

Studies on Physicocuemical Aspect of Eating Quality and Grading of Rice¹

Sung-Ching Hsieh²

ABSTRACT

Twenty-nine varieties of Japonica and Indica rices were used to estimate the relationships among different physicochemical properties of rice grains. Another set of 15 popular rice cultivars of Taiwan were used to study the method of rice grading. Protein content varied from 5.8% to 9.4% among the varieties. Indica varieties tended to have higher protein content. Amylose contents in Japonica varieties (19.7~23.2%) are generally lower than those in Indica varieties (20.5~29.0%). The gel consistency value of Japonica rice ranged from 67.0 mm to 83.5 mm and were greater than those of Indica varieties (29.0 mm~74.0 mm). A negative correlation ($r=-0.51$, $P<0.01$) between amylose content and protein content was observed. Amylose content and gel consistency were also correlated negatively ($r=-0.82$, $P<0.01$).

For grain appearance, gloss, translucency, white center, color and grain size, etc. were evaluated. All scores were pooled and statistically analyzed for grading the samples into a, b and c classes. Taichung Sen 3, Koshihikari, etc. were classified as grade "a". Hsinchu 64, Taichung 189, etc. were classified as grade "b", while Yoshino I, Kaoshiung 141, etc. were classified as grade "c". It is suggested that the methods used in this study could be applied to practical rice grading in Taiwan.

Key words: eating quality, rice grading, amylose, protein.

INTRODUCTION

Because of the rapid economic growth in Taiwan, the problem of commercial rice grading based on grain qualities attracts more attention by the authorities concerned in recent years. Efforts are being made by various research stations to develop the rice varieties with superior milling and eating qualities. In addition, grain size, shape and appearance are also taken into account, because they largely determine the market acceptability of milled rice. Thus, our breeding materials are evaluated for (1) milling recovery; (2) grain size, shape and appearance; (3) cooking and eating characters. Similar aspects of rice grain quality have been studied extensively by the International Rice Research Institute as well as in rice breeding programs of Japan and other countries.

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² Director, Taichung DAIS.

Eating quality is generally performed by cohesiveness, tenderness and gross of boiled rice and is controlled by amylose content, gel consistency, gelatinization temperature and protein content ^(6,7,9,11). Rice starch is composed of amylose and amylopectin. Their proportion in the grain influences greatly the cooking and eating qualities ^(10,15,16). Cooked rice is more fluffy when amylose content is high, and is more sticky when amylose content is relatively low.

Present studies are concerned about the physicochemical properties of starch and protein in relation to grain quality and to set up the criteria for rice grading which will be eventually applied to the commercial rice in Taiwan.

MATERIALS AND METHODS

1. Materials

Twelve Japonica (Ponlai or Keng) varieties, II Indica (Tsailai or Sen) varieties and 6 American varieties were used to study the relationships among chemical properties of rice starch, and 10 popular cultivars of Taiwan were used as the materials to set up the criteria for rice grading.

2. Methods

1) Chemical analysis

Protein analysis was done by both DBC and Kieldahl methods. Amylose content was determined by Juliano's ⁽⁸⁾ simplified assay and auto-analytical method. Gel consistency of rice starch was measured by the method used by Cagampang et al. ⁽¹⁾. The alkali digestion test was made following the method developed by Little et al. ⁽¹³⁾.

2) Eating quality test

A. The fresh rice grains (less than 6 months after the harvest) of 14 ±% moisture content were used.

B. For low amylose varieties of rice, a 20 g sample was mixed with 27 g of water (in a ratio of 1:1.35) in a 100 cc beaker and was sealed with a sheet of thin aluminum foil. Thirty minutes later, 4 such samples were put in an automatic rice cooker (TAC-IOH Tatung Co.). In case of high amylose varieties, a 20 g sample was mixed with 42 g of water in a ratio of 1 : 2.1, and the same procedure as that for the low amylose rice was applied.

C. Four cooked rice samples (including one of Tainan 5 used as the control) were placed in a plate, then the results of eating test by 10 experienced panelers were separately recorded in specially designed record sheet.

