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Influence of Cultivation Regions on Chemical Contents of Rice Kernel and Stickiness of Cooked Rice

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Abstract

In 29 samples of Koshihikari (*japonica* variety) from 26 agricultural experiment stations located south of the northeastern part of Japan, the differences in eating quality and chemical composition of rice were studied. The stickiness of the samples which was determined by the sensory test and compared to that of Nipponbare ranged from 0.2 to 1.60. These samples contained 1.10 to 1.63% nitrogen and 16.2 to 20.0% amylose. Both the nitrogen content and amylose content were not significantly correlated with the stickiness when individual samples were considered. However, the temperature after heading was found to affect the stickiness of Koshihikari. The optimum mean daily air temperature during 30 days after heading for stickiness was found to be around 25.5°C. Since the amylose content was negatively correlated with the stickiness when the mean daily temperature was less than 26°C, it is assumed that the higher amylose content observed in cold regions may reduce the stickiness. On the other hand, the nitrogen content was found to be negatively correlated with the stickiness for samples at similar temperature levels.

Discipline: Food
Additional key words: amylose, magnesium, nitrogen, potassium, temperature

Introduction

Koshihikari is the most popular variety in Japan mainly because of its good flavor and stickiness. This variety is cultivated from south of the Tohoku district to the Kyushu district and 29.7% (535,427 ha) of the total rice cultivation area was planted with Koshihikari in 1991. The eating quality of Koshihikari has been known to vary with the cultivation area and Koshihikari produced in the Hokuriku district generally commands a higher market price than Koshihikari produced in other districts. However, regional differences in the eating quality and the factors controlling them have not been investigated in detail.

Eating quality of rice is affected by the rice varieties and cultivation methods. Varietal differences in the eating quality of Japanese rice varieties have been correlated with the amylose content[3,6,8], nitrogen content[3,9-11] and Mg/K ratio[5,10]. Since the amylose content is influenced by the temperature during the ripening period[1,6,12], it has been reported that the regional differences in the eating quality in

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the Hokkaido district were partly caused by the variations in the amylose content[7]. Therefore, it is assumed that the increase in stickiness of cooked rice cultivated in warmer areas such as the southwestern regions of Japan is due to the lower amylose content caused by the high ripening temperature. However, in practice, some rice varieties in warmer areas have been known to be less sticky[16]. This fact suggests that the regional differences in eating quality of Japanese rice varieties cannot be explained by only environmental variations in the amylose content.

In this paper attempts were made to analyze the regional variations in the stickiness of cooked rice and in the contents of chemical components such as amylose, nitrogen and Mg/K ratio in Koshihikari planted in various regions in Japan.

Materials and methods

A total of 29 samples of Koshihikari were obtained from 26 national/prefectural agricultural experiment stations located from the northeastern to the southwestern regions of Japan in 1986. The plants were cultivated according to the standard methods applied at each experimental station. The mean daily air temperature during 30 days after heading was measured to monitor its effect on the stickiness and chemical composition of rice.

The samples were milled. Milled rice (500 g) was placed in a 2.0 *l* beaker and washed once. Tap water (625 m*l*) was added to the sample with a moisture content of 13.5%. The amount of water was adjusted based on the moisture content of the samples. Four samples in a 2.0 *l* beaker each were placed in the inner pot of a gas rice cooker in which 1.5 *l* of water had been put. The samples were then cooked together for 22 min.

The stickiness of cooked rice was compared to that of Nipponbare by applying the sensory test. The scale employed ranged from −5 (much less sticky) to 5 (much more sticky). About 20 judges were selected from the staff based on the consistency of their evaluation.

Brown rice (10 g) was dry-ashed and analyzed for K and Mg contents by atomic absorption spectrometry. The nitrogen content of brown rice was determined by a colorimetric method using an auto analyzer. The amylose content of milled rice was analyzed with an auto analyzer at Hokkaido Prefectural Agricultural Experiment Station.

