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Quality Characteristics of Extruded Brown Rice Noodles with Different Amylose Contents

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The quality characteristics of extruded noodles prepared from five kinds of brown rice with different amylose contents (15.96%–21.88%) were investigated. Cooking quality, texture, in-vitro digestibility and sensory attributes were determined to evaluate the properties of the brown rice noodles. The results showed that the brown rice noodles with higher amylose content exhibited higher water absorption rate, lower cooking loss, no broken noodles after cooking, and higher texture properties. Moreover, the brown rice noodles with higher amylose contents had lower in-vitro digestibility, higher contents of resistant starch and slowly digestive starch, and higher sensory scores. However, the brown rice noodle with the highest amylose content showed the lowest sensory scores, suggesting that there might be optimal amylose content for preparing brown rice noodles with good qualities, which might be 19.07%–20.45% in this study. The results might provide the basis for production of brown rice noodle products with good qualities for nutritional food markets.

Keywords: brown rice noodles, amylose content, cooking quality, in-vitro digestibility, sensory properties

Introduction

Brown rice contains plentiful health-promoting ingredients compared to white or milled rice, such as vitamins, dietary fiber, phytic acid, oryzanol, etc. As a kind of typical whole grains, brown rice could have potential effect on prevention of the risk of chronic diseases, such as obesity, type II diabetes, cancer and cardiovascular disease (Okarter and Liu, 2010). Furthermore, brown rice can be a staple material for gluten-free foods, which meets the needs of coeliac patients and consumers' perceptions of gluten-free products as healthier alternatives (Cai *et al.*, 2016; Chung *et al.*, 2014). However, brown rice is not widely utilized because of its firm texture and poor cooking properties.

Noodles are consumed worldwide, therefore it may be a

feasible way for the application of brown rice in the noodle products to enlarge its consumption. There were some reports that brown rice flours with heat-moisture or extrusion treatment were incorporated into wheat flour for preparing noodles (Chung *et al.*, 2012; Wu *et al.*, 2017;). Rice noodles also can be produced by other two different ways, which are extrusion or sheeting of rice batter on a rotating heated drum. During the processes, starch in rice flour is gelatinized via heating when the binding powder is imparted to the rice noodle stands, which affect the structure of the rice noodles as well as quality aspects, such as digestibility, cooking and texture properties (Frei, *et al.*, 2003; Fu, 2008; Chung *et al.*, 2011). Baek and Lee (2014) successfully produced extruded noodles preparing from white and brown rice, and found that

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antioxidant activities of the noodles were enhanced, which might encourage food industry to develop a variety of brown rice noodle products with health benefits. But the ratio of white and brown rice was not referred, and the cooking loss of the brown rice noodles was up to 39.01% and 54.94% for 6 and 9 min cooking, respectively.

There are many studies for the quality improvement of white or milled rice noodles through milling method (Tong *et al.*, 2015), and the addition of polysaccharides and transglutaminase (Kim *et al.*, 2014; Wandee *et al.*, 2015; Baek *et al.*, 2014; Klinmalai *et al.*, 2017). Some researchers also promote the qualities of white rice noodles via changes of amylose content using different varieties of rice (Han *et al.*, 2011; Srikaeo and Sangkhiaw, 2014; Jeong *et al.*, 2016). However, limited preceding studies are reported that have focused on the properties of extruded brown rice noodles, especially for the influence of amylose content on the quality of brown rice noodles. Because rice bran is included in brown rice, there may be quality differences between brown rice noodles and white rice noodles. Thus it is necessary for investigating the quality attributes of brown rice noodles because of nutritive values for brown rice and popular consumption of rice noodles worldwide.

In the present study, extruded brown rice noodles were prepared from five varieties of brown rice with different amylose contents. The objective of this study was to investigate the effect of amylose content in different varieties of brown rice on the properties of extruded noodles. Furthermore, the physicochemical properties of these brown rice noodles were characterized, such as cooking quality, texture properties, in-vitro digestibility, and sensory properties.

