Effect of Physicochemical Properties of High-Amylose Thai Rice Flours on Vermicelli Quality

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ABSTRACT

Certain physicochemical properties, including chemical composition, pasting, thermal parameters, and the gel texture of flour prepared from six cultivars of Thai rice with similar high-amylose content were determined. These properties were correlated with the quality of vermicelli prepared from these flours for cooking and textural properties. Flour prepared from a Thai rice cultivar currently used for commercial production of vermicelli served as reference for these comparisons. Many similarities, but some significant differences, in the physicochemical properties were observed between the test rice flours and to the reference cultivar. Vermicelli prepared from all of the test rice flours were within an acceptable range for cooking quality but showed greater variation in textural quality. Among the physicochemical properties, gel hardness was well correlated with cooking and textural quality of vermicelli, and was useful for predicting overall vermicelli quality.

Rice vermicelli is a popular noodle type in Southeast Asian countries. This noodle is produced by extruding a partially gelatinized preparation of wet-milled rice flour dough into thin vermicelli-sized noodles. Freshly extruded vermicelli noodles are often then fully cooked and dried for packaging and marketing. Desirable qualities of vermicelli are similar to those of other styles of noodle and include low loss of solids in cooking and appealing texture.

A number of physicochemical factors, as well as methods of processing, determine the final quality of the noodle product. For wheat noodles and other forms of wheat pasta, quality is influenced by both gluten protein and starch properties. Gluten in wheat is primarily responsible for the formation of noodle structure and the strength of noodles cooked by boiling. Rice contains no gluten. Thus, the quality of rice noodles depends solely on the physicochemical properties of starch, which functions as the structural network of the noodle product. Amylose crystallites in starch create a three-dimensional network in rice noodles by strongly linking short starch chains by junction zones (Mestres et al 1988). Rice cultivars with high-amylose content, low gelatinization temperature, and hard gel consistency were best suited for making rice noodle (Li and Luh 1980). Sookdang (1998) reported that only high-amylose rice could give a good quality of instant flat noodle for cooking and textural qualities. Rice of intermediate-amylose content yielded a softer product with higher cooking loss, while flour from low-amylose rice had no potential to make usable rice noodles, even when blended into a composite with flour from high-amylose rice. Bhattacharya et al (1999) found that the amylose content of rice flour was closely correlated to the texture of the vermicelli as well as other physicochemical properties of the flour, including flour swelling volume, Rapid Visco Analyser (RVA) pasting properties, and gel texture. There is little information concerning the dependence of the quality of rice vermicelli made from high-amylose rice on specific physicochemical properties of the flour. In this study, physicochemical properties of rice flours from six different high-amylose Thai rice cultivars were determined, and differences in these properties were related to the quality of rice vermicelli produced from these flours.

MATERIALS AND METHODS

Materials

Six high-amylose Thai rice cultivars were used. Sao Hai (SH), Suphanburi90 (SPR90), Chainat1 (CNT), Prajeenburi1 (PJ), Plaingam Prajeenburi (PNG), and Suphanburi1 (SPR1) were obtained from the Rice Research Centers in Thailand. SH, which is currently used to produce commercial vermicelli, served as the reference cultivar. Dry rough rice from each cultivar was dehulled and milled using a commercial milling machine. Rice flour was prepared by the wet-milling method (Sookdang 1998). The flour samples were passed through a 100-mesh sieve, packed in airtight plastic bags, and stored at 4°C until used. In addition, 10 other locally available brands of rice vermicelli were used as references to evaluate consumer acceptance of vermicelli produced from the test cultivars.

Proximate Analyses

Protein (N × 5.95) was determined by the microKjeldahl method. Fat and ash content were analyzed by Approved Methods 30-25 and 08-01 (AACC 2000). Moisture content was determined by preweighing, then drying samples at 105°C to constant weight. Amylose content was analyzed by the method of Juliano (1971). Gel consistency was determined using the method of Cagampang et al (1973).

