Gelatinization Characteristics of Nonwaxy Rice Starches

Nam-Soo Kim, Ho-Moon Sog, Young-Jung Nam and Byong-Yong Min

Food Research Institute/AFMC, Banwol, Kyunggi, 170—31 Korea

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멥쌀 전분의 호화특성

김남수 · 석호문 · 남영중 · 민병용

농수산물 유통공사 종합식품연구원

초   록

멥쌀 중에서 태백과 상풍 두품종으로부터 전분을 분리하고 그 전분특성을 규명하였다. 태백 전분의 아밀로스 함량은 16%, 입자의 크기는 3～8μ인 반면 상풍 전분의 아밀로스 함량은 17 %, 입자의 크기는 3～10μ였다. 호화온도가 높아짐에따라 팽윤도와 용해도는 증가하여 90°C에 서의 팽윤도는 태백전분이 12.12, 상풍 전분이 11.54였으며, 용해도는 태백 전분이 3.10%, 상 풍전분이 3.92%였다. 전분농도의 상승에 따라 pasting 온도의 감소는 상풍전분의 경우 보다 현 저하였으며, 최대점도는 태백전분이 높은 경향이었다. 태백과 상풍전분의 희석 용액에 있어서 광투과성의 증대는 85°C와 90°C의 호화온도 범위내에서 주로 이루어졌다. 태백전분과 상풍전분 의 호화 반응은 60～90°C의 호화온도 범위에서는 2단계로 나타나고 있었다. 1단계 호화반응시 의 활성화에너지는 태백전분이 26.53kcal/mole, 상풍전분이 25.14kcal/mole이었으며, 2단계 호 화 반응시의 활성화 에너지는 태백전분이 18.48～70.34kcal/mole, 상풍전분이 15.90～79.98kcal/ mole이었다.

Introduction

Rice (*Oryzae sativa* L.) has been the most important cereal in Korea. In recent years, demands for processed rice products have been increasing continuously. Therefore, to obtain rice products having good qualities, it is essential to examine properties of rice starch. Until now, Kim et al.[1-2] and Song et al.[3] reported physicochemical and viscosimetric properties of rice starch. Reports on the kinetic study and amylographic characteristics of rice starch were also found.[4-5]

The aim of this research is to elucidate physicochemical properties and gelatinization kinetics of nonwaxy rice starches.

Materials and Methods

Starch prepartion

Starch was isolated from Taebaeg and Sang-pung rice grain as reported previously.[6]

Analytical methods

Proximate compositions were determined routinely. Blue value and amylose content[7], microscopic examination[8], swelling power and solubility[9], light penetration of dilute starch suspension[10], and pasting properties were determined for the elucidation of physicochemical properties of rice starches.

Gelatinization extent

Gelatinization extent was determined according

to previous reports[11~13]. After gelatinization of 1% starch suspension according to time (2~120 mins) and temperature (60~95°C) in rapid amylograph accessory, 5ml of gelatinized starch suspension was picked up and centrifuged at 3,000xg for 30 mins. Then, 1ml of supernatant and 0.1ml of iodine solution (including 4% KI and 1% I_2) were pipetted into 50ml volumetric flask. After filling-up to the mark, absorbance at 600 nm(X) was determined. Alkali gelatinization of starch was done by mixing 0.5g of starch, 47.5 ml of distilled water, and 2.5 ml of 10N KOH and reacting for 5 mins. The centrifuged supernatant was treated as described above and absorbance at 600nm (X_e) was also determined.

Gelatinization extent (G.E.) $= \dfrac{X}{X_e}$

where,

X : gelatinization parameter at time t

X_e : gelatinization parameter at the end point

Results and Discussion

Physicochemical properties of nonwaxy rice starches are shown in Table 1.