Materials and Methods

Materials Five kinds of brown rice for preparing rice noodles were Heilongjiang Yuanli (HJY), Heilongjiang Changli (HJC), Jiangxi 2014Wan (JXW), Jiangxi 2014Zao (JXZ) and Hunan Zao (HNZ), which were produced from province of Heilongjiang, Jiangxi, and Hunan in China, respectively. Amylose (10130, 1 g) and amylopectin (10118, 5 g) from potato were obtained from Sigma Aldrich Fluka Inc. (Buchs, Switzerland). Pepsin from porcine gastric mucosa (P7125, ≥ 400 units/mg protein), α -amylase from porcine pancreas (A3176, 16 units/mg solid), pancreatin from porcine pancreas (P7545, 8 $\times$ USP) and sodium deoxycholate (D6750, $\geq 97\%$) were also purchased from Sigma-Aldrich Inc. (St. Louis, MO, USA). All other chemicals and reagents used in this study were of analytical grade and obtained from Rui Ze kang Chemical Co. (Beijing, China).

Chemical composition determination of brown rice The contents of starch, protein and fat in brown rice were determined by AOAC method of 996.11, 968.06 and 2003.06 (AOAC, 2006), respectively. Amylose content of the brown rice was determined by a colorimetric method of the blue amylose-iodine complex according to Mcgrance *et al.*, (1998). Each sample (100 mg) was

dissolved by heating in DMSO for 15 min in a water bath at 85°C, and was then diluted to 25 mL in a volumetric flask with deionized water. The resulting solution (1 mL) was diluted with deionized water (50 mL), and a solution (5 mL) of iodine (0.0025 mol/L) and potassium iodide (0.0065 mol/L) was added and mixed. After incubation at room temperature for 10 min, the absorbance at 600 nm was determined with a UV-visible spectrometer (Shimadzu Inc., Kyoto, Japan). The amylose content was calculated based on the standard curve, which was plotted for mixtures of amylose and amylopectin from potato containing 0%, 10%, 25%, 50%, 75%, and 100% amylose.

Preparation of brown rice noodles Brown rice was milled, screened through a 80 mesh sieve, and distilled water was added into the brown rice flours to achieve total water content of 37%. The brown rice noodles were then prepared using a CHQ800 rice noodle machine (Chenhuiqiu Rice Noodle Machinery Equipment Manufacturing Co., Ltd., Dongwan, China), which equipped with a single screw extruder for preparing rice noodles at the temperature of more than 95°C and an electric fan for the cooling process. The obtained brown rice noodles were steamed for 2 h at 100°C, dried at 30°C for 4 h, cut into length of 20 cm, and then stored at 4°C for further analysis.

Cooking quality of noodles Cooking properties of brown rice noodles, including cooking time, cooking loss and water absorption capacity, were measured according to AACC Method 66–50 (AACC, 2010). The disappearance time of the white core of noodles after being squeezed between two glasses was defined as optimal cooking time. Noodle sample (25 g) was cooked in boiling distilled water (400 mL) until optimal cooking time, rinsed in cold water and then drained for 30 s before being weighted. Water absorption capacity was calculated as the difference between noodle weight before and after cooking. Cooking loss was reported as ratio of the weight of the residue in cooking water and original noodle sample before cooking, and the residue in noodle cooking water was obtained from the evaporation in an air oven at 105°C. The determinations were carried out for three times on each noodle sample.

The cooked breaking rate of rice noodle samples was determined according to the method GB/T23587 of Vermicelli in People's Republic of China (GAQSIQ and SAC, 2009). The intact brown rice noodle samples (20 bars) were placed into 900 mL of boiling distilled water until the optimal cooking time. The noodle samples were collected, and the cooked breaking rate for each sample was expressed as follows: Cooked breaking rate (%) = [bar numbers of cooked breaking noodles/bar numbers of the starting material] $\times 100\%$.

The replicates for each measurement were determined in triplicate.

Texture properties of noodles The texture profile analyses of brown rice noodle samples were measured using a TA-XT2i texture analyzer (Stable Micro System Ltd., Godalming, UK). The noodles were cooked to the optimal cooking time, rinsed

immediately with cold water for 30 s, and then placed in ice water. Five bars of intact rice noodles were placed side by side on test board and evaluated within 5 min after cooling. The measurement conditions were: 75% compression ratio, 5.0 g triggering force, HDP/PFS probe at the test speed of 1.0 mm/s, time interval 3 s. The data of hardness, cohesiveness, springiness, chewiness and resilience for noodle samples were obtained from the force-time curves of the TPA. Each experiment was repeated for at least five times and the values were averaged.

A/LKB-F probe was used to determine the shearing force of brown rice noodle samples prepared as previously, and the test speed was 1.0 mm/s. The speed before and after test was 1.0 mm/s and 10.0 mm/s, respectively. The compression ratio and triggering force were 90% and 20 g, respectively. Three specimens for each treatment were performed, the replicates for each measurement were carried out for four times, and the values for twelve times of measurements were averaged.