3) Recording for grain appearance

A 15 g sample of milled rice grains were scattered in black plastic plate of 10 cm x 10 cm x 1 cm in size. The rice grains were subjected to visual inspection. Various physical characters such as white belly, etc. were recorded in the recording sheet.

4) Analysis of the data

The collected data were statistically analyzed to determine the grades.

RESULTS

1. Varietal differences in protein and amylose content and gel consistency

Among cereals, rice has protein of highly nutritious value. However, the protein content of milled rice is relatively low. As shown in Table I, protein content varied from 5.8% to 9.4% among the varieties evaluated. Indica varieties tended to have higher protein content.

Amylose content Japonica varieties is generally lower (17.7%~23.2%) than that in Indica varieties (20.5%~29.0%) (Table 1). A high value of gel consistency indicates soft eating taste, and smaller values of gel consistency indicate harder eating taste. The gel consistency values of Japonica rice ranged from 67.0 mm to 83.5 mm which are much higher than those of Indica varieties (29.0 mm~74.0 mm). Those of American varieties ranged from 64 mm to 76.5 mm, suggesting that they belonged to "soft" category.

Table 1. Varietal difference in protein content, amylose content, gel consistency and the value of alkali test in rice

Variety group	Variety	Protein content ¹ (%)	Amylose content ² (%)	Gel consistency (mm)	Alkali test scores
<i>Japonica</i>	Toyonishiki	7.31	17.70	74.50	2.30
	Sasanishiki	6.75	18.29	67.00	2.20
	Taitung 29	6.06	19.71	77.50	4.70
	Hsinchu 56	6.06	19.12	73.00	2.80
	Koshihikori	8.00	17.58	63.50	2.70
	Tainan 5	5.75	19.59	72.00	2.80
	Tainan 6	6.69	0.00	83.50	3.00
	Taichung 65	6.44	23.25	72.50	4.80
	Tainung 62	5.81	19.95	74.00	3.20
	Tainung 67	5.94	20.54	72.00	4.50
	Kaohsiung (sel.) 1	6.69	20.30	76.00	2.00
	Kaohsiung 139	6.19	19.00	71.50	2.20
<i>Indica</i>	Taichung Native 1	7.50	28.10	29.00	5.30
	Kaohsiung Sen 2	9.31	27.27	41.50	2.20
	Taichung Sen 3	6.06	20.54	73.00	2.00
	Taichung Sen 5	7.19	29.04	36.00	5.00
	Kaohsiung Sen 7	7.88	29.04	32.50	2.00
	Taichung Sen 10	6.69	21.48	74.00	2.00
	Chianung Sen 8	7.50	20.66	55.50	1.80
	Chianung Sen 16	7.38	29.75	59.00	1.50
	Tainung Sen 12	8.56	25.26	33.00	4.30
	Tainung Sen Yu 2611	8.00	28.10	29.00	5.50
	Hsinchu Ai Chu Chien	8.06	26.44	38.00	2.00
U.S.A.	Coloro	7.31	17.23	71.00	4.00
	Zenith	5.88	18.53	72.00	2.20
	Calrose	7.06	18.29	73.00	2.80
	Bluebonnet 50	8.44	23.37	65.50	1.70
	Century 231	9.06	17.58	64.00	3.00
	Nato	9.44	19.69	76.50	3.30

¹ By Kjeldahl method.

² By Simplified method.

The gelatinization temperature is another important factor related to the softness of cooked rice. The gelatinization temperature can be indirectly measured by the alkali digestion test. The results of the alkali test are given in the last column of Table 1. The results of alkali test varied among varieties, but there was no marked difference between Indica and Japonica groups.

2. Correlation between chemical characters related with eating quality

There was a negative correlation ($r=-0.51$) between gel consistency and protein content (Fig. 1). There was a negative correlation between amylose content and gel consistency ($r= -0.82$), indicating that the higher the amylose content the smaller the gel consistency (Fig. 2 and Table 2). These results are in agreement with the results obtained by Hsieh and Kuo ⁽⁴⁾.

