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Major Characteristics Affecting the Sensory Quality of Rice Marketed in Korea

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Abstract A total of 284 milled rice (MR) marketed in Korea were analyzed for grading characteristics (head rice, broken kernels, chalky kernels, and damaged kernels%), color characteristics (L-, a-, b-values, and whiteness), protein content (%), and the cooked rice (CR) sensory quality to investigate the key characteristics affecting the overall sensory quality of rice marketed in Korea. Relatively high correlation with the overall sensory quality of the CR was found in color characteristics such b-value of the CR (r=–0.779) and MR (r=–0.545), the a-value of the CR (r=0.513), and the whiteness (r=0.298) of the MR, compared to protein (r=–0.150), and the moisture (r=0.158) contents of the MR and the percentage of head rice (r= 0.195). Partial least squares (PLS) regression of the CR b-value with various characteristics of the MR showed that CR b-value was increased with MR b-value effectively, followed by protein content, damaged kernels, chalky kernels, and colored kernels of MR while it was decreased with whiteness and moisture content for the MR.

Keywords: sensory quality, rice marketed in Korea, color b-value

Introduction

Rice consumption in Korea and Japan has been decreasing every year, due to gradual changes in dining patterns by globalization. While 132.4 kg of rice per capita was consumed in Korea during 1980, 80.7 kg of rice per capita was consumed in 2005 (1). The self-sufficiency rate (%) for rice in Korea was 102.8 in 2004-2005, and the paddy surplus in 2004 was 1,037,000 tons, which was almost 23% of the production for the year (2), implying no need for rice imports. However, the amount of imported rice is expected to increase until 2014 by a 10 year extension to continue the minimum market access import quota for imported rice. This extension calls for doubling minimum rice imports until 2014, in return for delaying complete import liberalization until that time. In addition to rice agreements in the World Trade Organization, a recent matter on rice within the Free Trade Association world negotiations between the USA and Korea has increased concerns for rice over any other foodstuff in Korea.

It seems inevitable that Korea will accept complete import liberalization of rice in the future. Thus, Korean rice processors need to prepare for survival in a global market until the time of complete import liberalization. In order to survive in the market, product competitiveness needs to be accomplished by lowering costs and improving the quality of rice. Consumers tend to pay for quality rice, considering that rice is relatively inexpensive, and that there have been increases in household income. Rice expenditures accounted for only 1.8% of the total expenditures of urban households in 2004 (2). A recent survey (3,4) indicated that one of the most important characteristics for consumers in purchasing rice is its sensory quality. However, it is difficult to find information on the sensory quality of rice that is currently marketed in Korea. Sensory quality is usually measured by more than 100 untrained consumer panelists. In order to test more products than 1 consumer panel can evaluate during 1 session, say for example 50 rice samples, an incomplete block design is usually used. In a study by Meullenet *et al.* (5), 120 consumers each evaluated 7 rice samples among 19 rice samples, according to incomplete block design. However, in the field, it is still preferred that each consumer evaluate all of the test samples rather than a portion of the test samples.

Recently, Park *et al.* (6) showed that about 90% of consumer acceptance could be explained by the overall sensory quality scores of trained panelists, by using regression analysis between consumer acceptance and the overall sensory quality score with 24 rice samples. While more than 100 consumers are required for a consumer test, about 25 trained panelists can be used for the overall sensory quality score. Also, it's not practical to invite the same several consumers for more than 2 days of testing as compared to fewer numbers of trained panelists.

In this study, the influential characteristics of milled rice (MR) and cooked rice (CR) affecting the sensory quality of CR were investigated. This was done using a trained sensory quality panel with 51 brands of rice marketed in Korea in 2005 and collected 4 times, respectively.

