【Article】

Eating Quality Evaluation for Cooked Rice (1)

—Application of Maltiple Regression on the Sensory Evaluation and Physical Measurements.—

Masako Konishi*, Kuniyasu Ide*, Keiko Hatae**, Atsuko Shimada**

The relationship between overall acceptability and physicochemical properties was carried out on 31 types of rice employing sensory evaluation and objective analysis.

1. There was a high correlation between sweetness and overall acceptability in both analytical and preference tests (r=0.88 and r=0.92), but differences between samples were small.
2. For taste, a high correlation (r=0.95) between desirability of taste and overall acceptability was observed, but there was only a low correlation (r=0.23) between strength of taste and overall acceptability, and moreover, a low correlation (r=0.25) between preference and analytical tests.
3. A high multiple correlation coefficient (MR) of 0.97 for the overall acceptability using four attributes; desirability of stickiness, desirability of sweetness, whiteness, and transparency was obtained by the multiple regression analysis.
4. Desirability of stickiness, transparency, and whiteness, which make a large contribution to overall acceptability were substituted by objective measurements. Desirability of stickiness was expressed in terms of amylose ratio, thousand grain weight of rice, and whole rice grain rate (MR=0.87), transparency was expressed in terms of the L value and the luster as 60° and 75° angles of incidence (MR=0.66), and whiteness was expressed in terms of whiteness level and the b value (MR=0.71).
5. Overall acceptability of cooked rice was expressed in terms of three attributes, amylose ratio, L value and luster (60°), with a multiple correlation coefficient of 0.76.

Keywords: multiple regression analysis, objective measurement, cooked rice, sensory evaluation

Introduction

Rice is the staple food of Japanese people, and since the middle of the Taisho period (1912~1926), numerous studies[1)] have been conducted with regard to evaluating the eating quality of cooked rice. Most of these studies dealt with the physical properties[2~15)] of cooked rice by objective measurement, and sensory evaluations. Chikubu et al.[16,17)] reported that the eating quality of Japonica type rice was expressed in five objective ways which relate to some attributes influencing the physical properties of rice; Horino et al.[18~20)] reported that the eating quality of Japonica type rice was based on several mineral components and their proportions. These results were used in development of the rice taste analyzer[21,22)] utilizing a near-infrared photometer. The rice taste analyzer have been commercially available, but at present, they could not be considered to be sufficiently accurate[23,24,42)].

Sensory evaluation values that are used as the basis for the rice taste analyzer were judged less

* Tokyo Gas Co, Ltd. Fundamental Technology Research Laboratory.
** School of Human Life and Environmental Science, Ochanomizu University.

than adequate since only limited attributes which include appearance, aroma, taste, stickiness, hardness, and overall acceptability for judging rice quality were evaluated. This sensory testing method was developed by the Food Agency and the National Food Research Institute[25,26,34~36]. As reported earlier[27], Japanese people look for many different elements in the eating quality of cooked rice, and particularly cooked white rice. The appearance which includes gloss, whiteness, plumpness, and transparency are considered important in the eating quality of cooked white rice. Furthermore, preference test using hodonic scale alone is insufficient; therefore, analytical test using intensity scale is essential.

This study aimed to understand the eating quality of rice using sensory evaluations such as preference and analytical test[27]. Furthermore, the relation between sensory values and objective method values of the eating quality of rice, including appearance, which have not been studied before except for whiteness level,was carried out.

Materials and experimental methods

1. Materials

A total of 31 kinds of rice were used (Table 1)[28,29]. Brown rice, a domestically-produced brand rice was obtained immediately after harvest and was milled while other samples were procured in already milled form. The rice was stored for 0～6 months at 4°C.

1) Milling and pulverizing methods

Brown rice was milled using a household rice miller (National KG-1,000) to 90%, and the bran was removed with a thin cotton cloth. Objective measurement of the rice was done using either the grains, or rice powder pulverized to a maximum particle size of 300 μm with a cyclone sample miller (UDY Corporation).

2) Cooking method

Water was added to washed 500g of rice to give final volume of 1.5 times w/w. The rice was left immersed for 1 hour at 20°C, then cooked in a gas-powered rice cooker (Tokyo Gas: PA-106) and steamed. After 15 minutes steaming, it was lightly mixed and a cloth was placed over the cooking vesse. The vessel was left in a constant temperature and a humid chamber at 20°C and 60% respectively for 1 hour before use for sensory evaluations and objective measurements.

