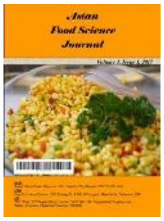

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Characteristics of Noodles Made from Rice Flours of Major Non-glutinous Rice Cultivars of Japan

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Authors' contributions

This work was carried out in collaboration between all authors. All authors read and approved the final manuscript.

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ABSTRACT

Rice flours from five species of major non-glutinous rice cultivars in Japan were used to produce noodles in this study, and these properties of noodles were evaluated and compared to those made from medium wheat flour. There was a large difference on moisture and apparent amylose contents of rice flours between the varieties, but there was almost no difference on damaged starch contents. Lower breaking strength was observed on rice noodles as compared to that made from medium wheat flour. On the other hand, rice noodles exhibited significant high adhesiveness (*p*=.05). By sensory analysis, rice noodles showed high adhesiveness and low smoothness.

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Akitakomachi flour was most appropriate for production of noodles using these flours. Commercially available grain vinegar (0-0.5%) was used instead of brackish water (*kansui*) to improve rice noodle quality. Noodle made with 0.5% grain vinegar particularly resulted in good quality in terms of breaking strength, adhesiveness, cohesiveness, and sensory evaluation. The results revealed that addition of grain vinegar significantly improved the texture to produce rice noodle with acceptable quality.

Keywords: Characterisation; major non-glutinous rice cultivars of Japan; noodle; preparation; rice flour.

1. INTRODUCTION

Food self-sufficiency rate based on calories is low in Japan and is the lowest among 10 developed countries such as Canada, Australia, America, and France [1]. The main causes are that eating habits of Japanese has been changed and westernised and demand for domestic agricultural products has decreased for cheaper imported foods. It requires aggressive use of domestic foodstuff to improve self-sufficiency in food products. It is expected consumption of rice for the staple food. However, there is a limit in its consumption as eating rice. Consumption decreases about 54 kg per person per year for FY2016 [2]. Recently, it is considered that flour foods as noodles and breads lead to high utilisation and increase on consumption of rice [3,4].

Many kinds of noodles are widely consumed as one of the important processed foods in Asian countries such as China, Republic of Korea, India, Thailand, Socialist Republic of Vietnam, and Japan [5-9]. These can be generally made from various cereal flours such as rice, wheat, and buckwheat. Among them, rice has been particularly used as a primary ingredient of noodles and baked goods as rice cracker. Gluten network in wheat dough plays an important role to produce noodles with superior cohesive, extensible, and viscoelastic textural properties. However, rice flour has low elastic gel-forming ability due to the absence of gluten.

In recent years, people with celiac disease are increasing [10]. It is known that about 1% cause it against the population ratio in Europe, America, and Japan [11]. Celiac disease is a chronic enteropathy caused by ingestion of gluten containing foods such as wheat, barley, and rye [12]. Therefore, only effective treatment is the removal of gluten from the diet and thereby people with celiac disease can improve their quality of life. That is, it is important for the prevention of celiac disease to avoid storage proteins, namely prolamins in wheat, hordein in barley, and secalin in rye [12]. Based on these, many researchers develop production methods of high qualities of gluten-free products, including noodles [5-9,13-16]. Besides, there are increasing consumer demands for these products because of health functions to reduce risk of celiac disease and allergic reactions as wheat allergy [17].

Generally, wheat based noodles are produced by mixing of raw materials and then by sheeting and cutting of dough. Due to absence of gluten on rice flour, it becomes imperative to improve the making properties of rice flours and the production methods of noodles for rice noodle production. It was reported that quality on rice noodle correlated with gel texture, swelling power, and paste viscosities by rapid visco analyzer (RVA) of starch in its flour [18]. Pitiphunpong and Suwannaporn [19] and Takahashi et al. [20] also reported that gel quality of rice depends on grain variety, amylose content, and aging period of rice. It is said that it is suitable for rice noodle production to involve rice cultivars with high amylose content, low gelatinisation temperature, and high gel consistency. For example, rice noodles are traditionally made from long-grain rice with high amylose content in Southeast Asia, Thailand [21]. Amylose with high content contributes to form gel network and to construct noodle structure [22]. On the other hand, products made from rice with intermediate amylose contents as rice for the staple food of Japan become softer with higher cooking loss, and it can not produce noodles using low amylose rice [23]. In this study, rice flours from five species of major non-glutinous rice cultivars with intermediate amylose contents in Japan were used to produce noodles and these properties were evaluated and compared to that made from medium wheat flour. Also, attempts were made to improve making properties and production method to obtain high quality of rice noodle for increase on consumption of rice for the staple food in Japan.