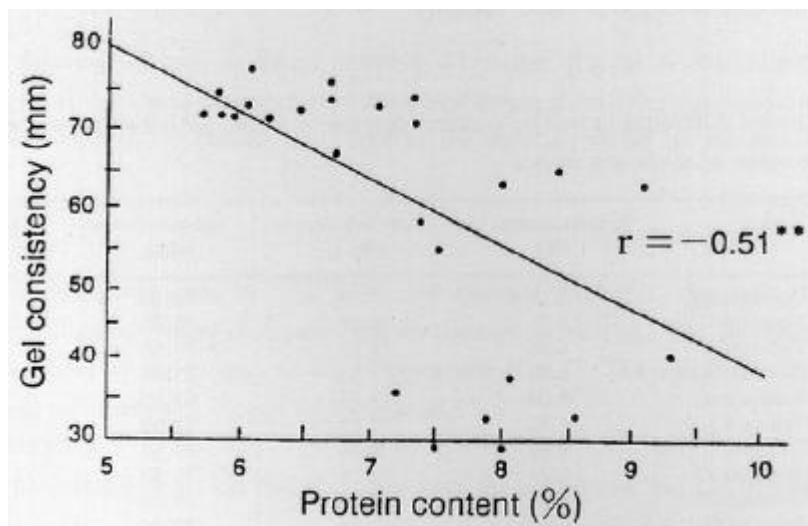


Fig. 1. Correlation between protein content and gel consistency in rice grain.

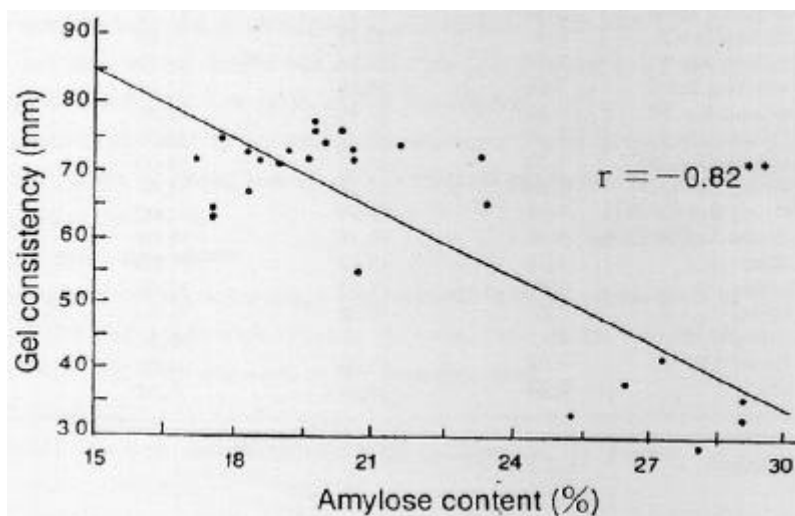


Fig. 2. Correlation between amylose content and gel consistency in rice grain.

Table 2. Correlation between different chemical characters related with eating quality in rice

	Protein content (by DBC method)	Amylose content (by Simplified method)	Amylose content (by Auto analysis)	Gel consistency	Alkali-test scores
Protein content (by Kjeldahl method)	0.95**	0.34	0.43*	-0.51**	-0.03
Protein content (by DBC method)		0.30	0.33	-0.44**	-0.05
Amylose content (by Simplified method)			0.87**	-0.82**	-0.21
Amylose content (by Auto analysis)				-0.79**	0.20
Gel consistency					-0.29

3. Physicochemical properties of rice cultivars in Taiwan

1) Milling recovery

Milling yield of rough rice represents the quantity of total milled rice that can be obtained from a unit of rough rice. The brown rice milling recovery rate in Japonica varieties ranged from 80.5% to 83% (Table 3). Milling rate is usually around 70 % in Indica rice, but differs according to varieties ⁽⁴⁾. The milled rice is separated into broken and whole grains and the proportion of whole grain is called "head rice" recovery which ranges from 62.1% to 70.8% in the Japonica cultivars in Taiwan. The long grain or Indica varieties are usually lower (about 60%) in head rice rate.