The stickiness was measured by HDP/PFS probe on the samples prepared as previously, and the measurement conditions were: 10 mm compression distance, 20 g triggering force, 0.5 mm/s test speed, time interval 2 s. Each experiment was repeated for at least five times and the values were averaged.

In vitro starch digestibility The starch digestibility of the brown rice noodle samples was determined according to methods of Gan *et al.* (2009) and Wolter *et al.* (2013). Each cooked noodle sample was homogenized, sodium phosphate buffer solution (80 mL, 50 mM, pH 6.9) was used to dilute 5.00 g of the noodle sample, and pH of the mixture was adjusted to 2.0. Pepsin solution (5 mL, 0.35 mg/mL) was added to the mixture, and then incubated for 30 min in a water bath at 37°C. NaOH (1 M) was added to adjust pH of the mixture to 6.8, a pancreatin/bile salt mixture (5 mL; 100 mmol/L sodium deoxycholate, 5 mg/mL pancreatin, and 100 mmol/L sodium bicarbonate solution) and α -amylase solution (2.5 mL, 1.25 mg/mL) were added and then incubated for a further 4 h at 37°C. Aliquots (5 mL) of reaction mixture were added into test tubes at 0, 5, 10, 20, 30, 45, 60, 90, 120, 180 and 240 min, respectively, and immediately placed in a boiling water bath for 5 min to inactivate α -amylase. 3,5-dinitrosalicylic acid reagent (DNS) (2 M sodium hydroxide, 0.04 M 3,5-dinitrosalicylic acid, 1.1 M potassium sodium tartrate in distilled water) was used to reacted with the aliquots in tubes, and the amounts of reducing sugars were measured at 540 nm. Maltose was used as the standard for the calculation of reducing sugars. Starch digestion rate (g/100 g) in noodle samples was expressed by total starch hydrolyzed at different times (0, 5, 10, 20, 30, 45, 60, 90, 120, 180 and 240 min), and data were shown as plot of hydrolysis degree vs. digestion time. The in vitro digestibility of each sample was measured for at least three replications.

The amount of starch fractions based on in vitro digestibility was calculated using the method of Englyst *et al.* (1992). The starch fraction which was hydrolyzed within 20 min incubation

was defined as rapidly digestible starch (RDS), the fraction that was not hydrolyzed after 180 min incubation was reckoned as resistant starch (RS). The difference between RDS and RS was calculated as slowly digestible starch (SDS).

Sensory analysis Sensory evaluation of brown rice noodle samples varying in amylose content was carried out according to Gao *et al.* (2015), and the brown rice noodle standards DBS 45/020 and DBS45/021 of Guangxi in China with modifications (HFPC of Guangxi, 2015). The evaluation criteria of brown rice noodle samples are shown in Table 1. The dried and fresh brown rice noodle samples were evaluated by eight food scientists and technologists from Academy State Administration of Grain in China. The fresh brown rice noodles were obtained after cooking to optimal times as described previously in this study.

Statistical analysis The average and standard deviation (SD) of at least three determinations for each sample were reported in this study. The data were compared by Duncan's test at the level of $p < 0.05$ using one-way analyses of variance (ANOVA) with SPSS 17.0 (SPSS Inc. Chicago, IL, USA).

Results and Discussion

Chemical composition and amylose content of brown rice for preparing noodles The chemical composition and amylose content of brown rice used for preparing noodles are shown in Table 2. The five varieties of brown rice were HJY, HJC, JXW, HNZ and JXZ, respectively, and the corresponding amylose content increased from approximately 15.96% to 21.88%. The percentage of amylose versus amylopectin in these brown rice varieties was about 19.01%, 20.22%, 23.56%, 25.70% and 28.01%, respectively, and increased with the increase of amylose content. The contents of starch, protein and fat in the five varieties of brown rice were 77.97%–81.44%, 8.74%–11.22% and 2.38%–3.00%, respectively. The differences of chemical composition may contribute to the quality of food that prepared from these brown rice varieties, especially for amylose content in rice. The amylose content might affect the rheological, resistant starch content of rice flours, thus change the texture, in-vitro digestibility and glycaemic index of rice noodles, which were reported by Srikaeo and Sangkhiaw (2014), and Jeong *et al.* (2016).

