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Effects of Annealing and Removal of the Water-Soluble Fraction of Dry-Milled Rice Flour on the Texture of Cooked Rice Noodles

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Abstract

Rice noodles were prepared using dry-milled rice flours, which were treated by annealing and removing the water-soluble fraction to improve the quality of noodles without using chemical additives. The combined treatment (TC) with annealing and water-soluble fraction removal decreased the cooking losses for *Goamibyeo* but not for *Chenmaai* and *Milyang*260, which had soft kernels and contained less damaged starch than the hard kernel rice after milling. TC significantly reduced the hardness and adhesiveness of cooked noodles, and increased the cohesiveness according to the texture profile analysis. A sensory evaluation detected an increase in mouth feel firmness and elasticity of cooked TC noodles. These results indicate that annealing at room temperature for 3 h followed by the removal of the water-soluble fraction is effective for reducing the cooking losses and improving the textural properties of noodles made from rice flour with high starch damage.

Keywords

Annealing, Cooking Lose, Rice Noodle, Texture, Water Soluble Fraction

1. Introduction

The desirable qualities of noodles are generally considered to be a low loss of solids during cooking and cooked noodles with a good mouth feel. Compared with wheat noodles, the main quality problems associated with rice noodle are the loss of starch materials during cooking and the mushy texture of the cooked noodles. Rice protein cannot form a gluten network in the same way as wheat proteins, so starch is important for creating a matrix that binds the remaining flour [1]. Amylose crystallites help to create a continuous network in rice noodles by linking together strongly at junction zones [2]. Therefore, long-grain rice cultivars with an intermediate to high amylose content (>22% amylose) and a high gel consistency are suitable for making rice noodles [3] [4].

The conventional process used to make rice noodles involves soaking the polished rice for several hours, followed by grinding, and steaming the rice slurry to gelatinize the rice starch in the flour [1]. The uptake of water during soaking reduces the amount of damaged starch [5]. The damaged starch content is correlated with the water retention capacity, which is the primary factor that affects the quality of noodles [6] [7] [8] [9]. Dry-milled rice flour has a marked tendency to lose its viscosity and thicken capacity during cooking [10]. Thus, chemically modified starch and various chemical additives are used widely in the rice noodle industry. Alternative time-saving methods have been developed to improve and simplify the noodle-making process without the use of chemical additives [11]. Rice flour can be mixed with gums and transglutaminase to improve the noodle-making properties and cooking quality [12]. The process used to produce instant rice noodles by pretreating rice flour with steam to partially gelatinize the starch has been patented [13]. Heat-moisture treatment of rice flour can also enhance the cooking and textural qualities of rice noodles [4]. Modifications based on heat-moisture treatment and annealing can facilitate the production of acceptable quality noodles from poor quality rice flour [14]. Annealing or heat-moisture treatments have been used selectively to produce various qualities of rice noodle because of their different rheological effects on the noodle texture [11] [15]. The objectives of the present study were to develop a method for the treatment of rice flour that reduces the cooking losses and improves the textural properties of cooked rice noodles without chemical additives.

2. Materials and Methods

2.1. Materials

Two *japonica* lines (*Goamibyeo* and *Milyang*260) and one *indica* line (*Chenmaai*) were grown under uniform field conditions at the National Institute of Crop Science, Korea. *Goamibyeo, Milyang*260 and *Chenmaai* are newly-developed varieties for noodle making [6] [16]. The paddy dried to get the final moisture content of 14% (wet basis) was dehulled and polished using commercial machines (SYTH-88, Ssangyong Co. Ltd., Incheon, Korea). The polished rice was vacuum-packed in plastic pouches, and stored at 4˚C until further experiments.

2.2. Determination of the Grain Hardness

The polished rice kernels were kept in a desiccator at room temperature (20˚C ~ 24˚C) for 24 h before analysis of dry kernel hardness, and the wet kernels were prepared by soaking 5 g of dry rice kernels in 10 mL of distilled water at room temperature for 4 h. The wet kernels were drained through a stainless steel sieve and tested immediately. The grain hardness was measured using a texture analyzer (TA Express, Texture Technologies Corp., Scarsdale, NY, USA) with a 20 kg load cell. The rice kernel was compressed using a stainless steel cylinder probe (5 mm diameter) until the kernel broke at a speed of 0.5 mm/s. The breaking force was used as the hardness of the kernel. The data were average measurements based on 30 random samples of each kernel.