2. MATERIALS AND METHODS

2.1 Materials

Rice flour samples from five species of non-glutinous rice cultivars *Akitakomachi*, *Koshihikari*, *Haenuki*, *Hitomebore*, and *Hinohikari* were purchased from Akitainsatuseihon Co. (Akita, Japan), Kichijiya kokuten Co. (Yamanashi, Japan), Yoshida seihun Co. (Yamagata, Japan), Sugaya Ltd. (Iwate, Japan), and Ooshima farm (Kumamoto, Japan), respectively. Market shares of these major rice cultivars account for about 65% of total domestic proportion of planted areas of Japan in 2016 [24]. Commercially available medium wheat flour was purchased from Kobe Bussan Co., Ltd. (Hyogo, Japan). Commercially available grain vinegar was obtained from Tamanoi Vinegar Co., Ltd. (Osaka, Japan). Amylose from potato was from Sigma-Aldrich Co., LLC (U.S.A). Amylopectin hydrate from waxy corn was from Tokyo Chemical Industry Co., Ltd. (Tokyo, Japan). Congo Red was from Junsei Chemical Co., Ltd. (Tokyo, Japan). All other chemicals were of analytical grade.

2.2 Morphological Characteristics of Starches

Morphological characteristics of starches on flour samples were observed using a biological microscope (JTO-1500T, Kenis Ltd., Osaka, Japan) equipped with a digital image processing system (220F-HD, Kenis Ltd., Osaka, Japan). The 0.1% Congo Red-ethanol was added to flour samples, and then these characteristics were observed after 15 min. The sizes of starches were also measured using software (Photo Measure Ver.3, Kenis Ltd., Osaka, Japan).

2.3 Determination of Moisture Contents

Moisture contents of medium wheat flour and rice flour samples were measured at 135℃ for 1 h using a Moisture Determination Balance (FD-600, Kett Electric Laboratory, Tokyo, Japan). The contents of noodles prepared were also measured at the same temperature for 2 h [25].

2.4 Determination of Apparent Amylose Contents

Apparent amylose contents of medium wheat flour and rice flour samples were determined by colorimetric method [26]. Five mg of flour samples was collected in 5 ml of measuring flask, and 0.5 ml of distilled water was added. These were mixed with 0.1 ml of 2.5 M NaOH, and then melted on a hot water bath. After cooling, mixture was neutralised with 0.25 ml of 1 M HCl, and filled up to 5 ml with distilled water. A 0.1 ml of this solution was sequentially mixed with 0.1 ml of 2% potassium iodide-0.2% iodine solution and 0.8 ml of distilled water in an Eppendorf tube. Absorbance of the solution was measured at 660 nm. On the other hand, 10 mg of amylose or amylopectin was separately collected in 10 ml of measuring flask, and 1.0 ml of distilled water was added. After addition of 0.2 ml of 2.5 M NaOH, mixture was melted on a hot water bath. After cooling, the mixture was neutralised with 0.5 ml of 1 M HCl, and filled up to 10 ml with distilled water. Solution was mixed amylose or amylopectin at specified mixing ratio (amylose : amylopection = 0:10, 1:9, 2:8, 3:7, and 4:6) was used for preparation of calibration curve.

2.5 Determination of Damaged Starch Contents

Damaged starch contents of medium wheat flour and rice flour samples were measured by acid solution process [27]. Flour samples (dried weight: 20 mg) were collected in 50 ml of Falcon tubes, and then mixed with 2.0 ml of 0.25 M HCl. After shaking at 160 rpm for 2 h at 55 ℃ using a shaking incubator (NB-205, N-BIOTEK Co., Ltd., Korea), mixtures were centrifuged at 2,400 x g for 20 min at 20 ℃. Supernatants were used for measurement of total sugar contents by phenol-sulfuric acid method. Reduced sugar contents were calculated by calibration curve used maltose. Starch damage degree was calculated as following equation.

Starch damage degree (%) = (maltose content of suparnatant/20) x 100 (1)

2.6 Determination of Water Absorption

Water absorption of medium wheat flour and rice flour samples was determined as described by Yamazawa et al. [28] with some modifications. 0.5 g of flour samples was collected in 50 ml of Falcon tubes, and then 25 ml of distilled water was added. After gentle shaking for 24 h at 20 ℃ using the same shaking incubator, these were centrifuged at 30,000 x g for 15 min at 20 ℃. The supernatants were discarded, and the residues obtained were weighed. Water absorption was expressed as the rate of water content (ml) absorbed by 1.0 g of flour.