Table 1. Samples

	Production Area	Ranking
Koshihikari	Niigata	◎A
Akitakomachi	Akita	A
Kinuhikari	Ibaraki	A
Kirara 397	Hokkaido	A
Sasanishiki	Miyagi	A
Hananomai	Yamagata	A
Fukuhikari	Fukui	A
Yukinosei	Niigata	A
Ozora	Mie	A'
Koganenishiki	Kochi	A'
Koshihikari	Chiba	A'
Koshihikari	Nagasaki	A'
Tsugaruotome	Aomori	A'
Nipponbare	Shiga	A'
Notohikari	Ishikawa	A'
Hatsuboshi	Chiba	A'
Minamihikari	Kagoshima	A'
Koganemasari	Kagoshima	B
Toyonishiki	Akita	B
Nakateshinsenbon	Okayama	B
Fuyo	Nara	B
Yukihikari	Hokkaido	B
Asukaminori	Nara	B'
Rinkusu' 89		
Nishiki	California U. S. A.	
Long grain rice	California U. S. A.	
standard price rice X		
standard price rice Y		
standard price rice Z		
Koshihikari (Stored rice)	Niigata	Storage (37°C 1 month)
Asukaminori (Stored rice)	Nara	Storage (37°C 1 month)

Table 2. Evaluation attributes

attributes	preference test	analytical test
transparency		○
gloss		○
whiteness		○
plumpness		○
aroma	○	○
taste	○	○
sweetness	○	○
hardness	○	○
stickiness	○	○
overall acceptability	○	

○: conducted

2. Sensory evaluations

In each session, two of the 31 rice samples were evaluated using a 7 point scale anchored from +3 to −3 (+3=greater/like extremely, −3=lesser/

dislike extremely). Nipponbare was used as the reference sample anchored as 0 in all sessions. Two sessions were conducted in a day for 15 days. The transparency, gloss, whiteness and plumpness that made up the appearance were evaluated by analytical test only. Other attributes, were also evaluated by analytical test and preference test to determine its desirability. Tests were also conducted for overall acceptability. The testing panel consisted of 15 researchers from Ochanomizu University (Table 2).

3. Objective measurement of rice

1) One thousand grain weight, whole rice grain rate, whiteness level

Evaluations were performed on rice grains. The weight of 1,000 grains of brown rice or milled rice was expressed as thousand grain weight. The whole rice grain rate (WRGR) for brown rice was considered as the proportion of whole grains relative to the total number of grains, calculated by grading into whole grains, immature grains, colored grains, opaque rice kernel, and cracked kernel rice. The WRGR for milled rice was considered to be the proportion of whole grains relative to the total number of grains, calculated by grading into whole grains, powdery grains, broken kernels, and colored grains. The grade of grain was determined by providing light on 1,000 grains of rice, discriminated by color and optical characteristics according to the amount of light passing through the rice using a rice grain discriminator (Ketto Electric Laboratory RN-500).

Whiteness level was measured using a photodiode whiteness lerel tester (Ketto Electric Laboratory c-300) according to the standard measuring method[30] published by the Food Agency.

2) Rice Composition

Composition was studied using rice powder. Water content was measured by heat drying at atmospheric pressure (105±1°C, 5 hours)[30]. Nitrogen was measured using micro-Kjeldahl method (Buchi 339), multiplied by 5.95 to obtain the amount of crude protein[37]. Ash content was measured by the 550°C direct ash conversion method[37]. Mineral composition was studied by shaking powdered rice for 24 hours in 1% aqueous hydrochloric acid (toxic metal measurement reagent), then filtering and using the filtrate. Sodium and potassium were measured with ion chromatograhy equipment (Dionex) under the following test conditions. Sample volume: 50 μl, column: Ion-pack cation column (cs-3), elution solvent: 20 mM hydrochloric acid, regeneration solution: tetrabutyl ammonium hydroxide, flow rate: 1.0 ml/min. For magnesium and calcium, 50 ml of the fluid sample was placed in a beaker, 5 ml of hydrochloric acid (toxic metal measurement reagent) added, then poured into a watch glass, leaving a path for vapor to escape. The mixture was then heated using a burner and allowed to undergo acid decomposition until the residue was approximately 40 ml. After cooling, purified water was added to make up to 50 ml again.Magnesium and calcium are then measured using an inductive coupled plasma emission spectrometry system (Seiko Denshi Kogyo: JY 48 P). Amylose and amylopectin proportions were measured by iodine coloration comparison[32] after adjusting the rice powder off with purified starch using the alkali method[31].

4. Objective measurements of cooked rice

1) Volume

Water was added to the cooking vessel until it was at the same height from the top of the vessel as the surface of the cooked rice. The amount of water was then measured in a measuring cylinder.