2.3. Preparation of the Rice Flour

The polished rice kernels were ground with a centrifugal force mill (KCFM-48, Korea Medi Ltd, Daegu, Korea), passed through an 115-mesh sieve (<125 μm), vacuum-packed in plastic bags, and stored at 4˚C until further experiments. The moisture content of flour was measured using an infrared moisture analyzer (MB45, Ohaus Co., Switzerland) at 105˚C for 1 h.

2.4. Determination of the Particle Size Distribution and Water Absorption Index (WAI) of Flour

The flour was dispersed using isopropyl alcohol. The mean size and distribution of flour were determined using a laser diffraction particle size analyzer (LS13 320, Beckman Coulter, Brea, CA, USA). The water absorption index (WAI) of the rice flour was determined using the AACC Approved Method 56 - 30 [17]. Rice flour (5 g) and water (30 mL) were vigorously mixed in a 100 ml centrifuge tube, incubated in a 37˚C water bath for 10 min, and then centrifuged (2000 × *g*, 30 min). The weight ratio of centrifuged precipitate to the amount of flour used in the test was taken as the water absorption index (WAI).

2.5. Determination of the Amylose and Damaged Starch Contents of Flour

The amylose content of flour was determined using amylose/amylopectin assay kit procedure (Megazyme International Ltd, Wicklow, Ireland). The procedure was a modification of a Concanavalin-A method by Yun and Matheson [18]. Damaged starch content of flour was analyzed using starch damage assay kit procedures (Megazyme International Ltd, Wicklow, Ireland). The procedure was followed by AACC Approved Method 76 - 31.01 [17].

2.6. Determination of the Water-Soluble Fraction

Rice flour was analyzed to determine the total soluble solids, according to Anderson *et al.* [19] and Aboubacar and Hamaker [20]. First, 2.5 g of flour and 30 mL of water were mixed at 30˚C for 30 min in 50 mL plastic centrifuge tubes. The mixture was stirred gently every 5 min using a metal spatula to break any clumps of flour and the tubes were centrifuged (140 × *g*, 10 min). The supernatant was removed carefully and analyzed to determine the total water-soluble fraction content using the phenol-sulfate method [21]. The data were average of five replicates.

2.7. Treatment of Rice Flour

The rice flour was treated using four different following conditions. TA was prepared following method. The rice flour was mixed with water to obtain 65% moisture content on a dry flour weight basis. The flour slurry which contained 65% moisture, was stirred gently for 5 min and annealed for 3 h at room temperature. TB was prepared with the same procedure with TA, but the annealing temperature was 50˚C. TC was prepared following method. One part of rice flour was mixed with ten parts of water, stirred gently for 5 min, annealed for 3 h at room temperature and centrifuged (140 × *g*, 10 min) to remove the water-soluble fraction and the precipitate was used as TC. TD was prepared with the same treatments of TC, but the annealing temperature was 50˚C. The moisture content of precipitate after centrifugation was about 66% ~ 67%. Extra formula water for TA, TB, TC, and TD was not necessary to make flat rice noodle.

2.8. Preparation of Rice Noodles

The rice noodles were processed according to the flat noodle-making method described by Cham and Suwannaporn [11] and Choi *et al*. [22]. The control rice flour was mixed with water (35:65, w/w) and 50 mL of the slurry was spread evenly on a stainless steel plate, steamed for 90 sec until complete gelatinization, and cooled to room temperature. It was not necessary to add any extra water to the treated rice flour for TA, TB, TC or TD, because they contained absorbed water. The sheets were scraped and hot air-dried at 70˚C for 15 min, and the moisture in the sheets was equilibrated by keeping them between moistened cheese-cloths for 3 h in an air-tight vinyl bag. The moistened noodle sheets were cut into small strips (width = 3 mm), hot air-dried at 50˚C for 1 h, and subjected to prolonged drying in a desiccator until the moisture content of the noodle strips reached 10% - 12%.

