한국농화학회지 Vol. 27, No. 3, Sept. 1984
J. Korean Agricultural Chemical Society

Tentative Classification of Milled Rice by Sorption Kinetics

Sung-Kon Kim, Soon-Ja Jeong*, Kwan Kim*, Jae-Chun Chae and Jung-Haeng Lee****

Department of Food and Nutrition, Dankook University, Seoul
*Department of Food Science and Technology, Chonnam National University, Kwangju
**Department of Agronomy, Dankook University, Cheonan Campus, Cheonan
(Received Sept. 10, 1984)

수화 특성에 의한 쌀의 분류

김성곤 · 정순자* · 김관* · 채제천 · 이정행****

단국대학교 식품영양학과
*전남대학교 식품가공학과
**단국대학교 농과대학 농학과

초 록

일반계 12품종 및 다수계 9품종에 대한 수화속도를 비교하였다. 실온에서의 쌀의 수분흡수 속도 또는 물의 확산 계수는 품종마다 독특한 값을 보였다. 쌀은 수분 흡수 속도에 따라 세 그룹으로 나눌 수 있었다. 일반적으로 식미가 좋은 품종으로 알려진 쌀은 수분 흡수 속도가 낮았으며, 대부분의 다수계 품종은 중간 정도의 수분 흡수 속도를 보였다.

Introduction

Although considerable progress has been advanced, much still remains to be understood on the physicochemical basis of rice quality.[1] In the previous study in our laboratory it was demonstrated that no two rice varieties had the same water uptake rate.[2]

In this study 21 varieties were employed to investigate the hydration kinetics of traditional (japonica) and high-yielding(j x indica) rice varieties. A tentative classification of milled rice was also attempted on the basis of water uptake rate of rice grain at room temperature.

Materials and Methods

Rice

Twelve varieties of traditional and 9 varieties of high-yielding rice were used. Milled rice samples were obtained from Office of Rural Development, Suwon, Korea.

Hydration rate

One gram of rice was immersed in tap water at set temperature(4°~30°C). In time intervals of 2~60 min., the weight of the grains after dried on a filter paper was determined. The moisture content of rice was calculated from the weight gain.

Analysis of hydration rate

The moisture gain in initial stage of hydration was analyzed according to the following equation:[3)]

$$\bar{m}-m_0=k\sqrt{t} \quad\cdots\cdots(1)$$

where

$$k=2/\sqrt{\pi}\,(m_s-m_0)(S/V)\sqrt{D} \quad\cdots\cdots(2)$$

In this experiment, m_s was determined by soaking rice grains having different initial moisture contents at 20°C for 15 min.[2,3)]

On the assumption of a prolate spheroid, the volume and surface area of rice grain were calculated by Eq. (3) and (4), respectively:[4)]

$$V=(4/3)\pi\ ab^2 \quad\cdots\cdots(3)$$

$$S=2\pi b^2+2\pi(ab/e)\sin^{-1}e \quad\cdots\cdots(4)$$

where $e=(\sqrt{a^2-b^2})/a$.

Temperature dependence of diffusion coefficient was analyzed by Eq. (5):

$$D=D_0\ \exp(-E_a/RT) \quad\cdots\cdots(5)$$

Results and Discussion

If Eq. (1) is applicable, the moisture gain of rice grain in initial stage of hydration should be approximately proportional to the square root of the absorption time. Figs. 1 and 2 clearly show that such a relation is held. However, the curves did not extrapolate to zero moisture gain at time zero, which indicates that there was a rapid initial absorption of water by rice grain. The phenomenon of nonzero intercept was reported in other cereals.[2,3,5~8)]

The values of m_s and volume-to-surface ratio of rice are given in Table 1. As evident from this table, the values of m_s and volume-to-surface ratio for high-yielding rice varieties were smaller and relatively uniform among varieties in comparison with those for traditional rice counterparts. No correlation between m_s and length, width, hardness, surface area or volume of rice grain was observed.

The water uptake rate (k) which was calculated from the slope of the lines in Figs. 1 and 2 is tabulated in Tables 2 and 3. The diffusion coefficient (D) at various soaking temperatures is also given in the same tables. As the soaking temperature was elevated, k and D values also increased. Considerable variations for k and D values among rice varieties are evident. No two rice varieties had the same k or D values. However, high-yielding rice varieties, in general, had greater k and D values than traditional ones.