2) Coloration, luster

A 120 g sample was placed evenly in a laboratory dish for color measurement. A chroma meter (Minolta: CR-200, CM-500) was used to measure Xxy, Lab, L*a*b*,WI (white chromaticity) and YI (yellow chromaticity). Luster was measured using a variable angle gloss meter (Nihon Denshoku VGS-300 A), obtaining the value of normal reflection/amount of scattered reflection when light is shone at angle of incidence of 60, 75 and 80 degrees.

3) Water content

Water content was measured by heat drying at atmospheric pressure[30].

4) Texture

Hardness, stickiness, adhesiveness, and cohesiveness were measured by a texturometer (Zenken). Eleven grams cooked rice was placed in a rice cup 38 mm wide and 13 mm deep, then compressed using an 18 mm diameter lucite plunger, with a mastication speed of 6 cycles/minute, clearance of 1.2 mm, chart speed of 750 mm/minute and a measurement voltage of 1 V.

Results and discussion

1. Sensory evaluations

Three types of Japanese standard price rice,

Table 3. Average values of sensory evaluation scores

					analytical test					preference test					
	transparency	gloss	whiteness	plumpness	aroma	taste	sweetness	hardness	stickiness	aroma	taste	sweetness	hardness	stickiness	overall acceptability
Koshihikari (Niigata)	0.67	1.00	0.40	0.87	0.07	0.60	0.33	−0.80	1.00	0.40	0.47	0.67	0.33	0.87	0.93
Akitakomachi	−0.13	0.47	−0.87	−0.13	−0.07	0.07	0.00	0.07	0.00	0.20	−0.20	0.00	0.27	0.00	0.07
Kinuhikari	0.73	1.13	−0.07	0.07	−0.60	0.47	0.20	−0.33	0.60	0.27	0.33	0.13	0.07	0.40	0.33
Kirara 397	−0.60	−0.33	−0.93	−0.47	0.73	0.40	−0.07	1.07	−0.73	−0.07	−0.27	−0.27	−0.20	−0.80	−0.67
Sasanishiki	−0.07	0.60	−0.80	−0.07	0.27	−0.13	−0.07	0.27	0.13	0.27	−0.27	−0.13	−0.53	0.00	0.00
Hananomai	−0.07	0.53	−0.33	0.07	0.07	0.07	−0.13	0.40	0.20	0.47	−0.20	0.07	−0.33	−0.20	−0.33
Fukuhikari	0.60	1.13	0.93	0.47	−0.33	−0.13	−0.07	−0.53	0.40	0.27	−0.07	0.00	0.00	0.13	0.13
Yukinosei	0.20	0.93	−0.33	0.33	−0.07	0.47	−0.07	−1.00	0.67	0.27	0.20	0.13	−0.53	−0.07	−0.20
Oozora	−0.13	0.13	−0.33	0.40	0.07	−0.07	−0.33	0.20	0.07	−0.47	−0.40	−0.20	0.00	−0.07	−0.47
Koganenishiki	0.07	0.53	0.07	0.07	−0.13	−0.13	−0.27	0.47	0.13	0.07	0.07	0.00	−0.27	−0.13	0.07
Koshihikari (Chiba)	0.80	1.47	0.27	0.27	−0.07	0.20	0.00	0.00	0.67	0.33	0.00	0.47	0.33	0.20	0.27
Koshihikari (Nagasaki)	0.53	1.20	−0.20	−0.07	0.00	0.27	−0.20	−0.73	1.13	0.13	−0.27	0.07	−0.20	0.40	−0.13
Tsugaruotome	0.73	0.67	−0.53	0.60	0.13	−0.13	0.27	−0.27	0.33	0.33	0.20	0.13	0.20	0.33	0.33
Nipponbare	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Notohikari	0.33	0.73	0.27	0.20	0.07	0.40	−0.07	−0.33	0.87	0.33	0.07	0.07	−0.20	0.27	0.07
Hatsuboshi	0.50	0.79	0.50	0.21	−0.43	−0.14	−0.14	−0.07	0.21	0.14	−0.14	−0.14	−0.14	−0.21	−0.43
Minamihikari	−0.07	−0.40	0.07	0.27	−0.07	−0.07	−0.53	0.20	−0.20	0.47	−0.53	−0.60	−0.13	−0.27	−0.40
Koganemasari	−0.27	−0.07	−0.20	0.29	0.07	−0.07	−0.33	0.87	−0.53	−0.13	−0.40	−0.27	−0.33	−0.53	−0.80
Toyonishiki	−0.33	−0.47	−0.27	−0.07	−0.07	−0.07	−0.40	0.33	−0.73	0.07	−0.33	−0.13	0.07	−0.60	−0.47
Nakateshinsenbon	0.47	0.47	−1.20	0.00	−0.13	0.40	0.13	0.00	0.60	−0.07	0.20	0.13	0.13	0.40	0.33
Fuyou	−0.53	−0.60	−0.53	−0.07	−0.07	0.13	−0.27	0.60	−0.33	0.00	−0.13	−0.40	−0.20	−0.27	−0.47
Yukihikari	−1.33	−1.07	−1.27	−0.40	0.53	−0.53	−0.53	1.13	−1.00	−0.47	−0.60	−0.40	−0.53	−1.07	−1.27
Asukaminori	−0.40	−0.33	−0.47	−0.20	0.00	−0.13	−0.53	0.33	−0.27	−0.80	−0.47	−0.40	0.07	−0.40	−0.53
Rinkusu '89	−1.50	−2.19	0.38	−2.00	1.44	0.63	−0.94	0.19	−1.87	−1.12	−1.37	−1.19	−0.94	−1.56	−2.00
Nishiki	0.20	0.47	0.20	−0.40	−0.20	0.20	−0.40	−0.20	0.07	−0.60	−0.87	−0.80	−1.00	−0.73	−1.27
Long grain rice	−2.00	−2.47	−0.20	−2.20	0.47	−0.87	−1.40	1.87	−2.60	−0.47	−1.53	−1.27	−1.80	−2.40	−2.53
standard price rice X	1.13	1.07	−0.33	0.13	−0.20	0.36	0.60	−0.67	1.07	0.20	0.33	0.47	0.00	0.47	0.20
standard price rice Y	−0.67	−0.53	−0.60	−0.27	−0.33	0.07	0.00	0.47	−0.07	−0.07	−0.20	0.00	−0.40	−0.47	−0.40
standard price rice Z	−0.80	−0.80	−0.40	−0.20	0.00	−0.07	−0.40	0.20	−0.27	−0.20	−0.53	−0.33	−0.40	−0.33	−0.80
Koshihikari (stored rice)	−0.67	−1.07	−1.53	−0.47	0.73	0.87	−0.13	−0.40	−0.53	−0.93	−0.73	−0.20	−0.33	−0.60	−0.93
Asukaminori (stored rice)	−1.53	−1.80	−1.13	−0.53	1.07	0.40	−0.73	0.80	−1.13	−1.00	−1.13	−0.80	−0.60	−0.87	−1.53

