Quality and Fortificant Retention of Rice Noodles as Affected by Flour Particle Size

By Nura Malahayati

Quality and Fortificant Retention of Rice Noodles as Affected by Flour Particle Size

Nura Malahayati,[1,†] Kharidah Muhammad,[2] Jamilah Bakar,[3] and Roselina Karim[3]

Cereal Chem. 92(2):211–217

ABSTRACT

Rice noodles, which are widely consumed noodles in Southeast Asia, were evaluated as a potential carrier for fortificants such as vitamin A, folic acid, and iron. Because flour particle size was found to affect the noodle properties, this study was conducted to investigate the effect of five different particle sizes (≤63, 80, 100, 125, and 140 µm) of dry-milled rice flour on the cooking quality, microstructure, texture, and sensory characteristics of the rice noodles. The retention of fortificant in the noodles at every stage of processing as affected by the flour particle size was also determined. It was found that the rice noodles produced from flour with the smallest particle size studied (≤63 µm) had the best quality and were the most liked by the consumers. In addition, the noodles had the most compact and regular structure, which could be attributed to having the most severely gelatinized starch. This starch would have caused the least leaching of the fortificant into the surrounding water during the boiling stage of the rice noodle processing. Retention of iron in the cooked fortified rice noodles prepared from flour with the smallest particle size was high at around 87%, whereas that of vitamin A and folic acid were below 15%. Because the losses of the fortificant from the rice noodles were mostly owing to the boiling process, further improvements of the rice noodle processing conditions are required for reduction of the vitamin losses.

Micronutrient deficiency is a serious global health problem that is widespread in developing countries. Deficiency of vitamin A, folic acid, and iron can severely afflict the health of pregnant and lactating women, infants, and children. Moreover, the Micronutrient Initiative (MI) and United Nations International Children's Emergency Fund (UNICEF) reported that inadequate intake of micronutrients resulted in the deaths of more than one million children, 250,000 birth defects, and the deaths of approximately 50,000 young women during pregnancy and childbirth (MI and UNICEF 2005). Fortification has been recognized by many national governments as an important strategy to help improve the health and nutritional status of millions of people (Wesley and Ranum 2004). Moreover, fortification can be implemented and sustained over a long period, making it the most cost-effective way to overcome micronutrient malnutrition (Wesley and Ranum 2004; WHO/FAO 2005). Previous experience has shown that fortification is technologically and economically effective in increasing micronutrient intake in the human population (Lotfi et al. 1996). Fortifying rice or rice products with micronutrients can be useful in overcoming nutrition deficiency problems.

Rice noodles, produced from rice flour, are one of the most popular and widely consumed noodles in Southeast Asia. Rice noodles can, therefore, be a potential carrier for fortificants such as vitamin A, folic acid, and iron. Traditionally, rice noodles are made from long-grain rice with medium to high amylose content (>22 g/100 g) (Juliano and Sakurai 1985; Fu 2008). The general process of preparation of rice noodles involves soaking the grains of rice, wet milling, cooking the rice slurry to gelatinize the rice starch, kneading the slurry to obtain a cohesive dough, extruding the dough, and finally subjecting the extruded rice noodles to boiling water. Rice proteins lack the functionality of wheat gluten in forming a cohesive dough structure. To create a uniform matrix in which the starch granules are embedded, it is a common practice to produce rice noodles in the food industry by boiling extruded rice dough that has been incorporated with a binding agent such as tapioca, maize, or sago starch (Hamdzah 1994).

Preparation of rice flour, a major component of rice noodles, is one of the important factors governing rice noodle quality. Among the quality attributes of rice noodles, cooking and textural characteristics are the two main attributes of rice noodle quality (Bhattacharya et al. 1999; Vangsawasdi et al. 2002; Yoenyongbuddhagal and Noomhorm 2002; Hormdok and Noomhorm 2007) that determine consumer acceptance. Rice noodles should have a short cooking time, little cooking loss, and optimum rehydration. Rice noodles are normally prepared from wet-milled rice flour. An alternative time-saving and energy-saving method has been conducted to prepare rice noodles from dry-milled flour in place of wet-milled flour (Yoenyongbuddhagal and Noomhorm 2002; Fu 2008). However, wet-milled flour tended to produce better rice noodle quality than dry-milled flour.

Flour particle size is an important characteristic influencing the quality of many products. Various reports have documented the influence of flour particle size on noodle quality (Suhendro et al. 2000; Hatcher et al. 2002; Yoenyongbuddhagal and Noomhorm 2002). The appropriate particle size of dry-milled flour on quality of fortified rice noodles and retention of vitamin A, folic acid, and iron in the noodles, however, has not been studied.

In this study, effects of different particle sizes of rice flour prepared by dry milling on the quality of fortified rice noodles and retention of vitamin A, folic acid, and iron in the noodle were investigated. The specific objectives of this study were 1) to examine the effect of dry-milled rice flour particle size (≤63, 80, 100, 125, and 140 µm) on the cooking quality, microstructure, texture, and sensory characteristics of the rice noodles, and 2) to investigate its effect on retention of vitamin A, folic acid, and iron at each stage of noodle processing.

MATERIALS AND METHODS

Rice Flour Preparation. A Malaysian rice variety (MR 219) was procured from a local supermarket. Rice grains were dry-milled with a rice miller (Good and Well, Malaysia) with a 200 µm sieve. Rice flour samples were sieved with a sieving machine (Analysette 3, Fritsch, Germany) equipped with 200 mm diameter sieves of 63, 80, 100, 125, and 140 µm particle sizes.

The chemical compositions and pasting properties of the rice flour sample were analyzed in preliminary research. Ash and moisture contents were determined following AOAC methods 923.03 and 925.10, respectively. Total fat was determined with FOSS Soxtec 2050 automated system (FOSS, Sweden), which complied with AOAC method 920.85. Total protein was determined following a Kjeldahl method based on AOAC method 920.87 (AOAC 2005). The amylose content was determined with the FIAstar

† Corresponding author. Phone: +62-711-8153837945.
E-mail: nura_malahayati@yahoo.com

[1] Department of Agricultural Technology, Faculty of Agriculture, Sriwijaya University, 30662 Ogan Ilir, South Sumatera, Indonesia.
[2] UPM-BERNAS Research Laboratory, Faculty of Food Science and Technology, Universiti Putra Malaysia, 43400 UPM Serdang, Selangor Darul Ehsan, Malaysia.
[3] Department of Food Technology, Faculty of Food Science and Technology, Universiti Putra Malaysia, 43400 UPM Serdang, Selangor Darul Ehsan, Malaysia.

http://dx.doi.org/10.1094/CCHEM-01-14-0011-R

method (FOSS, Sweden), and an enzymatic digestion assay kit (Megazyme, Ireland) was used to determine starch damage of rice flour samples following AACC International Approved Method 76-31.01. Pasting properties were determined with a rapid viscosity analyzer (Newport Scientific, Australia) based on AACCI Approved Method 61-02.01.

