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RESEARCH ARTICLE

Quality characteristics of noodles made from selected varieties of Sri Lankan rice with different physicochemical characteristics

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Abstract: The physicochemical properties of eight popular Sri Lankan rice varieties (Bg 300, Bg 352, Bg 403, Bg 94-1, Ld 356, Bw 272-6b, At 405 and At 306) and the quality characteristics of noodles made from these varieties of rice were investigated. The physicochemical properties investigated were amylose content (AC), crude protein, fat content, starch properties and amylograph pasting properties. Rice noodles were prepared by gelatinization of dough made with rice flour followed by cold extrusion. Rice noodle samples were evaluated for cooking loss, swelling ratio, tensile strength, extensibility, elastic recovery, firmness and sensory properties. AC of rice varieties ranged from 18.65±1.19% in At 405 to 30.43±0.20 % in Bg 94-1. Swelling volume and swelling power were significantly different ($p<0.05$) among the rice varieties tested. Amylograph pasting properties of rice varieties showed a significant ($p<0.05$) variation for all the pasting parameters. Cooking loss was high in At 405 (19.17±3.50), and low in Bg 403 (9.19±0.33). Tensile strength was significantly high for Bg 352 (16.7±3.4 g) and it was significantly low for At 405 (8.0±1.7 g). Overall acceptability of rice noodles prepared from At 405 had the significantly lower score and rice noodles from Bg 300 had a significantly higher value. The physicochemical and amylograph pasting properties of rice varieties had a significant influence on the cooking, textural and sensory properties of rice noodles. Amylose content showed significant negative correlation with cooking loss ($r = -0.802$, $p<0.001$) and significant positive correlation with swelling ratio ($r = 0.809$, $p<0.001$) of noodles. Amylose content showed positive significant correlation with tensile strength, extensibility and elastic recovery at $p<0.05$. Rice noodles made from local rice varieties with high amylose content showed desirable quality characteristics.

Keywords: Amylose, amylograph viscosity, cooking property, noodles, rice, textural quality.

INTRODUCTION

Rice (*Oryza sativa* L.) is the staple food in Sri Lanka and it provides 45% calorie and 40% total protein requirement of an average Sri Lankan (Mendis, 2006). More than 50 rice varieties have been recommended for cultivation in Sri Lanka by the Department of Agriculture (DOASL, 2006; Wickramasinghe & Nado, 2008).

Different rice varieties exhibit compositional variation for protein, lipid, starch content (amylose and amylopectin) and other minerals and vitamins. These compositional differences contribute to the diversity of chemical and physical properties of rice such as viscosity, starch gelatinization and water absorption (Juliano, 1985). These properties influence the eating and cooking quality of rice and have a considerable effect on quality characteristics of end products such as bread, noodles and other extruded products made from rice flour.

Traditionally, rice noodles are made from long grain rice with high amylose content (>25 g/100 g) (Juliano & Sakurai, 1985), which plays a critical role in creating a gel network and sets the noodle structure (Mestres *et al*., 1988). A highly significant correlation was reported between high amylose content of rice and general acceptability of rice noodles (Yoenyong-buddhagal & Noomhorm, 2002). Bhattacharya *et al*. (1999) reported that the broad variation in physical and chemical properties of rice had a marked influence on the textural quality of rice noodles. It has been reported that rice noodle characteristics correlated significantly with swelling power (SP), paste viscosities and gel texture of starch present in rice flour (Bhattacharya *et al*., 1999; Hormdok & Noomhorm, 2007).

A wide array of rice varieties is present in the country and their physicochemical characteristics vary. When different rice varieties are used for rice noodle

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production, variation in quality characteristics can be expected. A detailed study of the effect of Sri Lankan rice varieties on the quality of rice noodles is not documented to date.

The objectives of the present study were to investigate the physicochemical properties of locally grown rice varieties, the quality characteristics such as cooking, textural and sensory attributes of rice noodles and to determine the relationship between physicochemical characteristics of rice varieties and the quality of noodles made from flour of different varieties of rice.