Materials and Methods

Materials Seventy-one rice samples marketed in Korea were collected monthly 4 times, from March to June of 2005, by the National Council of Consumer Organizations. The cultivation site and cultivars of the 71 rice samples are listed in Table 1. The 71 rice samples were commercial brands whose total sales in 2004 were above US $762,000. The differences in milling date among the collected rice samples were within 1 week. The total 288 rice samples used for this study were harvested in 2004. Rice samples with random codes were sent to the Korea Food Research

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Table 1. List of rice samples

Sample no	Cultivation cite	Name of cultivar	Sample no	Cultivation site	Name of cultivar
1	Jeonnam	'Koshihikari'	37	Jeonnam	'Koshihikari'
2	Jeonbuk	'Hitomebore'	38	Gyeonggi	'Chucheongbyeo'
3	Gangwon	'Surabyeo'	39	Jeonnam	'Ilmibyeo'
4	Chungnam	'Chucheongbyeo'	40	Chungbuk	'Sangmibyeo', 'Daeanbyeo'
5	Chungnam	'Dongjinbyeo', 'Ilmibyeo'	41	Gyeongbuk	'SaeChucheongbyeo'
6	Gyeongnam	'Ilmibyeo', 'Namoyungbyeo'	42	Jeonbuk	'SinDongjinbyeo'
7	Chungbuk	'Chucheongbyeo'	43	Jeonbuk	'Koshihikari'
8	Jeonbuk	'SinDongjinbyeo'	44	Gyeongbuk	'SaeChucheongbyeo'
9	Gyeonggi	'Chucheongbyeo'	45	Gyeongnam	'Hwayeongbyeo', 'Junambyeo'
10	Gyeongbuk	'Chucheongbyeo'	46	Jeonnam	'Ilmibyeo'
11	Jeonnam	'Hitomebore'	47	Gyeongnam	'Chucheongbyeo'
12	Jeonbuk	'Ilmibyeo'	48	Jeonnam	'Koshihikari'
13	Gangwon	'Surabyeo'	49	Gyeongbuk	'Ilpumbyeo'
14	Gangwon	'Odaebyeo'	50	Gyeongnam	'Chucheongbyeo'
15	Chungnam	'Nampyeongbyeo'	51	Gyeongnam	'Donganbyeo', 'Ilmibyeo'
16	Jeonnam	'Dongjinbyeo'	52	Jeonbuk	'SinDongjinbyeo'
17	Chungnam	'Nampyeongbyeo'	53	Chungnam	'Junambyeo'
18	Gyeonggi	'Chucheongbyeo'	54	Gangwon	'Daeanbyeo', 'Ilpumbyeo'
19	Jeonnam	'Koshihikari'	55	Gyeongnam	'Mixed'
20	Gyeongbuk	'Ilpumbyeo'	56	Gyeongbuk	'Ilpumbyeo'
21	Jeonnam	'Hitomebore'	57	Gyeongbuk	'Ilpumbyeo'
22	Gyeonggi	'Chucheongbyeo'	58	Jeonnam	'Nampyeongbyeo'
23	Jeonnam	'Koshihikari'	59	Chungnam	'Koshihikari'
24	Gyeonggi	'Koshihikari'	60	Gyeongnam	'Ilmibyeo', 'Namoyungbyeo'
25	Chungbuk	'Chucheongbyeo'	61	Chungbuk	'Chucheongbyeo'
26	Chungnam	'Chucheongbyeo'	62	Chungnam	'Chucheongbyeo'
27	Gyeonggi	'Chucheongbyeo'	63	Jeonnam	'Dongjinbyeo'
28	Jeonnam	'Ilmibyeo'	64	Jeonnam	'Dongjinbyeo', 'Donganbyeo'
29	Chungnam	'SaeChucheongbyeo'	65	Gyeongbuk	'Ilpumbyeo'
30	Jeonnam	'Ilmibyeo'	66	Jeonbuk	'Ilmibyeo'
31	Gyeongbuk	'Chucheongbyeo'	67	Chungbuk	'Chucheongbyeo'
32	Jeonbuk	'Koshihikari'	68	Jeonnam	'Ilmibyeo'
33	Jeonbuk	'Ilmibyeo'	69	Gyeonggi	'Chucheongbyeo'
34	Gyeonggi	'Chucheongbyeo'	70	Gyeongbuk	'Hitomebore'
35	Chungnam	'Chucheongbyeo'	71	Gyeonggi	'Chucheongbyeo'
36	Jeonbuk	'Ilmibyeo'			

Institute to measure their physicochemical characteristics and sensory quality, and to the National Agricultural Product Quality Management Service (NAPQMS) to measure grading characteristics. The rice samples sent to each Institute were repacked with polyethylene film bags as 5 kg units, and stored in a refrigerator (5°C) until use. Each time the analysis was completed within 3 weeks of refrigerator storage.