Thermal Properties

Gelatinization temperature and total enthalpy of rice flour samples were determined with differential scanning calorimetry (DSC) (DSC-7, Perkin-Elmer, Norwalk, CT) using the method of Fan and Marks (1998). Rice flour samples (3 mg, dry basis) were placed in alumunium DSC pans and distilled water was added to give a water-to-flour ratio of 2.5:1. The samples were sealed and allowed to equilibrate overnight before DSC analysis. The sample pans were heated at 10°C/min from 40 to 120°C. The DSC analyzer was calibrated using indium; an empty pan was used as a reference.

Swelling Power

The swelling power of flour was obtained using the method reported by Schoch (1964) with slight modification. Flour samples (0.5 g) were dispersed in 15 mL of distilled water in centrifuge tubes, and the resulting suspensions were heated to 60, 70, 80, and 90°C in a water bath with periodic mixing over a 30-min period. These cooked paste samples were then centrifuged at 2,200 rpm for 15 min. The supernatants were withdrawn and placed in preweighed petri dishes and dried at 100°C to constant weight. The swelling power was calculated by the method of Schoch (1964).

Paste Viscosity and Gel Hardness

Paste viscosity was determined with a Rapid Visco Analyser (RVA, Model 4D, Newport Scientific, Australia) using Approved Method 61-02 (AACC 2000). The parameters determined were pasting temperature, peak viscosity, breakdown, final viscosity, setback, and consistency. The thickened mixtures from the RVA runs were used to analyze gel strength with a texture analyzer (model TA.XT2, Texture Technologies, Scarsdale, NY) following the method of Yamin et al (1999). The gels were compressed at 0.9 mm/sec to a distance of

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7.5 mm using a stainless steel punch probe (P/6, 6 mm diameter). The peak force measured was reported as the firmness of the gel. The fresh-cut surface of the gel was compressed at five to six locations and the average of the values obtained was calculated.

Vermicelli Preparation

Rice vermicelli samples were prepared following the commercial method which mostly used only high-amylose rice as the raw material without any additives. Water was continually sprayed on and mixed into wet-milled rice flour to obtain a mixture with 37% of moisture content. The moistened flour was molded into an annular cylinder of 9.5 cm o.d. × 2 cm i.d. × 7 cm height. The surface of the annular cylinder was gelatinized by placing it in a conventional steamer for 15 min. The sample was then further premixed by extrusion through a single-screw extruder with hole openings 1 cm in diameter. The vermicelli noodle was created by extrusion of the premixed dough through a fabricated single-screw extruder with hole openings 0.5 mm in diameter. The extruded noodle was then steamed for 2 hr to become totally gelatinized, rested for 12 hr at ambient temperature, and dried in an air oven at 40°C for 16 hr.

Evaluation of Vermicelli Quality

Vermicelli quality was evaluated according to Mestres et al (1988). Vermicelli sample (5 g) including the commercial sample controls (≈2 cm long) were boiled separately in 150 mL of distilled water for 4 min, drained for 5 min, and weighed immediately. The spent cooking water was centrifuged at 2,200 rpm for 10 min. The sediments and supernatants were separated and dried at 105°C to constant weight. The solid and soluble losses during boiling were expressed as the percentages of total original vermicelli noodle sample weight found in the dry matter of the sediment and supernatant of cooking water, respectively. Total percentage loss was the sum of these percentages, and the water absorption index was the percentage of weight increase in the cooked vermicelli sample compared with the dry starting sample.

For texture analysis, the texture profile was determined according to the method of Kim and Seib (1993) using cooked vermicelli samples 5 cm long, prepared as above. One cooked strand was placed on a plexiglass plate and compressed to 75% of vermicelli height using an aluminium-cylindrical probe (2 cm, probe model P/20). The pause between the first and second compressions was 0.5 sec. From the force-time curve of the texture profile analysis (TPA), the hardness (height of the peak), adhesiveness (negative area of the first compression), springiness (ratio of the distance recorded during the second compression to that recorded during the first compression), and cohesiveness (ratio of the area under the second peak to the area under the first peak) were determined.