Japonica and Indica type rice produced in California were used in addition to 23 types of domestic brand rice produced in different areas in Japan and with different Japan Grain Inspection Association grade, which included 5 ranks of eating quality of rice by sensory evaluation. The number of samples was expanded to a total of 31 by adding artificially aged rice produced by storing the highest and lowest ranking rice packed in polyethylene bags at 37°C for 1 month after milling.

Table 2 shows the result of preference and analytical test on various attributes. Four attributes for appearance (transparency, gloss, whiteness, and plumpness) were found to have desirable characteristics[27]. In this study, aroma, taste, and texture attributes were subjected to both preference and analytical tests while the appearance was subjected to analytical test only.

The average values for eating quality according to the sensory evaluations are shown in Table 3. Overall acceptability ranged from 0.93 to −2.53, showing that the samples had successfully included rice with a variety of eating qualities. Statistical analysis was done using a data processing software "Multi-Tokei" of "Social survey Research Information Inc.". A one-way analysis of variance showed that all 15 attributes, including overall acceptability were significant at P 0.01. Koshihikari from Niigata prefecture was evaluated as the most desirable in terms of overall acceptability and Indica type rice

Table 4. Correlation between analytical and preference test

attributes	correlation coefficients
aroma	−0.66**
taste	0.25
sweetness	0.91**
hardness	−0.52**
stickiness	0.95**

** a level of significance of 1%

from California was considered least desirable.

Table 4 shows the correlations between the analytical and preference test for aroma, taste, sweetness, hardness and stickiness. A significant negative correlation ($r=-0.66$ and $P<0.01$) was found in cooked rice with aroma. Strong aroma was suggested as the reason why consumers did not like the Indica type rice which was imported as an emergency measure due to bad harvest in cool summer[33], and our current evaluation results agreed with this phenomenon. For sweetness and stickiness, there were significant correlations ($r=0.91$ and $P<0.01$; $r=0.95$ and $P<0.01$, respectively) between the analytical and preference test. The sweeter and the more sticky the rice is,the greater is the preference. In contrast, the correlation between the analytical and preference test for taste was extremely low ($r=0.25$), showing the importance of quality more than strength of taste.