Characteristics related to grade The percentage of head rice, chalky kernels, and broken kernels were analyzed by hand picking and eye observation, based on the Inspection Handbook of Korean Agricultural Products (7) by professional inspectors at NAPQMS, Ministry of Agriculture and Forestry in Korea. Head rice is defined as rice kernels with ≥3/4 of a whole kernel. Chalky kernels are those with over half of their surface area as chalky. Damaged rice kernels are whole or broken kernels of rice that have been damaged or contaminated by water, insects, heat, or other means. Broken kernels are rice kernels with <3/4 of a whole kernel.

Color characteristics of MR and CR The color values (L-, a-, and b-value) of the MR and CR were measured using a colorimeter (CR-300; Minolta^R, Tokyo, Japan), where 12 g of the MR or CR were placed in a plastic container (41×12.5 mm, diameter×depth), and the container was embedded in a black sponge to prevent the effects of the surroundings on the color values. The whiteness of the MR was measured using a whiteness meter (C-300-3; Kett Electric Lab., Tokyo, Japan)

Moisture and protein contents The moisture contents of the MR and CR were determined by the AACC method 44-15A (8) and the protein content of the MR was measured by an Infratec™ 1241 Grain Analyzer (Foss-Tecator, Hagenas, Sweden).

Preparation of the CR for sensory quality analysis The CR was prepared as stated in Kim *et al.* (9). Briefly, the rice samples (800 g) were washed using a rice cleaner (PR-7J; Aiho, Tokyo, Japan) to prevent experimental errors during washing. After washing, water was added at 1.45 times the amount of rice, based on the 14% moisture content of the rice. The rice was cooked using a rice cooker (SJ-185R; Samsung Electric. Co., Suwon, Korea), and the CR was held for 10 min after cooking. The CR within 1 cm from the top and inner pan of the rice cooker was discarded, and the middle portion of the rice was transferred to a bowl (23.5×13.5 cm, diameter × depth). The CR in the bowl was mixed gently using a fork (length 35 cm) with 5 strokes of up and down motion, and then held for 5 min at room temperature. Mixing and holding of the CR was repeated twice, and then it was portioned for the sensory evaluation. CR samples (40 g) cooled to room temperature (about 28°C) were taken with a stainless ice cream scoop (diameter, 60 mm, Saejang Co., Seoul, Korea), placed in a bowl (90×40 mm, diameter×depth) with a lid, and presented to the panelists. For each panel, 6 CR samples were prepared. To present 6 samples per panel, 1 dummy rice sample was included and a total of 72 rice samples were presented.

Sensory quality of CR All of the panelists that participated in this study were employees of the Korea Food Research Institute, and were trained for at least over 1 year on the sensory quality of CR. They were trained to evaluate odor, appearance, texture, taste, and the overall quality of CR as described by Kim *et al.* (9). A 9-points category scale (1= very low, 9=very high) was used to measure the sensory quality of the CR. During training, various CR samples were presented to demonstrate either high or low quality, in terms of odor, appearance, texture, and taste, as described by Shin *et al.* (10). Most of the panelists agreed on the high and low quality of the CR for odor, appearance, texture, and taste. The panelists evaluated the overall quality of the CR based on its quality of odor, appearance, texture, and taste. Thirty out of 40 panelists were selected based on their panel performance, as described in Cross *et al.* (11).

After training, the selected panelists received 6 samples per panel, and the samples were presented in a monadic way with a 3-digit random code. The panelists had a 3 min break after finishing their evaluation of the 3rd of 6 samples. The presentation order of the 6 samples for each individual panelist was randomized, and the experiments were repeated 2 times.

Statistical analysis The entire experiments were repeated twice. To find the key characteristics affecting the sensory quality of the CR, correlation analysis, and stepwise regression analysis were performed between the overall sensory quality and physicochemical characteristics of the MR, and the moisture content, and color characteristics of the CR, using SAS (12). Partial least squares (PLS) regression was performed to find the relationship between the b-value of the CR and the various characteristics of the MR using Xlstat (13).

Results and Discussion

Characteristics related to grade The mean percentage of head rice was 93.5%, and it ranged from 79.4-99.2% (Table 2). The mean percentage of damaged kernels was 0.68%, and it was in the range of 0.0-3.16%. The average percentages of chalky kernels and broken kernels were 1.65 and 4.23%, respectively. Considering that the average percentages of head rice, damaged kernels, and chalky kernels were 90.5, 1.5, and 2.7%, respectively, for 140 rice samples marketed in Korea in 2003 (4), the grading quality of the rice marketed in 2005 had improved.

