Grain Quality Characteristics of Export Rices in Selected Markets

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ABSTRACT

Export rices from Bangkok and retail rices in Hong Kong, Rome, Italy, and Bonn, Germany, were analyzed for physical and chemical properties. Thai nonwaxy rices had long, slender grains but intermediate or low gelatinization temperatures (GT); the amylose content (AC) ranged from intermediate to high for nonaromatic rices and from intermediate to low for aromatic rices. Thai waxy rices were long or medium grain and had low GT. In Hong Kong, imported Thai nonwaxy rices were mainly aromatic with low GT and low to intermediate AC; China rices were mainly short, medium-shaped grain with low GT and high AC; Australian long- and medium-grain rices had low GT, and low to intermediate AC, while US long grain rices had low GT and variable AC. Samples from Rome were mainly of long- or medium-grain rices with low GT and low to intermediate AC. The Bonn samples were mainly raw and parboiled long-grain rices with intermediate to low GT and intermediate AC. Nonwaxy rices generally had high values for head rice and translucency.

Only 4% of the world's rice enters the international market (Efferson 1985). Thailand and the United States are the principal rice exporters. The physicochemical properties of brown and milled rices in the international trade have not been systematically studied. Market samples in various countries have been classified based on U.S. rice grades (Rivenburgh 1961) and cooking and eating qualities (Simpson et al 1965). The world rice market has been studied in terms of behavior and structure (Siamwalla and Haykin 1983) and market quality (Efferson 1985). The quality of rice in exporting countries—Thailand (Bhattacharya 1984, Attaviriyasook 1985), the United States (Webb et al 1985), Australia (Blakeney 1979), and China (Fang 1985)—and in all rice-producing countries (Juliano and Pascual 1980, Juliano 1985) has been reviewed.

This study focused on the grain characteristics of rice exported from Bangkok and rices in retail markets of rice-consuming but mainly rice-importing countries (Hong Kong) and countries in the European community where rice is not a traditional staple (Bonn, Germany, representing Northern Europe and Rome, Italy, representing Southern Europe; Kaosa-ard and Juliano 1989). The role of rice in Hong Kong was reviewed recently (Bruton 1987) and rice consumption was about 70 kg per capita annually. The properties of Italian rice varieties have also been reviewed (De Rege et al 1966, Baldi et al 1981). Rice consumption is about 2 kg per capita annually in Germany and 4.8 kg per capita in Italy (Kaosa-ard and Juliano 1989).

MATERIALS AND METHODS

Milled rice and brown rice samples were obtained from retail markets during November 1987 in Hong Kong, June 1988 in Bonn (Germany), and May 1988 in Rome (Italy). Their retail prices and packaging were also noted. Export rices from Bangkok were obtained through SGS Far East Ltd., Bangkok, during May 1986. Mean export prices during July 1986 were obtained from SGS later. Retail prices in Hong Kong, Rome, and Bonn were converted to U.S. dollars using the prevailing rate at the time of sampling: HK$7.764, L 1,258.7, and DM 1.7557, respectively, per U.S. dollar.

Rices were analyzed for mean length and width of 10 grains using a photoenlarger (10×), and length-width ratios were calculated. Other characteristics analyzed were head rice, using a Satake testing rice grader TRG 05A with suitable indented cylinder to remove brokens shorter than three-fourths of whole-grain length; translucency, using a Riken-Sanno rice meter (brown rice model); whiteness, with a Kett model C-3 whiteness meter; and color with a Minolta Chroma meter model CR-110 on L*a*b mode with granular material attachment. Grains with >50% chalky area and damaged grains were manually removed from each 50-g sample. Grains were defined as damaged when they were distinctly discolored or damaged by water, insects, heat, or other means. Brown rice samples (5 g) were milled for 0.5–1 min in a Kett Pearlest small-scale polisher to obtain milled rice for analysis of alkali spreading value, amylose content (AC), and gel consistency. Milled rices were analyzed for alkali spreading value (Little et al 1958).