2.9. Evaluation of the Cooked Noodles

The cooking properties and textures of the cooked noodles were determined using published methods [6]. The solid losses of noodles during cooking (cooking loss) were measured by evaporating the cooking water to dryness in a 100˚C oven and were expressed as the percentage of solids lost during cooking. The tensile strength of the cooked noodles was measured using a texture analyzer (TA Express), which was equipped with a Stable Micro Systems Kieffer dough and gluten extensibility rig (TA Express). The parameters recorded were Rmax as the maximum resistance to extension and the extensibility until rupture of the noodles. The texture profile analysis (TPA) of cooked noodles consisted of compressing 75% strain through the noodles after their surface was detected, using a texture analyzer (TA express) attached to a 20 mm stainless steel cylindrical probe according to the method of Han *et al*. [6]. The data were average measurements of 20 more noodles.

2.10. Sensory Evaluation of Cooked Noodle

The sensory test used 96 untrained and randomly selected panelists, including students, faculty, and staff from Keimyung University, who evaluated six noodle samples. A complete randomized block design was used to organize the serving of the noodles to each panelist. Sensory attributes of noodles, including mouthfeel firmness and elasticity were measured using a nine-point rating scales, *i.e.*, extremely weak (9) to strong extremely (1). Six products were tested, *i.e.*, three varieties each of the control rice noodles and treated rice flour (TC) that was annealed at room temperature where the water-soluble fractions were removed by centrifugation.

2.11. Statistical Analyses

The data were analyzed using SPSS version 20.0. Analysis of variance (ANOVA) was used to test the flour characteristics of different rice varieties and study the effect of treatments on the cooked noodle properties. Duncan's multiple range test ($p < 0.05$) was used to perform multiple comparisons. Pearson's correlation coefficient was used to analyze the correlations between the rice kernel and flour characteristics. Two-way ANOVA with the interactions was used to study the effect of rice varieties and treatment on the sensory attributes of cooked noodles.

3. Results and Discussion

3.1. Characteristics of the Rice Kernels and Flour

The amylose contents of the three rice varieties were 20.8% ~ 22.9% and there were no significant differences among varieties, as shown in Table 1. The kernels of *Goamibyeo* were significantly ($p < 0.05$) harder than those of other varieties, as shown in Table 1. After soaking in water, the wet hardness did not differ significantly ($p < 0.05$) among varieties. The mean particle size distribution of rice flour ranged from 11.5 to 18.1 μm. The damaged starch content (18.9%), water-soluble solids content (2.6), and water absorption index (WAI, 1.6 mg/mL) of *Goamibyeo* were significantly higher than those of the other two varieties. These characteristics of *Goamibyeo* flour indicated that the hard kernel rice produced more damaged starch during dry milling. The high level of starch damage induced the higher level of water-soluble fraction and WAI of the flour. Previous studies [10] also found that the damaged starch contents and WAI of dry-milled flours differed significantly ($p < 0.05$) among varieties. The statistical analysis in Table 2 confirms the high correlations between the damaged starch content, water-soluble fraction content, and WAI. WAI was correlated very significantly ($p < 0.01$) with damaged starch content (r = 0.983) and water soluble content (r = 0.924) of flour.

3.2. Characteristics of the Control Cooked Rice Noodles

The cooking losses of the control noodles were highest in *Goamibyeo,* which contained a high level of damaged starch and a high water-soluble fraction, as shown in Table 3. The cooking losses (9.5%) of *Goamibyeo* were significantly higher than those of the other two varieties (4.6% ~ 4.2%). Previous studies [6]

Table 1. Characteristics of dry-milled rice flour.

			Rice		
			Goamibyeo	*Chenmaai*	*Milyang*260
Kernel	Hardness (kg)	Dry	11.5 ± 3.3^a	9.4 ± 1.5^b	6.8 ± 2.0^c
		Wet	1.7 ± 0.4^a	2.0 ± 0.5^a	1.9 ± 0.5^a
Flour	Particle size (μm)	Mean	11.5	18.1	13.0
		Median	9.9	11.8	10.2
	Amylose content (%)		22.9 ± 1.6^a	22.3 ± 2.0^a	20.8 ± 1.0^a
	Damaged starch content (%)		18.9 ± 1.7^a	11.2 ± 0.6^c	15.4 ± 0.9^b
	Water absorption index		1.6 ± 0.0^a	1.3 ± 0.0^c	1.4 ± 0.0^b
	Water-soluble content (mg/mL)		2.6 ± 0.0^a	1.3 ± 0.0^c	2.4 ± 0.0^b

Dissimilar superscripts in the same row denote significant difference ($p < 0.05$).