Amylose contents were in the range of 16~17% and these values were considerably lower than those of barley starch[14]. Blue values matched well with amylose contents in both cultivars. The granule size was 3~8μ in Taebaeg starch and 3~10μ in Sangpung starch. The granule shape was polygonal or angular as reported previously[15]. Swelling power and solubility of Taebaeg and Sangpung starch are represented in Table 2.

Swelling power was increased when gelatinization temperature was raised. However, the trend of increase over 80°C was more conspicuous in

Table 1. Physicochemical properties of nonwaxy rice starch

	Taebaeg	Sangpung
Moisture(%)	10.1	10.8
Ash(%)	0.22	0.20
Protein(%)	0.14	0.09
Fat(%)	0.08	0.11
Amylose content(%)	16.0	17.0
Blue value[a]	0.46	0.49
Granule size(μ)	3~8	3~10
Granule shape	Polygonal, angular	Polygonal, angular

a : dry basis

Table 2. Swelling power and solubility of nonwaxy rice starch

Gelatinization temperature (°C)	Swelling power[a]		Solubility(%)[a]	
	Taebaeg	Sangpung	Taebaeg	Sangpung
60	3.26	5.20	1.39	1.98
70	4.50	6.79	1.63	1.51
80	9.52	9.43	1.49	2.15
90	12.12	11.54	3.10	3.92

a : dry basis

Table 3. Pasting properties of nonwaxy rice starch

Cultivar	Concn.[a] (%)	Pasting temp. (°C)	Maximum viscosity (B.U.)	Temp. at max. viscosity (°C)	Viscosity at 95°C (B.U.)	Viscosity at 95°C after 15 min(B.U.)
Taebaeg	6	78.0	465	95.0	465	420
	7	69.5	770	94.8	770	590
Sangpung	6	84.2	344	95.0	344	320
	7	66.8	600	95.0	600	510

a : dry basis

Taebaeg starch. Solubility was also increased at enhanced temperature. Values of swelling power and solubility of nonwaxy rice starch were relatively high, compared with those of barley starch[6].

Pasting properties of nonwaxy rice starches are described in Table 3.

Pasting temperatures of Taebaeg and Sangpung starch at 6% concentration were 78. 0 and 84. 2°C respectively. In the case of Sangpung starch, the abrupt decrease in pasting temperature was found at 7% concentration.The maximum viscosity of Taebaeg starch was higher than that of Sangpung starch. More serious break-down was found at 7% starch concentration in both cases [16~17].

The change of light penetration according to gelatinization temperature in 0. 1% dilute starch suspension is depicted in Fig. 1.

As shown in Fig. 1, there was no specific difference in light penetration in both cultivars. Waldt and Kehoe previously reported that the dilute starch suspension became clear and trans-
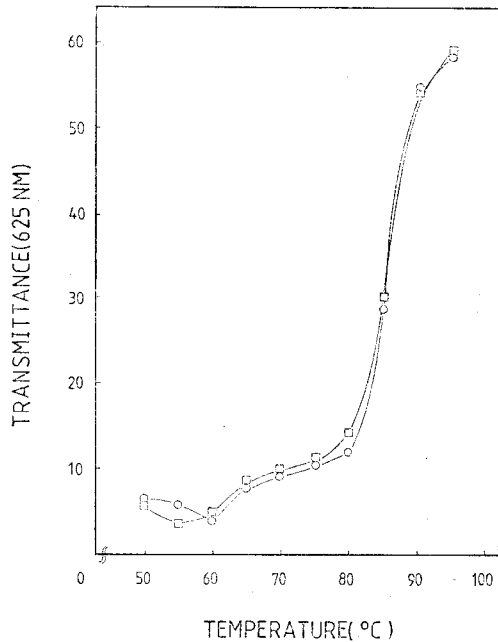