Milled rice (5 g) was ground in a Udy cyclone mill with a 60-mesh sieve and analyzed for colorimetric apparent AC (Juliano et al 1981), gel consistency of 100 and 90 mg flour per 2 ml of 0.2*N* KOH (Cagampang et al 1973), and crude protein by micro Kjeldahl method (Juliano and Pascual 1980). Gel consistency values were reported for 90 mg instead of 100 mg after we observed that many market samples of medium gel consistency gave hard values at 100 mg but not at 90 mg.

The aroma of Hong Kong rices was assessed after cooking 20–30 grains for 10 min in 20 ml of water in covered 50-ml test tubes in a boiling water bath and cooling. The aroma was rated as strong, moderate, slight, or none (IRRI 1971).

Grain length was classified (Khush et al 1979) as extra long (>7.50 mm), long (6.61–7.50 mm), medium (5.51–6.60 mm), or short (<5.50 mm). Grain shape based on length-width ratio was classified as slender (>3.00), medium (2.01–3.00), or bold (1.01–2.00) (Khush et al 1979). Starch final gelatinization temperature (GT) indexed by alkali spreading value was classified as low (6–7), intermediate (4–5), high-intermediate (3), or high (2) (Little et al 1958). Apparent AC was classified as waxy (0–2%), low (10–20%), intermediate (20.1–25.0%), or high (>25.0%). Gel consistency was classified as soft (61–100 mm), medium (41–60 mm), or hard (27–40 mm).

RESULTS AND DISCUSSION

Variety Classification

Thai export rices. Most samples had long slender grains except glutinous (waxy) rices (Table I). The export price of Thai Basmati was higher than for fragrant rice (Jasmine, Khao Dawk Mali), which in turn was higher than the nonaromatic rices. Nonglutinous (nonwaxy) rice had a slightly lower price than glutinous rice. Brokens were cheaper than head rice. Alkali spreading values showed a predominance of intermediate-GT rices among the nonaromatic milled rices; among fragrant and glutinous rices low-GT rices were prevalent. Thai Basmati showed intermediate GT, intermediate AC, and hard gel consistency. The nonaromatic, nonwaxy milled rices had intermediate to high AC, whereas the AC of fragrant rices was mainly low. Gel consistency of nonwaxy raw milled rice was usually hard, except fragrant rice with medium

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to soft values. The glutinous rices were relatively pure and had the specified (<2%) AC and soft gel consistency. The results on nonwaxy nonaromatic rices suggest that no specific variety type is used for export.

Protein content of Thai export market rices was lower than that reported (mean 7.45%) by Unnevehr et al (1985b). Thai rice imported into Indonesia had 6.9% protein (Unnevehr et al 1985b).

Parboiled rices exported from Bangkok were lower priced than raw rice and were exclusively long-grain, either slender or medium in shape (Table II). The medium-shaped grains had length-width ratios of 2.9–3.0, indicating that they are almost slender. GT based on alkali spreading value was either low or intermediate, whereas AC was either intermediate or high. Gel consistency values of parboiled rice showed variable values but tended to be softer than those of raw rice, as reported earlier from parboiling results (Biswas and Juliano 1988). Protein content was also lower than that reported by Unnevehr et al (1985b). The intermediate GT reaction of some parboiled rices from alkali spreading value suggests that parboiling temperatures may have been close to 100°C or at low steam pressure, since GT becomes low for all rices parboiled at 120°C regardless of alkali reaction of the raw grain (Biswas and Juliano 1988).