2.7 Color Measurement

Color analysis of medium wheat flour and rice flour samples was performed using a colorimeter (NR-11A, Nippon Denshoku Industries Co., Ltd., Tokyo, Japan) with illuminant D65 calibrated to black and white standards. The CIE $L^*a^*b^*$ system was used as the relation to human eye response to color. Results were shown as the mean of ten measurements. Moreover, color difference (ΔE^*ab) was calculated by following equation as a reference of the color on medium wheat flour.

$$\Delta E^*ab = [(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2]^{1/2} \quad (2)$$

0-0.5: trace; 0.5-1.5: slight; 1.5-3.0: noticeable; 3.0-6.0: appreciable; 6.0-12: much; more than 12: very much

Whiteness index was also calculated as described by Ulziijargal et al. [29].

$$\text{Whiteness index} = 100 - [(100 - L^*)^2 + a^{*2} + b^{*2}]^{1/2} \quad (3)$$

2.8 Preparation and Cooking of Noodles

Brackish water (*kansui*) was prepared by mixing potassium carbonate, sodium carbonate, and disodium hydrogenphosphate 12-water in the ratio of 7:11:2. One percentage of brackish water was added to flour samples [water contents added were determined from preliminary experiments as follows: *Akitakomachi* (80%), *Koshihikari* (74%), *Haenuki* (65%), *Hitomebore* (66%), and *Hinohikari* (67%), on flour weight basis], and was mixed using a spoon. After these were mixed a hundred times by hand, the dough obtained was rounded and covered with plastic wrap. These were rested at 25 ℃ for 20 min in an incubator (CN-25C, Mitsubishi Electric Engineering Co., Ltd., Japan). The dough was taken off and mixed again by hand. These were rounded, wrapped, and then were rested under the same conditions. Next, the dough was sheeted using a rolling pin, and then was loaded into a pasta maker (QF150, Shule Ltd., China) equipped with a dough sheeter (4 mm thickness). The sheet obtained was folded and rolled through three times. The dough sheet was cut into 1.5 mm-wide noodles with a roller cutter. After the extruded noodle strands obtained were stored at 5 ℃ for 70 h in airtight containers to promote the hydration, these were stored at room temperature for 20 min (fresh noodles). After 20 g of fresh noodle strands was cooked in 1 L of boiling distilled water for 90 s till the disappearance of white core, these were drained in a strainer and were washed with cool running water for 30 s. After removal of water using a paper towel, noodle strands were stored to prevent moisture loss in airtight containers at 5 ℃ until used.

2.9 Determination of Weight Change Rate

After fresh noodle strands were weighed, these were cooked as described above, and then were weighed. Weight change rate was calculated as following equation.

$$\text{Weight change rate (\%)} = (\text{weight of noodle strands after cooking}/\text{weight of noodle strands before cooking}) \times 100 \quad (4)$$

2.10 Textural Parameters of Noodles

Noodles were evaluated for textural properties using a rheometer (TPU-2, Yamaden Co., Ltd., Tokyo, Japan). Noodle strands after cooking as described above were cut into 3.0 cm pieces, and then these were compressed twice at a compression speed of 2.5 mm/s to a clearance of 0.2 mm with a cylindrical plunger No. 5 (5.0 mm diameter). From the force-time curve of texture profile, textural parameters [breaking force (hardness), adhesiveness, cohesiveness, and gumminess] were obtained. Three measurements were made for each noodle strand.

2.11 Sensory Evaluation

Cooked noodles were used for sensory evaluation. Sensory qualities of noodle strands were evaluated on the basis of appearance, color (whiteness), hardness, viscoelasticity, adhesiveness, chewiness, and smoothness by a panel of 4 trained panelists on a 5-point Hedonic scale.

2.12 Statistical Analysis

Except for color measurement, analyses were repeated 3 times independently and the results were expressed as the mean. The variance analysis ANOVA was subjected to data followed by Tukey's test ($p < 0.05$).

3. RESULTS AND DISCUSSION

3.1 Morphological Characteristics of Starches on Flours

Morphological characteristics of starches on flour samples were observed. As a result, starches of rice flours were observed as simple grains with polyhedral structures and aggregates of compound grains (Fig. 1A-1E). These were also observed as fragments of cells and microscopic particle grains without polyhedral structures. These average grain diameters were 2-9 µm (*Akitakomachi*: 2-9 µm, *Koshihikari*: 2-6 µm, *Haenuki*: 3-6 µm, *Hitomebore*: 4-6 µm, *Hinohikari*: 3-6 µm, respectively). Starch grains of medium wheat flour were as simple and large round shape with average diameters of 6-19 µm (Fig. 1F). Next, damaged starch grains of flours were observed after staining using Congo red solution. These average grain diameters were the same as those of starches that not damaged as follows: starches of rice flours: 2-8 µm (*Akitakomachi*: 2-6 µm, *Koshihikari*: 3-5 µm, *Haenuki*: 5-8 µm, *Hitomebore*: 5-6 µm, *Hinohikari*: 2-8 µm) and starch of medium wheat flour: 3-6 µm, respectively (Fig. 1). Flours are produced using a variety of milling techniques as jet milling (dry or wet), hammer milling (dry or wet), blade-milling, roll milling, and combination of roll and blade-milling and so on. Starch grains of flours are damaged by milling and are out of shape (these crystallinities decreased), and then damaged starch grains are produced. Simple grains with polyhedral structures and compound grains are observed in rice flours produced by wet mortar-and-pestle milling that has been used for a long time in Japan. On the other hand, microscopic particle grain of starches was not observed in the surface of rice flours produced using dry-jet milling. Thus, qualities of rice flours are affected by not only milling techniques but also its condition such as moistures, temperatures, and times, etc.