Fig. 1. Effects of gelatinization temperature on the light penetration of 0. 1% nonwaxy rice starch suspensions. ○—○ Taebaeg starch, □—□ Sangpung starch.
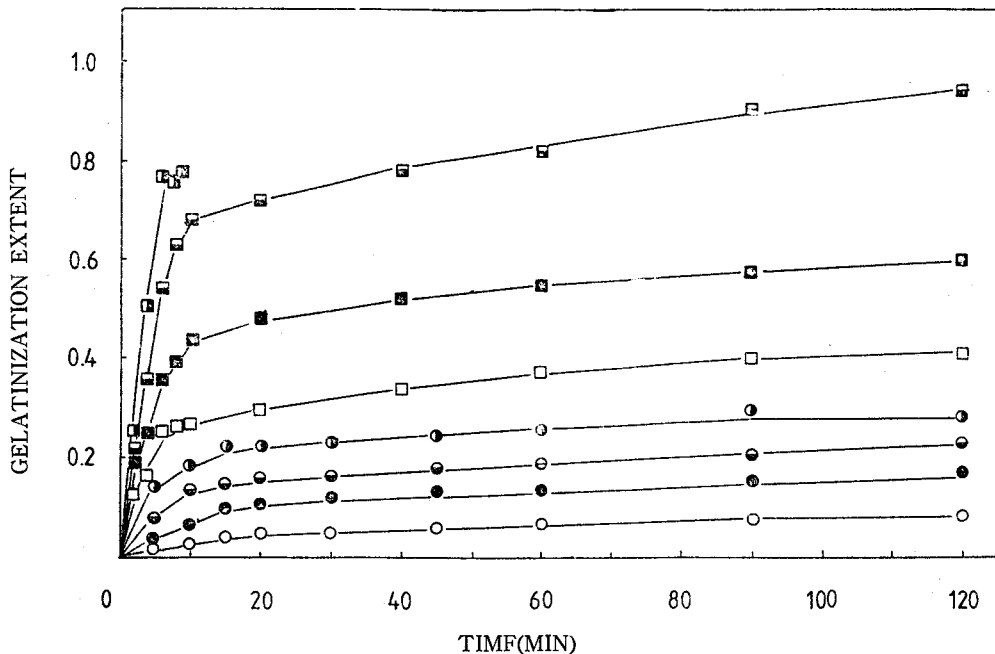

Fig. 2. Effects of gelatinization condition on gelatinization extents of 1% Taebaeg starch suspension. Gelatinization temperature : ○—○ : 60°C, ●—● : 65°C, ◕—◕ : 70°C, ◑—◑ : 75°C, □—□ : 80°C, ■—■ : 85°C, ▣—▣ : 90°C, ▣—▣ : 95°C.
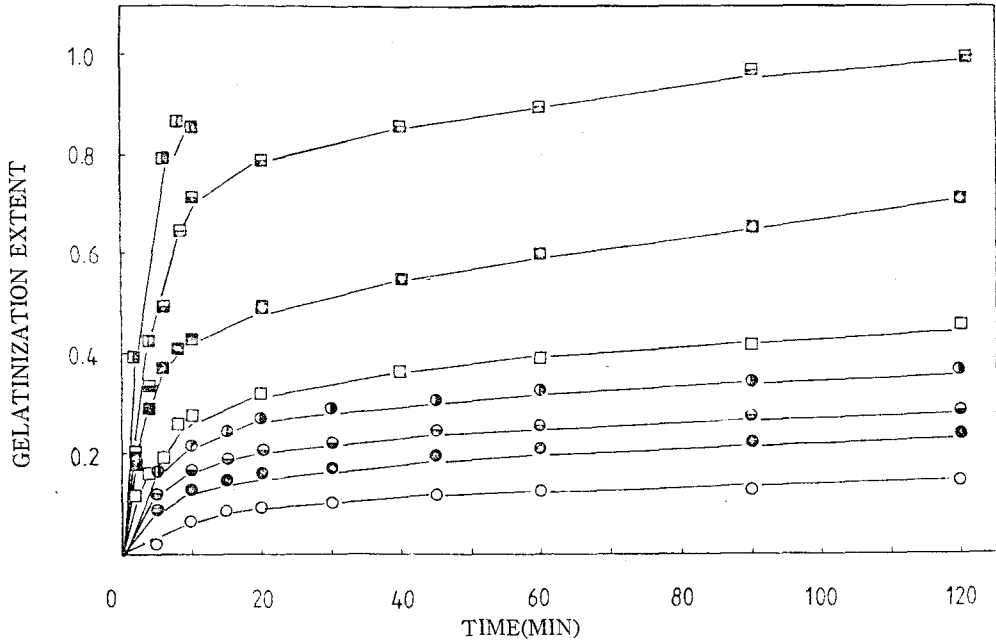
Fig. 3. Effects of gelatinization condition on gelatinization extents of 1% Sangpung starch suspension. Gelatinization temperature ; ○—○ : 60° C, ●—● : 65°C, ◐—◐ : 70°C, ◑—◑ : 75°C, □—□ : 80°C, ■—■ : 85°C, ▄—▄ : 90°C, ▐—▐ : 95°C.