Table 2. Correlation coefficients (r) of the kernel and flour characteristics.

	Dry kernel hardness	Water absorption index	Water-soluble content	Amylose content
Water absorption index	0.317			
Water-soluble content	0.395	0.924**		
Amylose content	0.286	0.450	0.496	
Damaged starch content	0.479	0.983**	0.941**	0.561*

Significant at $^{**}p < 0.01$, $^{*}p < 0.05$.

[22] of rice noodle quality have shown that the damaged starch content is significantly correlated to the cooking losses, which is the primary factor considered during the selection of high quality rice varieties for use in rice noodle production. Bhattacharya *et al*. [23] also reported that the water solubility of rice flour has a positive relationship with the cooking losses. Compared with wheat noodles, the main quality problem that affects rice noodles is the loss of solid materials during cooking, which produces noodles with a mushy texture [24]. Therefore, the loss during cooking is an important criterion when assessing the quality of rice noodles.

The TPA hardness (2.1 kg) of the control cooked noodles was highest in *Goamibyeo* whereas the Rmax (50.6 kg), which indicates the elasticity of noodles, was lowest in *Goamibyeo,* as shown in **Table 3**. *Chenmaai* and *Milyang*260 contained low levels of damaged starch and they had the lowest cooking losses, comparatively high elasticity and extensibility, and the cooked noodles had low hardness. The adhesiveness and cohesiveness were ranked in the following order: *Goamibyeo* < *Chenmaai* < *Milyang*260. The cohesiveness was closely related to the cooking losses of noodles, as shown in **Table 3**. Cohesiveness was defined as the amount of deformation that a material underwent before rupturing when a subject bit through the sample completely using their molars [25]. Thus, it measured the extent to which the noodle structure was

Table 3. Properties of the cooked noodle.

	Cooking loss (%)	Tensile strength		Texture profile analysis (TPA)			
		Rmax (kg)	Extensibility (mm)	Hardness (kg)	Adhesiveness (g/s)	Springiness	Cohesiveness
Goamibyeo							
Control	9.5 ± 1.1^{aa}	50.6 ± 12.4^{ab}	8.1 ± 1.1^{ab}	2.1 ± 0.5^{b}	29.9 ± 7.5^{ab}	0.96 ± 0.08^{a}	0.69 ± 0.05^{c}
TA	9.2 ± 0.1^{a}	56.9 ± 15.0^{a}	8.6 ± 1.2^{a}	1.9 ± 0.4^{b}	25.2 ± 7.9^{b}	0.95 ± 0.02^{a}	0.71 ± 0.04^{c}
TB	10.1 ± 0.6^{a}	55.3 ± 13.1^{a}	8.6 ± 1.4^{a}	2.4 ± 0.6^{a}	32.6 ± 8.2^{a}	0.94 ± 0.05^{a}	0.70 ± 0.04^{c}
TC	7.0 ± 0.1^{b}	56.6 ± 26.2^{a}	7.4 ± 2.1^{b}	0.9 ± 0.4^{c}	6.9 ± 4.2^{c}	0.95 ± 0.03^{a}	0.82 ± 0.10^{b}
TD	7.3 ± 0.2^{b}	41.3 ± 14.9^{b}	5.2 ± 1.2^{c}	0.6 ± 0.3^{c}	4.2 ± 3.3^{c}	0.99 ± 0.09^{a}	0.88 ± 0.06^{a}
Chenmaai							
Control	4.6 ± 0.2^{c}	79.5 ± 21.3^{ab}	12.8 ± 2.1^{a}	1.8 ± 0.5^{a}	31.4 ± 8.7^{ab}	0.96 ± 0.02^{ab}	0.75 ± 0.05^{b}
TA	5.4 ± 0.4^{b}	76.7 ± 20.2^{ab}	12.2 ± 1.9^{a}	1.6 ± 0.3^{b}	25.9 ± 8.4^{b}	0.96 ± 0.05^{ab}	0.73 ± 0.04^{b}
TB	5.3 ± 0.2^{a}	91.1 ± 21.2^{a}	13.4 ± 2.5^{a}	1.9 ± 0.3^{a}	34.9 ± 9.2^{a}	0.98 ± 0.09^{a}	0.73 ± 0.03^{b}
TC	4.9 ± 0.2^{bc}	66.4 ± 14.9^{b}	12.0 ± 2.9^{a}	0.6 ± 0.2^{c}	15.1 ± 4.1^{c}	0.96 ± 0.01^{ab}	0.86 ± 0.02^{a}
TD	4.8 ± 0.3^{c}	47.1 ± 16.2^{c}	10.1 ± 2.5^{b}	0.6 ± 0.2^{c}	18.0 ± 8.2^{c}	0.93 ± 0.06^{b}	0.87 ± 0.05^{a}
*Milyang*260							
Control	4.2 ± 0.7^{c}	61.9 ± 13.8^{a}	11.2 ± 2.1^{a}	1.8 ± 0.5^{a}	35.7 ± 14.9^{a}	0.93 ± 0.04^{a}	0.73 ± 0.04^{b}
TA	5.7 ± 0.3^{a}	55.7 ± 12.3^{ab}	10.2 ± 1.7^{a}	1.3 ± 0.4^{b}	28.8 ± 9.6^{a}	0.93 ± 0.04^{a}	0.71 ± 0.05^{b}
TB	5.6 ± 0.1^{ab}	61.7 ± 19.4^{b}	11.1 ± 1.8^{a}	1.5 ± 0.4^{ab}	27.4 ± 10.2^{a}	0.95 ± 0.02^{a}	0.72 ± 0.05^{b}
TC	5.1 ± 0.4^{ab}	59.0 ± 21.0^{ab}	11.3 ± 3.2^{a}	0.5 ± 0.2^{c}	14.9 ± 8.4^{b}	0.95 ± 0.02^{a}	0.87 ± 0.03^{a}
TD	4.8 ± 0.3^{bc}	48.9 ± 20.7^{b}	8.0 ± 2.3^{c}	0.6 ± 0.2^{c}	17.0 ± 3.5^{b}	0.94 ± 0.02^{a}	0.86 ± 0.04^{a}