METHODS AND MATERIALS

The following paddy samples were collected from Rice Research and Development Centres in Sri Lanka and their respective regional stations; Bg 300, Bg 403, Bg 94-1 and Bg 352 from Bathalagoda (Bg); At 306 and At 405 from Ambalantota (At); Bw 272-6b from Bombuwala (Bw); and Ld 356 from Labuduwa (Ld).

Preparation of raw materials: The grains were dehulled and polished using a commercial dehuller (Type LM 24-2C, Rubber roller, China) and a polisher (Model N-70, China) at a commercial grinding mill in Colombo. Rice was ground to make flour using the universal milling machine (Universal mill PE 402, Bauermeister, Germany) fitted with a 0.5 mm sieve attachment at the Industrial Technology Institute (ITI), Colombo.

Physicochemical analysis: Crude protein (Kjeldhal nitrogen using DK 6 heating digester and Kjeltec semi-automatic distillation unit, UDK 132, VELP Scientifica, Italy) (Nitrogen conversion factor=5.95) and crude fat (Soxotherm 5306 AK, Gerhardt, Bornheimer Strabecon, Bonn, Germany) were determined according to the AACC method (1995). Amylose content (AC) was determined according to the method of Juliano (1985).

Starch properties: The method of Crosbie *et al*. (1992) was used to study the starch properties. Flour samples (0.4 g db) were mixed with 12.5 mL water in centrifuge tubes. The mix was equilibrated at 25 ˚C for 5 min. It was then heated to 92.5 ˚C and kept at that temperature for 30 min. The samples were cooled in an ice water bath for 1 min, equilibrated at 25 ˚C for 5 min and centrifuged (ICE Centra - 4B Centrifuge, Damon, USA) at 3000 rpm for 5 min. The flour swelling volume (mL/g) was calculated by converting the resultant gels on volume basis.

The supernatant was carefully removed and the swollen starch sediment was weighed. Swelling power (SP) was expressed as the ratio of weight of wet sediment to the initial weight of dry flour (g/g). The supernatant was placed in the evaporating dish and dried at 130 ˚C for 4 h to get a constant weight. Solubility (g/g) was estimated as the ratio of the weight of dry flour supernatant to the initial weight of dried flour.

Amylograph pasting properties: Pasting properties of rice samples were studied using the Amylograph (Brabender, BD 172502, Duisburg, Germany) according to the AACC Method (1995). Rice flour (50 g, 12 % moisture basis) was weighed and mixed with 450 mL of distilled water to get 10 % (g/g) slurry. Prepared sample was transferred to a viscometer bowl. The test was started at 35 ˚C and held for 5 min, followed by heating to 95 ˚C at the rate of 1.5 ˚C/min and kept for 20 min. The sample was then cooled to 50 ˚C at the rate of 1.5 ˚C/min while maintaining the rotating speed of bowl at 75 rpm. Peak viscosity (PV), viscosity at the end of hold time at 95 ˚C / hot paste viscosity (HPV), final viscosity at the end of cooling to 50 ˚C / cold paste viscosity (CPV), breakdown (BD=PV-HPV) and setback (SB=CPV-PV) were recorded.

Preparation of rice noodles: Noodles were prepared using 1 kg of rice flour. Rice flour was mixed with water to form a dough in the Hobart mixer (Hobart CE 100, London, UK). The dough was gelatinized by placing in a kitchen steamer and steamed for 30 min. The dough was kneaded for 15 min to evenly distribute the gelatinized starch. The dough was then placed in a Pasta machine (Pama Roma MODP/ 15, Pama Parsi, Rome, Italy), fitted with a die of 0.1 cm diameter pore size and extruded to get strands. These strands were steamed for 15 min and dried at 40 ˚C for 4 h in an electric dryer (Pama Roma MODPR/12, Pama Parsi, Rome, Italy).