Rice flour with each particle size was fortified with a dry blended premix containing vitamin A, folic acid, and iron (FT091283AP, Fortitech Asia Pacific, Malaysia) at the level of 300 µg of vitamin A, 16 µg of folic acid, and 4.2 mg of iron per 100 g of flour, which was based on the Malaysian Food Regulations (Malaysian Ministry of Health 2007). Rice flour and premix were mixed by shaking evenly in a closed plastic bottle for 30 min. The fortified rice flour samples were packed in airtight plastic bags and stored at 4°C until used.

Rice Noodle Preparation. The processing of rice noodles was adopted from home industry (Hamdzah 1994) with some modifications, specifically that no binding agent was used in the noodle production. An alternative to the usage of binding agents, flours with different particle sizes were screened to produce good quality noodles in terms of cooking and textural characteristics. All the steps in the preparation of rice noodles were carried out under subdued lighting conditions (intensity 377.1 lumens) to minimize light destruction of the fortificant. Fortified rice flour with each particle size was mixed with boiled water. The amount of boiled water added was 60% of the total weight of the dough formed. The mixture was kneaded until the dough was well homogenized. The kneaded dough was extruded through the holes (3 mm in diameter) of a cylindrical shaped mold. The extruded noodles were boiled in water until they floated (10 min), transferred into cooled water (26–27°C) for decelerating gelatinization, and strained. The noodles processed with the aforementioned method were identified as fresh rice noodles (RN). A portion of the RN was dried in an air circulation oven (Venticell, Medcenter Einrichtungen, Germany) at 40°C overnight (about 16 h), and the noodles were termed dried rice noodles (DRN) with final moisture of 10–12%. Then, a portion of the DRN was cooked (boiled) for 10 min prior to consumption and labeled as cooked rice noodles (CRN).

Evaluation of Rice Noodle Cooking Quality and Texture. Cooking quality of the rice noodles was determined following AACCI Approved Method 66-50.01. Samples of DRN (5 g) were cut into small pieces (2.0 cm in length) and boiled in 60 mL of water until completely cooked (10 min). Cooked noodles were washed in 20 mL of distilled water, drained for 5 min, and weighed immediately. The cooking water was collected and transferred to a petri dish and dried at 105°C to a constant weight. Cooking loss was expressed as percentage of dry matter of the cooking water (solid loss) to dry weight of the noodles. The rehydration was calculated as the percentage increase in weight of the cooked noodles compared with the weight of dried noodles.

The cooked noodles were kept in a covered petri dish, and texture analysis was carried out within 15 min with a TA-XT Plus texture analyzer (Stable Micro Systems, U.K.), as described by Bhattacharya et al. (1999). A strand of cooked noodle with 3.5 mm thickness was compressed by a cylinder probe (35.0 mm diameter) until the deformation reached 75% at a speed of 1.0 mm/s. The pause between the first and second compressions was 0.5 s. From the force–time curve of the texture profile, textural parameters including hardness, adhesiveness, springiness, cohesiveness, and chewiness were obtained. Ten measurements were made for each sample.

Sensory Evaluation. Sensory evaluation of CRN prepared from flours with five different particle sizes (≤63, 80, 100, 125, and 140 µm) was determined by using the hedonic scale method of measuring food preference (Lawless and Heymann 2010). It was carried out with 50 consumers comprising students and staff at the Faculty of Food Science and Technology, Universiti Putra Malaysia. Testing was conducted in the sensory laboratory. Consumers were required to evaluate the aroma, appearance, taste, texture, and overall acceptability of the cooked rice noodles with the nine-point hedonic scale in which 1 = dislike extremely, 2 = dislike very much, 3 = dislike moderately, 4 = dislike slightly, 5 = neither like nor dislike, 6 = like slightly, 7 = like moderately, 8 = like very much, and 9 = like extremely. Rice noodle samples were presented to the consumers on plates coded with a three-digit random number. The order of samples by treatment was completely randomized. Drinking water was provided to the consumers between the tests for mouth rinsing.

Microstructure Observation. DRN and CRN were cut into 0.5 cm pieces and lyophilized. The lyophilized DRN and CRN were cut into 1–2 mm length, mounted on stubs with double-sided tape, and sputter coated with gold (SCD005 sputter coater, BAL-TEC, the Netherlands). The specimens were examined with a scanning electron microscope (XL30 ESEM series D6929, Philips, the Netherlands) at an accelerating voltage of 10 kV. Cross sections of the DRN were observed at ×3,000 magnification and at magnifications of ×43 and ×500 for the surfaces and cross sections of the CRN.

Determination of Vitamin A. Vitamin A contents (as retinol contents) of rice flour, fortified rice flour, and rice noodle samples (RN, DRN, and CRN) were determined with an HPLC system (1200 series, Agilent Technologies, U.S.A.) according to AACCI Approved Method 86-06.01. The sample (5 g) was saponified with 10 mL of 50% potassium hydroxide solution at 85°C for 45 min and swirled every 10 min. The retinol was then extracted by a solvent mixture of 1:1 ethanol–tetrahydrofuran. The retinol in the samples was quantitated by using an HPLC with UV detection at 323 nm. The standard (Sigma Aldrich, U.S.A.) used for the retinol determination was prepared in the same manner as the samples. Retinol content of each sample was calculated by comparing the peak areas of retinol in samples and those of standards.