Statistical Analyses

Rice vermicelli preparation and all analyses were performed in triplicate. Data were subjected to analysis of variance followed by the Fisher's least significant difference test (LSD) to compare means at $P < 0.05$ by using Statgraphics v. 7.0 software. Pearson's correlation coefficients were calculated using SPSS v. 9.0 software.

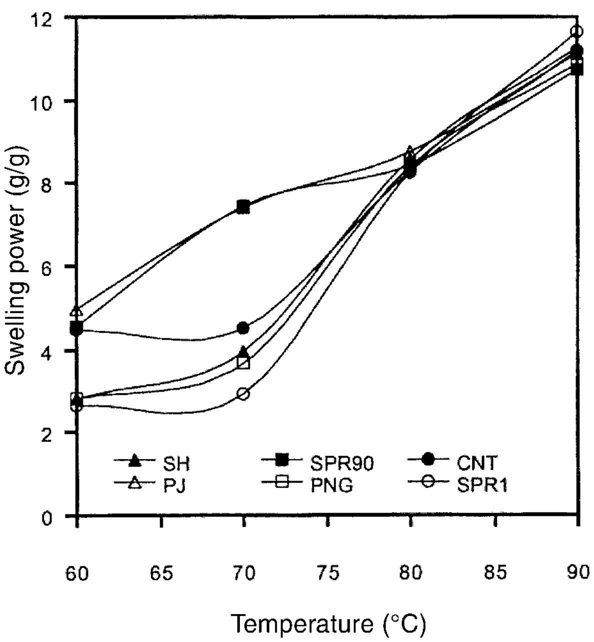

Fig. 1. Swelling patterns of high-amylose rice flours.

RESULTS AND DISCUSSION

Chemical Composition

Amylose content was 32–36% for all samples, including the reference flour SH (Table I). These values fit the classification of high-amylose content (>25%) as defined by Juliano (1985). The amylose content of the flour prepared from SPR1 was significantly greater than that of the reference flour ($P < 0.05$). The protein content of all samples fell in the narrow range of 7.06–8.96%. All of the test flours, except SPR1, had higher protein content than the reference ($P < 0.05$). The crude fat content of all samples was 0.11–0.69%; that of SH was significantly lower than the values for the five test flours. Total ash content was 0.21–0.32%. There was no significant difference between SH and the other samples, except for PNG. According to the gel consistency classification by Juliano (1985), all samples had hard gel consistency (data not shown)

Thermal Properties

The thermal parameters from endotherms are shown in Table I. The T_o of the rice flour samples varied from 61°C for SPR90 to 72°C for SPR1, whereas the T_p range was 65°C for SPR90 to 76°C for SPR1 and the T_c range was 73°C for SPR90 to 84°C for SPR1. Gelatinization temperatures for all samples were comparable

TABLE I
Physiochemical Properties of High-Amylose Rice Flours

Cultivar[a]	Amylose Content (%)	Thermal Property[b]				RVA Pasting Property[c]						Gel Hardness (g)
		T_o	T_p	T_c	ΔH	PT	PV	BD	FV	CS	SB	
SH	33.6a–c[d]	69.9b	74.5d	82.9c	12.6b	78b	310a	85d	373a	153c	62a	23.5a
SPR90	34.9b–d	61.7a	65.5a	73.2a	8.6a	69a	156b	44a	228b	115a	71b	24.7a
CNT	35.2cd	71.6c	75.2e	82.3c	12.6b	79b	287c	82d	364c	157cd	77c	27.6b
PJ	33.3ab	62.1a	66.3b	74.0b	9.5a	70a	264d	53b	345d	137b	83d	29.0b
PNG	32.9a	69.7b	73.7c	82.3c	11.7b	81c	240e	65c	314e	142b	75bc	28.6b
SPR1	36.7d	72.5d	76.3f	84.5d	12.2b	80b	230f	90e	304f	162d	73bc	29.0b