Cooking and textural quality of noodles: Dried noodles (25.0 g) were cut into small pieces (5.0 cm in length) and boiled in 250 mL of water for 5 min with occasional stirring. The cooking time of noodles was determined by pressing the noodle between two glass plates and disappearance of the white core was examined with naked eyes. Cooking time is the time taken for the white core to disappear when the noodle strand is boiled in water (Chen *et al*., 2002). Cooked samples were drained for 5 min and immediately weighed. The drained water was collected and the volume was noted. Twenty millilitres of the drained water was transferred to an evaporating dish and dried at 105 ˚C until a constant weight was attained. Cooking loss (%) was calculated based on the dry weight of noodles (SLS, 1989). Rehydration or swelling ratio was estimated as the percentage increase in weight of cooked noodles compared to weight of dried noodles (Suhendro *et al*., 2000).

Testing for tensile strength was carried out using Tensile Tester (Tinius Olsen HIOKS-5698, Red Hill, England) as described by Bhattacharya *et al*. (1995). A strand of cooked noodles was wound around parallel rollers of the tensile tester. The upper arm was set to travel apart from the lower arm at the speed of 1 mm/s. The maximum force (g) required to break the noodles gives an indication of the sample's resistance to breakdown, and the distance (mm) to breakdown indicates the extensibility. The experiments were replicated 10 times.

Firmness and elastic recovery were determined according to the methods described by Sowbhagya and Ali (2001). Noodle strands were compressed using a constant load (50 N) with a Relaxation tester (Elastocon AB, EB 02, Sweden) for 5 min. Load was removed and allowed to recover for 5 min. Thickness measurements were taken before compression, after compression and after recovery. Firmness (F) and elastic recovery (ER) were calculated from the average of readings as follows,

$$F (\%) = [e_1/e]*100$$
$$ER (\%) = [(e_2 - e_1)/(e - e_1)]*100$$

where,

e = thickness of strands (mm) before compression
e_1= thickness of strands (mm) after compression
e_2= thickness of strands (mm) after recovery

Sensory evaluation: The prepared noodles were evaluated by 12 screened and trained panellists at ITI. The sensory quality of noodles was evaluated based on the preference for appearance, flavour, hardness, stickiness and overall acceptability using a 7- point hedonic scale, where 1-represented the least preference and 7-the most preference. Samples were evaluated by the panellists in individual booths. Sample size of 20g was served in a small glass cup coded with three digit random numbers.

Statistical Analysis: Data were analysed by Analysis of Variance (ANOVA) and mean separation was done by Fishers Least Square difference (LCD) at $p<0.05$. The sensory data were subjected to Freidman non-parametric two-way ANOVA using SAS (v. 6.12) package. Pearson correlation coefficients among parameters were calculated using SAS Proc corr (v. 6.12).

RESULTS AND DISCUSSION

Physicochemical characteristics of rice

The amylose content of tested varieties of brown rice is given in Table 1. Based on the amylose content (AC), rice can be classified as waxy rice (1-2 %), low amylose rice (2-20 %), intermediate amylose rice (20-25 %) and high amylose rice (>25 %) (Yoenyong-buddhagal & Noomhorm, 2002). All varieties used in the study belong to high amylose type rice except At 405, which belongs to the low amylose type. Significant differences ($p<0.05$) were observed among the AC of the rice varieties studied. Bg 94-1 had significantly higher AC with 30.43±0.20 %.

Fat content of rice ranged from 1.36±0.03% for Bg 94-1 to 0.56±0.09% in Bg 300. High amylose type rice tends to have less starch and lipids than the intermediate rice (Bhattacharya *et al*., 1999). However, the present study does not show any such relationship. The highest and lowest fat contents were observed in high amylose type rice varieties (Table 1). Protein content ranged from 6.84±0.20% in Bg 94-1 to 11.18±0.22% in Ld 366, which has red pericarp. Protein content was comparatively low in Bathalagoda rice varieties.