Hong Kong imported rices. The major sources of imported rice in Hong Kong are Thailand, China, Australia, and the United States (Table III). Chinese rice was the least expensive, consisting mainly of short, medium-shaped grains with low GT and high AC (Fang 1985). Thai rice had mainly long slender grains, low GT, low AC, and soft gel consistency, indicative of fragrant or aromatic rices (Table I). The retail prices were, as expected, higher than the wholesale export prices ex Bangkok. Australian rices

TABLE I
Classification of Selected Properties of 73 Thai Export Raw Rices (Bangkok, May 1986)

Sample	Mean Price (US$/t)	Sample (no.)	Length[a]		L/W Ratio[a]		Alkali Spreading Value[c]			Apparent Amylose Content[d]				Gel Consistency[e]			Crude Protein (% wet basis)	
			L	M	S	M	L	I	HI	Wx	L	I	H	S	M	H	Range	Mean
White rice																		
100%	220	10	10	0	10	0	1	8	1	0	1	3	6	0	2	8	6.2–7.1	6.6
5%	205	5	5	0	5	0	1	4	0	0	0	5	0	0	0	5	6.5–7.1	6.9
10%	206	5	2	3	3	2	0	5	0	0	0	0	5	1	0	4	6.0–7.0	6.5
25%	180	5	1	4	3	2	1	4	0	0	0	2	3	0	0	5	5.9–6.6	6.2
White rice brokens																		
A-1 superspecial	155	3	...	...	...	...	2	1	0	0	0	0	3	0	0	3	6.3–6.4	6.3
A-1 special	115	7	...	...	...	...	0	7	0	0	0	4	3	0	1	6	5.5–6.4	6.2
Fragrant rice 100%	290	9	9	0	9	0	9	0	0	0	8	1	0	4	5	0	6.1–7.0	6.4
Fragrant brokens A-1	123	7	...	...	...	...	4	3	0	0	5	1	1	1	4	2	5.8–6.6	6.2
Thai Basmati	700	1	1	0	1	0	0	1	0	0	0	1	0	0	0	1	...	7.7
Glutinous rice 10%	240	6	2	4	4	2	6	0	0	6	0	0	0	6	0	0	5.8–6.7	6.3
Glutinous rice short grains 10%	240	5	1	4	1	4	5	0	0	5	0	0	0	5	0	0	5.8–6.2	6.0
Glutinous brokens	180	2	...	...	...	...	2	0	0	2	0	0	0	2	0	0	5.5,5.5	5.5
Total/mean	209	65	31	15	36	10	31	33	1	13	14	17	21	19	12	34	5.5–7.1	6.4
Brown rice																		
Brown rice 100%	175	5	3	2	3	2	0	5	0	0	0	4	1	0	3	2	6.7–7.1	6.9
Thai Basmati	465	1	0	1	1	0	0	1	0	0	1	0	0	0	0	1	...	7.6
Black glutinous	205	1	0	1	0	1	1	0	0	1	0	0	0	1	0	0	...	8.0
Mixed, red and white	175	1	1	0	1	0	0	1	0	0	0	1	0	0	0	1	...	6.8
Total/mean	215	8	4	4	5	3	1	7	0	1	1	5	1	1	3	4	6.7–8.0	7.1

[a]L = Long 6.61–7.50 mm, and M = medium 5.51–6.60 mm.
[b]S = Slender >3.00, and M = medium 2.01–3.00.
[c]Gelatinization temperature type: L = low 6–7, I = intermediate 4–5, and HI = high-intermediate 3.
[d]Wx = Waxy 0–2.0%, L = low 10.1–20.0%, I = intermediate 20.1–25.0%, and H = high >25.0%.
[e]S = Soft 61–100 mm, M = medium 41–60 mm, and H = hard 27–40 mm.

TABLE II
Classification of Selected Properties of 25 Thai Export Parboiled Rices (Bangkok, May 1986)