[a] SH = Sao Hai, SPR90 = Suphanburi90, CNT = Chainat1, PJ = Prajeenburi1, PNG = Plai-ngam Prajeenburi, SPR1 = Suphanburi1.
[b] T_o = onset temperature, T_p = peak temperature, T_c = conclusion temperature (measured in °C); ΔH = enthalpy of gelatinization (J/g).
[c] PT = pasting temperature (measured in °C). PV = peak viscosity, BD = breakdown (PV – minimum viscosity) , FV = final viscosity, CS = consistency (FV – minimum viscosity), SB = setback (FV – PV). Measured in Rapid Visco Analyser units (RVU).
[d] Means for each characteristic followed by the same letter are not significantly different at $P < 0.05$ by LSD test.

to those of other rice flour as reported by Fan and Marks (1998). The enthalpies of gelatinization (ΔH) varied from 8.6 J/g for SPR90 to 12.6 J/g for SH and CNT. SPR90 and PJ appeared to have significantly lower ΔH than the other samples. Gelatinization temperature and ΔH are indicators of the overall crystallinity of amylopectin (Fredriksson et al 1998), which is directly related to the structure of amylopectin. Yuan et al (1993) demonstrated that starch with greater amounts of long branched chains of amylopectin exhibited higher T_o and ΔH than starch with fewer long branched chains. This is because the longer chains have a greater ability to form double helices, which required greater thermal energy to dissociate. Thus, it can be hypothesized from these results that SPR90 and PJ flours, with lower T_o and ΔH contain fewer long branched amylopectin chains, and that SPR1 flour, which had higher values of T_o and ΔH had a greater content of long branched chains.

Swelling Power

The swelling powers of the rice flour samples at different temperatures are presented in Fig. 1. It is apparent from these curves that the swelling power of rice flour increased with increasing temperature and furthermore that the swelling patterns were different, even for samples with similar amylose contents. At lower temperatures, the swelling power of PJ and SPR90 was markedly greater than that for the other flours, which is in agreement with the DSC gelatinization temperatures for these samples. While swelling power approached the same values at higher temperatures, differences still existed at the highest temperature (90°C), increasing in the order SPR90<PNG<PJ<CNT<SH<SPR1. Sasaki and Matsuki (1998) reported that starch containing high proportions of long chain amylopectin showed high swelling power. This is in agreement with the observation that SPR1, which may have relatively more long amylopectin chains in the thermal experiments, had the highest swelling power at 90°C.

Paste Viscosity

Pasting properties for the rice flour samples measured by RVA are shown in Table I. A wide variation in all pasting parameters was observed among the rice flour samples, even those with simiar amy-

TABLE II
Correlation Between Flour Properties for High-Amylose Rice Flours[a]

	Amylose	Protein	Fat	T_o	T_p	T_c	ΔH	SP	PT	PV	BD	FV	CS	SB
Protein	–0.35													
Fat	–0.51	0.19												
T_o	0.36	–0.68	–0.04											
T_p	0.32	–0.70	–0.05	1.00**										
T_c	0.27	–0.75	–0.03	0.99**	0.99**									
ΔH	0.17	–0.59	–0.10	0.96**	0.97**	0.96**								
SP	0.57	–0.67	–0.62	0.64	0.64	0.63	0.62							
PT	0.39	–0.19	0.17	0.22	0.19	0.20	0.04	–0.28						
PV	–0.30	–0.15	–0.21	0.50	0.54	0.53	0.72	0.48	–0.57					
BD	0.42	–0.70	–0.37	0.93**	0.94**	0.93**	0.94**	0.83*	0.03	0.63				
FV	–0.30	–0.11	–0.17	0.48	0.52	0.50	0.69	0.47	–0.62	0.99*	0.59			
CS	0.33	–0.63	–0.27	0.90*	0.90*	0.88*	0.92**	0.85*	–0.20	0.72	0.96**	0.71		
SB	–0.07	0.42	0.38	–0.28	–0.31	–0.35	–0.33	–0.07	–0.53	–0.08	–0.35	0.02	–0.09	
Gel	0.10	–0.12	0.41	0.16	0.13	0.11	0.04	0.26	–0.40	0.01	0.04	0.10	0.28	0.84*