Color characteristics of MR and CR Color characteristics of MR is used for determination of milling ratio instead of measuring weight of brown rice and MR. The average L- and b-values in this study were 70.3 and 9.70, respectively, while those for rice marketed in 2003 were 68.8 and 10.9 (4), respectively, implying that the color intensity of the 2005 MR was whiter and less yellow (Table 2). A similar trend was found for whiteness. While the average whiteness of the 2005 MR was 39.6, that of rice marketed in 2003 was 38.6 (4). Whiteness is a reflective index of light in the range of 0-100. The whiteness 0 means complete darkness, while whiteness 100 means white smoke generated by burning magnesium ribbon. The recent changes in whiteness and the head rice percentage for rice marketed in Korea imply that rice processors are putting more effort towards enhancing the quality of rice than before. Among various color systems whiteness is known to be a better indicator in predicting milling ratio of MR than others (14,15).

Moisture and protein contents The moisture content of MR was in the range of 9.67-15.27%, and that of CR was in the range of 59.2-64.7%. Above results indicated relatively wide range of moisture content in MR, implying the need for quality control of MR during milling. The average moisture contents of MR and CR were 13.4 and 62.5% respectively. The sensory quality of MR is known to be affected by protein content (16) and amylose content (17). When compared to MR marketed in 2003, the protein content of MR marketed in 2005 tended to be lower, where the protein content of the 2005 MR was 6.43%, and that from 2003 was 6.60%.

Sensory quality of CR The overall sensory quality of the CR was in the range of 4.36-7.71 and the average overall sensory quality of the CR were 6.63. According to previous studies on the sensory quality of MR (6), MR with an overall sensory quality score of less than 5.0 could be classified as unpalatable rice, while that with an overall sensory quality score of greater than 7.0 could be classified as palatable rice. The overall sensory score distributions of the 71 rice samples at each time are in Fig. 1, showing it was similar each time.

The average storage time for MR in domestic markets was reported to be 10.1 days, and the smaller the size of the market, the more likely storage time was reported to be longer than 10 days (6). In this study, all of the rice samples were purchased at a major large-sized market, and most of the rice samples selected for this study were produced in

Table 2. Characteristics of rice[1] marketed in Korea

Variable		Mean	SD[2]	Minimum	Maximum
Milled rice					
Grading characteristics	Head rice (%)	93.3	3.69	79.4	99.2
	Colored (%)	0.01	0.02	0.00	0.15
	Damaged (%)	0.68	0.39	0.00	3.16
	Chalky (%)	1.65	1.39	0.04	6.99
	Broken (%)	4.23	2.71	0.28	14.79
Color value	L	70.3	2.25	58.3	78.3
	a	-1.33	0.13	-1.88	-0.41
	b	9.70	0.78	7.96	12.73
Whiteness		39.6	1.81	34.4	43.6
Moisture content (%)		13.4	0.82	9.67	15.27
Protein (%)		6.43	0.33	5.60	7.23
Cooked rice					
Color value	L	72.8	1.37	68.5	75.7
	a	-2.18	0.10	-2.64	-1.89
	b	0.75	0.46	-0.29	3.28
Moisture content (%)		62.5	0.50	59.2	64.7
Overall sensory quality		6.63	0.53	4.36	7.71

[1]Based on 284 rice samples marketed in Korea; 71 commercial brands of rice were collected monthly 4 times from March to June, 2005.
[2]Standard deviation.

Table 3. Correlation coefficients (r)[1] between the overall sensory quality and physical characteristics of MR and CR

Variable		Overall sensory quality
Milled rice		
Characteristics related to grade	Head rice (%)	**0.195**
	Colored kernels (%)	**-0.188**
	Damaged kernels (%)	**-0.244**
	Chalky kernels (%)	**-0.237**
	Broken kernels (%)	-0.104
Color value	L	0.002
	a	**-0.138**
	b	**-0.545**
	Whiteness	**0.298**
	Moisture content (%)	**0.158**
	Protein (%)	**-0.150**
Cooked rice		
Color value	L	**-0.134**
	a	**0.513**
	b	**-0.779**
Moisture content (%)		**0.130**

[1]Based on 284 rice samples marketed in Korea; 71 commercial brands of rice were collected monthly 4 times from March to June, 2005; values in bold are significantly different from 0 with a significance level $\alpha = 0.05$.

rice processing plants equipped with low temperature storage facilities. The similar distributions of the overall sensory scores at each time might be explained by the considerable quality control efforts put forth by producers, and the relatively short storage time as MR prior to testing.