Sample	Mean Price (US$/t)	Sample (no.)	Length[a]		L/W Ratio[b]		Alkali Spreading Value[c]		Apparent Amylose Content[d]		Gel Consistency[e]			Crude Protein (% wet basis)	
			L	M	S	M	L	I	I	H	S	M	H	Range	Mean
Milled rice															
Parboiled 100%	195	8	8	0	7	1	5	3	4	4	5	2	1	6.1–7.1	6.8
Parboiled 5%	185	8	8	0	7	1	4	4	2	6	2	3	3	6.0–7.2	6.4
Parboiled 10%	180	1	1	0	1	0	1	0	1	0	0	0	1	...	6.7
Parboiled 15%	175	1	1	0	1	0	1	0	1	0	0	0	1	...	6.2
Parboiled 35%	163	1	1	0	1	0	0	1	1	0	0	0	1	...	6.5
Total/mean	187	19	19	0	17	2	11	8	9	10	7	5	7	6.0–7.2	6.6
Brokens															
Parboiled A-1 special	125	2	...	...	...	...	2	0	1	1	0	1	1	6.5,6.6	6.6
Brown rice															
Parboiled	185	4	4	0	3	1	4	0	4	0	4	0	0	7.0–7.5	7.3

[a]L = Long 6.61–7.50 mm, and M = medium 5.51–66.0 mm.
[b]S = Slender >3.00, and M = medium 2.01–3.00.
[c]Apparent gelatinization temperature type: L = low 6–7 and I = intermediate 4–5.
[d]I = Intermediate 20.1–25.0%, and H = high >25.0%.
[e]S = Soft 61–100 mm, M = medium 41–60 mm, and H = hard 27–40 mm.

TABLE III
Classification of Selected Properties of 93 Milled Rices in Hong Kong Retail Markets (November 1987)

Source	Price (US$/kg) Range	Price (US$/kg) Mean	Sample (no.)	Length[a] L	Length[a] M	Length[a] S	L/W Ratio[b] S	L/W Ratio[b] M	L/W Ratio[b] B	Alkali Spreading Value[c] L	Alkali Spreading Value[c] I	Alkali Spreading Value[c] HI	Apparent Amylose Content[d] L	Apparent Amylose Content[d] I	Apparent Amylose Content[d] H	Gel Consistency[e] S	Gel Consistency[e] M	Gel Consistency[e] H	Crude Protein (% wet basis) Range	Crude Protein (% wet basis) Mean
China	0.33–0.60	0.43	24	0	8	16	2	20	2	22	2	0	0	5	19	2	7	15	6.3–9.5	7.6
Thailand	0.41–0.69	0.52	34	34	0	0	34	0	0	29	3	2	22	9	3	30	4	0	6.1–6.9	6.6
Australia	0.53–0.71	0.63	14	8	6	0	8	4	2	14	0	0	7	7	0	13	1	0	6.0–6.5	6.2
USA	0.46–0.66	0.56	6	5	1	0	5	1	0	5	1	0	1	3	2	5	0	1	6.2–7.4	6.6
Mixed	0.55–0.73	0.64	12	12	0	0	12	0	0	12	0	0	7	5	0	8	4	0	5.9–7.1	6.7
Unidentified	0.57–0.61	0.59	3	1	2	0	1	2	0	3	0	0	1	0	2	1	1	1	6.6–7.0	6.8
Mean/total	0.33–0.73	0.53	93	60	17	16	62	27	4	85	6	2	38	29	26	59	17	17	5.9–9.5	6.8

[a]L = Long 6.61–7.50 mm, M = medium 5.51–6.60 mm, and S = short <5.50 mm.
[b]S = Slender >3.00, M = medium 2.01–3.00, and B = bold 1.01–2.00.
[c]Gelatinization temperature type: L = low 6–7, I = intermediate 4–5, HI = high-intermediate 3, and H = high 2.
[d]L = Low 10.1–20.0%, I = intermediate 20.1–25.0%, and H = high >25.0%.
[e]S = Soft 61–100 mm, M = medium 41–60 mm, and H = hard 27–40 mm.

had both long and medium grains, low GT, low or intermediate AC, and soft gel consistency typical of the two grain types grown (Blakeney 1979). The U.S. samples had long and medium grains with low GT, variable AC, and soft gel consistency. In Hong Kong, it is common to mix varieties to obtain the desired quality requirements (Kaosa-ard and Juliano 1989). The mixed samples were mainly long, slender grains and had low GT, low to intermediate AC, and soft to medium gel consistency. Unidentified samples were one long- and two medium-grain milled rices with low GT, low or high AC, and variable gel consistency. Crude protein content was highest for rices from China. The protein content of imported Thai rice was similar to that of exported fragrant Thai rice in Table I.