Relationship between D and a reciprocal absolute temperature is shown in Fig. 3. The results in Fig. 3 offered an interesting fact.

Table 1. Effective surface moisture content and volume-to-surface ratio of milled rice

Variety	Effective surface moisture content (m_s, gH_2O/g)	V/S (cm)
Traditional		
Sobaegbyo	0.340	0.0545
Chugwangbyo	0.341	0.0546
Boggwangbyo	0.313	0.0536
Koshihikari	0.363	0.0553
Nongbaeg	0.321	0.0541
Yeomyungbyo	0.342	0.0545
Chucheongbyo	0.296	0.0527
Jinjubyo	0.363	0.0527
Sumjinbyo	0.343	0.0531
Samnambyo	0.342	0.0538
Nagdongbyo	0.380	0.0532
Sangpungbyo	0.345	0.0543
High-yielding		
Milyang 23	0.332	0.0511
Nampungbyo	0.320	0.0500
Youngpungbyo	0.333	0.0505
Baegyangbyo	0.339	0.0534
Milyang 30	0.345	0.0501
Samgangbyo	0.325	0.0492
Seogwangbyo	0.380	0.0510
Cheongcheongbyo	0.351	0.0534
Pungsanbyo	0.385	0.0492

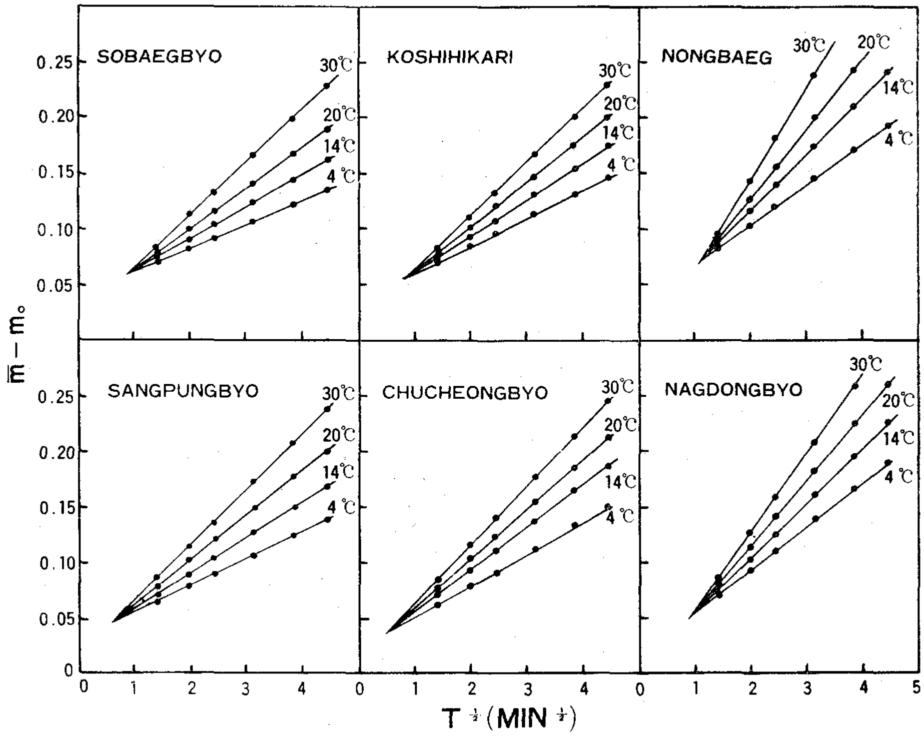

Fig. 1. Relation between the moisture gain and the square root of the absorption time for traditional rice varieties.