Relationship between overall sensory quality and physical and chemical characteristics The correlation coefficients between the overall sensory quality and the physical and chemical characteristics are in Table 3. The color b-value of the CR had the highest correlation coefficient with overall sensory quality. Among the characteristics of the MR, the color b-value also had a higher correlation with overall sensory quality than with the other characteristics.

A high color b-value in MR could be explained by a low degree of milling, as Lieve *et al.* (18) has explained, as well as improper handling of the paddy after harvesting, such as high temperature drying (19). In Japan, whiteness is one of the recommended characteristics for MR quality control at milling companies, and 'whiteness index of brown rice+20' is used as the guideline for the whiteness of MR (20). While color L-, a-, and b-values are independent each other, whiteness is dependent on color L-, a-, and b-values. The results of this study indicate that the color b-value could be better in predicting the overall sensory quality of CR than the whiteness of MR.

In addition to the color values, damaged kernels, chalky kernels, and colored kernels showed negative correlations with the overall sensory quality of the CR. It seems that MR with a higher percentage of head rice tends to be higher for overall sensory quality in CR. The results for stepwise regression of the overall sensory quality can be expressed as follows:

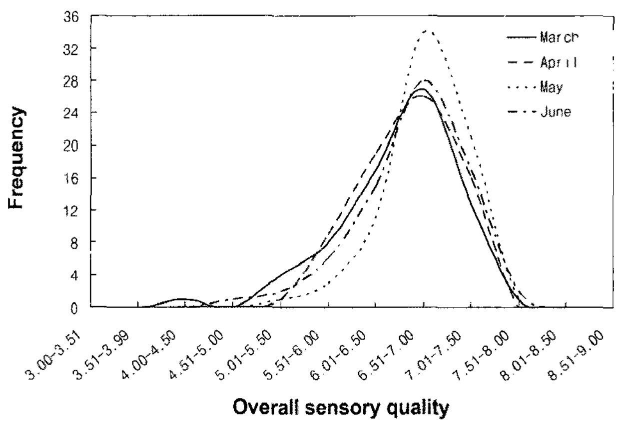

Fig. 1. Distribution of overall sensory quality scores of 71 rice samples dependent on testing time.

Overall sensory quality = −2.74 + 0.29 protein + 0.02 head rice + 0.09 damaged kernels − 0.95 b-value in CR + 0.09 moisture content in CR ($R^2 = 0.65$)

The above results imply that it's not easy to completely explain the sensory quality of rice with one or two characteristics. The standardized coefficients (Table 4) of the characteristics in predicting the overall sensory quality of the CR indicated that the most influential characteristic was the b-value of the CR, followed by the b-value, a-value, and whiteness of the MR. These results suggested that the color characteristics were more important than the composition of the rice, such as protein or moisture content, for the sensory quality of rice marketed in Korea. The above result for the effect of protein content on palatability was similar to that of Matsue *et al.* (21), which

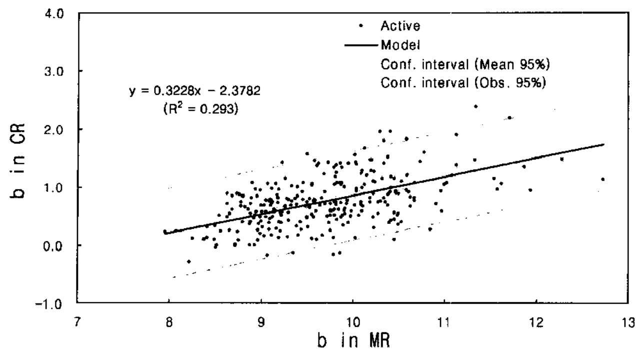

Fig. 2. Linear regression for the b-values of cooked rice (CR) by the b-values of milled rice (MR).