Table 1: Physicochemical properties of rice

Variety	Amylose (%)	Fat (%, db)	Protein (%, db)
Bg 352	$28.94 \pm 1.78^{a,b}$	0.85 ± 0.06^{e}	8.40 ± 0.43^{c}
Bg 300	26.76 ± 1.64^{c}	0.56 ± 0.09^{f}	7.84 ± 0.07^{d}
Bg 403	$29.17 \pm 0.35^{a,b}$	$1.03 \pm 0.05^{c,d}$	7.34 ± 0.14^{e}
Bg 94-1	30.43 ± 0.20^{a}	1.36 ± 0.04^{a}	6.84 ± 0.20^{f}
Ld 356	$27.23 \pm 0.81^{b,c}$	0.75 ± 0.15^{e}	11.18 ± 0.22^{a}
Bw 272-6b	25.51 ± 1.50^{c}	$1.17 \pm 0.18^{b,c}$	9.76 ± 0.03^{b}
At 405	18.65 ± 1.19^{d}	$0.89 \pm 0.04^{d,e}$	8.55 ± 0.44^{c}
At 306	25.87 ± 1.05^{c}	$1.28 \pm 0.10^{a,b}$	10.02 ± 0.08^{b}

In each column means with same superscript are not significantly different ($p < 0.05$); db=dry basis

Table 2: Starch properties of rice

Variety	Swelling power (g/g)	Swelling volume (mL/g)	Solubility (g/g)
Bg 352	8.33 ± 0.44^{b}	$8.92 \pm 0.73^{b,c}$	0.012 ± 0.007^{a}
Bg 300	8.28 ± 0.28^{b}	$8.89 \pm 0.23^{b,c}$	0.007 ± 0.006^{b}
Bg 403	$7.96 \pm 0.18^{b,c}$	9.25 ± 0.22^{b}	0.012 ± 0.003^{a}
Bg 94-1	$7.77 \pm 0.14^{b,c}$	8.49 ± 0.22^{b}	0.015 ± 0.009^{a}
Ld 356	$8.19 \pm 0.29^{b,c}$	9.29 ± 0.15^{b}	0.013 ± 0.005^{a}
Bw 272-6b	8.92 ± 0.40^{a}	10.41 ± 0.42^{a}	0.013 ± 0.003^{a}
At 405	8.33 ± 0.28^{b}	10.18 ± 0.28^{a}	0.008 ± 0.004^{a}
At 306	$8.12 \pm 0.47^{b,c}$	9.38 ± 0.40^{b}	0.013 ± 0.004^{a}

In each column means with same superscript are not significantly different ($p < 0.05$)

Starch properties of rice

When starch is heated in the presence of excess water to temperatures above the gelatinization temperature, the granules imbibe water and swell causing starch to leach into the solution. The degree of swelling and the amount of solubilization depends on the chemical binding within the granules (Zhou *et al*., 2002). Presence of strong intermolecular bonds and high amylose content reduces the extent of swelling by forming an extensive network. The degree of swelling and level of solubilization also depends on the extent of chemical bonding within the granules (Bhattacharya *et al*., 1995).

Swelling power indicates the ability of starch to hydrate under a specific cooking condition (92.5 ˚C/30 min). Swelling volume and swelling power were significantly different ($p<0.05$) among rice varieties (Table 2). Rice variety Bg 94-1 showed the lowest swelling power (7.77±0.14 g/g) and swelling volume (8.49±0.22 mL/g), while Bw 272-6b showed the highest swelling power (8.92±0.40 g/g) and swelling volume (10.41±0.42 mL/g). Starch leaching during gelatinization is estimated by solubility. A significant difference ($p<0.05$) was observed for solubility of rice starches and the rice variety Bg 300 had the significantly lowest solubility.