Results and discussion

Fig. 1 shows the means for stickiness, nitrogen content, amylose content, Mg/K ratio of Koshihikari and the mean daily temperature during 30 days after heading for the districts. The stickiness of cooked rice of Koshihikari, ranging from 0.20 to 1.60, varied among the regions. In general, the samples from the Hokuriku district were stickier than those from other districts. Such a tendency was also reported for other Japanese varieties[16].

The means, ranges and coefficients of variation of stickiness, chemical composition and mean daily temperature of 29 samples of Koshihikari and their correlation coefficients are presented in Table 1.

The nitrogen content of the samples ranged from 1.10% to 1.63%. Although the nitrogen content has been correlated with the ripening temperature[4,13], no correlation was found in this study. The lack of correlation was presumably due to the difference in the amount of fertilizer applied at each experimental station. Amylose content ranged from 16.2% to 20.0% and was negatively correlated with the temperature, which is consistent with the results reported in previous studies[1,6,12]. The Mg/K ratio ranged from 1.46 to 1.83. Although in general the contents of Mg and K increased with the temperature, the correlation between the Mg/K ratio and temperature was not significant, suggesting that the Mg/K ratio does

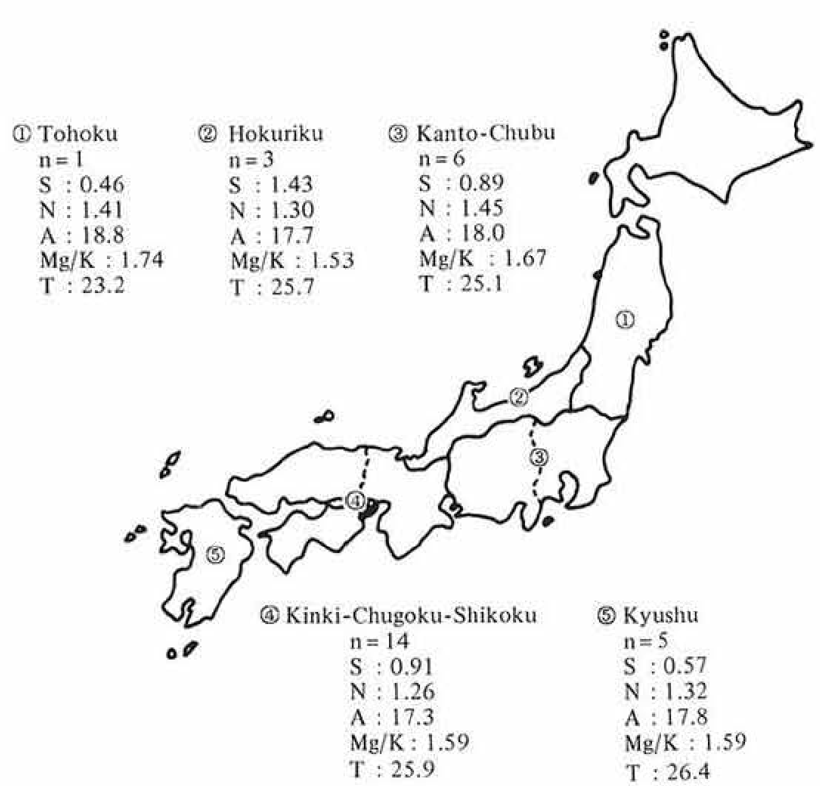


Fig. 1. Means of stickiness, chemical composition and temperature in various districts
29 samples of Koshihikari were cultivated in various regions. Stickiness of cooked rice determined by sensory test was compared to that of Nipponbare using a scale ranging from −5 (much less sticky) to 5 (much more sticky).
n: Number of samples, S: Stickiness of cooked rice, N: Nitrogen content of brown rice (%), A: Amylose content of milled rice (%), Mg/K: Mg/K ratio of brown rice (Eq/Eq), T: Mean daily air temperature (°C) during 30 days after heading.