Determination of Folic Acid. Folic acid contents of rice flour, fortified rice flour, and rice noodle samples (RN, DRN, and CRN) were determined with an HPLC system (1200 series, Agilent Technologies) according to the method of Alaburda et al. (2008). Sample (5 g) was extracted with 50 mL of tetraborate–trichloroacetic acid buffer (pH 8.5). The extract was purified by solid phase extraction on a strong anion exchange (500 mg/3 mL) cartridge and then quantitated with HPLC at 280 nm with a UV detector. Standard folic acid solution in 0.1M sodium hydroxide was used to prepare a calibration curve. The calibration curve was linear in the range of measurements. For quantitative determination of folic acid peak areas of the sample, sample chromatograms were correlated with the concentrations according to the calibration curve of the folic acid (Sigma Aldrich) stock standard solution.

Determination of Iron. Iron (elemental iron) contents of rice flour, fortified rice flour, and rice noodle samples (RN, DRN, and CRN) were determined with an atomic absorption spectrophotometer (AA400, Perkin Elmer, U.S.A.) according to AACCI Approved Method 40-70.01. The ground sample (5 g) was charred in a muffle furnace and then ashed in a muffle furnace at 500°C overnight. The completely ashed sample was digested in 10 mL of concentrated hydrochloric acid. The digested sample was cooled and diluted to 100 mL with distilled deionized water. The absorbance was then measured at 248.3 nm with the atomic absorption spectrophotometer. Calibration of the measurements was performed with commercial standard solution (64271, Merck, Germany).

Statistical Analysis. Three replicates were prepared for each sample, and three replicates were taken under each of the specific tests. All results were calculated on a dry weight basis to facilitate the direct comparison of the results, particularly for different sample types. Data were subjected to analysis of variance followed by Fisher's least significant difference test to compare treatment means; differences were considered at a significance level of 95% ($P < 0.05$) with SPSS version 19 software.

RESULTS AND DISCUSSION

Chemical Compositions and Pasting Properties of the Rice Flour Sample. The chemical composition of all samples was as follows: moisture, 8.50–8.58%; ash, 0.40–0.48%; protein, 7.37–7.45%; fat, 0.45–0.49%; amylose, 23.14–23.30%; and starch damage, 12.34–12.86%. There were no significant differences in the chemical compositions of rice flour with different particle sizes owing to the same grinding and sieving process being used to prepare dry-milled rice flour.

Pasting temperatures of rice flour samples were 80.81–82.37°C. Pasting temperature was reduced as particle size decreased ($P < 0.05$). Peak viscosity, hot paste viscosity, breakdown, final or cold paste viscosity, and setback of rice flour samples varied with ranges of 221.21–237.36, 150.67–160.56, 70.54–76.81, 317.38–332.53, and 95.17–97.06 RVU, respectively. Peak viscosity, hot paste viscosity, breakdown, and final viscosity of the rice flours with larger particle sizes were significantly lower than those of the flours with smaller particle sizes ($P < 0.05$). The results for setback, which indicated the retrogradation tendency of the flours, were relatively similar in all five flours studied.

Effect of Flour Particle Size on Rice Noodle Cooking Quality and Texture. The optimum cooking time of rice noodle samples was 10.0 ± 0.12 min. Cooking quality of the rice noodle samples is presented in Table I. Cooking loss and rehydration significantly decreased with a decrease in the particle size of the rice flour ($P < 0.05$). This decrease was because the smaller particle size rice flour had a higher surface area that allowed for rapid absorption of water, and starch granule swelling quickly resulted in starch that easily gelatinized at a lower temperature. This concept was supported by the lower pasting temperature and the higher paste viscosities (peak viscosity, hot paste viscosity, breakdown, and final viscosity) for finer flours, indicating a higher proportion of gelatinized starches in the smaller particle size flours. The amount of gelatinized starch is important for rice noodle structure because it acts as a binder during extrusion (Fu 2008). These results indicated that reduction of rice flour particle size enhanced the cooking quality of the rice noodles. The lower degree of rehydration of the noodles did not result in unacceptable texture, as shown later in the sensory evaluation section.

Table I shows that the textural properties of rice noodles were affected by rice flour particle size. Hardness, adhesiveness, springiness, cohesiveness, and chewiness of noodles prepared from small particle size flour were significantly higher than those of noodles prepared from larger particle size flour ($P < 0.05$). The rice noodles had firmer texture, less stickiness, and higher springiness, cohesiveness, and chewiness, representing better quality rice noodles (Bhattacharya et al. 1999; Sowbhagya and Ali 2001; Fu 2008). These differences were because the starch granules in the rice noodles prepared from finer flours were more severely gelatinized than those prepared from coarser flours, because more heat and water penetrated into the cores of the starch granules in the smaller particle size flours. This condition was also supported by the lower pasting temperature and the higher paste viscosities for finer flours, indicating that smaller particle size flour reached the onset gelatinization temperature more quickly and exhibited greater thickening behavior than larger particle size flour. Therefore, the flour sample with the smallest particle size produced the best rice noodles in terms of texture. This observation was in agreement with the result found by Hatcher et al. (2002), who stated that cooked wheat noodles made from fine particle size flour had the best textural parameters. Similarly, the better texture quality of noodles prepared from smaller particle size flours was in agreement with the smaller particle size effect on sorghum noodles (Suhendro et al. 2000) and also on rice vermicelli (Yoenyongbuddhagal and Noomhorm 2002).

Sensory Evaluation of Rice Noodles. Results of sensory evaluation of the rice noodles in terms of aroma, appearance, taste, texture, and overall acceptability are presented in Table II. Scores obtained with hedonic scales for appearance, taste, texture, and overall acceptability of rice noodles prepared from smaller particle size flours were significantly higher than those of noodles prepared from larger particle size flour ($P < 0.05$). Particle size of flour did not affect the aroma of the rice noodles. The aroma of rice noodles was a minor quality attribute from a consumer point of view compared with other characteristics.

Rice noodles prepared from the smallest particle size flour received scores close to and higher than 7 (like moderately) for appearance, texture, and overall acceptability attributes and obtained scores higher than 6 (like slightly) for taste. Regarding appearance, texture, and overall acceptability attributes, rice noodles prepared from the smallest particle size had the longest strand, best retention of shape, best firmness, least adhesive, absence of discoloration, and highest glossiness and transparency, which determined the highest score by consumer acceptance.