3.2 Moisture Contents of Flours

Moisture contents of flour samples were investigated. Those of *Koshihikari*, *Haenuki*, and *Hinohikari* flours were high as follows: 13.0, 13.8, and 13.6%, respectively, as well as that of medium wheat flour (14.0%) (Table 1). On the other hand, those of *Akitakomachi* and *Hitomebore* flours were low as follows: 10.9 and 11.0%, respectively. According to Standard Tables of Food Composition in Japan 2018 [30], moisture content of rice flour is reported about 11.1%. These contents are affected by harvesting period, storage methods and periods, moisture contents of brown rice or rice, milling conditions, and storage condition after milling and so forth.

3.3 Apparent Amylose Contents of Flours

Apparent amylose contents of flour samples were measured. Among them, content of *Hitomebore* flour was the highest about 19.9%, followed by *Akitakomachi* (17.8%) and medium wheat flours (17.0%) (Table 1). On the contrary, contents of *Koshihikari* and *Haenuki* flours were low about 15.1 and 16.3%, respectively. It is known that the content varies from the cultivars of rice from 0 to about 35%. These are all rice cultivars with middle amylose contents. Amylose contents of rice flours affect noodle-making qualities of rice noodles [31]. Generally, it is adequate for noodle making to use rice flours with high amylose contents such as *Hoshinishiki* (amylose content: 25.9±1.2%), *Hoshiyutaka* (29.5±0.5%), *Koshinokaori* (25.8±0.2%), *Mizuhochikara* (23.3±0.4%), *Momiroman* (26.2±1.0%), and *Yumetoiro* (29.1±0.1%) [32]. In fact, Ministry of Agriculture, Forestry and Fisheries of Japan selects rice cultivars as *Amichanmai*, *Kitamizuho*, *Koshinokaori*, *Fukunoko*, *Hoshiaoba*, *Mizuhochikara*, *Momiroman*, and *Yumeaoba* for noodle production among rice cultivars for rice flour [33].

3.4 Damaged Starch Contents of Flours

There are some techniques to mill rice such as jet milling, stamp milling, hammer milling, blade-milling method, combination of roll and blade milling, and combination of enzyme (pectinase) treatment and jet milling [31]. Starch granules of rice are usually damaged in the milling process, resulting damaged starches. Damaged starch contents of rice flours were investigated. The content on *Koshihikari* flour (21.1%) was slightly lower than those on *Akitakomachi*, *Haenuki*, *Hinohikari*, and *Hitomebore* ones (22.3-22.8%) (Table 1). On the contrary, the content on medium wheat flour was fairly high about 25.1% compared to those on rice flours. It can produce rice flours with different characteristics of starches by milling techniques [34-36]. However, application properties of these flours are affected by physicochemical properties such as damaged starch contents, particle size distribution, water absorption, and maximum viscosity by Brabender amylograph of flours, in addition to properties of raw material rice [31]. Ogawa and Nagai [37] investigated the effect of milling methods on qualities of rice flours. They reported that it was tendency to become small on particle size in rice with high moisture contents in the case of the same milling methods. In any case it is desired rice flours with low damaged starch contents for a high quality of noodle production.