Dissimilar superscripts in the same column of each rice varieties denote significant difference ($p < 0.05$) between treatments. TA, annealing for 3 h at room temperature; TB, annealing for 3 h at 50˚C; TC, annealing for 3 h at room temperature and removal of the water-soluble fraction; TD, annealing for 3 h at 50˚C and removal of the water-soluble fraction.

disrupted during the first compression [26]. A high cohesiveness indicated a strong internal connection within the noodle, which reduced the cooking losses. Tensile testing was used to assess the elasticity and breaking strength because these properties show how well the sample holds together during cooking, which reflects the cooking tolerance and cooking quality of the noodles [23]. Overall, the data suggested that, *Chenmaai* and *Milyang*260 were more suitable than *Goamibyeo* during the tests of the control noodles.

3.3. Effect of Removing the Water-Soluble Fraction of Annealed Flour on the Cooking Losses of Rice Noodles

The annealing of rice flour at room temperature (TA) and 50˚C (TB) did not reduce the cooking losses, as shown in Table 3. Indeed, the cooking losses were increased after annealing with *Chenmaai* (5.3% ~ 5.4%) and *Milyang*260 (5.7% ~ 5.6%). Cham and Suwannaporn [11] reported that the cooking and textural qualities of rice noodles produced using hydrothermal modification were not significantly different from those made with commercial rice noodle flour. They indicated that the annealing process only improved the crystallinity of existing helices, thereby "perfecting" the starch crystallites without the formation of additional helices. They found that heat and moisture treatment improved the crystallinity of starch granules to a greater extent than annealing.

However, the cooking losses of the noodles changed significantly when the water-soluble fractions of the flour were removed, as shown in **Table 3**. The removal of the water-soluble fraction by centrifugation after annealing the flour at room temperature (TC) and 50˚C (TD) reduced the cooking losses from 9.5% to 7.0% - 7.3% for the *Goamibyeo* noodles. However, it did not reduce the cooking losses with *Chenmaai* (4.8% ~ 4.9%) and *Milyang*260 (4.8% ~ 5.1%), which contained less damaged starch than *Goamibyeo*. Pre-treatment of removing the water-soluble fraction of annealed rice flour was only effective to reduce the cooking loss of high starch damaged rice noodle.