TABLE I
Cooking and Textural Qualities of Rice Noodles Prepared by Using Flours with Different Particle Sizes[z]

	Cooking Quality		Textural Quality				
Particle Size (µm)	**Cooking Loss (%)**	**Rehydration (%)**	**Hardness (g)**	**Adhesiveness (g·s)**	**Springiness**	**Cohesiveness**	**Chewiness (g·mm)**
≤63	8.05 ± 0.14a	299.39 ± 2.96a	2,369.00 ± 8.06a	87.93 ± 12.94a	0.78 ± 0.16a	0.49 ± 0.04a	911.67 ± 27.82a
80	8.47 ± 0.20b	307.56 ± 3.16b	2,186.00 ± 18.71ab	56.67 ± 17.79b	0.67 ± 0.06ab	0.52 ± 0.03a	774.67 ± 15.64ab
100	9.15 ± 0.08c	319.08 ± 2.32c	2,168.67 ± 4.74ab	60.00 ± 22.54b	0.70 ± 0.01ab	0.51 ± 0.02a	775.67 ± 51.05ab
125	10.17 ± 0.10d	334.44 ± 6.39cd	2,063.67 ± 9.30bc	51.00 ± 7.00b	0.72 ± 0.04ab	0.48 ± 0.02ab	704.67 ± 28.11ab
140	10.81 ± 0.05e	350.93 ± 11.93d	1,848.67 ± 4.80c	49.00 ± 9.00b	0.68 ± 0.44ab	0.42 ± 0.05b	535.67 ± 10.58b

[z] Values are means ± SDs of triplicate determinations. Means for each characteristic followed by the same letter within the same column are not significantly different at $P < 0.05$ by LSD test.

TABLE II
Mean of Hedonic Scales for Consumers' Acceptance of Rice Noodles Prepared by Using Flours with Different Particle Sizes[z]

Particle Size (µm)	Aroma	Appearance	Taste	Texture	Overall Acceptability
≤63	5.74 ± 1.93a	7.32 ± 1.13a	6.12 ± 1.45a	6.92 ± 1.26a	7.02 ± 1.12a
80	5.64 ± 1.69a	6.44 ± 1.18b	5.80 ± 1.46ab	6.24 ± 1.39b	6.36 ± 1.17b
100	5.58 ± 1.75a	5.76 ± 1.32c	5.36 ± 1.60b	5.22 ± 1.48c	5.56 ± 1.36c
125	5.74 ± 1.52a	5.14 ± 1.40d	5.24 ± 1.48b	4.44 ± 1.46d	4.80 ± 1.46d
140	6.00 ± 1.57a	4.30 ± 1.58e	5.14 ± 1.74b	3.66 ± 1.73e	3.98 ± 1.61e

[z] Values are means ± SDs; $n = 50$. Nine-point hedonic scale: 1 = dislike extremely; 2 = dislike very much; 3 = dislike moderately; 4 = dislike slightly; 5 = neither like nor dislike; 6 = like slightly; 7 = like moderately; 8 = like very much; and 9 = like extremely. Means for each characteristic followed by the same letter within the same column are not significantly different at $P < 0.05$ by LSD test.

Microstructure of Rice Noodles. The particle size of rice flour influenced the starch gelatinization, which in turn affected the noodle microstructure. The microstructures of DRN prepared by using flours with different particle sizes are shown in Figure 1. Starch gelatinization in the rice noodles influenced the network formation of bonded swollen starch granules present in the porous structure of the DRN. A stronger and higher proportion of gelatinized starch in the rice noodles prepared with finer particle size flours caused more rupture of the swollen granules and resulted in these noodles having the least porous and most regular structure with more visible swollen starch granules (Fig. 1A) than in those prepared from coarser flours (Fig. 1E).

Figure 2 shows the cross sections of CRN, which exhibited completely gelatinized rice noodle structure with a visibly swollen starch network. CRN prepared from the smallest particle size flour showed the most regular structure with the fewest pores (Figs. 2A and F), because the smallest particle size flour had the most severe gelatinization and the most physical entrapment, which in turn gave the best network. In contrast, CRN prepared from the largest particle size flour exhibited the most irregular structure with the most pores (Figs. 2E and J). This result was consistent with the findings that the starch granules in rice noodles prepared from finer flours were more severely gelatinized, resulting in lower cooking loss than for noodles prepared from coarser flours.

Effect of Flour Particle Size on Retention of Vitamin A, Folic Acid, and Iron in Rice Noodles During Different Stages of Processing. Vitamin A and folic acid were not detected in rice flour samples. The initial content of iron in rice flour samples was 0.99–1.04 mg/100 g. Vitamin A, folic acid, and iron contents of fortified rice noodle samples (RN, DRN, and CRN) prepared by using flours with five different particle sizes are shown in Figures 3, 4 and 5. The particle size of rice flour substantially influenced the retention of fortificants in the rice noodle samples. The retention of fortificants in the rice noodle samples significantly decreased ($P < 0.05$) with an increase in the particle size of rice flour, because rice noodles prepared from small particle size flour had a stronger and higher proportion of gelatinized starch, resulting in a more compact noodle structure. This condition resulted in less leaching of the fortificants into the surrounding water during the boiling process and CRN preparation.

The health claim regulation states that fortified products must contain at least 15% of the recommended daily intake for the specific nutrient per serving of food (Bui and Small 2009). The retention of fortificants in the rice noodle samples decreased with an increase in the particle size of the rice flour. Vitamin A, folic acid, and iron retention in CRN was in the range of 15.36–7.71, 12.66–7.26, and 87.58–86.78%, respectively, for the five types of rice noodle samples. Thus, rice noodles prepared with finer particle size flour could be a good vehicle for iron fortification, but losses of vitamin A and folic acid would still be substantial.

Besides flour particle size, another factor that affected the retention of fortificants in the rice noodle samples was processing. The mean retention of vitamin A in the five types of rice noodle samples decreased from 100% in fortified rice flour to 31.82 ± 3.17% in RN, 27.48 ± 3.45% in DRN, and 11.16 ± 2.16% in CRN. There were losses of vitamin A at each stage of rice noodle processing. These large losses of fat-soluble vitamin A, however, occurred when the noodles were cooked in boiling water. This result might be because vitamin A rapidly loses its activity when heated in the presence of oxygen, especially at higher temperatures. This result was in good agreement with that of Lešková et al. (2006), who stated that boiling seemed to be the most damaging process (up to 67% losses) affecting vitamin A stability. Lee et al. (2000) reported that about 20% of retinyl palmitate was measured in excess water during boiling of retinyl palmitate–fortified Ultra Rice.