Table 1. Means, ranges and coefficients of variation (CV) of stickiness, chemical composition and temperature during ripening in 29 samples of Koshihikari grown in various regions and correlation coefficients among these characters

Character	Mean	Range	CV (%)	Correlation coefficients					
				Nitrogen	K	Mg	Mg/K	Amylose	Temp.
Stickiness	0.89	0.20 − 1.60	5.8	−0.317	0.022	0.014	−0.010	−0.096	0.100
Nitrogen (%)	1.32	1.10 − 1.63	10.0		0.141	0.432*	0.383*	−0.188	0.000
K (mg/100 g)	266	235 − 299	5.7			0.615**	−0.322	−0.606**	0.545**
Mg (mg/100 g)	133	118 − 149	6.4				0.547**	−0.500**	0.378*
Mg/K (Eq/Eq)	1.61	1.46 − 1.83	5.4					0.024	−0.115
Amylose (%)	18.2	16.2 − 20.0	4.5						−0.428*
Temperature (°C)[a)]	25.7	23.1 − 27.7	5.3						

a): Mean daily temperature during 30 days after heading.
*, ** Significant at 5 and 1% levels, respectively.

not change with the temperature.

The nitrogen content and amylose content were not correlated with the stickiness of cooked rice when individual samples were considered. There was also no significant correlation between the Mg/K ratio and stickiness.

Fig. 2 shows the relationship between the temperature during ripening and the stickiness of Koshihikari. Although the correlation between the amylose content and stickiness of all samples was not significant, the temperature after heading significantly influenced the stickiness of Koshihikari grown in various regions. The optimum mean daily air temperature during 30 days after heading for stickiness was about 25.5°C. Thus, both high temperature and low temperature during the ripening period tended to reduce the stickiness of Koshihikari.

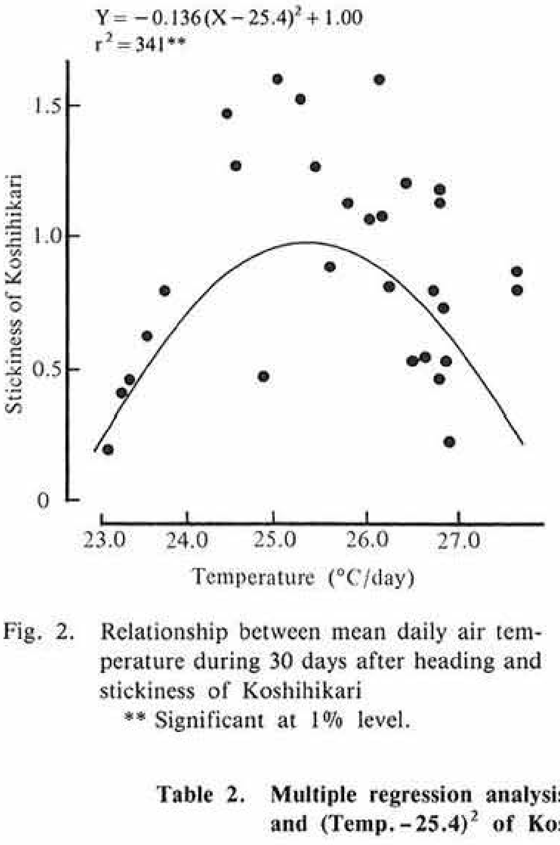


Fig. 2. Relationship between mean daily air temperature during 30 days after heading and stickiness of Koshihikari
** Significant at 1% level.

Among the amylogram properties, maximum-viscosity and break-down have been shown to be positively correlated with the stickiness of cooked rice[3,14] and they were reported to show higher values for the rice samples produced in a warmer area[15].

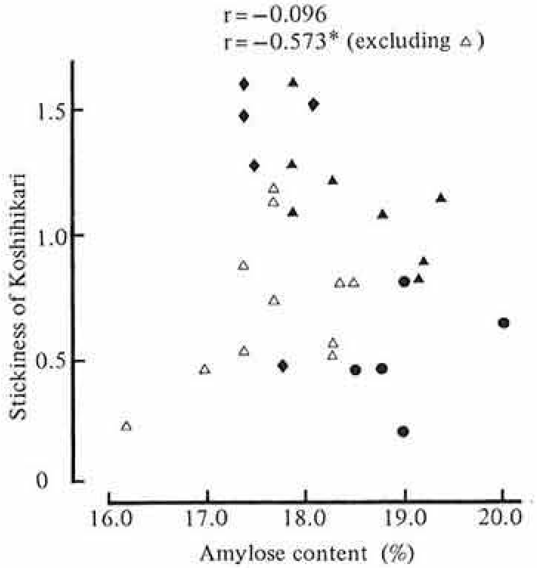
On the other hand, cooking quality characteristics such as water absorption ratio and volume expansion ratio are known to show larger values in warmer areas[2]. Therefore, it is considered that rice produced in warmer areas tends to be less sticky than in other areas, because in general the water absorption ratio and volume expansion ratio are negatively correlated with the stickiness of cooked rice[14]. Thus, the effect of the temperature on stickiness, which was reported previously, seems to differ from that of amylogram properties, which also does not correspond to the observations made during this study.