Table 5 shows the standard deviation of each attribute. The standard deviation was large in gloss, strength of stickiness, and presence of transparency. The standard deviation of each of these three attributes was greater than that of the overall acceptability. In contrast, the attributes with particularly small standard deviation were strength of taste and strength of sweetness.

Twelve attributes were found to have significant correlation coefficients with the overall acceptability ($P<0.01$), particularly on desirability of taste, sweetness and stickiness ($r=0.95$). In contrast, there was no significant correlation on whiteness and strength of taste.

To substitute sensory evaluation with objective method for overall acceptability, the sensory evaluation attributes contributing to overall acceptability were clarified using a stepwise regression analysis. As a result, four attributes; desirability of stickiness, desirability of sweetness, whiteness and transparency, were found to contribute to overall acceptability with a high multiple correlation coefficient ($r=0.97$).

Table 5. Character of each attibute

attributes	average	standard deviation	correlation coefficients[(1)]
transparency	−0.12	0.56	0.87**
gloss	0.05	0.99	0.87**
whiteness	−0.27	0.34	0.21
plumpness	−0.10	0.38	0.86**
analytical[(2)]			
aroma	0.09	0.18	−0.64**
taste	0.11	0.12	0.23
sweetness	−0.21	0.15	0.88**
hardness	0.11	0.39	−0.66**
stickiness	−0.07	0.66	0.89**
preference[(3)]			
aroma	−0.07	0.19	0.76**
taste	−0.28	0.22	0.95**
sweetness	−0.16	0.19	0.92**
hardness	−0.24	0.19	0.85**
stickiness	−0.26	0.41	0.95**
overall acceptability	−0.42	0.52	1.00

(1) correlation coefficients between overall acceptability and each attribute
(2) analytical test ＋ : strong − : weak
(3) preference test ＋ : like − : dislike
** a level of significance of 1%

2. Objective measurements of rice and cooked rice

Thirty one types of rice and cooked rice were evaluated for their composition using objective method. Table 6 shows the average values, atandard deviations and coefficients of variation. The coefficients of variation were used to compare the dispersion for measurements of each attribute.

Since there was a high correlation between the thousand grain weight of brown rice and that of milled rice, only the results for thousand grain weight of milled rice with its large coefficient of variation was shown. Hokkaido's Kirara 397 and Yukihikari had extremely low whiteness level but high protein values. Inatsu[13] reported that average protein content of 214 rice samples produced in the Sorachi area in Hokkaido were higher than for Tohoku and Hokuriku regions, but were similar to those in other regions. Consequently, the Hokkaido rice used in this study had high protein values. Indica type rice are said to have relatively high proportions of amylose, and our Long grain rice samples (Indica type) has 26%, but Rinksu'89 (Indica type) has only 18% which was similar to Japonica type rice (short grain). Potassium, magnesium, calcium, and sodium were most abundant in all types of rice. This concurred with the findings reported by Horino et al.[19]. Texturometer measurements showed that Long grain rice (Indica type) had the highest value for hardness, 17.9 T. U., and the lowest value for stickiness, 0 T. U..

The appearance of rice, which includes coloration and luster were measured.

Until now, food colors have been used to as a gauge to grade the quality of agricultural[38] food and animal products[39]. Study on whiteness level[28,29] and coloration in rice which describes quality control of brown rice using image processing of transmitted light[39] were reported. Using WI (white chronaticity: ASTM E 313) and YI (yellow chromaticity: ASTM E 313), values of Yxy, Lab, and L*a*b* for color specifications in the measurement of cooked rice[37~39], we found high correlations in L, L* and WI values, and b, b* and YI values, and between the values, L and b values had the largest coefficients of variation. The L value was Hunter"s lightness level of light and the b value represented yellow-blue. Futhemore there was a high correlation between a and a* values, but only a* values are shown in Table 6 because their coefficient of variation was larger than a. The x and y values representing chromaticity were the same for all rice samples, so we did not show the data.

In general, the value of luster (G value) is expressed in terms of the luster of glass with coefficient of refraction n=1.567 as a standard set to 100, regardless of the angle of incidence. The G values of 31 types of rice were 1.63~4.03 at 60°, 1.39~3.45 at 75°, 0.11~0.93 at 80°. All G values were lower than a standard and with low coefficient correlations between 60° and 75° (r=−0.25), 75° and 80° (r=−0.24), and 60° and 80° (r=0.77).

3. Relation between sensory evaluations and objective measurements

An attempt was made to use objective measurements to substitute sensory evaluation for desirability of stickiness, transparency and whiteness, where these attributes were considered to contribute to the overall acceptability by stepwise regression analysis.