[a] T_o, T_p, T_c = gelatinization onset, peak, and conclusion temperatures, ΔH = enthalpy of gelatinization, SP = swelling power at 80°C, PT = pasting temperature, PV = peak viscosity, BD = breakdown (PV – minimum viscosity), FV = final viscosity, CS = consistency (FV – minimum viscosity), SB = setback (FV – PV), Gel = gel hardness. *, ** = significant at $P < 0.05$ and 0.01, respectively.

TABLE III
Cooking and Textural Qualities of Rice Vermicelli Prepared from Different Rice Cultivars

	Cooking Quality (%)				Textural Quality			
Sample[a]	Solid Loss	Soluble Loss	Total Loss	WAI	Hardness (g)	Adhesiveness (g/sec)	Springiness	Cohesiveness
Commercial	<2.2	<2.3	<4.5	74.4–77.7	435.9–679.1	0.5–0.7	0.88–0.92	0.48–0.57
SH	2.4b[b]	2.0b	4.4c	77.4c	489.2a	1.9ab	0.83bc	0.34bc
SPR90	1.3a	2.5c	3.8bc	74.9ab	599.7ab	2.5a	0.77a	0.29a
CNT	1.8ab	1.3a	3.1ab	75.1ab	722.5c	1.2b	0.87c	0.35c
PJ	1.3a	1.3a	2.6a	74.3ab	690.8bc	1.4b	0.87c	0.33b
PNG	1.2a	1.7b	2.9ab	75.7bc	704.4bc	1.5b	0.81ab	0.32b
SPR1	1.7ab	1.3a	3.0ab	73.3a	818.9c	1.2b	0.84bc	0.32b

[a] SH = Sao Hai, SPR90 = Suphanburi90, CNT = Chainat1, PJ = Prajeenburi1, PNG = Plai-ngam Prajeenburi, SPR1 = Suphanburi1.
[b] Means for each characteristic followed by the same letter are not significantly different at $P < 0.05$ by LSD test.

TABLE IV
Correlation Between Flour and Rice Vermicelli Properties[a]

Property[b]	Amylose	Protein	Fat	T_o	T_p	T_c	ΔH	SP	PT	PV	BD	FV	CS	SB	Gel
Solid	0.21	–0.39	–0.71	0.55	0.58	0.57	0.69	0.61	–0.04	0.67	0.76	0.60	0.64	–0.67	–0.52
Soluble	–0.17	0.19	–0.03	–0.44	–0.43	–0.39	–0.43	–0.62	0.60	–0.50	–0.46	–0.58	–0.69	–0.66	–0.82**
Total	–0.04	–0.09	–0.46	0.03	0.06	0.09	0.14	–0.09	0.42	0.09	0.15	–0.01	–0.10	–0.93**	–0.98**
WAI	–0.60	0.06	0.03	0.10	0.15	0.18	0.30	–0.30	0.11	0.46	0.11	0.39	–0.01	–0.68	–0.73
Hard	0.51	–0.25	0.24	0.33	0.28	0.25	0.13	0.39	–0.07	–0.17	0.21	–0.10	0.36	0.67	0.90*
Adh	–0.14	0.32	–0.07	–0.60	–0.59	–0.56	–0.60	–0.66	0.52	–0.59	–0.59	–0.65	–0.80	–0.52	–0.76
Spring	0.08	0.01	–0.33	0.32	0.32	0.27	0.44	0.64	–0.77	0.75	0.48	0.81	0.67	0.44	0.44
Cohe	0.21	–0.36	0.00	0.86*	0.86*	0.83*	0.87*	0.29	0.45	0.46	0.76	0.41	0.65	–0.50	–0.25