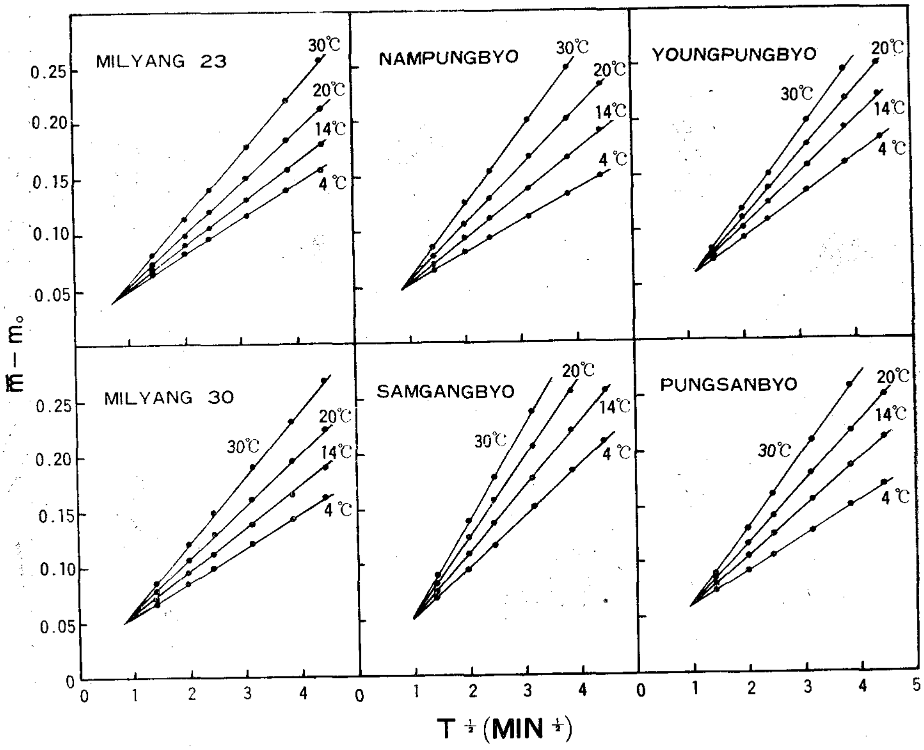

Fig. 2. Relation between the moisture gain and the square root of the absorption time for high-yielding rice varieties.

Table 2. Calculated values of the soaking rate parameters of traditional rice varieties at various soaking temperatures

Variety	Soaking temp. (°C)	$k\times10^2$ (cm/min)	$D\times10^4$ (cm²/min)	Variety	Soaking temp. (°C)	$k\times10^2$ (cm/min)	$D\times10^4$ (cm²/min)
Sobaegbyo	4	2.103	0.216	Chucheongbyo	4	2.801	0.667
	14	2.781	0.378		14	3.718	1.176
	20	3.599	0.633		20	4.157	1.470
	30	4.740	1.098		30	5.225	2.322
Chugwangbyo	4	2.211	0.274	Jinjubyo	4	3.270	0.467
	14	2.891	0.515		14	4.414	0.852
	20	3.378	0.703		20	5.363	1.257
	30	4.484	1.239		30	6.746	1.989
Boggwangbye	4	2.709	0.454	Sumjinbyo	4	3.561	0.658
	14	4.244	1.115		14	4.644	1.118
	20	4.985	1.539		20	5.693	1.681
	30	7.420	3.741		30	7.168	2.664
Koshihikari	4	2.482	0.296	Samnambyo	4	3.950	0.775
	14	3.335	0.535		14	5.200	1.343
	20	3.941	0.747		20	5.952	1.826
	30	4.978	1.192		30	7.835	3.049
Nongbaeg	4	3.574	0.887	Nagdongbyo	4	3.808	0.530
	14	5.019	1.749		14	4.981	0.906
	20	6.263	2.723		20	5.886	1.266
	30	8.154	4.615		30	7.462	2.034
Yeomyungbyo	4	2.780	0.408	Sanggpungbyo	4	2.368	0.329
	14	3.849	0.781		14	3.133	0.576
	20	4.660	1.145		20	3.820	0.855
	30	6.049	1.929		30	4.892	1.403

Changes of D value as function of soaking temperature for certain varieties showed the same pattern. For example, the relation between D and absolute temperature for Baegyangbyo and Nampungbyo was parallel.

The activation energies of soaking for milled rice are given in Table 4. The temperature dependence of D was calculated from Eq. (5) and is presented in Table 4. The activation energy was in the range of 4~5.5 kcal/mole, which is in good agreement with the previous results.[2)]

The results in this experiment demonstrated that the water uptake rate and D values are characteristic of rice variety. Based on the water uptake rate at 20°C, an attempt was made to classify the milled rice. As shown in Table 5, rice samples could be tentatively classified into three groups. Most high-yielding rice varieties fell into Group II, while traditional rice varieties were evenly distributed into three groups. The rices in Group I are generally considered as having good-eating quality. This may imply that water uptake rate of milled rice could be used for quality classification. In our laboratory, a much larger lot is under investigation to varify such possibility.