Cooking properties of brown rice noodles with different amylose contents The optimal cooking time, water absorption, cooking loss and cooked breaking rate of brown rice noodles with different amylose contents are presented in Table 3. The optimal cooking time of the brown rice noodles was 9.86, 10.79, 11.61, 11.99 and 13.24 min, respectively, increased with the increase of amylose content in brown rice noodle samples. The water absorption of the brown rice noodles was 48.47%–174.90%, and the brown rice noodles of JXW, HNZ, JXZ with higher amylose content had the higher water absorption of 174.90%, 172.41% and 113.80%, respectively. The cooking loss of the brown rice noodles was 19.67%–51.98%, and the brown rice noodles of JXW, HNZ,

Table 1. Scoring criteria of sensory analysis for brown rice noodles varying in amylose contents

Sample types	Scoring items	Scores of each item	Scoring criteria
Dried brown rice noodles	Colour	10	Grayish yellow, good luster, no parti-colour, 8.5-10; Uniform colour, general luster, less parti-colour, 6~8.4; Uneven colour, pore luster, more parti-color, 1~6;
	Appearance	10	Smooth surface, uniform structure, no obvious crack, 8.5~10; General surface, structure and crack, 6~8.4; Coarse surface, fragmentary structure, obvious crack, 1~6;
Fresh brown rice noodles	Colour	10	Grayish yellow, good luster, no parti-colour, 8.5-10; General colour and luster, less parti-colour, 6~8.4; Uneven colour, pore luster, more parti-color, 1~6;
	Appearance	20	Fine, smooth and uniform surface structure, 17-20; General surface structure, 12~17; Coarse and uneven surface structure with expansion, severe deformation, 1~12;
	Odour	10	Inherent smell and strong smell of brown rice noodles, no other odor, 8.5~10; General smell, 6~8.4; Impure or weak smell, or other peculiar smell, 1~6;
	Hardness	15	Moderate biting force for chewing, moderate hardness, 13~15; General hardness, 9~13; More hardness or more soft, 1~9;
	Viscosity	10	Refreshing, non sticky for chewing, 8.5~10; General viscosity, 6~8.4; Not refreshing, sticky, 1~6;
	Elasticity	25	Al dente, springiness, 21~25; General springness, 15~21; Bad bite force, no springiness, 1~15;
	Smooth	10	Soft smooth 8.5~10; General smooth, 6~8.4; not smooth, rough 1~6;

Table 2. Chemical composition of five varieties of brown rice

Brown rice varieties	Starch (%)	Amylose (%)	Percentage of amylose/ amylopectin (%)	Protein (%)	Fat (%)
HJY	78.50±1.88b	15.96±1.56c	19.01±2.20c	9.36±0.20c	2.78±0.10b
HJC	81.44±0.29a	16.82±0.15c	20.22±0.22c	8.74±0.07d	2.81±0.08ab
JXW	77.97±0.11b	19.07±0.02b	23.56±0.04b	11.22±0.22a	3.00±0.22a
HNZ	78.71±0.80b	20.45±0.25ab	25.70±0.40ab	11.04±0.17a	2.38±0.03c
JXZ	80.34±0.57ab	21.88±0.38a	28.01±0.62a	10.57±0.08b	2.63±0.03b

Data are reported as dry basis (db).

Data are shown as mean ± standard deviation (n = 3).

Different letters in the same column following each figure indicate significant differences ($p < 0.05$).

Table 3. Cooking properties of extruded noodles prepared from brown rice with different amylose contents

Noodle Samples	Optimal cooking time (min)	Water absorption (%)	Cooking loss (%)	Cooked breaking rate (%)
HJY	9.86±0.25d	97.61±5.80c	39.17±1.68b	13.33±2.45b
HJC	10.79±0.36c	48.47±9.81d	51.98±3.37a	20.00±2.50a
JXW	11.61±0.50b	174.90±4.09a	19.67±0.64c	0.00±0.00c
HNZ	11.99±0.11b	172.41±4.52a	22.56±0.15c	0.00±0.00c
JXZ	13.24±0.12a	113.80±10.96b	36.24±4.88b	0.00±0.00c

Data are shown as mean ± standard deviation (n = 3).

Different letters in the same column following each figure indicate significant differences ($p < 0.05$).