The step of drying the rice noodles for 12 h at 40°C for preparation of DRN resulted in a 4% loss of vitamin A. This result was supported by the findings of O'Brien and Roberton (1993), who reported that during the processing of macaroni, oven drying for 9–12 h at 50°C resulted in a 14% loss of vitamin A. Furthermore, the presence of iron could have accelerated the degradation of vitamin A in the rice noodle samples (Manan et al. 1991; Manan and Ryley 1994; Wirakartakusumah and Hariyadi 1998; Pinkaew et al. 2012), because iron can produce a catalytic effect on oxidative decomposition of vitamin A.

The mean retention of folic acid in the five types of rice noodle samples decreased from 100% in fortified rice flour to 45.76 ± 3.18%

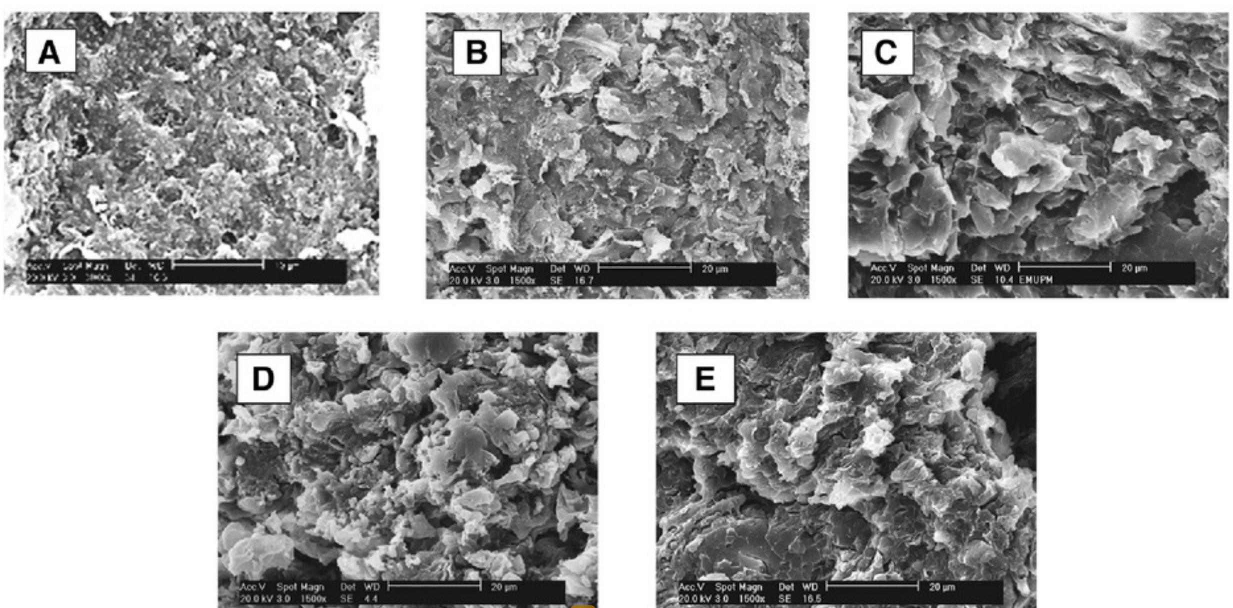

Fig. 1. Cross sections of dried fortified rice noodles prepared by using flours with different particle sizes. **A,** ≤63 µm; **B,** 80 µm; **C,** 100 µm; **D,** 125 µm; and **E,** 140 µm at ×3,000 magnification.

in RN, 44.63 ± 3.50% in DRN, and 9.73 ± 2.29% in CRN. The loss of folic acid in rice noodles during processing was caused predominantly by leaching rather than oxidation. Furthermore, Arcot and Shresta (2005) reported that unlike most of the foods in which folates are bound to the macromolecules forming a complex food matrix, added folic acid in fortified foods might have only been physically bound and, thus, could be released by simple boiling. Several studies have reported that leaching was the major factor responsible for the loss of folic acid in foods. Dang et al. (2000) reported that boiling contributed to a loss of about 50% of folic acid in chickpeas and peas.