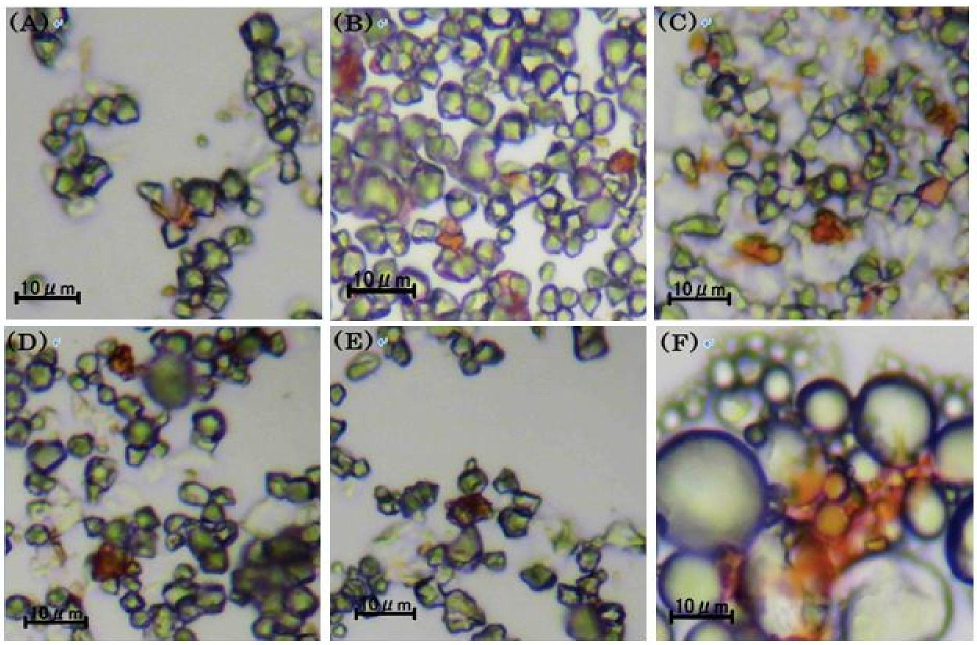

Fig. 1. Morphological characteristics of starches on flours
(A) Akitakomachi flour, (B) Koshihikari flour, (C) Haenuki flour, (D) Hitomebore flour, (E) Hinohikari flour, (F) Medium wheat flour

Table 1. Characteristics of rice flours made from major non-glutinous rice cultivars of Japan

	Medium wheat flour	***Akitakomachi* flour**	***Koshihikari* flour**	***Haenuki* flour**	***Hitomebore* flour**	***Hinohikari* flour**
Moisture content (%)	14.0 ^{a}	10.9 ^{b}	13.0 ^{a}	13.8 ^{a}	11.0 ^{b}	13.6 ^{a}
Apparent amylose content (%)	17.0 ^{b}	17.8 ^{b}	15.1 ^{c}	16.3 ^{c}	19.9 ^{a}	12.1 ^{d}
Damaged starch content (%)	25.1 ^{a}	22.8 ^{b}	21.1 ^{c}	22.8 ^{b}	22.3 ^{b}	22.8 ^{b}
Water absorption (%)	72.6 ^{e}	165.1 ^{a}	117.2 ^{d}	117.7 ^{d}	141.5 ^{b}	126.8 ^{c}
Color						
L^*	98.23 ^{b}	99.67 ^{a}	99.75 ^{a}	99.65 ^{a}	98.83 ^{b}	97.36 ^{c}
a^*	0.61 ^{a}	-0.10 ^{b}	-0.08 ^{b}	-0.07 ^{b}	-0.08 ^{b}	-0.23 ^{c}
b^*	8.49 ^{a}	5.35 ^{c}	5.24 ^{c}	5.23 ^{c}	5.88 ^{c}	7.83 ^{b}
Color difference (ΔE^*ab)	-	Appreciable	Appreciable	Appreciable	Noticeable	Slight
Whiteness index	91.31 ^{b}	94.64 ^{a}	94.76 ^{a}	94.76 ^{a}	94.01 ^{a}	91.73 ^{b}

3.5 Water Absorption

Water absorption of flour samples was determined. As a result, the rate of *Akitakomachi* flour was the highest about 165.1%, and decreased in the order as follows: *Hitomebore*, *Hinohikari*, *Haenuki*, and *Koshihikari* flours (Table 1). On the other hand, the rate of medium wheat flour was the lowest about 72.6% among these flours tested. The correlation between moisture contents of flours and water absorption were estimated. The correlation coefficient was moderately higher, R^2 = 0.7533. However, there were no correlation between damaged starch contents and water absorption at all. It might be due to the use of different rice cultivars. Shoji et al. [38] investigated water absorption properties of rice flours prepared using different milling techniques. There are no relationships between particle diameter of starch and its properties on rice flour prepared by wet-hammer milling method. Rice flour with smaller particle diameters prepared by dry-jet milling method, however, showed high starch damage degree and gelatinisation degree. Its water absorption velocity was slow and saturated water absorption became higher. That is, starch properties of rice flours affected water absorption properties, as shown by the correlation between water absorption velocity coefficient and starch damage degree on flours. Naganuma [39] tried to investigate physicochemical and cooking properties of milled rice to develop various types of rice flours and to improve eating qualities. Rice flour samples with mean particle diameter of 40, 20, 5, and 2.5 μm were prepared by jet milling method and were tested. As a result, the more the diameter became smaller, the more moisture contents of flours decreased. Among these flours, flours with diameters of 5 and 2.5 μm showed high damaged starch contents and water absorbencies. In general, there was an increase in water absorption as damaged starch content increased in rice flour [40].