JXZ with higher amylose content had the lower cooking loss, which were 19.67%, 22.56% and 36.24%, respectively. The cooked breaking rate of brown rice noodles of HJY and HJC was 13.33% and 20.00%, respectively, significantly higher than those of JXW, HNZ, JXZ with higher amylose content, and the cooked breaking rate of JXW, HNZ and JXZ was 0%. Generally, the brown rice noodle samples with higher amylose content had higher water absorption and lower cooking loss, and there were no broken noodles by cooking for optimum times with boiled water. Similar results of cooking loss were obtained by Jeong *et al.* (2016), who indicated that the cooking loss of the extruded rice noodles cooked for 2 and 4 min significantly decreased with the increase of amylose content.

As the important quality attributes of noodles, the parameters of water absorption, cooking loss and cooked breaking rate were used to determine the solid loss of materials to the cooking water, which represented the ability of noodles to maintain structural integrity during cooking process (Yalcin and Basman, 2008; Kim *et al.*, 2014; Tong *et al.*, 2015). In the present study, the brown rice noodles of JXW and HNZ had the highest water absorption, lowest cooking loss and lowest cooked breaking rate among all the noodle samples, which might be in connection with the higher amylose content of the brown rice material (Table 2). Some researchers demonstrated that amylose content significantly affect cooking, texture and sensory properties of rice noodles, and the recommended amylose content of polished rice for preparing rice noodles was approximately 21%–25% (Wang *et al.*, 2013; Gao *et al.*, 2015; Ding *et al.*, 2004). However, from the perspective of cooking properties, the optimal amylose content for making brown rice noodles might be 19.07%–20.45% in this study. The brown rice was used for producing rice noodles, and rice bran was included in the raw materials, therefore, the optimal amylose content for preparing brown rice noodles might be different from white or polished rice for preparing rice noodles. Therefore, the effect of amylose content in brown rice on the quality of brown rice noodles was investigated in this study.

Texture properties of brown rice noodles with different amylose contents Texture properties of brown rice noodles with different amylose contents were measured after cooking for optimal cooking time (Table 4). The hardness, cohesiveness, chewiness, resilience and shearing force of brown rice noodles generally increased with the increase of amylose content. Conversely, brown rice noodles of JXW, HNZ and JXZ with higher amylose content had lower adhesiveness, springiness and stickiness. The results could be consistent with Baik *et al.* (2003), who reported that the hardness and cohesiveness of noodles were positively correlated with the amylose content of white salted noodles. Kim *et al.* (1996) also indicated that bean starch noodles with higher amylose content had higher hardness values than potato starch noodles with lower amylose content. This might be because the brown rice flour with higher amylose contents had higher degrees of starch gelatinization

Table 4. Texture properties of extruded noodles prepared from brown rice with different amylose contents

Noodle Samples	Hardness/g	Adhesiveness/g	Springiness	Cohesiveness	Chewiness	Resilience	Shearing force/g	Stickiness/g
HJY	8168.12 ± 552.85c	-570 ± 38.48a	0.89 ± 0.02a	0.64 ± 0.01c	4663.78 ± 257.39b	0.31 ± 0.01d	231.32 ± 26.20b	1572.99 ± 285.24b
HJC	6492.98 ± 937.64d	-542 ± 100.42a	0.87 ± 0.03ab	0.64 ± 0.02c	3698.05 ± 557.98c	0.28 ± 0.02e	184.65 ± 21.47c	2463.36 ± 216.21a
JXW	9768.12 ± 623.65b	-103.53 ± 7.11c	0.84 ± 0.03bc	0.72 ± 0.01ab	5882.09 ± 543.73a	0.40 ± 0.01b	360.35 ± 28.26a	221.31 ± 7.07d
HNZ	10280.69 ± 303.06ab	-85.65 ± 5.14c	0.84 ± 0.02bc	0.74 ± 0.02a	6378.01 ± 382.83a	0.45 ± 0.00a	349.29 ± 40.63a	157.57 ± 10.74d
JXZ	11311.69 ± 1173.06a	-241.13 ± 19.94b	0.83 ± 0.02c	0.69 ± 0.04b	6476.96 ± 1027.14a	0.37 ± 0.03c	329.03 ± 43.44a	516.87 ± 50.59c

Data are shown as mean ± standard deviation (n = 5).

Different letters in the same column following each figure indicate significant differences ($p < 0.05$).

Fig. 1. In vitro starch hydrolysis rate of noodles prepared from brown rice with different amylose contents. Values are means for three replications of simulant chewing and digestion experiments.