This study aimed to understand physical properties using sensory values and objective method values of desirability of stickiness, transparency and whiteness. As a result, it was possible to represent the attributes by the objective measurements show below.

*Stickiness (Y)

Y=−0.18 amylose ratio+0.19 thousand grain weight of rice
(−0.66**) (0.35**)

−0.05 whole rice grain rate+3.28
(−0.28*)

r=0.87

*Transparency (Y)

Y=0.68 luster [60°]−0.08 L value
(0.55*) (−0.31)

+0.36 luster [75°]+2.82
(0.23)

r=0.66

*Whiteness (Y)

Y=0.09 whiteness level −0.37 b value −2.32
(0.52*) (−0.43**)

r=0.71

( ): standardized partial regression coefficient
**: P<0.01
*: P<0.05

Results of analysis of variance on each of the multiple regression formulae were a significant at P<0.01.

It was reported[41] that transparency of surface

Table 6. Objective Measurement

	whole rice grain rate (brown rice) (%)	thousand grain weight (milled rice) (g)	whole rice grain rate (milled rice) (%)	whiteness level	water content (milled rice) (%)	protein (%)	ash content (%)	amylose ratio (%)	Mg (mg %)	K (mg %)	Na (mg %)
Koshihikari (Niigata)	68.25	18.15	82.55	38.0	13.2	5.5	0.47	15	39.7	105.5	10.1
Akitakomachi	78.95	19.85	92.80	36.0	13.1	6.7	0.46	16	35.4	80.0	10.8
Kinuhikari	69.40	18.55	88.55	37.2	14.0	6.2	0.47	13	30.1	99.9	2.4
Kirara 397	72.70	19.50	94.20	32.7	13.6	7.8	0.49	17	40.0	95.8	11.6
Sasanishiki	79.30	18.70	91.80	37.1	13.2	7.1	0.46	15	39.0	88.0	13.7
Hananomai	80.90	20.20	94.95	34.5	13.4	5.3	0.48	16	38.4	93.1	18.1
Fukuhikari	76.05	19.95	88.65	38.8	13.4	5.7	0.46	15	37.4	86.9	20.5
Yukinosei	66.65	19.05	88.35	38.9	12.5	6.6	0.42	15	35.6	87.1	21.7
Ozora	66.45	19.00	81.50	39.7	12.3	6.5	0.49	19	39.6	94.7	23.4
Koganenishiki	75.15	18.90	92.45	38.2	14.1	6.2	0.47	17	33.8	89.9	26.2
Koshihikari (Chiba)	78.20	20.00	92.90	37.4	13.5	6.1	0.43	15	26.0	80.6	22.2
Koshihikari (Nagasaki)	49.40	17.45	90.65	36.8	13.4	6.8	0.52	13	41.1	94.4	22.3
Tsugaruotome	81.55	19.70	89.70	38.9	13.8	5.3	0.40	17	33.6	84.0	10.9
Nipponbare	84.30	20.40	92.60	38.3	13.4	5.8	0.56	16	34.8	91.7	8.6
Notohikari	70.85	19.15	87.60	39.5	13.5	6.7	0.45	15	35.8	82.4	23.1
Hatsuboshi	73.95	20.50	88.70	38.0	13.0	5.7	0.41	15	32.3	73.8	1.2
Minamihikari	86.30	20.15	95.50	38.3	12.6	6.0	0.46	18	29.8	88.3	15.4
Koganemasari	82.95	19.55	96.65	35.5	12.5	7.3	0.43	19	23.0	89.0	12.3
Toyonishiki	70.90	19.30	93.75	36.4	13.3	6.3	0.48	18	36.5	88.8	24.5
Nakateshinsenbon	73.30	20.20	91.40	35.8	13.8	5.9	0.47	15	33.7	102.2	23.3
Fuyo	74.30	18.85	93.20	36.1	14.3	6.1	0.47	18	33.7	149.4	20.6
Yukihikari	63.90	18.25	96.35	31.8	13.5	7.9	0.55	18	42.5	104.3	15.2
Asukaminori	65.50	18.70	88.60	35.1	13.5	6.1	0.43	19	32.9	94.1	24.0
Rinkusu 89		14.30	88.85	43.1	12.3	7.6	0.40	18	28.3	80.6	11.9
Nishiki		18.80	97.30	40.6	11.5	5.6	0.40	16	24.6	82.0	5.4
Long grain rice		19.00	97.00	39.6	12.3	7.4	0.50	26	35.0	77.8	15.6
standard price rice X		19.45	91.85	37.7	12.7	5.4	0.50	15	44.0	99.6	18.6
standard price rice Y		17.45	92.00	39.3	12.8	6.9	0.44	16	26.3	90.9	21.1
standard price rice Z		17.85	95.25	37.5	13.4	7.0	0.45	18	29.5	83.2	19.9
Koshihikari (stored rice)		18.20	85.75	36.3	13.8	5.5	0.47	15	39.7	106.0	10.1
Asukaminori (stored rice)		19.10	90.15	35.0	13.4	6.1	0.44	19	32.9	76.7	11.5
average	73.44	18.97	91.34	37.4	13.2	6.4	0.46	17	34.4	91.6	16.0
standard deviation	8.19	1.20	3.92	2.28	0.62	0.75	0.04	2.43	5.31	13.77	6.77
coefficients of variation	11.16	6.33	4.29	6.10	4.70	11.72	8.70	14.29	15.44	15.03	42.31