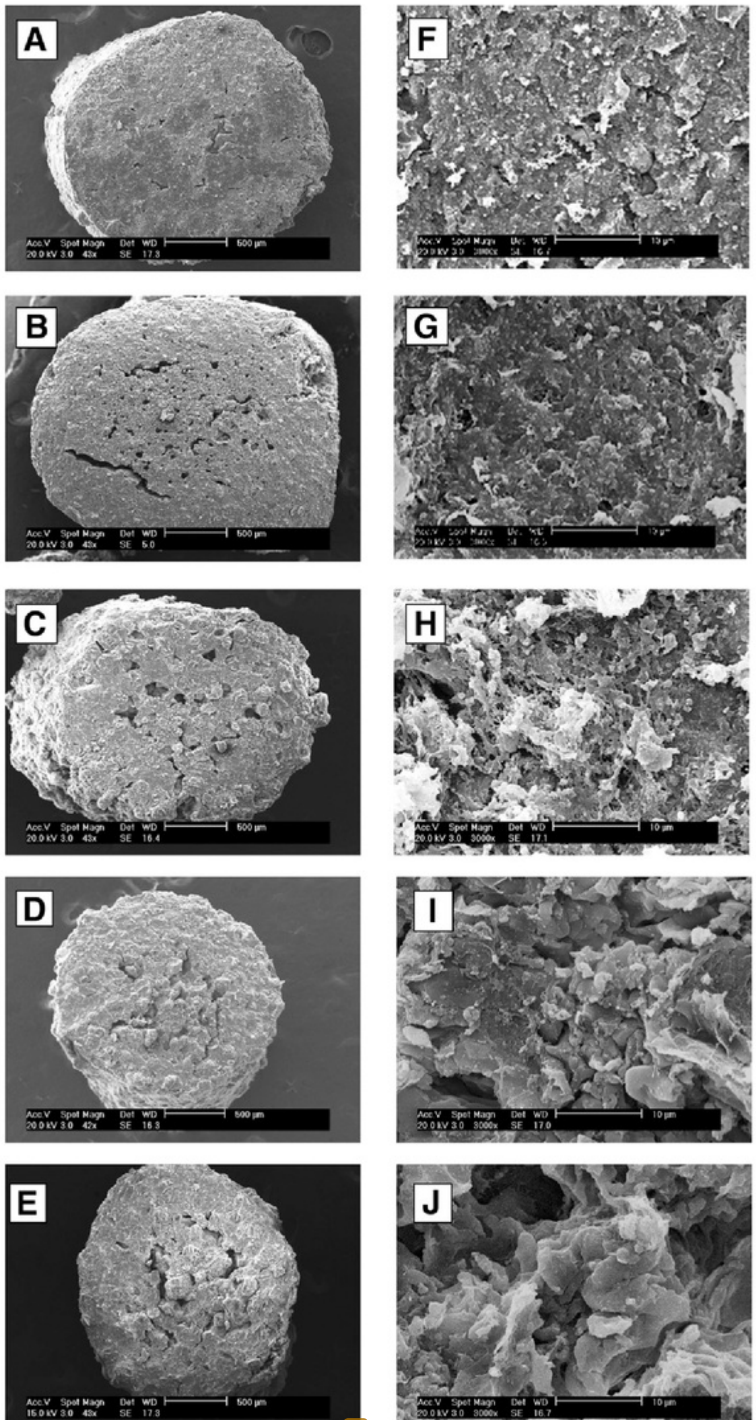

Fig. 2. Cross sections of cooked fortified rice noodles prepared by using flours with different particle sizes. **A,** ≤63 µm; **B,** 80 µm; **C,** 100 µm; **D,** 125 µm; and **E,** 140 µm at ×50 magnification. **F,** ≤63 µm; **G,** 80 µm; **H,** 100 µm; **I,** 125 µm; and **J,** 140 µm at ×1,500 magnification.

For Asian noodles, boiling contributed to losses of about 38 and 40% of folic acid in white salted noodles and yellow alkaline noodles, respectively (Bui and Small 2007). Similar to vitamin A, the presence of iron could increase the folic acid loss (Li et al. 2011).

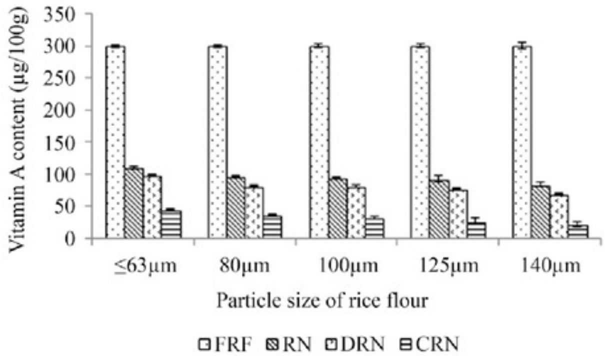

Fig. 3. Vitamin A contents (µg/100 g) of fortified rice noodles prepared by using flours with different particle sizes. Vitamin A contents are means ± SDs of triplicate determinations. FRF = fortified rice flour; RN = fresh rice noodles; DRN = dried rice noodles; and CRN = cooked rice noodles.

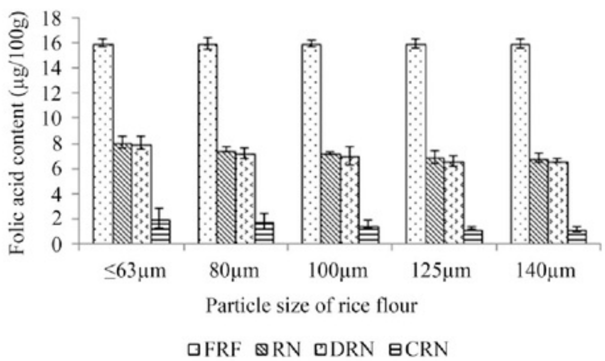

Fig. 4. Folic acid contents (µg/100 g) of fortified rice noodles prepared by using flours with different particle sizes. Folic acid contents are means ± SDs of triplicate determinations. FRF = fortified rice flour; RN = fresh rice noodles; DRN = dried rice noodles; and CRN = cooked rice noodles.

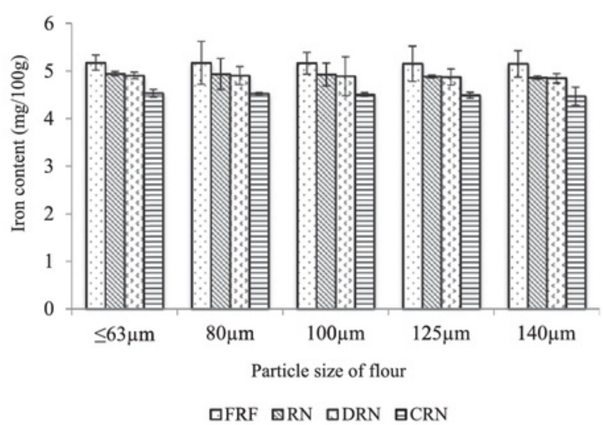

Fig. 5. Iron contents (mg/100 g) of fortified rice noodles prepared by using flours with different particle sizes. Iron contents are means ± SDs of triplicate determinations. FRF = fortified rice flour; RN = fresh rice noodles; DRN = dried rice noodles; and CRN = cooked rice noodles.

Compared with vitamins, iron as a mineral was very stable under extreme processing conditions (Watzke 1998; Singh et al. 2007). The mean retention of iron in the five types of rice noodle samples decreased from 100% in fortified rice flour to 95.10 ± 0.48% in RN, 94.59 ± 0.28% in DRN, and 87.23 ± 0.31% in CRN. The loss of iron was low compared with other studies, most of which have reported losses of 20% (Adams and Erdman 1988; Lachance and Fisher 1988; Bishnoi and Khetarpaul 1995). Hu (2005) reported that an oxidation reaction might happen to the iron fortificants when they were cooked. However, iron has good oxidation resistance during food processing because it starts from a zero oxidation state. Relatively large losses of iron occurred when the noodles were cooked in boiling water. This result was supported by the findings of Watzke (1998), who reported that the primary mechanism of loss of iron as with other minerals was through leaching into the cooking water.