Nomenclature

a : Long radius of rice grain (cm)

Table 3. Calculated values of the soaking rate parameters of high-yielding rice varieties at various soaking temperatures

Variety	Soaking temp. (°C)	$k\times10^2$ (cm/min)	$D\times10^4$ (cm^2/mn)
Milyang 23	4	3.022	0.457
	14	3.843	0.739
	20	4.618	1.067
	30	5.657	1.602
Nampungbyo	4	2.776	0.414
	14	3.947	0.838
	20	5.098	1.398
	30	6.602	2.344
Youngpungbyo	4	3.522	0.629
	14	4.873	1.205
	20	5.605	1.599
	30	6.753	2.314
Baegyangbyo	4	3.198	0.661
	14	4.431	1.134
	20	5.530	1.767
	30	6.907	2.757
Milyang 30	4	3.103	0.376
	14	4.051	0.698
	20	4.748	0.958
	30	5.932	1.496
Samgangbyo	4	4.732	1.028
	14	5.880	1.587
	20	6.717	2.071
	30	8.345	3.197
Seogwangbyo	4	3.090	0.301
	14	4.398	0.609
	20	5.170	1.020
	30	6.686	1.407
Cheongcheongbyo	4	2.878	0.414
	14	4.048	0.832
	20	4.954	1.227
	30	6.547	2.142
Pungsanbyo	4	3.117	0.289
	14	4.300	0.550
	20	5.406	0.869
	30	6.831	1.388

b : Short radius of rice grain (cm)

D : Diffusion coefficient (cm^2/min)

Table 4. Temperature dependence of diffusion coefficient of milled rice

Variety	D=Do exp (−Ea/RT)
Traditional	
Sobaegbyo	D=0.4332 exp (−5200/RT)
Chugwangbyo	D=0.1615 exp (−4500/RT)
Boggwangbyo	D=10.0655 exp (−6500/RT)
Koshihikari	D=0.1742 exp (−4600/RT)
Nongbaeg	D=2.1173 exp (−5300/RT)
Yeomyungbyo	D=0.5450 exp (−5000/RT)
Chucheongbyo	D=0.1342 exp (−4000/RT)
Jinjubyo	D=0.3277 exp (−4600/RT)
Sumjinbyo	D=0.3343 exp (−4500/RT)
Samnambyo	D=0.3282 exp (−4400/RT)
Nagdongbyo	D=0.1940 exp (−4300/RT)
Sangpungbyo	D=0.2306 exp (−4700/RT)
High-yielding	
Milyang 23	D=0.0966 exp (−4000/RT)
Nampungbyo	D=1.6738 exp (−5500/RT)
Youngpungbyo	D=0.1864 exp (−4200/RT)
Baegyangbyo	D=0.7476 exp (−5000/RT)
Milyang 30	D=0.1097 exp (−4200/RT)
Samgangbyo	D=0.1015 exp (−3600/RT)
Seogwangbyo	D=0.4065 exp (−5000/RT)
Cheongcheongbyo	D=0.9644 exp (−5300/RT)
Pungsanbyo	D=0.4306 exp (−5000/RT)

D_0 : Diffusion constant (cm^2/min)

E_a : Activation energy (cal/mole)

e : Eccentricity

m_0 : Initial moisture content ($g\ H_2O/g$, dry basis)

$\bar{m}$: Moisture content at given absorption time ($g\ H_2O/g$, dry basis)

m_s : Effective moisture content ($g\ H_2O/g$, dry basis)

R : Gas constant (1.987cal/mole °K)

S : Surface area of rice grain (cm^2)

T : Absolute temperature (°K)

t : Hydration time (min)

V : Volume of rice grain (cm^3)