Sensory evaluation (IRRI 1971) of aroma level of the 93 cooked rice samples showed the highest level for low-AC samples and the lowest for high-AC samples (Table IV). The results are consistent, the aromatic rices being mainly Thai fragrant rices (jasmine rice) (Kaosa-ard and Juliano 1989) with low AC (Juliano et al 1964; Unnevehr et al 1985a,b). Thailand was the major source of rice samples in the study, followed by China (Table III).

TABLE IV
Relationship Between Aroma Level of Cooked Rice and Apparent Amylose Content of 93 Nonwaxy Milled Rices from Hong Kong Retail Markets

Aroma Level of Cooked Rice	Apparent Amylose Content Type: Low	Intermediate	High	Total
Strong	6	1	0	7
Moderate	5	4	0	9
Slight	19	11	16	46
None	9	12	10	31
Total	39	28	26	93

Rices in Roman markets. The samples from Rome were mostly milled rice, but seven brown rice samples were included (Table V). Twenty percent were parboiled, mainly 11 samples of Ribe. Italian varieties of raw milled rice predominated; there were 19 Arborio, 15 Ribe, 10 Roma, 9 Originario, 8 Padano, and 6 San Andrea samples. Varieties were long to medium but relatively wide or coarse, resulting in a medium shape classification. Retail prices were higher than those in Hong Kong markets (Table III). Italian rices tended to be cheaper than imported rice. Raw rice was cheaper than parboiled rice, except for the variety Carnaroli, of intermediate AC (Baldi et al 1981) and hard gel consistency, which had a higher retail price (U.S. $2.57 and 3.58) than even parboiled rices. All Italian rices had low GT, low to intermediate AC, and mainly soft gel consistency, as reported earlier (Baldi et al 1981, De Rege et al 1966, Juliano and Pascual 1980). The AC range for any variety was within the 5% level except for Padano (6.6%) and Originario (6.0%). These values were larger than those reported for French varieties grown in different locations, showing a 5.3% range in starch AC (Morrison and Nasir Azudin 1987). Imported rices were mainly long-grain rices from Thailand, the United States, and Indonesia and short-grain rices from China. These rices were mostly of intermediate AC, soft gel consistency, and low GT.

Protein content was 7.1–8.6% in brown rice and 5.5–8.8% in milled rice, the highest being in U.S. parboiled rice (Table IV).

Rices in Bonn markets. Since brand names were used instead of variety names in the imported rice samples in the Bonn markets,

TABLE V
Classification of Selected Properties of 84 Raw and 21 Parboiled Rices in Retail Markets in Rome, Italy (May 1988)

Variety and Form	Price (US$/kg) Range	Price (US$/kg) Mean	Sample (no.)	Length[a] L	Length[a] M	Length[a] S	L/W Ratio[b] S	L/W Ratio[b] M	L/W Ratio[b] B	Alkali Spreading Value[c] L	Alkali Spreading Value[c] I	Apparent Amylose Content[d] L	Apparent Amylose Content[d] I	Apparent Amylose Content[d] H	Gel Consistency[e] S	Gel Consistency[e] M	Gel Consistency[e] H	Crude Protein (% wet basis) Range	Crude Protein (% wet basis) Mean
Brown rice																			
Italian, raw	2.15–2.62	2.38	2	1	1	0	0	2	0	2	0	2	0	0	2	0	0	7.1,7.3	7.2
Imported, raw	···	2.22	1	1	0	0	0	1	0	1	0	1	0	0	1	0	0	···	7.4
Italian, parboiled	2.37–2.84	2.69	3	2	1	0	0	3	0	3	0	3	0	0	1	2	0	7.3–7.6	7.4
Imported, parboiled	···	4.85	1	1	0	0	1	0	0	1	0	0	1	0	1	0	0	···	8.6
Milled																			
Italian, raw	0.94–3.58	1.61	76	34	27	15	0	52	24	76	0	54	19	3	49	23	4	5.5–8.8	6.9
Imported, raw	1.51–4.45	3.08	5	4	0	1	4	0	1	2	2	1	3	0	2	3	0	5.7–7.1	6.6
Italian, parboiled	1.67–3.02	2.18	13	6	7	0	1	12	0	13	0	13	0	0	13	0	0	5.9–7.3	6.8
Imported, parboiled	1.51–4.77	3.00	4	4	0	0	4	0	0	4	0	0	4	0	4	0	0	6.8–8.6	7.5