Table 5. The RDS, SDS, and RS levels of extruded noodles prepared from brown rice with different amylose contents

Noodle Samples	RDS (%)	SDS (%)	RS (%)
HJY	54.81±5.12a	24.47±2.60c	20.72±2.52c
HJC	55.01±0.96a	14.83±1.77d	30.16±0.81b
JXW	33.35±0.27c	42.93±0.21a	23.72±0.06c
HNZ	26.20±2.28c	33.19±2.44b	40.61±4.72a
JXZ	44.59±3.37b	24.44±4.77c	30.97±1.40b

Data are shown as mean ± standard deviation (n = 3). Different letters in the same column following each figure indicate significant differences (*p* < 0.05).

and retrogradation, which caused greater stability to extrusion during the process for preparing brown rice noodles (Jeong *et al.*, 2016). However, springiness of brown rice noodles in this study were contrary to the results of previous study (Jeong *et al.*, 2016), which demonstrated that greater elastic properties were clearly observed in the high amylose rice samples. This might be attributed to the water content in flours, which was 37% in the brown rice flour for preparing noodles, but the water content of the flours in previous study was 89.3% for the determination of viscoelastic property (Jeong *et al.*, 2016). Additionally, rice bran existed in brown rice noodles might also affect their texture properties (Antoine *et al.*, 2003; Vitaglione *et al.*, 2008).

In vitro starch digestibility of brown rice noodles with different amylose contents Different appearance of hydrolysis curves for the brown rice noodle samples with different amylose contents are given in the plot of in vitro starch hydrolysis rate versus digestion time (Figure 1), and the levels of RDS, SDS, and RS are presented in Table 5. The hydrolysis degree of all the brown rice noodle samples increased with digestion time. The brown rice noodle sample of HJY with the lowest amylose content had the highest hydrolysis degree among all the brown rice noodle samples. The brown rice noodle sample of HJC, JXW, HNZ and JXZ with higher

amylose content had lower hydrolysis degree than that of HJY did, and the brown rice noodle sample of HNZ had the lowest hydrolysis degree among all the samples. Correspondingly, the brown rice noodle sample of HJY with the lowest amylose content nearly exhibited the highest RDS content and the lowest RS content, which were approximately 54.81% and 20.72%, respectively; meanwhile, the brown rice noodle sample of HNZ with higher amylose content showed the lowest RDS content and the highest RS content, which were about 26.20% and 40.61%, respectively. Similar results were obtained by several studies (Srikaeo and Sangkhiaw, 2014; Choi *et al.*, 2010; Hu *et al.*, 2004), which also found that glycaemic index (GI) decreased and resistant starch content increased as amylose content increased in rice-based food systems. Amylose content is reckoned one of the most important factors that affect the GI values and RS content, and foods that are rich in amylose content are related to lower glucose levels and slower emptying of human gastrointestinal tract than those with lower amylose content (Srikaeo and Sangkhiaw, 2014; Behall *et al.*, 1989; Morita *et al.*, 2007).

Generally, the brown rice noodle sample of HNZ and JXZ with higher amylose content showed the lower RDS content (26.20% and 44.59%, respectively) and the higher RS content (40.61% and 30.97%, respectively). But the brown rice noodle sample of JXZ with highest amylose content had the higher RDS content and the lower RS content than that of HNZ did (Table 5). This might be attributed to the differences of starch structure, starch morphology, degree of branching in terms of steric hindrance, and consequently mass transfer resistance among different varieties of brown rice used for preparing rice noodles (Behall *et al.*, 1988; Fuentes-Zaragoza *et al.*, 2010; Singh *et al.*, 2010). Some studies reported that the granular structure of the starch could be changed by amylopectin with enriched long chains, which resulted in the resistance of starch to in vitro or in vivo digestion (Kubo *et al.*, 2010; Butardo *et al.*, 2011), and the amount of amylopectin long chains were positively correlated with RS contents (Tsuiki *et al.*, 2016). In addition, other constituents in brown rice could also play an important role on the digestive rate of starch and GI values, which contained proteins, flavor enhancers and dietary fiber, and so on (Marangoni and Poli, 2008; Srikaeo and Sopade, 2010).