CONCLUSIONS

Rice noodles could be a good vehicle for iron fortification because up to 87% of the iron was retained in the cooked rice noodles. Losses of vitamin A and folic acid from the rice noodles were high, whereby only 8–15% of vitamin A and 7–13% of folic acid were retained after cooking, even when the particle size of the flour was reduced from 140 µm to less than 63 µm. Reduction in the particle size of the rice flour not only led to a reduction in the losses of the fortificants but also to an improvement in the cooking quality, texture, and sensory properties of the rice noodles. Because the losses of the fortificants from the rice noodles were mostly owing to processing, further efforts will be made to optimize the processing conditions.

ACKNOWLEDGMENTS

The authors thank Padiberas Nasional Berhad (BERNAS) and Universiti Putra Malaysia for financial support of this research.

LITERATURE CITED

AACC International. Approved Methods of Analysis, 11th Ed. Method 40-70.01. Elements by atomic absorption spectrophotometry. Approved October 16, 1991. Method 61-02.01. Determination of the pasting properties of rice with the Rapid Visco Analyser. Approved October 15, 1997. Method 66-50.01. Pasta and noodle cooking quality—Firmness. Approved November 1, 1989. Method 76-31.01. Determination of damaged starch—Spectrophotometric method. Approved November 8, 1995. Method 86-06.01. Analysis of vitamins A and E by high-performance liquid chromatography. Approved November 8, 2000. Available online only. AACCI: St. Paul, MN.

Adams, C. E., and Erdman, J. W., Jr. 1988. Effect of home food preparation practices on nutrient content of foods. Pages 557–606 in: Nutritional Evaluation of Food Processing. E. Karmas and R. S. Harris, eds. Van Nostrand Reinhold: New York, NY.

Alaburda, J., de Almeida, A. P., Shondu, L., Ruveiri, V., and Sabino, M. 2008. Determination of folic acid in fortified wheat flours. J. Food Compos. Anal. 21:336-342.

AOAC. 2005. Official Methods of Analysis, 16th Ed. Methods 920.85, 920.87, 923.03, and 925.10. AOAC: Washington, DC.

Arcot, J., and Shresta, A. 2005. Folate: Methods of analysis. Trends Food Sci. Technol. 16:253-266.

Bhattacharya, M., Zee, S. Y. and Corke, H. 1999. Physicochemical properties related to quality of rice noodles. Cereal Chem. 76:861-867.

Bishnoi, S., and Khetarpaul, N. 1995. Effect of various domestic processing and cooking methods on HCl-extractability of minerals from pea seeds. Nahrung/Food 39:514-520.

Bui, L. T. T., and Small, D. M. 2007. Folates in Asian noodles: III. Fortification, impact of processing, and enhancement of folate intakes. J. Food Sci. 72:C288-C293.

Bui, L. T. T., and Small, D. M. 2009. Riboflavin in Asian noodles: The impact of processing, storage and the efficacy of fortification of three product styles. Food Chem. 114:1477-1483.

Dang, J., Arcot, J., and Shrestha, A. 2000. Folate retention in selected processed legumes. Food Chem. 68:295-298.

Fu, B. X. 2008. Asian noodles: History, classification, raw materials, and processing. Food Res. Int. 41:888-902.
Hamdzah, A. R. 1994. Model perusahaan makanan bihun. Malaysian Research and Development Institute. Mardi: Serdang, Malaysia.
Hatcher, D. W., Anderson, M. J., Desjardins, R. G., Edwards, N. M., and Dexter, J. E. 2002. Effects of flour particle size and starch damage on processing and quality of white salted noodles. Cereal Chem. 79:64-71.
Hormdok, R., and Noomhorm, A. 2007. Hydrothermal treatments of rice starch for improvement of rice noodle quality. LWT–Food Sci. Technol. 40:1723-1731.
Hu, B. 2005. A study on elemental irons and iron compounds for food fortification. In: Nutrition Safari for Innovative Solutions: 18th International Congress of Nutrition. Durban, South Africa.
Juliano, B. O., and Sakurai, J. 1985. Miscellaneous rice products. Pages 569-618 in: Rice: Chemistry and Technology, 2nd Ed. B. O. Juliano, ed. American Association of Cereal Chemists: St. Paul, MN.
Lachance, P. A., and Fisher, M. C. 1988. Effects of food preparation procedures in nutrient retention with emphasis on food service practices. Pages 505–556 in: Nutritional Evaluation of Food Processing. E. Karmas and R. S. Harris, eds. Van Nostrand Reinhold: New York.
Lawless, H. T., and Heymann, H. 2010. Sensory Evaluation of Food: Principles and Practices, 2nd Ed. Springer: New York, NY.
Lee, J., Hamer, M. L., and Eitenmiller, R. R. 2000. Stability of retinyl palmitate during cooking and storage in rice fortified with Ultra Rice™ fortification technology. Inst. Food Technol. 65(5):915-919.
Lešková, E., Kubíková, J., Kováčiková, E., Košická, M., Porubská, J., and Holčíková, K. 2006. Vitamin losses: Retention during heat treatment and continual changes expressed by mathematical models. J. Food Compos. Anal. 19:252-276.
Li, Y. O., Diosady, L. L., and Jankowski, S. 2011. Folic acid stability in the presence of various formulation components including iron compounds in fortified extruded Ultra Rice® over prolonged storage at 40°C and 60% relative humidity (RH). Int. J. Food Sci. Technol. 46: 379-385.
Lotfi, M., Mannar, M. G. V., and Merx, R. J. H. M., and Naber-van den and Heuvel, P. 1996. Micronutrient fortification of foods: Current practices, research, and opportunities. Micronutrient Initiative/International Agriculture Center: Ottawa, ON, Canada.
Malaysian Ministry of Health. 2007. Malaysian food regulations. Malaysian Government Printer: Kuala Lumpur, Malaysia.
Manan, F., and Ryley, J. 1994. Effect of supplementary iron on vitamin A stability in food. J. Islamic Acad. Sci. 7:181-184.
Manan, F., Guevara, L. V., and Ryley, J. 1991. The stability of all trans retinol and reactivity towards transition metals. Food Chem. 40:43-54.
Micronutrient Initiative and International Children's Emergency Fund. 2005. Vitamin and Micronutrient Deficiency: A Global Progress Report. UNICEF: New York, NY.
O'Brien, A., and Roberton, D. 1993. Vitamin fortification of foods (specific applications). Pages 233–245 in: Technology of Vitamins in Foods. P. B. Ottaway, ed. Blackie Academic and Professional: Glasgow, Scotland.
Pinkaew, S., Wegmuller, R. and Hurrell, R. 2012. Vitamin A stability in triple fortified extruded, artificial rice grains containing iron, zinc and vitamin A. Int. J. Food Sci. Technol. 47:2212-2220.
Singh, S., Gamlath, S., and Wakeling, L. 2007. Nutrition aspects of food extrusion: A review. Int. J. Food Sci. Nutr. 42:916-929.
Sowbhagya, C. M., and Ali, S. K. 2001. Vermicelli noodles and their quality assessment. J. Food Sci. Technol. 38:423-432.
Suhendro, E. L., Kunetz, C. F., McDonough, C. M., Rooney, L. W., and Waniska, R. D. 2000. Cooking characteristics and quality of noodles from food sorghum. Cereal Chem. 77:96-100.
Vangsawasdi, P., Noppharat, M., Hiranyaprateep, N., and Tirapong, N. 2002. Relationship between rheological properties of rice flour and qualities of vermicelli. Department of Microbiology, Department of Food Engineering, King Mongkut's University of Technology: Bangkok, Thailand.
Watzke, H. J. 1998. Impact of processing on bioavailability examples of minerals in foods. Trends Food Sci. Technol. 9:320-327.
Wesley, A., and Ranum, P., eds. 2004. Fortification Handbook: Vitamin and Mineral Fortification of Wheat Flour and Maize Meal. Micronutrient Initiative: Ottawa, ON, Canada.
WHO/FAO. 2005. World Health Organization Guidelines on Food Fortification with Micronutrients for the Control of Micronutrient Malnutrition. WHO: Geneva, Switzerland.
Wirakartakusumah, M. A., and Hariyadi, P. 1998. Technical aspects of food fortification. Food Nutr. Bull. 19(2):101-108.
Yoenyongbuddhagal, S. and Noomhorm, A. 2002. Effect of raw material preparation on rice vermicelli quality. Starch/Stärke 54:534-539.