[a]L = Long 6.61–7.50 mm, M = medium 5.51–6.60 mm, and S = short <5.50 mm.
[b]S = Slender <3.00, M = medium 2.01–3.00, and B = bold 1.01–2.00.
[c]Gelatinization temperature type: L = low 6–7 and I = intermediate 4–5.
[d]L = Low 10.1–20.0%, I = intermediate 20.1–25.0%, and H = high >25.0%.
[e]S = Soft 61–100 mm, M = medium 41–60 mm, and H = hard 27–40 mm.

we classified samples by grain type. Long and extra long slender grain samples were equally represented as raw milled and brown rices (Table VI). Such superlong rices (>7.5 mm long) are characteristic of Surinam varieties, and are not seen in the U.S. (Webb et al 1985) or Thai long-grain varieties (Attaviriyasook 1985, Kaosa-ard and Juliano 1989). They were generally of intermediate GT (with some of low GT) and intermediate AC (with some of high AC). Gel consistency was from medium to soft. Short-grain milled rice had mainly low GT, low to intermediate AC, and soft gel consistency. Parboiled rices were mainly long-grain whereas precooked rices were either long- or short-grain. Parboiled rices had low GT, intermediate AC, and soft gel consistency, typical of U.S. long-grain rices. Precooked rices had properties similar to those of raw rices. Protein content was higher in brown rice than in milled rice, with the short-grain milled rice having a lower protein content.

Physical Properties

Brown rice. Because of similarities in physical properties, brown rice samples are discussed according to rice type. All raw and parboiled brown rice samples had high head rice yield (Table VII). All physical properties were similar and chalky grains were no more than 3%. Bonn raw rices had up to 9.6% damaged grains. In contrast, parboiled brown rices had no chalky grains but still had damaged grains. The Roman samples had more damaged parboiled rice than raw rice. Parboiling increased grain

TABLE VI
Classification of Selected Properties of 64 Raw and 42 Processed Rices in Retail Markets in Bonn, Germany (June 1988)

Sample	Price (US$/kg) Range	Price (US$/kg) Mean	Sample (no.)	Length[a] EL	L	M	S	L/W Ratio[b] S	B	Alkali Spreading Value[c] L	I	Apparent Amylose Content[d] L	I	H	Gel Consistency[e] S	M	H	Crude Protein (% wet basis) Range	Mean
Raw																			
Brown rice, long	1.70–2.56	2.00	4	2	2	0	0	4	0	3	1	0	4	0	0	4	0	8.6–9.0	8.8
Milled rice, long	1.13–5.22	2.31	42	20	22	0	0	42	0	10	32	0	37	5	11	29	2	6.8–8.7	7.8
Milled rice, short	1.42–2.04	1.63	15	0	0	1	14	0	15	15	0	5	10	0	11	3	1	5.4–7.3	6.2
Brokens, long	1.13	1.13	3	0	3	0	0	3	0	2	1	0	3	0	0	3	0	6.9–8.2	7.6
Mean/total (milled)	1.13–5.22	2.08	60	20	25	1	14	45	15	27	33	5	50	5	22	35	3	5.4–8.7	7.4
Processed																			
Brown rice, parboiled, long	3.75–4.43	4.17	3	0	3	0	0	3	0	3	0	0	3	0	3	0	0	8.0–8.6	8.3
Milled rice, parboiled, long	1.47–6.81	3.41	32	4	28	0	0	32	0	32	0	0	32	0	29	3	0	7.1–8.5	8.0
Milled, precooked, long	6.81	6.81	2	2	0	0	0	2	0	2	0	0	2	0	2	0	0	8.3,8.7	8.5
Milled, precooked, short	3.17–4.53	3.62	5	0	0	0	5	0	0	5	0	2	3	0	5	0	0	5.8–6.0	5.9
Mean/total (milled)	1.47–6.81	3.61	39	6	28	0	5	34	5	39	0	2	37	0	36	3	0	5.8–8.7	7.7