parent when gelatinization temperature rose[18]. In this experiment, most of the increase in light penetration was found between the gelatinization temperature of 85°C and 90°C. However, the increase in light penetration was diminished after 90°C like the results of previous publcations[3],[18].

The gelatinization extent according to gelatinization condition is shown in Fig. 2 and Fig. 3. Until 90°C, the gelatinization extent increased continuously in both cultivars.

The gelatinization reaction of starch suspension can be expressed as follows[19].

$$\frac{dx}{dt} = k(1-x) \quad \cdots\cdots\cdots\cdots\cdots\cdots (1)$$

where,

x : gelatinization extent

k : reaction rate coefficient

Equation (1) is transformed to equation (2)

$$\ln 1/1-x = kt \quad \cdots\cdots\cdots\cdots\cdots\cdots (2)$$

Relationships between gelatinization time(t) and ln 1/1−x in Taebaeg and Sangpung starch suspension are drawn in Fig. 4 and Fig. 5.
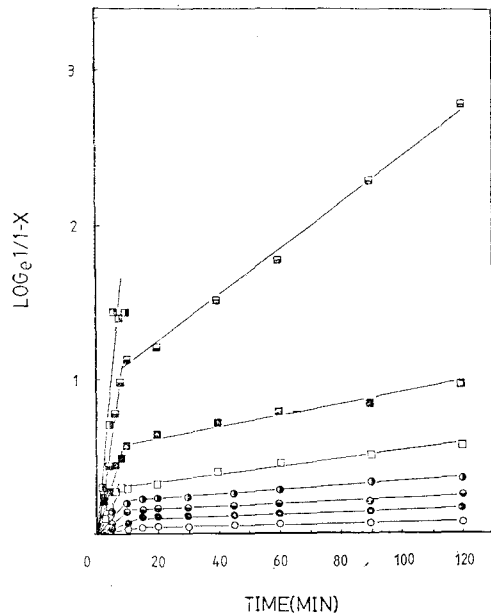

Fig 4. The semilog plot of gelatinization time versus ln 1/1-x in 1% Taebaeg starch suspension. Gelatinization temperature ; ○—○ : 60°C, ●—● : 65°C, ◐—◐ : 70°C, ◑—◑ : 75°C, □—□ : 80°C, ■—■ : 85°C, ▄—▄ : 90°C, ▐—▐ : 95°C,