[a] T_o, T_p, T_c = gelatinization onset, peak, and conclusion temperatures, ΔH = enthalpy of gelatinization, SP = swelling power at 80°C, PT = pasting temperature, PV = peak viscosity, BD = breakdown (PV – minimum viscosity) , FV = final viscosity, CS = consistency (FV – minimum viscosity), SB = setback (FV – PV), Gel = gel hardness. *, ** = Significant at $P < 0.05$ and < 0.01, respectively.
[b] Solid = solid loss, Soluble = soluble loss, Total = total loss, WAI = water absorption index, Hard = vermicelli hardness, Adh = adhesiveness, Spring = springiness, Cohe = cohesiveness.

lose content. Pasting temperatures of rice flour samples varied between 69°C for SPR90 and 81°C for PNG. PJ and SPR90 exhibited lower gelatinization temperatures and began swelling at lower temperatures compared with the other samples. Consistent with these results, PJ and SPR90 exhibited lower pasting temperatures than the other samples. The peak viscosities of the rice flour samples were 156 RVU (SPR90) to 310 RVU (SH). These values were somewhat higher than reported Bhattacharya et al (1999) for other cultivars of high-amylose rice. This can be attributed to the difference in rice cultivar. The peak viscosity of the paste formed by the reference cultivar, SH, was higher than that of the other samples because the SH granules swelled at a high and consistent rate compared with the other samples. The breakdown values for the rice flour samples was from 44 RVU for SPR90 to 90 RVU for SPR1. Granules with a lower breakdown value reflect higher stability. On cooling of starch paste, the exudate from swollen starch granules forms an extensive network that surrounds the gelatinized granules, resulting in an increase in viscosity. The final viscosity values of all rice flour samples were from 228 RVU for SPR90 to 373 RVU for SH, and were higher than the corresponding peak viscosity values. This resulted in positive setback values of 62 RVU for SH to 83 RVU for PJ. Consistency, defined as total setback in Zeng et al (1997), varied from 115 RVU for SPR90 to 162 RVU for SPR1. On basis of consistency, SPR1 tended to have the highest degree of retrogradation. The effect of amylose content on pasting properties of starch (Zeng et al 1997) could not be applied to these results because the samples all had similar amylose content. The structure of amylose and amylopection play an important role in the pasting characteristics of starch. Takeda et al (1989) reported that increases in molecular weight of amylose and amylopectin, decreases in the amount of long-branch chain length, and decreases in branching degree of amylopectin all resulted in pastes with increased peak viscosity and breakdown, and decreased setback and final viscosity. Because the samples in this study had similar amylose contents but varied in the above parameter values, it may be hypothesized that these rice flour samples contained different amylose and amylopectin molecular structures.

Gel Hardness

The gel hardness values of the flour samples were 23 g for SH to 29 g for SPR1 (Table I). The values were comparable to values reported by Bhattacharya et al (1999) for other high-amylose rice cultivars. The mechanical properties of starch gels depends on various factors, including the rheological characteristics of the amylose matrix, the volume fraction and rigidity of gelatinized starch granules, as well as the interactions between dispersed and continuous phases of the gel (Biliaderis 1998). These factors, in turn, are dependent on the amylose content and the structure of amylopectin (Yamin et al 1999). Samples that exhibited harder gels tended to have higher amylose content and longer amylopectin chains. Amylose and amylopectin fractions that exhibited high final viscosity and consistency values tended to yield gels of harder texture (Mua and Jackson 1997). The results obtained in this study are consistent with these observations because pastes with the highest consistency tended to yield gels of the hardest texture.