3.6 Color

Color characteristics of flour samples were observed. *Akitakomachi* (99.67), *Koshihikari* (99.75), and *Haenuki* (99.65) flours had high L^* values, but *Hinohikari* flour (97.36) was the lowest among these flours (Table 1). The L^* value of medium wheat flour (98.23) was in the middle of these flours as well as that of *Hitomebore* flour (98.83). The b^* value (8.49) was the highest in medium wheat flour among these flours, followed by *Hinohikari* flour (7.83). The values were the lowest and were almost the same in *Akitakomachi* (5.35), *Koshihikari* (5.24), *Haenuki* (5.23), and *Hitomebore* (5.88) flours. The ΔE^*ab values were calculated, and color difference was evaluated to medium wheat flour as follows: *Hinohikari* (slight), *Hitomebore* (noticeable), and *Akitakomachi*, *Koshihikari*, and *Haenuki* (appreciable), respectively. Next, whiteness indexes were calculated. As a result, the whiteness of *Akitakomachi*, *Koshihikari*, *Haenuki*, and *Hitomebore* flours was strong in comparison to those of medium wheat and *Hinohikari* flours (Table 1).

3.7 Properties of Noodles

Rice noodles were prepared using rice flours and these properties were compared to that of noodle using medium wheat flour (Fig. 2). Moisture content after cutting-out was the highest in noodle made from *Akitakomachi* flour (48.3%), and those made from *Koshihikari* (47.2%), *Hinohikari* (46.0%), *Haenuki* (45.0%), and *Hitomebore* (43.6%) flours. The content was the lowest (34.8%) in noodle made from medium wheat flour (Table 2).

On the other hand, the content after cooking was the highest in noodle made from *Koshihikari* flour (73.1%) and was the lowest in that made from *Hitomebore* flour (67.6%). There was not much of a difference in contents on noodles made from other flours and medium wheat flour. Weight change rate calculated from these results was the highest in noodle made from medium wheat flour (197.3%), followed by that made from *Koshihikari* flour (169.1%). Noodles made from *Akitakomachi* and *Hitomebore* flours showed the lowest rate. That is, water absorption by cooking on noodle made from medium wheat flour was high, but those of noodles made from rice flours were generally low, although there was a difference between the rice varieties. Breaking strength of noodles was measured. As a result, highest breaking strength of 735.7 gf was observed for noodle made from medium wheat flour whereas noodles made from *Koshihikari* and *Haenuki* flours showed the lowest values with 313.8 and 333.7 gf, respectively (Table 2). On the contrary, noodles made from *Hitomebore* and *Hinohikari* flours exhibited intermediate breaking strength. Adhesiveness of noodle made from *Hinohikari* flour was the lowest (3,920 J/m^3), followed by that of noodle made from medium wheat flour (6,860 J/m^3). On the other hand, noodle made from *Hitomebore* flour showed remarkably high adhesiveness (397,880 J/m^3), suggesting noodle with strong stickiness. Cohesiveness of noodles made from other flours ranged from 0.45 to 0.63, and these values were higher as compared to those of noodles made from *Haenuki* (0.18) and *Hinohikari* (0.19). Generally, it is said that noodle with cohesiveness around 0.4 shows good cohesive. Gumminess value is determined by multiplying cohesiveness value with breaking strength. Noodle made from *Hitomebore* flour showed higher gumminess of 371.7 gf, followed by that made from medium wheat flour (333.1 gf) whereas that made from *Haenuki* flour showed the lowest value (60.1 gf) (Table 2).

Fig. 2. Noodles made from each flour sample

(A) Akitakomachi flour, (B) Koshihikari flour, (C) Haenuki flour, (D) Hitomebore flour, (E) Hinohikari flour, (F) Medium wheat flour

Table 2. Characteristics of rice noodles made from flours of major non-glutinous rice cultivars of Japan

	Medium wheat flour	***Akitakomachi* flour**	***Koshihikari* flour**	***Haenuki* flour**	***Hitomebore* flour**	***Hinohikari* flour**
Moisture content after cutting-out (%)	34.8 ^{d}	48.4 ^{a}	47.2 ^{b}	45.0 ^{c}	43.6 ^{c}	46.0 ^{b}
Moisture content after cooking (%)	69.4 ^{b}	70.6 ^{b}	73.1 ^{a}	70.8 ^{b}	67.6 ^{c}	69.9 ^{b}
Weight change rate (%)	197.3 ^{a}	148.0 ^{d}	169.1 ^{b}	158.8 ^{c}	144.3 ^{d}	155.0 ^{c}
Breaking strength (gf)	735.7 ^{a}	495.4 ^{c}	313.8 ^{d}	333.7 ^{d}	590.0 ^{b}	624.0 ^{b}
Adhesiveness (J/m^3)	6,860 ^{e}	148,960 ^{b}	74,480 ^{c}	20,580 ^{d}	397,880 ^{a}	3,920 ^{e}
Cohesiveness	0.45 ^{c}	0.58 ^{a}	0.53 ^{b}	0.18 ^{d}	0.63 ^{a}	0.19 ^{d}
Gumminess (gf)	333.1 ^{b}	287.3 ^{c}	166.3 ^{d}	60.1 ^{f}	371.7 ^{a}	118.6 ^{e}