Sensory evaluation of brown rice noodles varying in amylose contents Sensory evaluation is reckoned as an indispensable method that can reflect the comprehensive performance and consumers' subjective estimation of noodle quality to be evaluated (Li *et al.*, 2012; Zhou *et al.*, 2013). The sensory quality of brown rice noodles with different amylose content was characterized by means of panelist's scores on sensory parameters, such as colour, appearance, odour, firmness, viscosity, elasticity and smooth as presented in Table 6. Colour, appearance and total scores of dried brown rice noodles decreased with the increase of amylose content, but there was no significant difference among noodle samples of JXW, HNZ and JXZ with higher amylose content, as well as the

Table 6. Sensory scores of dried and fresh brown rice noodles varying in amylose contents

Sample types	Scoring items	Sensory scores of noodle samples				
		HJY	HJC	JXW	HNZ	JXZ
Dried brown rice noodles	Colour	7.7±0.4a	7.4±0.4a	6.6±0.5b	6.4±0.7b	6.5±0.7b
	Appearance	8.0±0.5a	7.9±0.5a	7.6±0.4ab	7.4±0.7ab	7.0±0.8b
	Total Scores	15.7±0.8a	15.3±0.6ab	14.2±0.7bc	13.8±1.0c	13.5±1.5c
Fresh brown rice noodles	Colour	7.7±0.6a	7.5±0.5a	7.6±0.7a	7.4±0.8a	7.2±1.0a
	Appearance	15.7±1.6a	15.1±1.7a	16.7±1.2a	16.7±0.8a	15.0±1.7a
	Odour	7.8±0.6a	7.8±0.6a	7.3±0.4a	7.4±0.4a	7.3±0.3a
	Firmness	10.2±1.4a	10.7±1.6a	11.7±2.4a	11.8±2.4a	10.6±2.2a
	Viscosity	7.1±0.9ab	7.1±0.8ab	8.0±0.8ab	8.2±0.6a	6.9±1.0b
	Elasticity	19.6±3.4a	19.3±3.9a	20.3±2.4a	20.5±2.5a	17.9±3.7a
	Smooth	7.0±0.6ab	7.0±0.6ab	7.6±0.5a	7.5±0.5ab	6.7±0.7b
	Total Scores	75.1±6.9a	74.5±7.5a	79.2±4.9a	79.5±4.9a	71.6±8.5a

Data are shown as mean ± standard deviation (n = 8).

Different letters in the same row following each figure indicate significant differences ($p < 0.05$).

noodle samples of HJY and HJC. The fresh noodles of HNZ had the highest sensory total scores, followed by JXW, HJY, HJC and JXZ, which were approximately 79.5, 79.2, 75.1, 74.5 and 71.6, respectively. The corresponding amylose contents of HNZ, JXW, HJY, HJC and JXZ were 20.45%, 19.07%, 15.96%, 16.82% and 21.88%, respectively (Table 2). It demonstrated that sensory results of fresh noodles did not completely depend on amylose content, and there might be an appropriate amylose content to obtain brown rice noodle sample with better sensory quality of as referred previously in this study. However, there were no significant differences among these fresh noodle samples for the sensory parameters and total scores. Consumers' subjective preference might be the reason that no significant differences appeared for sensory parameters and total scores among brown rice noodles varying in amylose content. The results of sensory evaluation were different between dried brown rice noodles and fresh noodles, especially for appearance. The appearance score for dried noodles of HJY was the highest, but the highest scores were obtained for fresh noodles of JXW and HNZ. This might be because of cooking loss, some dry matters left to water after cooking, therefore changes of appearance and colour occurred between dried brown rice noodles and fresh brown rice noodles. Generally, the noodle samples of HNZ and JXW with higher amylose content exhibited higher sensory scores, and the results were in accordance with cooking quality, texture properties and in vitro digestibility of brown rice noodles.

Conclusions

The extruded brown rice noodles were prepared from five varieties of brown rice with different amylose contents, and the cooking quality, texture properties, in-vitro digestibility and sensory attributes of the noodles were investigated. The results showed that the noodle quality generally depended on the amylose

content, and the brown rice noodles with higher amylose content had better cooking quality, proper texture properties, lower in-vitro hydrolysis rate of starch, higher content of SDS and RS, and higher sensory scores. Furthermore, the noodles of JXW and HNZ exhibited the best overall quality among these samples, suggesting that the optimal amylose content for making brown rice noodles might be 19.07%–20.45% in this study. The brown rice cultivars with different amylose contents play critical roles in the physicochemical properties of the final noodle samples. The results of the study may provide the basis for the development of brown rice based foods with good qualities and health benefits.

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