Table 3. Physicochemical properties of rice cultivars in Taiwan

Variety	Milling recovery		Grain appearance				Cooking and eating quality			
	Brown rice (%)	Head rice (%)	Size	Shape	Degree of translucency	White center & belly	Gel. tem.	Amylose content	Protein content	Gel consistency
Tainan 5	82.8	65.7	Short	Bold	3	1	Low	18.31	6.89	Soft
Tainan 7	83.1	69.4	Short	Bold	2	1	Low	17.61	6.31	Soft
Hshin0chu 64	83.3	64.7	Short	Bold	2	2	Low	18.57	6.09	Soft
Tainung 68	81.5	69.8	Short	Bold	3	1	Low	18.85	6.37	Soft
Taichung 189	82.9	68.8	Short	Bold	3	1	Low	17.22	6.26	Soft
Taipei 309	89.8	70.8	Short	Bold	3	1	Low	19.56	6.10	Soft
Kaushiung 141	80.8	64.4	Short	Bold	3	1	Low	19.52	6.60	Soft
Yoshino 1	80.7	62.1	Short	Bold	4	4	Low	18.13	5.99	Soft
Taichung Yu 278	80.5	66.5	Short	Bold	3	1	Low	18.93	6.47	Soft
Taichung Yu 287	82.3	66.1	Short	Bold	3	3	Low	19.35	6.62	Soft

2) Grain size, shape, and appearance

Grain size and shape vary among varieties. In general, long grains are preferred in India, U.S.A. and European countries, but in Southeast Asia including Taiwan and Japan, medium and short grains are preferred. The cultivars given in Table 3 belong to short grain of bold type which are shorter than 5.55 mm.

Grain appearance is largely determined by endosperm opacity, the amount of chalkiness, either on the dorsal side of the grain (white belly) or in the center (white center), and the condition of the "eye". Six classes are used to determine the degree of endosperm chalkiness in the present study, while four classes are used by IRRL. Except for Tainan 7, Hsinchu 64, and Yoshino I, all other cultivars given in Table 3 have a translucence grade of 3. Hsinchu 64, Taichung Yu287, and Yoshino I had larger white center graded 2, 3 and 4 degrees, respectively, Tainan 5, Tainan 7, Tainung 68, Taichung 189, Taipei 309, Kaoshiung 141, and Taichung Yu 278 had smaller white center of degree 1. In general, the smaller the white center, the higher the translucency and the better the grain quality. Amylose content of popular Japonica cultivars in Taiwan given in Table 3 ranged from 17.2% to 19.4%, all being soft in gel consistency. The protein content of these cultivars are about 6 %.

4. Grading of grain quality of popular rice cultivars in Taiwan

Rice quality is graded by test panel scores which are based on milling rate, grain appearance and eating quality. The results of experiments are shown in Table 4. The pooled scores of grain appearance and taste panel given in Table 4 indicated that the tested varieties can be grouped into a, b, and c classes after statistical analysis of the data. There were significant differences among a, b, and c groups but no statistical difference among the varieties within the same group. Taichung Sen 3, Koshihikari, Tainung 67, Tainan 7, and Toyonishiki can be regarded as the first-grade, and Taichung 189, Taichung Sen 10, Hsin-chu 64, Taipei 309, and Taichung 65 are the second-grade, while Taichung-yu 278, Yoshino I, Kaohsiung 141, Taichung Yu 287, and Kaohsiung Sen 7 are the third-grade rices. It is noticed from Table 4 that the scores of grain appearance agreed very well with the pooled scores of grain appearance and eating quality with the exception of Taichung-Yu 278. Eating quality scores did not fit very well with the pooled scores. This is due to different taste feelings of the panelers. More exercise of the panelers and increased number of them will be needed.