The difference in swelling power may be attributed to the difference in amylose content, viscosity patterns and weak internal organization resulting from negatively charged phosphate groups within the rice starch granules (Sing *et al*., 2006). Swelling behaviour of cereal starches has been reported as a property of their amylopectin content, where amylose acts as an inhibitor of swelling (Bhattacharya *et al*., 1995; Sing *et al*., 2006). This could be the reason for rice variety with low AC (At 405) having a high swelling volume.

Amylograph pasting properties of rice

Pasting properties are regarded as one of the most important indices in the evaluation of starch properties of rice (Zhou *et al*., 2002). Paste viscosity profile or gelatinization pattern recorded in Brabender Amylograph for rice varieties showed a significant ($p<0.05$) variation for all the pasting parameters (Table 3).

Peak viscosity (PV) indicates the highest viscosity yield by starch during the gelatinization under given conditions (Shuey & Tipples, 1994). The PV ranged from 813±58 BU in At 306 to 1240±150 in Bg 300. The high PV of Bg 300 reflects the ability of starch granules to swell freely before their physical breakdown. At 306, which had the lowest PV, indicates lower tendency for swelling of starch granules.

The viscosity measured after 20 minutes at 95 °C or hot paste viscosity (HPV) gives an indication of the stability of hot paste (Shuey & Tipples, 1994). HPV is influenced by the rate of amylose exudation, amylose-lipid complex formation, granule swelling and competition between exudated amylose and remaining granules for free water (Bhattacharya *et al*., 1999). HPV ranged from 576±159 in At 406 to 897±55 in Bg 352.

Cold paste viscosity (CPV) describes retrogradation tendency of soluble amylose upon cooling (Bhattacharya *et al*., 1999). CPV increases upon cooling, which may be due to the aggregation of elements present in the hot paste such as swollen granules, fragments of swollen granules and starch molecules dispersed as colloids (Sing *et al*., 2006; Shuey & Tipples, 1994). CPV of rice samples ranged from 762±161 BU in At 405 to 2137±185 BU in Bg 352.

Table 3: Amylograph pasting properties of rice

Variety	Peak viscosity (PV) (BU)	Hot paste viscosity (HPV) (BU)	Cold paste viscosity (CPV) (BU)	Set back (SB) (BU)	Breakdown (BD) (BU)
Bg 352	1193 ± 31^{a}	897 ± 55^{a}	2137 ± 185^{a}	943 ± 162^{a}	$297 \pm 55^{b,c}$
Bg 300	1240 ± 150^{a}	$770 \pm 125^{a,b}$	1620 ± 231^{b}	$380 \pm 87^{c,d,e}$	$470 \pm 36^{a,b}$
Bg 403	1230 ± 26^{a}	$653 \pm 91^{b,c}$	1420 ± 30^{b}	$190 \pm 20^{d,e}$	577 ± 115^{a}
Bg 94-1	1203 ± 60^{a}	$647 \pm 93^{b,c}$	1373 ± 108^{b}	170 ± 53^{e}	557 ± 119^{a}
Ld 356	1133 ± 70^{a}	850 ± 56^{a}	1570 ± 262^{b}	$437 \pm 225^{c,d}$	$283 \pm 68^{b,c}$
Bw 272-6b	1177 ± 236^{a}	867 ± 99^{a}	1987 ± 273^{a}	$810 \pm 270^{a,b}$	$310 \pm 257^{b,c}$
At 405	$1030 \pm 204^{a,b}$	576 ± 159^{c}	762 ± 161^{c}	-268 ± 101^{f}	$454 \pm 63^{a,b,c}$
At 306	813 ± 58^{b}	587 ± 63^{c}	1377 ± 150^{b}	$563 \pm 92^{b,c}$	263 ± 66^{c}

In each column means with same superscript are not significantly different ($p < 0.05$)
BU - Brabender Units, 1BU equivalent to 2.93 centipoises