Eating Quality Evaluation for Cooked Rice (1)

つづき

	Ca (mg %)	volume (l)	water content (cooked rice) (%)	hardness (T.U.)	stickiness (T.U.)	cohesiveness (T.U.)	Y value	L value	b value	a * value	G value 60°	G value 75°	G value 80°
Koshihikari (Niigata)	24.7	1.22	61.8	9.41	1.07	0.55	34.8	70.66	3.15	−2.15	2.94	2.00	0.37
Akitakomachi	37.5	1.22	60.7	11.30	1.11	0.39	39.2	68.94	4.31	−2.04	2.85	1.80	0.32
Kinuhikari	22.0	1.32	59.6	9.96	1.04	0.44	38.3	68.22	3.48	−1.88	3.15	1.63	0.75
Kirara 397	20.0	1.37	59.0	9.72	0.61	0.40	40.7	72.69	4.35	−1.70	2.22	1.52	0.28
Sasanishiki	17.6	1.37	60.0	10.18	0.98	0.41	39.1	71.99	3.27	−1.93	3.35	1.88	0.77
Hananomai	39.0	1.37	60.4	10.33	0.98	0.42	38.5	70.84	3.79	−1.81	3.20	1.40	0.60
Fukuhikari	24.7	1.39	60.8	9.62	0.93	0.41	38.4	70.11	2.62	−2.04	3.76	1.49	0.93
Yukinosei	29.6	1.47	59.9	10.55	0.89	0.42	40.1	70.14	3.49	−2.11	4.03	2.26	0.79
Ozora	28.0	1.41	60.4	11.81	0.86	0.40	39.3	66.96	4.17	−2.01	3.13	1.68	0.55
Koganenishiki	28.0	1.43	61.1	10.99	0.82	0.42	39.7	72.51	3.30	−1.89	3.13	1.78	0.37
Koshihikari (Chiba)	23.0	1.51	60.8	10.11	0.88	0.44	38.2	65.30	4.59	−2.03	3.56	2.29	0.93
Koshihikari (Nagasaki)	41.8	1.34	59.8	10.17	0.84	0.41	38.0	68.95	4.54	−1.84	3.12	2.28	0.45
Tsugaruotome	18.7	1.35	59.9	10.88	1.04	0.42	36.1	65.39	3.70	−2.20	3.62	2.27	0.78
Nipponbare	33.2	1.44	60.4	11.13	0.99	0.53	37.4	65.92	3.76	−2.05	2.47	2.15	0.17
Notohikari	23.5	1.33	61.0	10.52	0.79	0.42	40.4	67.27	3.85	−1.87	2.38	1.73	0.11
Hatsuboshi	19.7	1.44	59.9	10.88	0.91	0.41	38.4	67.48	3.08	−1.90	1.63	2.69	0.19
Minamihikari	26.7	1.59	60.2	12.64	0.65	0.39	39.3	67.72	3.46	−1.97	2.09	2.85	0.19
Koganemasari	25.1	1.44	59.9	13.38	0.59	0.41	40.3	69.00	3.46	−1.97	2.30	3.45	0.18
Toyonishiki	26.0	1.42	60.4	12.39	0.63	0.39	40.4	68.55	3.63	−2.05	2.20	2.54	0.34
Nakateshinsenbon	24.0	1.46	59.6	10.93	0.88	0.41	38.8	63.37	4.56	−2.06	1.91	2.64	0.21
Fuyo	24.7	1.45	60.2	10.80	0.65	0.41	38.6	66.97	3.46	−1.88	2.33	2.34	0.35
Yukihikari	22.9	1.22	59.6	11.66	0.60	0.38	42.4	66.91	4.91	−1.89	2.09	1.85	0.43
Asukaminori	37.0	1.53	60.8	12.34	0.74	0.42	39.2	74.16	3.65	−1.81	2.04	2.68	0.40
Rinkusu 89	28.1	1.49	62.2	10.72	0.70	0.39	45.1	74.27	2.60	−1.54	2.41	2.33	0.64
Nishiki	36.0	1.41	62.6	10.40	1.30	0.44	38.8	62.52	3.12	−2.11	2.81	2.06	0.83
Long grain rice	47.1	1.54	59.0	17.90	0.00	0.49	42.8	73.06	4.15	−1.95	2.20	1.21	0.45
standard price rice X	28.0	1.49	61.6	10.64	0.78	0.42	36.8	71.72	2.89	−2.16	2.42	1.91	0.13
standard price rice Y	29.0	1.38	60.3	11.85	0.70	0.39	41.4	70.03	2.94	−2.19	2.26	2.20	0.32
standard price rice Z	39.3	1.49	58.1	12.70	0.68	0.41	41.9	72.96	4.43	−1.95	2.04	2.12	0.32
Koshihikari (stored rice)	22.6	1.45	62.6	11.13	0.65	0.41	37.1	69.03	4.63	−1.87	2.34	1.57	0.25
Asukaminori (stored rice)	26.2	1.46	61.7	13.18	0.54	0.41	39.5	69.98	4.88	−1.97	1.98	1.39	0.35
average	28.2	1.41	60.4	11.30	0.80	0.42	39.3	69.15	3.75	−1.96	2.64	2.06	0.44
standard deviation	7.30	0.09	1.02	1.61	0.23	0.04	2.04	3.00	0.66	−0.14	0.62	0.50	0.25
coefficients of variation	25.89	6.38	1.69	14.25	28.75	9.52	5.19	4.34	17.60	−7.14	23.48	24.27	56.82