Table 3. Sensory evaluation of rice noodles made from flours of major non-glutinous rice cultivars of Japan

	Medium wheat flour	*Akitakomachi* flour	*Koshihikari* flour	*Haenuki* flour	*Hitomebore* flour	*Hinohikari* flour
Appearance	5	5	5	1	5	5
Color (whiteness)	1	5	4	2	4	2
Hardness	5	5	5	5	5	5
Viscoelasticity	5	5	1	4	5	5
Adhesiveness	1	5	4	5	5	5
Chewiness	5	4	4	4	4	3
Smoothness	5	1	1	1	1	1

Table 4. Characteristics of rice noodles made from non-glutinous rice cultivar *Akitakomachi* flour by addition of commercially available grain vinegar

	Medium wheat flour*	0% grain vinegar	0.1% grain vinegar	0.2% grain vinegar	0.3% grain vinegar	0.4% grain vinegar	0.5% grain vinegar
Moisture content after cutting-out (%)	34.8 [b]	47.9 [a]	48.6 [a]	48.2 [a]	47.6 [a]	47.5 [a]	47.4 [a]
Moisture content after cooking (%)	69.4 [a]	70.2 [a]	69.9 [a]	70.4 [a]	69.0 [b]	69.4 [a]	70.3 [a]
Weight change rate (%)	197.3 [a]	157.0 [b]	156.5 [b]	150.0 [d]	146.1 [e]	153.6 [c]	153.3 [c]
Breaking strength (gf)	735.7 [a]	244.9 [d]	392.9 [c]	396.9 [c]	392.9 [c]	400.0 [c]	441.8 [b]
Adhesiveness (J/m^3)	6,860 [f]	103,880 [a]	69,580 [b]	41,160 [d]	59,780 [c]	35,280 [e]	33,320 [e]
Cohesiveness	0.45 [c]	0.58 [a]	0.54 [b]	0.61 [a]	0.56 [b]	0.57 [a]	0.52 [b]
Gumminess (gf)	333.1 [a]	142.0 [d]	212.2 [c]	242.1 [b]	220.0 [c]	228.0 [c]	229.7 [c]
Sensory evaluation							
Appearance	5	5	5	5	5	5	5
Color (whiteness)	1	5	5	5	5	5	5
Hardness	5	2	4	4	3	4	5
Viscoelasticity	5	2	5	5	4	4	4
Adhesiveness	1	3	2	2	2	1	1
Chewiness	5	4	5	5	5	5	5
Smoothness	5	4	4	5	5	4	4

**Noodles were made using brackish water.*

3.8 Sensory Evaluation

Sensory analysis of rice noodles was performed and was compared to that of noodle using medium wheat flour. As a result, except for noodle made from *Haenuki* flour, all noodles had appearances with highest scores (Table 3). Color on noodle made from *Akitakomachi* flour was best among these noodles, followed by noodles made from *Koshihikari* and *Hitomebore* flours. Noodles from *Haenuki* and *Hinohikari* flours showed low scores because of low L^* value and high b^* value on *Hinohikari* flour. On the other hand, noodle made from medium wheat flour was tinged with yellow, suggesting coloring of flavonoids by brackish water. All noodles had good hardness and viscoelasticity except for that made from *Koshihikari* flour. Noodles made from rice flours showed high adhesiveness unlike in the case of that made from medium wheat flour. Chewiness was best in noodle made from medium wheat flour, followed by in noodles made from *Akitakomachi*, *Koshihikari*, *Haenuki*, and *Hitomebore* flours (Table 3). Smoothness in rice noodles was far inferior to that in noodle made from medium wheat flour. It could produce high quality of noodle using *Akitakomachi* flour among these rice flours.

3.9 Improvement of Rice Noodle Quality

Brackish water is used for improvement of the qualities in noodle production as follows: 1) to improve extensibility and elasticity of noodle, 2) to impart flavor and stickiness, 3) to develop a color by flavonoids and so forth. However, it could not improve extensibility and elasticity of rice noodles by addition of brackish water in dough, although noodles had a color tinged with yellow (data not shown).