3.4. Effect of Removing the Water-Soluble Fraction of the Annealed Flour on the Textural Properties of Rice Noodles

Removing the water-soluble fraction after annealing the flour (TC and TD) had a much more pronounced effect than annealing alone (TA and TB) on the textural properties of all varieties of cooked noodles, as shown in **Table 3**. The elasticity (Rmax) and extensibility were not changed greatly by TC but they were reduced significantly by TD. Reduced elasticity is not good for the noodle quality [22]. Thus, TD did not yield an appropriately cooked noodle texture. With TC, the Rmax of the noodles changed slightly compared with the control. Rmax decreased in *Chenmaai* (66.4 kg) and *Milyang*260 (59.0 kg) but increased in *Goamibyeo* (56.6 kg).

The TPA properties of noodles produced with TC and TD were significantly different from those made with the control. With TC and TD, the TPA results showed that there were significant decreases in the hardness and adhesiveness but increases in the cohesiveness. The decline in hardness may reflect the reduced core hardness of the cooked noodles (data not shown). The noodles cooked differently in their core and surface zones because of variation in the accessibility of water during boiling [27]. It is assumed that differences in the cooking of each zone may be attenuated by TC treatment and the decline in hardness may have resulted from a reduction in the volume of the uncooked hard core of the noodles. Therefore, the reduction in the TPA hardness indicated that the hard core of the noodles had softened during the cooking period and that the cooking losses were reduced by the TC treatment.

An increased level of cohesiveness indicated strong internal connections, which reflected the cooking tolerance and contributed to the reduced cooking losses of noodles boiling [27]. A decrease in the adhesiveness indicated a "clean and smooth" noodle surface, which suggested that there was a low level of amylose leaching from the treated rice flour [11]. The springiness was not affected significantly by the rice varieties and treatments. Ross [27] explained that springiness of TPA should be considered as an elasticity of noodles. The Rmax and springiness data in **Table 3** suggest that the TC treatment did not affect the elastic properties of the cooked noodles. These results indicate that the removal of the water-soluble fraction combined with annealing at room temperature improved the quality of the cooked noodles, which had low cooking losses, good textural properties, lower hardness and adhesiveness, and greater cohesiveness when produced from rice flour with highly damaged starch, such as *Goamibyeo* noodles.

3.5. Sensory Characteristics of the Cooked Rice Noodles

Sensory evaluations of cooked noodles were conducted to compare the control and TC-treated flour noodles as shown at **Table 4**. Two-way ANOVA revealed a significant effect of rice varieties ($p = 0.0002$) and TC treatment ($p < 0.0001$) on the mouthfeel firmness. Significant effects were also investigated from the rice varieties ($p = 0.0023$) and TC treatment ($p = 0.0003$) on the mouthfeel elasticity. There was no significant interaction between rice varieties and TC treatment on both mouthfeel firmness ($p = 0.7172$) and elasticity ($p = 0.1229$) as shown at **Table 4**. These results indicated that the difference in the sensory test was not only due to TC treatment but also to rice varieties.

The mouthfeel firmness was increased with TC-treated noodles (5.3 ~ 5.9). The increased mouthfeel firmness had a positive effect because softness indicated a mushy texture, which is the most unfavorable textural characteristic of cooked rice noodles. The increased mouthfeel firmness with TC contrasted with the reduced TPA hardness in **Table 3**. Instead, the mouthfeel firmness had positively related with the TPA cohesiveness in **Table 3**. This result was probably

Table 4. Mean sensory evaluation score of mouthfeel firmness and elasticity of cooked noodles prepared using different rice varieties, after treatment by removing the water soluble-fraction and annealing.