[Received January 21, 2014. Accepted October 15, 2014.]

Quality and Fortificant Retention of Rice Noodles as Affected by Flour Particle Size

ORIGINALITY REPORT

26%

SIMILARITY INDEX

PRIMARY SOURCES

1	onlinelibrary.wiley.com Internet	337 words — 6%
2	Sorada Yoenyongbuddhagal. "Effect of Raw Material Preparation on Rice Vermicelli Quality", Starch - Stärke, 11/2002 Crossref	323 words — 6%
3	Rungarun Hormdok, Athapol Noomhorm. "Hydrothermal treatments of rice starch for improvement of rice noodle quality", LWT - Food Science and Technology, 2007 Crossref	140 words — 3%
4	"Abstracts of the Asian Congress of Nutrition 2019", Annals of Nutrition and Metabolism, 2019 Crossref	86 words — 2%
5	Hormdok, R.. "Hydrothermal treatments of rice starch for improvement of rice noodle quality", LWT - Food Science and Technology, 200712 Crossref	73 words — 1%
6	Takeshi Nagai, Anri Takagi, Norihisa Kai, Yasuhiro Tanoue, Nobutaka Suzuki. " Development of acceptable high-quality noodles using nonglutinous rice cultivar flours ", Cereal Chemistry, 2019 Crossref	57 words — 1%
7	Bhattacharya, M., S. Y. Zee, and H. Corke. "Physicochemical Properties Related to Quality of Rice Noodles", Cereal Chemistry, 1999.	55 words — 1%

Crossref

8 Ling-Zhi Cheong, Chin-Ping Tan, Kamariah Long, Nor Aini Idris, Mohd. Suria Affandi Yusoff, Oi-Ming Lai. "Baking performance of palm diacylglycerol bakery fats and sensory evaluation of baked products", European Journal of Lipid Science and Technology, 2011 — 49 words — 1%
Crossref

9 www.pjbs.org — 40 words — 1%
Internet

10 Supawadee Cham, Prisana Suwannaporn. "Effect of hydrothermal treatment of rice flour on various rice noodles quality", Journal of Cereal Science, 2010 — 40 words — 1%
Crossref

11 Hyun-Jung Chung, Ahra Cho, Seung-Taik Lim. "Effect of heat-moisture treatment for utilization of germinated brown rice in wheat noodle", LWT - Food Science and Technology, 2012 — 36 words — 1%
Crossref

12 Nura Malahayati, Kharidah Muhammad, Jamilah Bakar, Roselina Karim. "Quality and Fortificant Retention of Rice Noodles as Affected by Flour Particle Size", Cereal Chemistry Journal, 2015 — 36 words — 1%
Crossref

13 Fari, M.J.M., D. Rajapaksa, and K.K.D.S. Ranaweera. "Quality characteristics of noodles made from selected varieties of Sri Lankan rice with different physicochemical characteristics", Journal of the National Science Foundation of Sri Lanka, 2011. — 25 words — < 1%
Crossref

14 Pakkawat Detchewa, Masubon Thongngam, Jay-Lin Jane, Onanong Naivikul. "Preparation of gluten-free rice spaghetti with soy protein isolate using twin-screw extrusion", Journal of Food Science and Technology, 2016 — 24 words — < 1%
Crossref

15 www.agri.ubu.ac.th

Internet

17 words — < 1%

---

16 Zhan-Hui Lu, Lilia S. Collado. "Rice noodles", Elsevier BV, 2019
Crossref

13 words — < 1%

---

17 www.thaiscience.info
Internet

11 words — < 1%

---

18 psasir.upm.edu.my
Internet

10 words — < 1%

---

19 Luyan Liao, Huihui Liu, Zengpeng Gan, Weiguo Wu. "Structural properties of sweet potato starch and its vermicelli quality as affected by heat-moisture treatment", International Journal of Food Properties, 2019
Crossref

7 words — < 1%

---

20 Noorlaila Ahmad, Asmeda Rajab. " Textural and cooking qualities of dry noodle made from semi-wet and wet MR253 flours ", Cereal Chemistry, 2018
Crossref

6 words — < 1%

EXCLUDE QUOTES	ON	EXCLUDE MATCHES	< 2%
EXCLUDE BIBLIOGRAPHY	ON		