At present, some improvement of rice noodle quality progress by addition of acids such as acetic acid [41]. It is said that addition of acids in dough shows the effects to delay the boiling elongation of noodles, to prevent that individual noodles stick together, and to improve the chewiness or firmness and its elasticity of noodles. Therefore, commercially available grain vinegar solution (0.1-0.5%) was prepared and then these were added to *Akitakomachi* flour (mixing ratio is of 100 g of flour: 80 ml of each concentration of vinegar solution) instead of brackish water. Distilled water was used as control (0% grain vinegar solution). Noodle was prepared as mentioned above. After the extruded noodle strands obtained were stored at 5 ℃ for 24 h in airtight containers to promote the hydration, these were used for evaluating of noodle qualities. The results of rice noodle qualities prepared using grain vinegar are presented in Table 4. Moisture contents after cutting-out were measured. The contents of rice noodles were the same regardless of concentration of grain vinegar (47.4-48.6%), but these were remarkably higher than that of noodle made from medium wheat flour (34.8%). On the other hand, except for rice noodle using 0.3% grain vinegar, as for moisture contents after cooking, there were no significant differences among these noodles tested (69.4-70.4%). From these results, weight change rate was high on rice flour noodles using 0-0.2% grain vinegars, followed by these using 0.4 and 0.5% grain vinegar. Noodle using 0.3% grain vinegar showed the lowest rate (146.1%). Breaking strength of noodles was investigated. Lowest hardness (244.9 gf) was observed for noodle made from without grain vinegar whereas hardness on noodles with grain vinegar generally increased with increasing the concentration of grain vinegar. Adhesiveness of noodles was evaluated. It drastically decreased by addition of grain vinegar, and on the whole it decreased according to increase in the concentration of grain vinegar. It could greatly improve adhesiveness of noodles made using 0.4 or 0.5% grain vinegar as compared to that of noodle made using brackish water (Table 2). Cohesiveness of noodles ranged from 0.52 to 0.61 regardless of concentration of grain vinegar and presence or absence of grain vinegar addition. Next, sensory analysis of noodles was performed. As a result, all noodles scored the highest for appearance and color. Noodle made without grain vinegar scored low for hardness, but it generally increased with increasing concentration of grain vinegar. Viscoelasticity of noodles was significantly improved with addition of grain vinegar. Adhesiveness of noodles decreased according to increase of the concentration of grain vinegar. In particular, noodle made with 0.5% grain vinegar scored the lowest as well as that made from medium wheat flour. These results indicated by the results of texture analysis on noodles made with or without grain vinegar. Moreover, chewiness and smoothness of noodles remarkably improved compared to those of noodle made using brackish water.

Heo et al. [8] prepared flour using polished rice (Shindonjin variety, Republic of Korea) under dry- and wet-milling condition and then produced noodles. Cooking loss in dry-milled noodles was higher than that in wet-milled noodles. Increased loss was attributed to high water solubility derived from high damaged starch content on flour. That is, they indicated that rheological and cooking properties of rice noodles affected by milling methods and its conditions. Jeong et al. [15] investigated physicochemical properties of extruded rice noodles made from three rice varieties (Baegjinju, Hanareum 2, and Milyang 278) with different amylose contents. Flour with high amylose contents showed high stability to dual-mixing and high degrees of gelatinisation and retrogradation on starches of rice. It could produce noodles with harder texture using rice flours with high amylose content. Hormdok and Noomhorm [5] prepared two types of hydrothermal treated rice starches, and the property on gelatinisation, swelling, RVA paste viscosities, and gel hardness of starch was evaluated. The noodle made from rice flour and 50% substitution of rice starches showed the same properties as that of commercial noodles; the use of hydrothermal treatment of rice starch could improve the quality of rice noodles. Similarly, Cham and Suwannaporn [42] reported that hydrothermal treatment of rice flour could improve rice noodle quality and produce various qualities of rice noodles. Transglutaminase

(TGase) catalyses reaction between ε-amino group on protein bound lysine residues and c-carboxyamide group on it bound glutamine residues, resulting covalent crosslinking of protein. These contribute to the texture of food products. It is possible to improve quality of rice noodles, although products as noodles made from gluten-free dough have low protein contents and lysine residues. Kim et al. [9] tried to prepare rice noodle by addition of rice protein isolate with TGase. These treatments increased the viscosity of noodle and decreased of cooking loss and water turbidity of it. On the other hand, Sandhu et al. [6] studied noodle quality on rice and potato starches. As a result, it could produce noodle with harder texture using rice starch due to lower cooking loss. Moreover, it could also produce good quality of noodles with lower cooking time, higher weight of cooked noodle, transparency, and slipperiness by addition of potato starch to rice starch in the ratio of 1:1. As just described, many researchers try to improve the rice noodle qualities using several techniques. It is required to make cohesive structure and to uniform matrix by protein and starch granules of rice dough due to absence of gluten.

4. CONCLUSION

In the present study, we prepared noodles made from rice flours from five species of major non-glutinous rice cultivars with intermediate amylose contents in Japan. Also, we tried to improve making properties and production method to obtain high quality of noodle. The results indicated that addition of commercially available grain vinegar significantly improved the texture on noodle, and particularly it could produce acceptable high quality of rice noodle made from *Akitakomachi* flour with 0.5% grain vinegar.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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