[a]EL = Extra long >7.50 mm, L = long 6.61–7.50 mm, M = medium 5.51–6.60 mm, and S = short <5.50 mm.
[b]S = Slender >3.00, M = medium 2.01–3.00, and B = bold 1.01–2.00.
[c]Gelatinization temperature type: L = low 6–7, I = intermediate 4–5, and HI = high-intermediate 3.
[d]L = Low 10.1–20.0%, I = intermediate 20.1–25.0%, and H = high >25.0%.
[e]S = Soft 61–100 mm, M = medium 41–60 mm, and H = hard 27–40 mm.

TABLE VII
Physical Attributes of Raw and Parboiled-Processed Brown and Milled Nonpigmented Rices ex Bangkok and in Retail Markets in Hong Kong, Rome, and Bonn

Rice Type and Source	Sample (no.)	Head Rice (%)	Chalky Grains (%)	Damaged Grains (%)	Translucency (%)	Whiteness (%)	Chroma Meter L*	Chroma Meter a*	Chroma Meter b*
Brown, raw									
Bangkok	6	92–97	...	...	30–50	19–24	61–67	1–3	19–20
Rome	3	96–98	0–2.3	0	36–42	18–23	59–64	2	20
Bonn	4	95–96	1.4–3.0	1.8–9.6	32–40	21–22	63–64	1–2	13–18
Brown, parboiled									
Bangkok	4	97–98	...	...	69–72	13–15	55–58	3–4	22–24
Rome	4	98–100	0	4.2–14.2	74–88	12–14	54–55	3–4	23–24
Bonn	3	94–98	0	1.8–5.0	74–100	12–14	55–57	3–4	24
Milled, raw									
Bangkok 100–25%	35	56–92	...	...	70–100	36–44	72–76	−2~1	11–14
Bangkok (waxy) 10%	11	46–98	...	...	30–38	46–56	80–83	−1	11–16
Hong Kong	93	78–100	0–2.0	0–1.0	64–100	39–47	73–76	−3~−1	11–16
Rome, local	76	92–99	0–34.1	0.3–15.2	51–100	38–53	73–80	−2~0	11–15
Rome, imported	5	95–100	0.6–2.5	0.4–2.6	76–100	34–46	70–77	−2~0	13–14
Bonn	57	37–98	0.6–8.9	0–9.7	45–100	34–50	72–79	−2~1	13–18
Milled, parboiled									
Bangkok 100–35%	19	65–98	...	...	96–100	17–25	63–68	−2~1	19–26
Rome, local	13	96–99	0	1.0–5.4	100	18–22	61–65	0–2	24–28
Rome, imported	4	97–98	0	1.0–7.3	100	18–22	60–65	0–2	25–27
Bonn	34	88–99	0	0–11.6	100	15–30	58–72	−1~3	23–26
Milled, precooked									
Bonn	7	93–98	0–2.3	0–3.6	30–32, 100	44–54	76–82	−3~−2	13–15
Brokens									
Bangkok, raw	17	0–37	...	...	44–91	36–46	74–79	−1~1	13–16
Bangkok (waxy)	2	0	...	...	20–22	54–55	83–84	−1	12
Bangkok, parboiled	2	0–4	...	...	82	21–24	64–65	0–1	20–22
Bonn	3	0	3.0–8.0	1.5–14.8	20–50	40–42	74–76	−1	15–16

translucency but reduced Kett whiteness and Chroma meter L* values and increased Chroma meter a* and b* values. Black glutinous brown rice had only 2% translucency, 7% Kett whiteness, and a Chroma meter L* value of 40, but the lowest Chroma meter b* value of 8. A mixture of red and nonpigmented brown rice from Bangkok had 22% translucency, 15% whiteness, and Chroma meter L* of 57, Chroma meter a* value of 3, and Chroma meter b* value of 15. Thus, pigments reduced brown rice translucency, Kett whiteness, and Chroma meter L* and b* values.