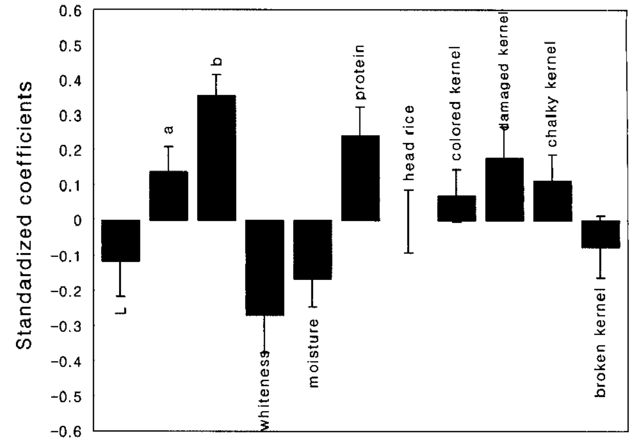

Fig. 3. Standardized coefficients for partial least squares regression analysis of the b-value of CR by different characteristics of MR. The bars on the plot represent a 95% confidence interval of each variable.

showed that the palatability of rice from different locations in the Kyushu and Chugoku districts was not correlated with protein content. This could be explained by the variety of rice marketed in Korea, which is short grain rice with a narrow range of protein content.

Considering that the correlation coefficient (r) between the overall sensory quality and b-value of the CR was −0.779 (Table 3), about 60% (R^2=0.607) of the overall sensory quality can be explained by just the b-value of the CR. However, only 29.3% of the b-value of the CR can be explained by the b-value of the MR, implying that more factors than the MR b-value are involved in the formation of the CR b-value, even though a higher b-value for the MR tended to show a higher b-value for the CR (Fig. 2). The rice with a higher CR b-value was expected to be lower in sensory quality and have a higher MR b-value. An increase in the b-value, or yellowing, can be caused by delayed or improper drying of the rice (22). Dillshunty *et al.* (19) showed that rice storage at high temperatures causes severe problems for the rice color. The color of MR could also be affected by the degree of milling, as Lieve *et al.* (18), Park *et al.* (23), Yoon and Kim (24), and Siebenmorgen *et al.* (25) have mentioned.

In order to investigate the effects of the different characteristics of the MR on the b-value of the CR, partial least squares (PLS) regression was done. PLS regression is recommended in cases where the number of variables is high, and where it is likely that the explanatory variables are correlated (13). The results of PLS regression for the b-value of the CR show that the MR b-value had a higher standardized coefficient than the other characteristics of MR measured in this study (Fig. 3). The CR b-value increased with the b-value, protein content, colored kernels, damaged kernels, chalky kernels, and color a-value, while it decreased with whiteness, moisture content, color L-value, and head rice kernels.

Considering their low correlation coefficients with sensory quality (Table 3), the color L-value, and broken kernels were not effective characteristics for the sensory quality of the CR in this study. Among the standardized coefficients of MR characteristics in Fig. 3, that for head rice (%) was relatively low, implying little effect for the color b-value of the CR. A higher b-value for the CR could be caused by higher b- and a-values, protein content, damaged kernels, chalky kernels, and colored kernels of MR, while higher whiteness, L-value, and moisture content may result in a lower b-value for CR.

Considering that approximately 60% of the CR sensory quality could be explained by the b-value of the CR, the overall results of this study suggest that the sensory quality of market rice could be enhanced by decreasing the color b-value. Additionally, sensory quality of the CR could be improved by decreasing the protein content, damaged kernels, and chalky kernels, and by increasing the whiteness and moisture content. Further research on changes in the CR b-value during cooking, in relation to changes in the chemical components of the rice, are needed in order to elucidate the mechanism of sensory quality for CR.

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Table 4. The results of stepwise regression for overall sensory quality with the various characteristics of MR and CR

Variable	DF	Parameter estimate	Standard error	*t*-Value	Pr > |*t*|	Standardized estimate
Intercept	1	-2.74	2.363	-1.16	0.246	0
b in cooked rice	1	0.29	0.064	4.52	<0.0001	0.179
Protein	1	0.02	0.005	3.63	0.0003	0.141
Head rice	1	0.09	0.055	1.66	0.0978	0.067
Moisture content in cooked rice	1	-0.95	0.045	-21.03	<0.0001	-0.836
Damaged kernels	1	0.09	0.034	2.88	0.0042	0.107

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