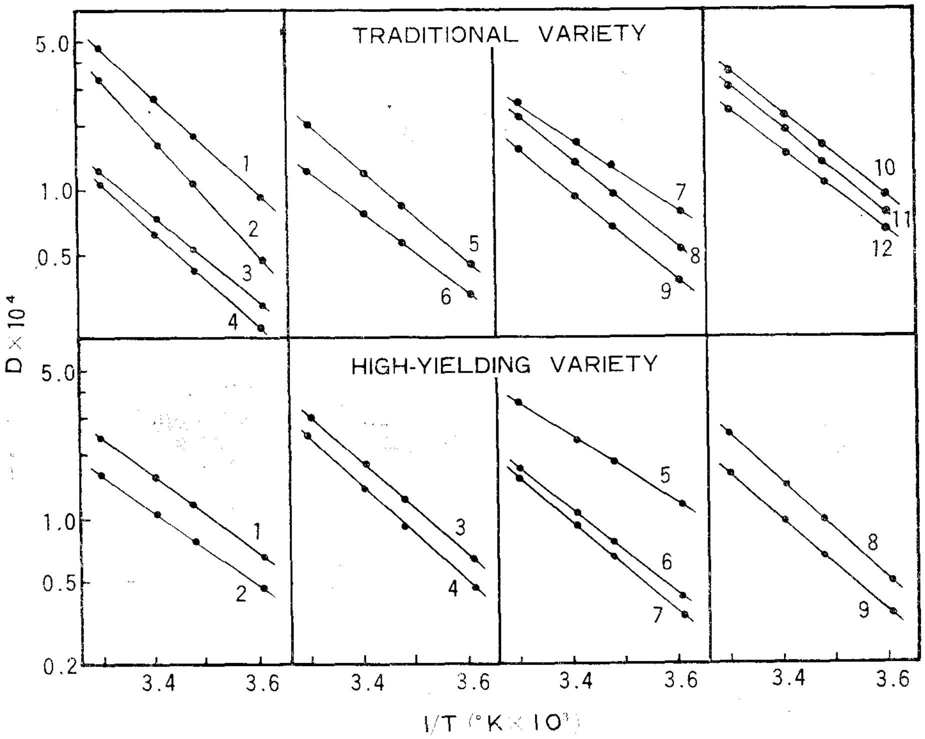

Fig. 3. Diffusion coefficient as a function of reciprocal absolute temperature.

Traditional variety

1. Nongbaeg
2. Boggwangbyo
3. Chugwangbyo
4. Sobaegbyo
5. Yeomyungbyo
6. Koshihikari
7. Chucheongbyo
8. Jinjubyo
9. Sangpungbyo
10. Samnambyo
11. Sumjinbyo
12. Nagdongbyo

High-yielding variety

1. Youngpungbyo
2. Milyang 23
3. Baegyangbyo
4. Nampungbyo
5. Samgangbyo
6. Milyang 30
7. Seogwangbyo
8. Cheongcheongbyo
9. Pungsanbyo

Table 5. Classification of milled rice based on water uptake rate at 20°C

	Water uptake rate ($k\times10^2$, cm/min)		
	Group I (3.4∼4.2)	Group II (4.5∼5.7)	Group III (5.8<)
Traditional variety	Sobaegybyo Chugwangbyo Koshihikari Sangpungbyo Chucheongbyo	Boggwangbyo Yeomyungbyo Jinjubyo Sumjinbyo	Samnambyo Nagdongbyo Nongbaeg
High-yielding variety		Seogwangbyo Milyang 23 Cheongcheongbyo Nampungbyo Youngpungbyo Pungsanbyo Baegyangbyo	Milyang 30 Samgangbyo

Abstract

Hydration of twelve japonica (j) and nine j x indica rice varieties was analyzed in terms of mathematical rate equation and a tentative classification of milled rice was attempted primarily on the basis of water uptake rate of rice grain at room temperature. No two rice varieties had the same water uptake rate or diffusion coefficient. The rice samples could be classified into three groups. Rices which are considered as having good eating quality had lower water uptake rate.

References

1. Juliano, B.O.: IRRI Research Paper Series No. 77, Internation Rice Research Institute, Philippines (1982).
2. Lee, S.O., Kim, S.K, Lee, S.K.: J. Korean Agr. Chem. Soc., 26 : 1(1983).
3. Becker, H.A.: Cereal Chem., 37 : 309(1960)
4. Beyer, W.H.: CRC Standard Methmatical Tables, CRC Press, West Palm Beach(1978)
5. Cho, E.K., Pyun, Y.R., Kim, S.K. and Yu, J.H.: Korean J. Food Sci. Technol., 12 : 285 1980).
6. Mok, C.K., Lee, H.Y., Nam, Y.J. and Min, B.Y.: Korean J. Food Sci. Technol., 15 : 136 (1983).
7. Lee, J.S. and Kim, S.K.: Korean J. Food Sci. Technol., 15 : 220(1983).
8. Kim, K.J., Pyun, Y.R., Cho, E.K., Lee, S. K. and Kim, S.K.: Korean J. Food Sci. Technol., 16 : 311(1984).