spreading of celiac disease over the world (Gallagher, Gormley, & Arendt, 2004). Good rice noodle should be white in color and have a soft texture. However, most of the dried rice noodle has a hard texture after cooking (rehydration) which is an inferior point. Hence, many manufacturers add salt into the dried rice noodle to prevent the hardness and increase the elasticity of the cooked rice noodle. However, there is no scientific report on the effect of salt on the texture of rice noodle.

One of the important factors that influences the texture of wheat and rice noodle is the microstructure. It is well known that the presence of salt in wheat noodle affects the noodle microstructure by enhancing the development of gluten network. Dexter, Matsuo, and Dronzek (1979) reported that salt enhances the development of the gluten network in wheat noodles, resulting in a smooth structure and uniform gluten network. This structure leads to a strong, high resistance wheat noodle. Similarly, salt was also reported to strengthen the gluten network of bread dough (Lynch, Bello, Sheehan, Cashman, & Arendt, 2009; Salovaara, 1982). Wu, Beta, and Corke (2006) found that the elastic modulus and viscous modulus of oriental wheat noodle increased with an increased NaCl level. Unlike wheat noodle, the information on the microstructure of rice noodle is limited. Scanning electron micrographs of the cross-section of dried rice noodle revealed that the

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inner structure of the noodle was dense and compact (Kongkiattisak & Songsermpong, 2012). This structure gives the hard texture of rice noodle (Satmalee & Charoenrein, 2009). Since there is no gluten in rice noodle, the amylose network was reported to contribute the main structure of rice noodle (Mestres, Colonna, & Buleon, 1988). However, rice noodle contains a protein content as high as 7% (Phothiset & Charoenrein, 2007). Therefore, the addition of salt may affect the properties of the protein in rice noodle. Unfortunately, there is no evidence of the effect of salt on the protein network and the microstructure of rice noodle.

With the power of Nuclear Magnetic Resonance Imaging (MRI), the water content distribution inside pasta and other wheat noodles during boiling has been studied for decades (Hills, Babonneau, Quantin, Gaudet, & Belton, 1996; Kojima, Horigane, Yoshida, Nagata, & Nagasawa, 2004; Lai & Hwang, 2004; McCarthy, Gonzalez & McCarthhy, 2002). The shape of water distribution inside pasta has been well related to its texture. The high water content at the pasta surface and the low water content at the center of pasta gives the firm texture (al dente), while the homogeneous water content distribution gives the soft texture (Gonzalez, Mccarthy, & Mccarthy, 2000; Irie, Horigane, Naito, Motoi, & Yoshida, 2004) However, there is no report on the water distribution in dried rice noodle during cooking.

In order to be able to improve the quality of dried rice noodle, understanding on the role of salt on microstructure of dried rice noodle, water distribution inside the dried noodle during cooking, and the texture of cooked rice noodle is necessary. Thus, this work aimed to investigate the effect of NaCl on the microstructure of dried rice noodle, water migration in rice noodle during cooking, and the texture of cooked rice noodle. The microstructure of dried rice noodle with NaCl was observed using Scanning Electron Microscopy (SEM) and Confocal Laser Scanning Microscopy (CLSM). The water distribution in the rice noodle during cooking was monitored using Nuclear Magnetic Resonance Imaging (MRI) for the first time. The relationship between the microstructure of dried rice noodle, water distribution in rice noodle during cooking, and the texture of cooked noodle was discussed.

2. Materials and methods

2.1. Materials

2.1.1. Rice flour

Rice flour was prepared from high amylose rice grain (Chai Nat cultivar) according to Cham and Suwannaporn (2010) as follows. Rice grains were soaked in water for 4 h and then wet milled using a colloid mill (Masuko Sangyo, MKPM6-2, Japan). Rice flour slurry was centrifuged using a basket centrifuge (Washino, Thailand). The rice flour cake was dried in a tray dryer at 45 °C until the moisture content was 10–12%. The dried rice flour cake was milled with a hammer mill (Ultra-Centrifugal Mill, Type ZM 1; Retsch GmbH, Haan, Germany) and sieved through a 0.150 mm sieve. Fine rice flour samples were packed in polyethylene bags, sealed, and kept at 4 °C until use.