All the properties studied in this work were correlated to one another and the results are shown in Table II. The content of amylose, as well as other chemical constituents, varied little among the different rice cultivars; no correlation could be detected between any of these values and the other parameters measured. The values for thermal parameters obtained by DSC analysis were correlated ($P < 0.01$), as in Bhattacharya et al (1999). Peak viscosity was positively correlated only with final viscosity. The higher peak paste viscosity might have been the result of a leaching of a greater amount of amylose into the free water and a higher degree of starch swelling. This resulted in a more viscous network formed during cooling and a consequent increase in the final viscosity (Miller et al 1973). This conclusion is also in agreement with the results of Bhattacharya et al (1997). The breakdown value was positively correlated with swelling power at 80°C, as well as with the DSC parameters and consistency. These relationships probably reflect differences in the molecular structures of amylopectin in the different rice cultivars. There is evidences that starch containing amylopectin with a high degree of polymerization exhibits higher T_o and ΔH, as well as a higher retrogradation rate (Fredriksson et al 1998) and greater breakdown value (Shibanuma et al 1996). Setback and gel hardness was significantly correlated each other, which was consistent with the results of Bhattacharya et al (1997).

Rice Vermicelli Quality

In this experiment, the cooking quality and texture were assessed for the six test rice cultivars and for 10 commercial vermicelli products used as references. The quality values measured for the references served as examples of acceptable quality levels. The cooking parameters of all rice vermicelli samples are presented in Table III. Some differences in the solid, soluble, and total cooking losses were noted between rice cultivars. Solid losses varied from 1.2% for PNG to 2.4% for SH. Soluble loss and total loss ranged from 1.3% for CNT, PJ, and SPR1 to 2.5% for SPR90 and from 2.6% for PJ to 4.4% for SH, respectively. Water absorption index (WAI) was 73% for SPR1 to 77% for SH. Although SH exhibited the highest values for cooking losses and WAI, its values were still in the ranges of commercial reference samples. When compared with the commercial products, all rice vermicelli samples were considered acceptable in terms of cooking properties, in spite of the slightly low WAI for SPR1.

Some textural properties of cooked vermicelli samples obtained from TPA are summarized in Table III. Hardness values of single vermicelli strands varied considerably from 489 g for SH to 819 g for SPR1. The hardness values for SPR90 and SH were in the ranges of the commercial references, while those of the other test cultivars were slightly over the upper limit for the references, indicating a harder texture for these vermicelli samples. SPR90 vermicelli exhibited significantly more adhesiveness and lower springiness and cohesiveness than the other samples. Thus, while cooked vermicelli made with SPR90 exhibited adequate firmness, it tended to be stickier, less springy, and less cohesive than the other test cultivars and the commercial reference products. All test rice cultivars had adhesiveness, springiness, and cohesiveness values that were significantly different from those for the commercial reference samples. This could be attributed to differences in the rice cultivars and in processing conditions. However, among the test rice samples, SH, which is commonly used for making rice vermicelli, tended to give vermicelli with the properties most similar to those of the commercial reference products.

Correlation coefficients between vermicelli and flour properties are summarized in Table IV. Soluble loss, total loss, and hardness were significantly correlated to gel hardness. This result supported the importance of gel texture properties on cooked rice noodle of Bhattacharya et al (1999). WAI and other textural parameters were not significantly correlated to any of the flour properties. In contrast to the findings of Bhattacharya et al (1999), RVA pasting parameters were not well correlated with properties of rice vermicelli made from various high-amylose Thai rice cultivars. Gel hardness was the only flour property correlated highly with the important vermicelli qualities. Ross et al (1997) explained that the structure of flour gel was more closely correlated to the structure of starch in noodles than it was to that in RVA paste. Moreover, pasting property was determined in high-shear conditions, where granule integrity was completely disrupted, which might not occur with intact gelatinized granules.

CONCLUSIONS

All six high-amylose Thai rice cultivars studied had variations in proximate chemical composition. The flour samples prepared from these rice cultivars exhibited differences in gelatinization and pasting properties, as well as in gel texture. While the flours from all the cultivars could be processed into rice vermicelli, the differences in chemical compositions and physicochemical properties of the flour samples resulted in differences in cooking and textural quality. Of these, gel hardness was correlated highly with both cooking and textural quality of vermicelli. Thus, this property could be used to predict the vermicelli quality from flour.

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