Table 4: Textural characteristics of cooked rice noodles

Variety	Tensile strength (g)	Extensibility (mm)	Elastic recovery (%)	Firmness (%)
Bg 352	16.7 ± 3.4[a]	11.4 ± 2.3[a]	50.3 ± 6.1[a]	8.6 ± 2.7[a]
Bg 300	13.2 ± 3.8[b]	11.8 ± 2.5[a]	46.6 ± 8.2[a]	87.9 ± 2.4[a,b]
Bg 403	12.2 ± 2.3[b]	11.8 ± 2.1[a]	37.3 ± 9.0[b]	85.8 ± 3.9[b]
Bg 94-1	12.1 ± 4.6[b]	9.2 ± 3.1[b]	48.6 ± 8.5[a]	88.2 ± 3.4[a,b]
Ld 356	10.7 ± 3.6[b,c]	10.2 ± 2.6[a,b]	35.6 ± 10.3[b]	89.0 ± 1.4[a]
Bw 272 6b	11.9 ± 3.3[b]	10.3 ± 1.5[a,b]	49.4 ± 12.6[a]	87.6 ± 1.1[a,b]
At 405	8.0 ± 1.7[c]	6.1 ± 1.6[c]	26.2 ± 5.4[c]	86.7 ± 2.6[a,b]
At 306	13.5 ± 3.0[b]	6.0 ± 1.8[c]	52.2 ± 14.5[a]	88.5 ± 3.1[a]

In each column values with same superscript are not significantly different ($p < 0.05$)

Table 5: Sensory attributes of noodles prepared from different rice varieties

Variety	Appearance	Flavour	Hardness	Stickiness	Overall acceptability
Bg 352	6.3[a,b]	5.4[a]	5.7[a,b]	5.9[a]	5.7[a,b]
Bg 300	6.5[a]	5.5[a]	5.9[a]	6.0[a]	6.2[a]
Bg 403	6.1[a,b,c]	5.5[a]	5.3[a,b]	5.8[a]	5.6[a,b]
Bg 94-1	6.4[a]	5.3[a]	5.4[a,b]	5.6[a]	5.5[a,b]
Ld 356	5.9[a,b,c]	5.5[a]	5.6[a,b]	5.9[a]	5.6[a,b]
Bw 272-6b	5.7[b,c]	5.3[a]	5.7[a]	5.7[a]	5.5[a,b]
At 405	3.5[d]	5.5[a]	3.1[c]	2.1[c]	2.7[c]
At 306	5.5[c]	5.1[a]	4.8[b]	4.7[b]	4.9[b]

In each column values with same superscript are not significantly different ($p < 0.05$)
seven point Hedonic scale

Table 6: Correlation between physicochemical properties of rice varieties and noodle quality

Physicochemical properties of rice	Noodle quality					
	Cooking loss	Swelling ratio	Elastic recovery	Firmness	Tensile strength	Extensibility
Amylose	-0.802***	0.809***	0.388*	0.082	0.403*	0.427*
Fat	-0.017	0.037	0.215	0.023	-0.046	-0.229
Protein	0.367**	-0.071	-0.026	0.231	-0.085	-0.184
Swelling volume	0.479**	-0.324*	-0.198	-0.066	-0.255	-0.238
Swelling power	0.225	0.011	0.089	0.055	-0.084	0.058
Solubility	-0.109	0.193	0.118	0.024	0.034	0.146
Peak viscosity	-0.541**	0.296	0.079	0.085	0.102	0.380
Hot paste viscosity	-0.182	0.402**	0.239	0.188	0.189	0.286
Cold paste viscosity	-0.399*	0.673**	0.500*	0.181	0.460**	0.424**
Setback	-0.213	0.616**	0.516**	0.163	0.462**	0.307*
Breakdown	-0.374*	-0.067	-0.136	-0.085	-0.069	0.121

* = Significant at $p<0.05$
** = Significant at $p<0.01$
*** = Significant at $p<0.001$