Fig. 5. The semilog plot of gelatinization time versus ln 1/1-x in 1% Sangpung starch suspension. Gelatinization temperature ; ○—○ : 60°C, ●—● : 65°C, ◒—◒ : 70°C, ◐—◐ : 75°C, □—□ : 80°C, ■—■ : 85°C, ▤—▤ : 90°C, ▥—▥ : 95°C.
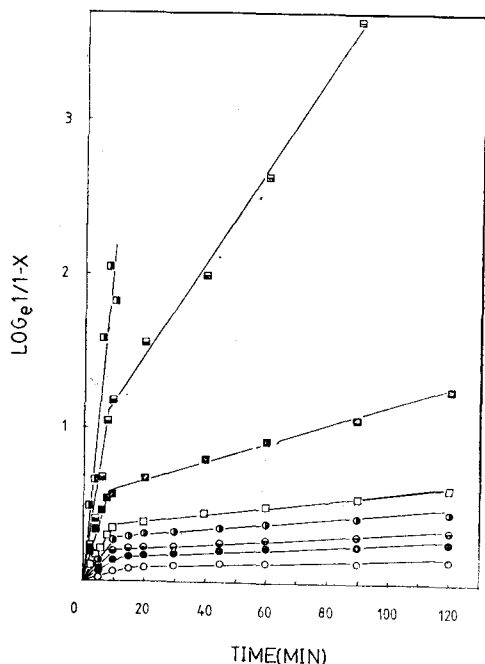
As described earlier[20-21], the gelatinization reaction of rice starch suspension also occurred in 2 stages until the gelatinization temperature reached 90°C. At 95°C, the gelatinization reaction of both starch suspensions occurred in single stage. The knots (representing the crystallites

and junction zone) and ties (representing the entangled chains in amorphous region) mechanism of starch gelatinization was presented by some researchers[22]. According to it, there are two ways to gelatinize the starch granule by a rapid process of cutting the knots or by a slow process of disentangling the ties. As sufficient energies were not provided under 90°C, there occurred fast 1st stage gelatinization reaction (cutting the knots) and slow 2nd stage gelatinization reaction (disentangling the ties) concomitantly. This fact resulted in the bent straight line in time vs ln 1/1-x plot.

In Table 4, gelatinization rate coefficients deduced from Fig. 4 and Fig. 5 are recorded.

In each case of Taebaeg and Sangpung starch suspension, gelatinization rate coefficients became greater according to the increase in gelatinization temperature and gelatinization rate coefficients of 1st stage gelatinization reaction were higher than those of 2nd stage gelatinization reaction. Sangpung starch suspension showed relatively higher gelatinization rate coefficients than Taebaeg starch suspension. This fact strongly suggests that Sangpung starch suspension be gelatinized faster than Taebaeg starch suspension.

The result of Table 4 was redrawn following Arrhenius equation (Fig. 6, Fig. 7).

Gelatinization rate coefficients of 2nd stage gelatinization reaction appeared as 2 different straight lines.

Table 4. Gelatinization rate coefficients of rice starch suspensions

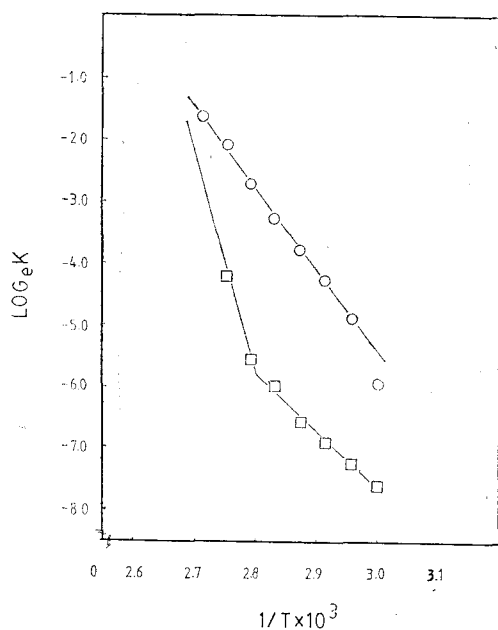| Temperature(°C)	Rate coefficient of Taebaeg(min⁻¹)		Rate coefficient of Sangpung(min⁻¹)	
	1st stage	2nd stage	1st stage	2nd stage
60	2.6×10^{-3}	5.0×10^{-4}	6.0×10^{-3}	7.0×10^{-3}
65	7.7×10^{-3}	7.0×10^{-4}	0.0168	1.2×10^{-3}
70	0.0142	8.3×10^{-4}	0.0195	1.3×10^{-3}
75	0.0226	1.4×10^{-3}	0.0274	1.9×10^{-3}
80	0.0378	2.5×10^{-3}	0.0372	2.3×10^{-3}
85	0.0663	3.8×10^{-3}	0.0691	6.3×10^{-3}
90	0.1270	0.0150	0.1235	0.0306
95	0.2000	0.2000	0.2200	0.2200