5. Effects of locations on rice grain quality

It is well known that environmental factors in different locations will influence on grain quality of rice. The milled rice of Tainung 67 collected from 10 locations in Changhua area were subjected to grading based on similar criteria mentioned already. The results are shown in Table 5. The products of the same variety at different locations, showed different grades a, b, and c. It is therefore difficult to define the best-quality variety which is adapted to all locations. The uniform cultural practices and careful post-harvest handling of rice are essential for the production of high quality rice.

Table 4. Grading of grain quality of rice cultivars determined by grain appearance and test panel scores

Variety	Grain appearance (A)			Taste panel score (B)			Pooled score (A+B)/2		
	Average point	Order	Class	Average point	Order	Class	Average point	Order	Class
Taichung Sen 3	0.864	2	a ¹	0.841	1	a	1.025	1	a
Koshihikari	0.871	1	a	0.614	2	a	0.954	2	a
Tainung 67	0.514	4	a	0.472	5	a	0.747	3	a
Tainan 7	0.384	5	a	0.408	6	a	0.434	4	a
Toyonishki	0.596	3	a	-0.601	14	c	0.298	5	a
Taichung 189	0.207	6	b	-0.060	9	b	0.218	6	b
Taichung Sen 10	-0.062	8	b	0.093	7	b	0.070	7	b
Hshinchu 64	-0.237	10	b	0.496	4	a	-0.072	8	b
Taipei 309	-0.116	9	b	-0.219	10	b	-0.188	9	b
Taichung 65	-0.018	7	b	-0.460	13	c	-0.241	10	b
Taichung Yu 278	-0.257	11	b	-0.362	12	c	-0.368	11	c
Yoshino 1	-0.761	13	c	0.564	3	a	-0.441	12	c
Kaoshiung 141	-0.421	12	c	-0.297	11	c	-0.475	13	c
Taichung Yu 287	-0.791	15	c	0.538	8	b	-0.706	14	c
Kaoshiung Sen 7	-0.772	14	c	-1.543	15	c	-1.275	15	c

¹ a, b, and c classes are determined by the levels of significance after statistical analysis.

Table 5. Difference in grain quality of rice due to the localities of cultivation in Changhua area

Variety	Location	Grain quality scores ¹	Class
Koshihikari	Er-lin	0.590	a
Tainung 67	Yen-lin	0.526	a
Tainung 67	Chi-chio	0.450	a
Koshihikari	Taichung	0.286	b
Tainung 67	Yen-lin	0.172	b
Tainan 5	Er-lin	0.081	b
Tainung 67	Chi-hu	0.164	b
Tainung 67	Pei-tou	0.026	b
Tainung 67	Ten-chion	-0.029	b
Tainan 5	Chi-hu	-0.080	b
Tainung 67	Er-lin	-0.218	b
Tainung 67	Chu-tun	-0.220	b
Tainung 67	Pi-tou	-0.323	b
Mixture	Unknown	-0.451	c
Tainung 67	Chi-hu	-0.875	c

¹ The value of $\frac{1}{2}$ (A+B), see Table 4.

DISCUSSION

With the rapid economic growth, people in Taiwan are more concerned about quality than quantity of rice in recent years. The authorities concerned are going to establish the rice grading system so as to determine the marketing price according to the quality grades. What is the base to be used to determine the grades of rice? This is an important question which we have to solve.