2.2. Methods

2.2.1. Preparation of the dried rice noodles

Dried rice noodles were prepared according to the modified method of Hormdok and Noomhorm (2007) as follows. Rice flour was mixed with deionized water to obtain the concentration of 40 g flour/100 g sample. Sodium chloride was added to the rice flour slurry to obtain concentrations of 0, 3, and 5 g NaCl/100 g flour. The slurry was equilibrated for 3 h at room temperature. Sixty grams of slurry were poured onto a stainless plate and spread to form a sheet. The tray with slurry sample was steamed at 100 °C for 3 min to obtain a fresh rice noodle sheet with a thickness of 1.00 ± 0.01 mm. The tray with the noodle sheet was cooled at room temperature and the sheet was pulled from the tray. Noodle sheets were pre-dried for 20 min in a tray dryer at 60 °C then incubated for 24 h at 25 °C which is the same procedure as is used in the noodle industry. The noodle sheets were cut into 13 × 250 mm strips and dried at 45 °C for 1 h. The final moisture content of the dried rice noodle strips was about 9–10% wet basis.

2.2.2. Magnetic resonance imaging (MRI)

2.2.2.1. Standard water content sample. A known water content standard sample was prepared according to Thammathongchat, Fukuoka, and Watanabe (2005). NaCl at concentrations of 0, 3, and 5 g NaCl/100 g flour was added to flour. A specific amount of distilled water was added to the mixture of NaCl and flour to achieve water content of the mixtures of 0.45, 0.5, 0.65, 0.75, and 0.85 kg water/kg sample. The mixtures, which had a water content lower than 0.5 kg water/kg sample, were packed into plastic pouches, vacuum sealed and kept at room temperature for 3 h. After that, they were heated at 100 °C for 30 min and subsequently cooled in iced water for 2 min. The heated rice flour samples were cut into 5 × 10 mm^2 pieces and wrapped with LLD-PE film. The mixtures, which had a water content higher that 0.5 kg water/kg sample, were poured into a cylinder polypropylene (PP) tube with a screw cap (id 12 mm × 120 mm) and kept at room temperature for 3 h. The mixture inside the tube was mixed well using a vortex stirrer before being heated in hot water at 100 °C. The sample tube was removed from the hot water and shaken using the vortex stirrer for 10 s each minute for the first 5 min. The total heated time was 30 min (Kojima, Horigane, Yoshida, Nagata, & Nagasawa, 2001). The heated PP tube with the mixture was subsequently cooled for 2 min after heating. The mixture were removed from the PP tube, cut into a small cylindrical piece (4 mm id., 10 mm length), and wrapped with LLD-PE film. The known water content samples were placed in a glass bin and inserted into the MRI (Bruker AM 400 WB, 7.1 T, Karlsruhe, Germany). The T_2 images of the known water content samples were obtained using the MSME sequence with the following parameter values: repetition time (TR) was 1500 ms, echo time (TE) was 27.0 ms, field of view (FOV) was 3.0, pixel matrix was 256 x 256 and scan number (ns) was 1. After T_2 measurement, the water content of each sample was measured by oven drying at 100 °C for 24 h.

2.2.2.2. Cooked rice noodle sample. The 5 cm length noodle strips of each dried rice noodle sample were boiled in distilled water at 100 °C for 2, 4, 6 10 and 12 min. After boiling, the rice noodles were immediately cooled in water at room temperature for 1 min to stop further cooking. Excessive water on the surface of noodles was softly wiped off with a paper towel. The cooked rice noodles were cut into 10 mm × 5 mm pieces and were wrapped with LLD-PE film to prevent moisture loss and placed into a glass bin. The T_2 values of water in the cooked noodle samples were measured using MRI with the same parameters that were used in the measurement of the known water content standard samples. Water distribution inside the cooked rice noodles at each cooking time was measured in triplicate and three noodle strands were measured for each replicate. After T_2 measurement, the water contents of noodle samples were measured by oven drying at 100 °C for 24 h.

2.2.3. Textural properties

The dried rice noodle is fully gelatinized during steaming process, so the cooking process is actually the rehydration process. A cooking time at 100 °C for 4 min is considered as the optimum cooking time because the water content of the cooked rice noodle