Rice	Treatment	Sensory evaluation score	
		Mouthfeel firmness	Mouthfeel elasticity
Goamibyeo	Control	4.4 ± 1.7	4.0 ± 1.7
	TC	5.3 ± 1.5	4.7 ± 1.8
Chenmaai	Control	5.6 ± 1.7	5.2 ± 1.8
	TC	5.9 ± 1.9	5.1 ± 2.0
*Milyang*260	Control	4.4 ± 1.8	4.6 ± 2.0
	TC	5.7 ± 1.5	5.9 ± 1.6
ANOVA* (*p* value)			
Rice		0.0002	0.0023
Treatment		<0.0001	0.0003
Rice x Treatment		0.7172	0.1229

TC, annealing for 3 h at room temperature and removal of the water-soluble fraction. *Two-way ANOVA was run for each sensory attribute.

because the TPA hardness was measured at 75% deformation in the compressive test whereas the sensory perception of firmness may require more than one physical measurement. The mouthfeel firmness reflected complex sensory feelings, such as the hardness, springiness, and cohesiveness at 100% deformation when chewing the noodle [27].

4. Conclusion

A combined treatment of annealing for 3 h at room temperature and the removal of the water-soluble fraction reduced the cooking losses with hard kernel rice flour noodles. The textural properties of all noodle varieties were improved by the combined treatment. The elasticity and extensibility of TC-treated noodles did not differ substantially, or were reduced slightly, compared with the control, whereas the TPA hardness and adhesiveness decreased significantly, and the cohesiveness increased. Reduced adhesiveness indicated a "clean and smooth" noodle while the increase in the cohesiveness reflected the strong internal connections, which contributed to the reduced cooking losses. The reduction in the TPA hardness indicated that the hard core of the noodles had softened during the cooking period, while the cooking losses were reduced by the TC treatment. The sensory evaluation determined the effects of the treatment on the textural properties of the cooked noodles. The increased mouthfeel firmness and TPA cohesiveness indicated that the cooked noodle texture was improved because cooked rice noodles with a mushy texture are the main quality problem.

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References

[1] Juliano, B.O. and Sakurai, J. (1985) Rice Flour Products. In: Juliano, B.O., Ed., *Rice: Chemistry and Technology.* AACC., St Paul, MN., 591-599.

[2] Mestres, C., Colonna, P. and Buleon, A. (1988) Characteristics of Starch Networks within Rice Flour Noodles and Mungbean Starch Vermicelli. *Journal of Food Science,* **53**, 1809-1812. https://doi.org/10.1111/j.1365-2621.1988.tb07848.x

[3] Kohlwey, D.E., Kendall, J.H. and Mohindra, R.B. (1995) Using the Physical Properties of Rice as a Guide to Formulation. *Cereal Foods World,* **40**, 728-732.

[4] Yoenyongbuddhagal, S. and Noomhorm, A. (2002) Effect of Physicochemical Properties of High-Amylose Thai Rice Flours on Vermicelli Quality. *Cereal Chemistry,* **79**, 481-485. https://doi.org/10.1094/CCHEM.2002.79.4.481

[5] Preston, K.R., Kilborn, R.H. and Dexter, J.E. (1987) Effects of Starch Damage and Water Absorption on the Alveograph Properties of Canadian Hard Red Spring Wheats. *Canadian Institute of Food Science and Technology Journal,* **20**, 75-80b. https://doi.org/10.1016/S0315-5463(87)71093-1

[6] Han. H.M., Cho, J.H. and Koh, B.K. (2011) Processing Properties of Korean Rice Varieties in Relation to Rice Noodle Quality. *Food Science and Biotechnology,* **20**, 1277-1282. https://doi.org/10.1007/s10068-011-0176-5

[7] Nishita, K.D. and Bean, M.M. (1982) Grinding Methods: Their Impact on Rice

Flour Properties. *Cereal Chemistry*, **59**, 46-49.

[8] Hatcher, D.W., Kruger, J.E. and Anderson, M.J. (1999) Influence of Water Absorption on the Processing and Quality of Oriental Noodles. *Cereal Chemistry*, **76**, 566-572. https://doi.org/10.1094/CCHEM.1999.76.4.566

[9] Metcalf, S.L. and Lund, D.B. (1985) Factors Affecting Water Uptake in Milled Rice. *Journal of Food Science*, **50**, 1676-1679, 1684. https://doi.org/10.1111/j.1365-2621.1985.tb10563.x

[10] Han. H.M., Cho, J.H. and Koh, B.K. (2012) Effect of Grinding Method on Flour Quality in Different Rice Cultivars. *Journal of the Korean Society of Food Science and Nutrition*, **41**, 1596-1602. https://doi.org/10.3746/jkfn.2012.41.11.1596