Milled rice. Head rice yield of milled rice was more variable than that of brown rice (Table VII). Chalky and damaged grains were also more variable in the samples from Rome and Bonn than in those from Hong Kong. Translucency was high for nonwaxy grains and low for waxy grains from Bangkok. Waxy rice has higher Kett whiteness and Chroma meter L* values than nonwaxy rice. Compared with raw brown rice, raw milled rice had higher translucency, Kett whiteness, and Chroma meter L* values and lower Chroma meter a* and b* values. Imported and local samples in Rome had similar properties. Weevil infestation seen in a few samples upon arrival from Hong Kong was removed after storage at −50° C for a few days.

Parboiled milled rice had better head rice than raw milled rice and had no chalky grains, but it did have damaged grains (Table VII). Its translucency was superior to that of raw rice, but whiteness and Chroma meter L* values were lower, and Chroma meter a* and b* values were higher. The results were similar to those observed in brown rices.

Compared with raw rice, precooked long- and short-grain rices in Bonn had higher head rice, much fewer chalky and damaged grains, more variable translucency, and higher whiteness and Chroma meter L* values (Table VII). Chroma meter a* and b* values were also similar to those of raw rice.

Rices classified as brokens contained some head rice but tended to have lower translucency and a similar but narrower range of whiteness and Chroma meter values as raw rice.

This study showed distinct preferences for specific rice quality types for each export market and for particular food preparations. Export nonwaxy rices from Thailand were mainly long-grain rices with intermediate or low GT and high to intermediate AC for raw and parboiled nonaromatic rices and low GT, low AC for raw fragrant rices. Waxy (glutinous) rices had either long or medium grains and low GT. Aromatic rices (Khao Dawk Mali and Basmati) were priced higher than nonaromatic rices. Rices in Hong Kong imported from Thailand were mainly fragrant rices. Most of the Hong Kong rices had low to intermediate AC and low GT except those imported from China which had high AC and short grains. Raw and parboiled rices in Rome retail markets ranged from long to short, from medium- to bold-shaped Italian varieties with low GT and low to intermediate AC. In contrast, raw and precooked milled rice in retail markets in Bonn had extra long to long slender grains, intermediate to low GT, and intermediate to high AC; there were also short bold grains, low-GT, and intermediate- to low-AC rices. Parboiled rices were mainly the long-grain type. Brown rice was represented in all markets except Hong Kong. Mean protein content of milled rice was below 7% in all markets except Bonn, Germany. The physical properties of the various waxy or nonwaxy varieties within the same rice type—brown raw, brown parboiled, milled raw, and milled parboiled—were similar. Head rice yields were high in export rices.

Aroma (low to intermediate AC), long grain, and high percentage of head rice were some of the important considerations for export prices for Thai rice. Kaosa-ard and Juliano (1989) showed that quality characteristics were important considerations in the traditionally rice-consuming economies such as Hong Kong: long-grain, high head rice, and soft gel consistency in the Hong Kong samples. High percentage of chalky grains and harder gel consistency were important considerations in the Rome samples. In Bonn, not a traditional rice-consumption market, only high percentage of head rice was significantly related to price; the level of processing, lot size, and packaging type were the important price considerations (Kaosa-ard and Juliano 1989).

Similar studies should be undertaken in other rice-consuming countries to obtain benchmark information on grain quality preferred by consumers and to assist rice breeding programs. Characterization of export rices from Pakistan would also be desirable to supplement the data on Thai export rices.

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