treatment of metals at a 60° angle of incidence could be objectively evaluated by luster. Metal and rice are very different materials, but there was a similarity in their transparency using objective measurement.

In the objective measurements, although L, L*, and WI are color indexes representing white-black and they were expected to have strong relation to whiteness evaluated by sensory test, the combination of whiteness level of rice and b value in multiple regression analysis was more suitable for expressing the whiteness of coofed rice.

Since overall acceptability could be successfully expressed in terms of the multivariate linear regression model using sensory values (multiple correlation coefficient was 0.97), we substituted the sensory values with objective measurements. The criterion variable was overall acceptability, and the explanatory variables were the eight objective measurements selected by multiple regression analysis: desirability of stickiness, whiteness, and transparency.

Overall acceptability (Y)

Y = −0.18 amylose ratio + 0.29 luster [60°]
(−0.60**)   (0.25)
−0.03 L value + 3.87
(−0.12)

( ): standardized partial regression coefficient
**: P<0.01
*: P<0.05

Overall acceptability could be expressed in terms of amylose ratio, L value and luster (60°), with a multiple correlation coefficient (r=0.76 and P<0.01).

The current study has attempted to express overall acceptability using only objective measurements which contribute to appearance and texture. Further study is required to clarify the relationship between objective measurements and desirability of sweetness, an important contributor to overall acceptability.

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米飯の食味評価法の検討

—官能検査と理化学的測定結果に対する重回帰分析の応用—

小西雅子*，井出邦康*，畑江敬子**，島田淳子**

31種類の米の詳細な官能検査および理化学的測定を行い，米の総合的なおいしさと物性値の関係を検討した。

1. 甘味は，分析型，嗜好型検査ともに総合的な食味との相関が0.88，0.92と高いが，試料間の差が小さかった。
2. 味は，味の好ましさと総合的な食味との間に0.95と高い相関がみられたものの，味の強弱と総合的な食味の相関が0.23と低く，かつ分析型と嗜好型検査の相関が低かった。
3. 重回帰分析を行った結果，総合的な好ましさは，粘りの好ましさ，甘味の好ましさ，白さ，透明感の4項目で表され，重相関係数は0.97と高い値であった。
4. 総合的な好ましさに高い寄与を示す粘りの好ましさ，透明感，白さを理化学的測定値に置き換えた。粘りの好ましさはアミロース，精米の千粒重および整粒率で，透明感はL値と入射角60°，75°の光沢度で，白さは白度とb値，で表すことができ，重相関係数は0.87，0.66，0.71であった。
5. 米飯の総合的な好ましさは，アミロース比，L値，光沢度(60°)の3項目で表すことができ，重相関係数は0.76であった。

キーワード：重回帰分析，理化学的測定，米飯，官能検査

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* 東京ガス(株)基礎技術研究所
** お茶の水女子大学生活科学部