[11] Cham, S. and Suwannaporn, P. (2010) Effect of Hydrothermal Treatment of Rice Flour on Various Rice Noodles Quality. *Journal of Cereal Science*, **51**, 284-291. https://doi.org/10.1016/j.jcs.2010.01.002

[12] Yalcin, S. and Basman, A. (2008) Effects of Gelatinisation Level, Gum and Transglutaminase on the Quality Characteristics of Rice Noodle. *International Journal of Food Science and Technology*, **43**, 1637-1644. https://doi.org/10.1111/j.1365-2621.2007.01674.x

[13] Toh, T.S. (1996) Rice-Noodles Preparation. European Patent 0738473A2.

[14] Hormdok, R. and Noomhorm, A. (2007) Hydrothermal Treatment of Rice Starch for Improvement of Rice Noodle Quality. *LWT-Food Science and Technology*, **61**, 1-9. https://doi.org/10.1016/j.lwt.2006.12.017

[15] Stute, R. (1992) Hydrothermal Modification of Starches: The Difference between Annealing and Heat-Moisture Treatment. *Starch /Starke*, **44**, 205-214. https://doi.org/10.1002/star.19920440603

[16] Song, Y.C., Lim, S.J., Lee, J.S., Kim, H.Y., Yeo, U.S., Park, N.B., Kwak, D.Y., Kang, J.R., Yang, S.J., Hwang, H.G., Oh, B.G., Moon, H.P. and Lim, M.S. (2008) A New High Amylose Rice Variety "*Goamibyeo*". *Korean Journal of Breeding Science*, **40**, 447-451.

[17] AACC (2000) Approved Methods of the AACC, Method 56-30. 10th Edition, American Association of Cereal Chemists International, St Paul, MN.

[18] Yun, S.H. and Matheson, N.K. (1990). Estimation of Amylose Content of Starches after Precipitation of Amylopectin by Concanavalin-A. *Starch/Starke*, **42**, 302-305. https://doi.org/10.1002/star.19900420805

[19] Anderson, R.A., Conway, H.F., Pfeifer, V.F. and Griffin Jr., E.L., (1969) Gelatinization of Corn Grits by Roll and Extrusion Cooking. *Cereal Science Today*, **14**, 1-3.

[20] Aboubacar, A. and Hamaker, B.R. (2000) Low Molecular Weight Soluble Starch and Its Relationship with Sorghum Couscous Stickiness. *Journal of Cereal Science*, **31**, 119-126. https://doi.org/10.1006/jcrs.1999.0262

[21] Dubois, M., Gilles, K.A., Hamilton, J.K., Rebers, P.A. and Smith, F. (1956) Colorimetric Method for Determination of Sugars and Related Substances. *Analytical Chemistry*, **28**, 350-356. https://doi.org/10.1021/ac60111a017

[22] Choi, S.Y., Cho, J.H. and Koh, B.K. (2012) A Rice Noodle Making Procedure for Evaluating Rice Flour Noodle-Making Potential. *Journal of the Korean Society of Food Science and Nutrition*, **41**, 1823-1829. https://doi.org/10.3746/jkfn.2012.41.12.1823

[23] Bhattacharya, M., Zee, S.Y. and Corke, H. (1999) Physicochemical Properties Related to Quality of Rice Noodles. *Cereal Chemistry*, **76**, 861-867. https://doi.org/10.1094/CCHEM.1999.76.6.861

[24] Jobling S. (2004) Improving Starch for Food and Industrial Applications. *Current Opinion in Plant Biology*, **7**, 210-218. https://doi.org/10.1016/j.pbi.2003.12.001

[25] Munoz, A.M. (1986) Development and Application of Texture Reference Scales. *Journal of Sensory Studies*, **1**, 55-83. https://doi.org/10.1111/j.1745-459X.1986.tb00159.x

[26] Kim, Y.S., Wiesenborn, D.P., Lorenzen, J.H. and Berglund, P. (1996) Suitability of Edible Bean and Potato Starches for Starch Noodles. *Cereal Chemistry*, **73**, 302-308.

[27] Ross, A.S. (2006) Instrumental Measurement of Physical Properties of Cooked Asian Wheat Flour Noodles. *Cereal Chemistry*, **83**, 42-51. https://doi.org/10.1094/CC-83-0042