The grain quality of rice is conditioned by its physicochemical properties which are influenced greatly by genotype and environmental factors such as locations, cultural practices and post harvest management. Grain appearance generally plays an important role in grain quality determination ^(4,17). Grain appearance is determined mainly by the opacity of endosperm, the amount of chalkiness, either on the dorsal side of the grain (white belly) or in the center (white center), and the condition of the "eye". In some varieties the grain tends to break more frequently at the "eye" pit left by the embryo when it is milled. This will influence greatly the rate of head rice recovery. Most Japonica varieties such as Tainan 5, Taichung 189, etc. had the head rice recovery rate of 65~70%. The longer the grain length, the lower the head rice rate. These results are in agreement with those from previous experiment ⁽¹²⁾. Translucency and gloss of rice grain are closely related with eating quality⁽²⁾. The translucency of Japonica type cultivars such as Tainan 5, Tainung 68, Taichung 189, Kaoshiung 141, etc. are the same as that of Japanese high-quality rice Koshihikari ⁽⁵⁾. Translucency is a heritable trait ⁽¹²⁾, and selection for this character is effective. In Taiwan, selection for non-chalky grains is made only in the later generations (F5-F6), so that it is difficult to eliminate chalky grains. For instance, the grain of the most popular variety, Tainung 67, have some degree of chalkiness. Therefore, selection for non-chalky grain should be made in an earlier generation in rice breeding programs.

Cooking and eating characteristics are largely determined by the properties of starch that makes up 90% of milled rice. Gelatinization temperature, amylose content, gel consistency and protein content influence the cooking and eating qualities of milled rice ^(6,12). Cooking and eating qualities of milled rice are influenced greatly by amylose content ^(6,9,11,14). High-amylose rices cook dry, are less tender, and become hard upon cooling, while low-amylose rices cook moist and sticky. The Keng or Japonica rices are usually lower in amylose content (18~20%) and relatively sticky and glossy, while Sen or Indica rices are higher in amylose content (27~28%) and are dry, fluffy and harder in texture when cooked ^(6,9,14).

Eating quality also differs among varieties with the same level of amylose content ^(5,15,16). This is due to difference in gel consistency which influences the tenderness of cooked rice ⁽¹⁾. In Taiwan, gel consistency is evaluated only with the products of advanced yield trials or those of later generations. More rapid methods of testing should be developed so that it would be possible to evaluate this trait in earlier generations. Protein content is another important character for grain quality. It is influenced by both genotype and environmental conditions and ranges from 5 to 9 percent as reported in this and other papers ^(3,7). As mentioned earlier, grain and eating qualities of rice are determined by grain appearance, chemical properties, etc. The measurement of chemical properties is time consuming and can not cover all

quality factors. According to studies made in Japan, only 75 % of grain quality can be measured by chemical analysis, and the rest depends on human taste panel scores. In the present study, the scores for grain appearance and the scores of taste panel test were coupled together to determine the final grades of the rice sample. By statistical analysis, this technique of rice grading seems to be applicable in Taiwan at the present time. The taste panel scores are greatly influenced by taste feelings of the individual panelers and sometimes can be biased. To eliminate such human error, a method to determine the grading of rice by physicochemical factors is hoped to be developed in the future.

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稻米食味的理化性及稻米分級之研究¹

謝順景²

摘 要

本研究利用29個粳、稻品種為材料，探討稻米各種理化性與稻米品質間之關係；另使用15個廣被栽培的臺灣品種進行稻米分級法之基本研究。結果得知稻米蛋白質之含量介於5.8%~9.4%之間，隨品種不同而不同，秈稻之蛋白質含量有較高的傾向。粳稻之直鏈澱粉(amylose)含量(19.7~23.2%)一般介於67.0 mm~83.5 mm之間，而一般較秈稻者(29 mm~74.0 mm)為軟。蛋白質含量與直鏈澱粉含量之間有負相關關係($r=-0.51$)直鏈澱粉含量與膠體軟硬之間亦有負相關關係 ($r=-0.82$)。

稻米分級基本研究係根據米粒之外貌(光澤透明度、腹白度，米之顏色及大小等)及米飯之物理性(光澤、顏色、彈性、粘性等)及食味(香氣及柔軟性等)來評定。供試品種經按本場研究所(暫)設定之標準予以評分。數據經綜合統計分析後可區分成a、b及c三群，其中越光、台中秈三號等歸為a群(一級)新竹64號、台中 189號等為b群(二級)，而吉町一號、高雄141號等歸為c群(三級)。由本試驗所創方法可應用於台灣稻米之分級。

關鍵字：食味品質、米質分級、直鏈澱粉、蛋白質。

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² 台中區農業改良場場長。