Fig. 6. Arrhenius plot of gelatinization rate coefficients in 1% Taebaeg starch suspension. Symbol ; ◯—◯ : 1st stage gelatinization reaction, □—□: 2nd stage gelatinization reaction.

Fig. 7. Arrhenius plot of gelatinization rate coefficients in 1% Sangpung starch suspension. Symbol ; ◯—◯ : 1st stage gelatinization reaction, □—□ : 2nd stage gelatinization reaction.

From the slopes of Fig. 6 and Fig. 7, activation energies of gelatinization reaction in Taebaeg and Sangpung starch suspension were calculated (Table 5).

Kubota et al[4] and Donovan[23] previously indicated that the gelatinization reaction of starch suspension is limited by the chemical reaction rate of starch components with water and/or the physical transforming rate such as the melting of starch crystalline regions, unlike the
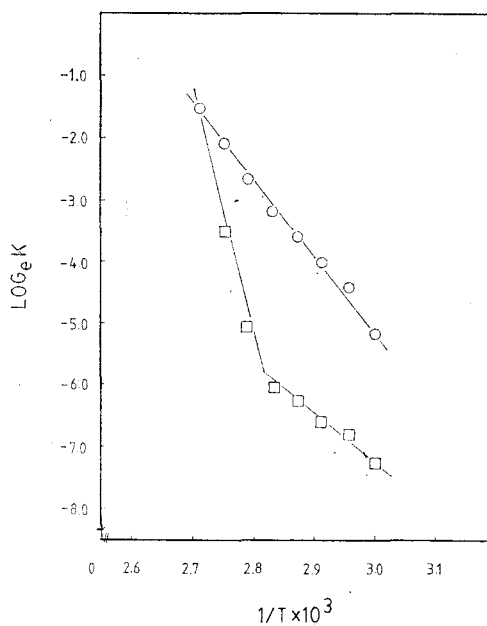
diffusion-limited heterogenous catalytic reactions such as cooking of cereal grains[24,25]. From the different activation energies of 2nd stage gelatinization reactions, it is inferred that the slow process of starch gelatinization occurs very fast above 85°C than below 85°C in Taebaeg starch suspension and above 80°C than below 80°C in Sangpung starch suspension.

Abstract

starches, isolated from Japonica and nonwaxy rices, were analyzed for gelatinization characteristics.

Amylose contents of Taebaeg and Sangpung starch were 16 and 17%, respectively. The portion of large-sized particles was more pronounced in the case of Sangpung starch. Swelling power and solubility increased according to the rise in gelatinization temperature. The decrease of pasting temperature according to the increase

Table 5. Activation energy of rice starch suspensions

Cultivar	Ea (kcal/mole)	
	1st stage	2nd stage
Taebaeg	26. 53	18. 48 (below 85°C)
		70. 34 (above 85°C)
Sangpung	25. 14	15. 90 (below 80°C)
		79. 98 (above 80°C)

in starch concentration in Sangpung starch was higher than that of Taebaeg starch. Most of the increase in light penetration was accomplished between 85 and 90°C. Gelatinizationreactions of Taebaeg and Sangpung starch appeared as 2 different stages up to the gelatinization temperature of 90°C.

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