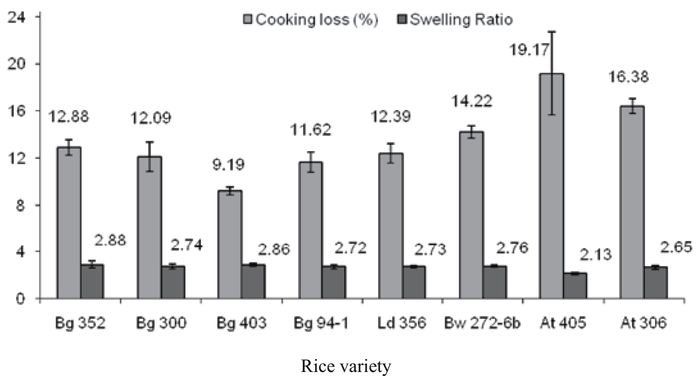

Figure 1: Cooking loss and swelling ratio of noodles prepared by different rice varieties

Breakdown viscosity (BD) is the measure of the susceptibility of cooked starch granules for disintegration, which is determined by the difference between PV and HPV (Sowbhagya & Ali, 2001). Rice variety Bg 403 and Bg 94-1 had significantly higher values for BD. Setback (SB) viscosity is an essentially derived tool that describes the difference between CPV and HPV. SB value indicates the recovery of the viscosity during cooling of heated starch suspension (Sing *et al*., 2006). Lowest SB value for rice variety At 405 is an indication that this variety is softer after cooking. At 405 has shown a low value for HPV, CPV, SB and BD.

Cooking quality of rice noodles

Cooking loss and rehydration are important features for determining noodle quality. Rice noodles should have short cooking time with negligible loss of solids in cooking water. Low rehydration usually results in noodles with hard and coarse texture, but excess water uptake often results in soft and sticky noodles (Yoenyong-buddhagal & Noomhorm, 2002).

All rice noodle samples showed an optimum cooking time of 5 minutes. Cooking quality characteristics of rice noodles is shown in Figure 1. Cooking loss was significantly different among the rice varieties and high in noodles made from At 405 (19.17±3.50) while it was low in Bg 403 (9.19±0.33). All high amylose rice varieties had comparatively low cooking loss. High cooking loss is undesirable as it indicates high solubility of starch, resulting in turbid cooking water, low cooking and sticky mouth feel (Bhattacharya *et al*., 1999). Cooking loss correlated negatively with AC of rice ($r = -0.802$, $p<0.001$). Swelling ratio was significantly ($p<0.05$) low for At 405 (2.13±0.08). There were no significant differences observed among the other varieties, which had comparatively similar values for rehydration.

Textural properties of cooked rice noodles

Texture of cooked noodles is the most critical characteristic, which determines consumer acceptance of the product. In this study, aspects of noodle texture were evaluated using tensile testing, elastic recovery and firmness (Table 4).

Tensile testing assesses the breaking strength and the breaking length of noodles. These properties correlated well with each other and it is an indication of how well the noodle strands resist breakdown (Seib *et al*., 2000). It also gives an indication on how the samples hold together during cooking and reflects the cooking tolerance and cooking quality of noodles (Bhattacharya *et al*., 1999). Tensile strength was significantly ($p<0.05$) high for Bg 352 (16.7±3.4 g) and significantly low for At 405 (8.0±1.8 g). Other varieties had comparable values for tensile strength. The distance to break the noodle strands is the measure for extensibility (Bhattacharya *et al*., 1999). The extensibility ranged from 6.0±1.8 in At 306 to 11.8±2.5 in Bg 300. Noodles prepared from At 405 flour had the lowest tensil strength and required shorter time to break, which indicates low extensibility. Increased tensile strength and extensibility were found in noodles made from high amylose rice. The results indicated that noodles became more difficult to stretch and break with the increase of AC of rice. Tensile strength of noodles showed a positive correlation with AC ($r = 0.403$, $p<0.05$).