The results of multiple regression analysis for

Table 2. Multiple regression analysis of stickiness on chemical composition and $(Temp. - 25.4)^2$ of Koshihikari grown in various regions

Dependent variable		Independent variable				Multiple correlation coefficient
		Nitrogen	Amylose	Mg/K	$(Temp. - 25.4°C)^{2}$ a)	
Stickiness	S.C. b)	−0.408	−0.176	0.150		0.380
	t value c)	−1.990	−0.930	0.746		
	S.C	−0.513	−0.119	0.150	−0.652	0.744**
	t value	−3.356**	−0.850	1.007	−4.686**	

a): (Mean daily temperature during 30 days after heading − 25.4°C)²
b): Standard partial regression coefficient.
c): t value of standard partial regression coefficient.
** Significant at 1% level.



● : 23.0 ≦ T < 24.2, ◆ : 24.2 ≦ T < 25.4
▲ : 25.4 ≦ T < 26.5, △ : 26.5 ≦ T < 27.7
T : Mean daily air temperature during 30 days after heading (°C)
* Significant at 5% level

Fig. 3. Relationship between amylose content of milled rice and stickiness of Koshihikari

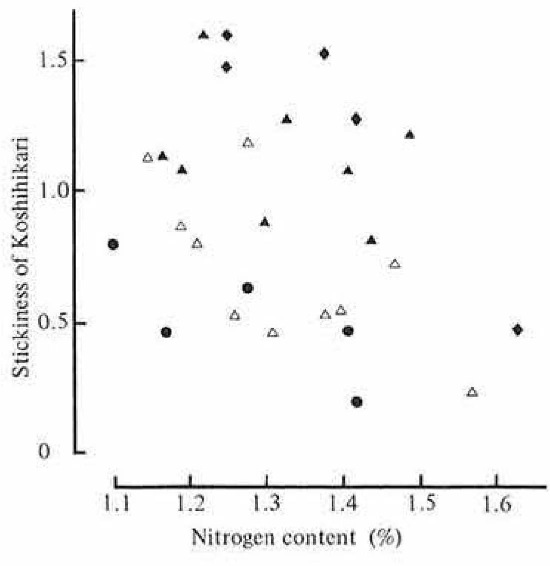


Fig. 4. Relationship between nitrogen content of brown rice and stickiness of Koshihikari See the note in Fig. 3.

stickiness are shown in Table 2. Stickiness could not be well represented by such independent variables as nitrogen content, amylose content and Mg/K ratio. However, when the temperature factor $(\text{Temp.} - 25.4°\text{C})^2$ was added as an independent variable, the multiple correlation coefficient of stickiness became significant at 1% level. In this multiple regression, both T values of standard partial regression coefficients of nitrogen content and $(\text{Temp.} - 25.4°\text{C})^2$ were significant at 1% level. This observation suggests that the stickiness of Koshihikari is affected by the ripening temperature and nitrogen content of rice kernel which may presumably be associated with nitrogen fertilization.

Amylose content was negatively correlated with stickiness when the temperature was less than 26°C (Fig. 3). Therefore, the higher amylose content observed in cool areas may reduce the stickiness of Koshihikari. In contrast, when the mean daily temperature exceeded 26°C, the stickiness of Koshihikari tended to decrease in spite of the low amylose content, for unknown reasons.