The predominant characteristics of the quality of noodles related to textural characteristics such as translucency, colour, uniformity of appearance, mechanical strength and integrity, absence of sticky surface, which are characterized by firmness and elasticity (Sowbhagya & Ali, 2001). Elastic recovery of noodles ranged from 26.2±5.4 % in At 405 to 52.2±14.5 % in

At 306. Firmness of noodles ranged from 85.8±3.9 % in Bg 403 to 89.0±1.4 % in Ld 356. Noodles with higher firmness and elastic recovery can result in good quality noodles with low cooking loss (Chen *et al*., 2002).

Sensory attributes of rice noodles

The sensory attributes of rice noodles are given in Table 5. The appearance of rice noodles was significantly different amongst the noodles made out of different rice varieties. Noodles from rice variety At 405 and At 306 had a significantly ($p<0.05$) low value for appearance, and the appearance was disliked by most of the panellists. Noodles made from all Bg varieties had higher values for appearance and were accepted by most of the panellists. There was no significant ($p<0.05$) difference observed for the flavour of rice noodles. The flavour of cooked noodles is a minor quality attribute from the consumer point of view compared to other characteristics.

Hardness of rice noodles made out of Bg varieties was higher. Rice noodles made from Bg 300 had significantly ($p<0.05$) higher value for hardness and were preferred by most panellists. Hardness and stickiness of rice noodles made from At 405 were significantly lower and this type was less preferred by the panellists. The rice noodles made from At 405 were very sticky and adhesive and this could be the reason for lower preference by the panellists. The panellists preferred hardness and stickiness of rice noodles made from other rice varieties. Hardness and stickiness of rice noodles are attributes of amylose content.

Based on the scores for overall acceptability, rice noodles made from At 405 flour had the significantly ($p<0.05$) lowest score and were disliked by most of the panellists. Rice noodles made from Bg 300 flour had a significantly higher value. Results of the sensory attributes of rice noodles indicates that the panellists preferred less sticky rice noodles. The panellists preferred non sticky and hard noodles, irrespective of the flavour.

Relationship between physicochemical properties of rice and quality characteristics of noodles made from different varieties of rice flour

Correlation analyses between physicochemical properties of rice varieties and the corresponding noodle qualities were examined. Pearson correlation coefficients were summarized in Table 6.

The amylose content significantly correlated negatively with cooking loss ($r = -0.802$, $p<0.001$) positively with swelling ratio ($r = 0.809$, $p<0.001$) of noodles. AC positively correlated significantly at $p<0.05$ with tensile strength, extensibility and elastic recovery. Desirable quality characteristics of rice noodles were observed among noodles made from the local rice varieties with high AC.

Fat content of the different varieties of rice did not have a significant effect on the rice noodle properties. A significant positive correlation was observed between protein content of rice and cooking loss in noodles. Flour solubility was expected to have a positive correlation with cooking loss as shown in studies of Yoenyong-buddhagal & Noomhorm (2002). In the present study it was negative and not significant. Swelling power of rice flour had a very poor relationship to noodle characteristics and was not significant.

Amylograph peak viscosity showed a significant negative correlation with ($r = -0.541$, $p<0.01$) cooking loss. HPV correlated negatively with cooking loss but was not significant. HPV showed a significant positive correlation with swelling power ($p=0.402$, $p<0.01$). Positive correlation found between HPV textural parameters and PV with swelling ratio and extensibility of noodles was not significant. A high HPV generally represents low cooking loss and superior eating quality (Bhattacharya *et al*., 1999). Cold paste viscosity correlated negatively with the cooking loss ($r=0.399$, $p<0.05$), and positively with rehydration ($r=0.673$, $p<0.01$), elastic recovery ($r=0.501$, $p<0.01$), tensile strength ($r=0.460$, $p<0.01$) and extensibility ($r=0.424$, $p<0.01$). Setback viscosity correlated positively with swelling power, elastic recovery, tensile strength and extensibility at $p<0.01$. Breakdown correlated negatively with cooking loss.

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