For samples at similar temperature levels, the stickiness tended to consistently decrease with the increase of the nitrogen content of brown rice (Fig. 4). This fact indicates that the difference in stickiness within the same cultivation area may mainly be due to the variation in the nitrogen content of the rice kernel.

References

1) Asaoka, M. et al. (1985): Developmental changes in the structure of endosperm starch of rice (*Oryza sativa* L). *Agric. Biol. Chem.*, **49**, 1973–1978.
2) Chikubu, S., Endo, I. & Tani, T. (1965): Qualities of rices by early seasonal cultivation or early sowing depend upon rice varieties and growing regions. 2. Cooking qualities of rice grain. *Rep. Natl. Food Res. Inst.*, **20**, 13–20 [In Japanese with English summary].
3) Chikubu, S. et al. (1985): Establishment of

palatability estimation formula of rice by multiple regression analysis. *J. Jpn. Starch Sci.*, **32**, 51 – 60 [In Japanese with English summary].

4) Honjyo, K. (1971): Studies on protein content in rice grain. I. Variation of protein content between rice varieties and the influence of environmental factors on the protein content. *Jpn. J. Crop Sci.*, **40**, 183 – 189 [In Japanese with English summary].

5) Horino, T., Haraki, T & Ae, N. (1983): Phosphorus, potassium and magnesium contents and their balance in cereal grain. *Jpn. J. Crop Sci.*, **52**, 461 – 467 [In Japanese with English summary].

6) Inatsu, O. (1979): Improvement of the quality of rice grown in Hokkaido. *J. Jpn. Soc. Starch Sci.*, **26**, 191 – 197 [In Japanese with English summary].

7) Inatsu, O. (1988): Studies on improving the eating quality of Hokkaido rice. *Rep. Hokkaido Prefect. Agric. Exp. Stn.*, **66**, 1 – 82 [In Japanese with English summary].

8) Minami, M. & Doi, A. (1971): Physicochemical studies on the qualities of Hokkaido rice. 1. Relation between the palatability characteristics of rice and the growing conditions. *Bull. Hokkaido Prefect. Agric. Exp. Stn.*, **24**, 43 – 55 [In Japanese with English summary].

9) Minami, M. & Doi, A. (1973): Physicochemical studies on the qualities of Hokkaido rice. 2. Relation between the palatability characteristics of rice and protein content of brown rice. *Bull. Hokkaido Prefect. Agric. Exp. Stn.*, **26**, 49 – 58 [In Japanese with English summary].

10) Okamoto, M., Horino, T & Sakai, M. (1992): Relation of nitrogen content and Mg/K ratio of brown rice to stickiness of cooked rice. *Jpn. J. Breed.*, **42**, 595 – 603 [In Japanese with English summary].

11) Sasaki, T. et al. (1977): Physicochemical characteristics and tastes of rice varieties in Hokkaido. *Bull. Hokkaido Prefect. Agric. Exp. Stn.*, **37**, 1 – 10 [In Japanese with English summary].

12) Takeda, T. & Sasaki, T. (1988): Temperature response of amylose content in rice varieties of Hokkaido. *Jpn. J. Breed.*, **38**, 357 – 362 [In Japanese with English summary].

13) Tamaki, M. et al. (1989): Physico-ecological studies on quality formation of rice kernel. I. Effect of nitrogen top-dressed at full heading time and air temperature during ripening period on quality of rice kernel. *Jpn. J. Crop. Sci.*, **58**, 653 – 658.

14) Tani, T. et al. (1969): Physicochemical properties related to palatability evaluations of cooked rice. I. *J. Jpn. Soc. Food Nutr.*, **22**, 452 – 461 [In Japanese with English summary].

15) Yoshikawa, S. & Nishimaru, S. (1965): Qualities of rices by early seasonal cultivation or early sowing depend upon rice varieties and growing regions. 5. Statistical analysis of three years' data by electronic computer. *Rep. Natl. Food Res. Inst.*, **20**, 46 – 54 [In Japanese with English summary].

16) Yoshikawa, S. et al. (1965): Sensory evaluation of cooked rice by early seasonal cultivation or early sowing. *Rep. Natl. Food Res. Inst.*, **20**, 66 – 77 [In Japanese with English summary].

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