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Effects of Various Salts on the Reheating Behavior of Retrograded Rice Starch and Cooked Rice

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Abstract

The influence of sodium salts and chlorides at various concentrations (0.05, 0.10, 0.50, and 1.00%) on the reheating behavior of retrograded rice starch and cooked rice was investigated. The degree of gelatinization of the all retrograded rice starch gels and the cooked rice containing sodium salts and chlorides increased after reheating compared to the starches without salt. Gelatinization also showed an increasing trend as the concentration of sodium salts and chlorides increased. The increase of gelatinization after reheating the samples containing sodium salts and chlorides was greater than 38.0%. The reheated retrograded rice starch and cooked rice containing Na_3PO_4 showed the lowest set back value and retrogradation rate constant. Among all the samples, the cooked sample containing Na_3PO_4 showed the highest increment of gelatinization after reheating. Also, this same sample showed the lowest retrogradation degree.

Key words: reheating, sodium salts, chlorides, retrograded rice starch, retrograded cooked rice

INTRODUCTION

The retrogradation of gelatinized starch is a phenomenon of great importance to the food industry. It is a process in which the molecules of gelatinized starch reassociate to form crystallites (1,2). Over a longer storage time, the branches of amylopectin associate to produce staling of the food (3). Impact factors of starch retrogradation were water content, temperature, pH, additives, and ratio of amylose and amylopectin. Among the factors, the sodium salts and chlorides in the gelatinized starch solution make a bridge between amylose and amylopectin, with the resulting effect of maintaining the gelatinized state and to starch without salt retrogradation through (4). It is well known that retrogradation characteristics are markedly altered by the addition of salts (4, 5). Sodium chloride reportedly increases starch retrogradation as (4,5) or decreases retrogradation (5). It may be due to different concentrations of salts and starch source.

On the other hand, starch that has been pasted/cooked and dried without excessive retrogradation can be partially redispersed in water. Such a starch is called pregelatinized or instant starch. It has been gelatinized, but has also been pasted, which means many granules have been destroyed, so it should more properly be called prepasted starch (3). The pregelatinized or prepasted starch is important in most ready-to-eat processed starch food, like aseptically-packed cooked rice, which has become popular in households and food service operation (6). Also, the re-heating (secondary heating) of almost ready-to-eat starch foods immediately prior to eating can cause gelatinization of the retrograded starch. A small quantity of ungelatinized starch remains after the first heating (7,8). The study of the influence of various salts on reheating of retrograded rice starch and cooked rice is not totally sufficient yet.

In this study, we investigated the effect of various concentrations of sodium salts and chlorides on the reheating behavior of the retrograded rice starch and the cooked rice.

MATERIALS AND METHODS

Materials

Rice (Chu Cheong byeo) was purchased from the Paju nonghyup in Gyeonggi, 2010. Rice starch was used a reagent grade (S-7260, Sigma-Aldrich, Inc., St. Louis, MO, USA). The sodium salts were NaCl (Showa chemical Co., Tokyo, Japan), CH_3COONa (Kishida chemical Co., Osaka, Japan), and Na_3PO_4 (Junsei chemical Co., Tokyo, Japan). The chlorides were KCl (Showa chemical Co.),

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$CaCl_2$ (Showa chemical Co.), and $MgCl_2$ (Showa chemical Co.). All chemicals and enzymes (Sigma Chemical Co, St. Louis, MO, USA) used were analytical reagent grade.

Preparation of the retrograded rice starch and the cooked rice samples

Retrograded rice starch: The retrograded rice starch was prepared as follows. First, the gelatinized starch was prepared. A glass bottle containing 2% (w/v) starch slurry was autoclaved for 20 min, and then ethanol was added to the rice starch solution. The resulting precipitate was filtered and dried in a freeze dryer (Ilshin, Gyeonggi-do, Korea) operating at -50°C and 1.33 Pa. This was powdered to 150 μm. Then, to prepare the retrograded starch, the water content of the gelatinization rice starch was adjusted to 65% (w/v) by adding of distilled water. These mixtures were stored for 2 days at 4°C. After that, the samples were frozen at a temperature of -70°C and then freeze-dried as described above.

Retrogradation of cooked rice: The milled rice was cooked by electric cooker. The water content of sample was 65% (w/v) and the distilled water contained sodium salts and chlorides at different concentrations (0.05, 0.10, 0.50 and 1.00%). Then, the cooked rice samples were stored at 4°C for 3 days for retrogradation. After that, the samples were frozen at -70°C and then dried in a freeze dryer (Ilshin) operating at -50°C and 1.33 Pa. This was powdered to 150 μm.

Reheating of the retrograded rice starch and the cooked rice

Distilled water containing various sodium salts and chlorides (0.05, 0.10, 0.50, and 1.00%) was added to the retrograded rice starch powder to 95% (w/v), which was reheated by autoclave (JK-AT-60, JK Tranding Co., Seoul, Korea) for 20 min at 121°C. After reheating, the samples were frozen at -70°C and then freeze-dried by freeze dryer (Ilshin) operating at -50°C and 1.33 Pa. In case of the retrograded cooked rice samples, distilled water was added to the retrograded cooked rice powder samples to 95% (w/v) and reheated by autoclave (JK-AT-60, JK Tranding Co., Seoul, Korea) for 20 min at 121°C. After that, the samples were frozen at -70°C and then freeze-dried as before.

Degree of gelatinization and retrogradation

Alteration of gelatinization of the retrograded rice starch and the cooked rice were determined by measuring the reducing sugar corresponding to the enzymatic degradation of the retrograded starch (9). The amount of reducing sugar was determined through phenol-sulfuric acid assay. Briefly, 20 mg of powdered sample was dispersed in 5 mL distilled water in a 50 mL centrifuge tube, into which 25 mL glucoamylase solution (about 20 units) was added. After incubation for 1 hr at 40°C, the reaction was stopped by adding 2 mL of 25% trichloroacetic acid (TCA). After centrifugation of the solution at 16,000×*g* for 5 min, 2 mL of a diluted supernatant solution containing 10～70 mg/mL of sugar was transferred into a test tube, and then 1 mL of 5% phenol was added, followed by the rapid addition of 5 mL of concentrated sulfuric acid. The tubes were allowed to stand for 10 min, shaken, and placed in a 30°C water bath for 20 min before the readings were taken. The absorbance of the characteristic yellow-orange color was measured at 490 nm. The degree of retrogradation (DR) was calculated according to the following equation;

$$\mathrm{DR}\ (\%) = 100 - (\mathrm{B/A}) \times 100$$

where B is the absorbance of reducing sugar produced from starch fraction to be tested at time t, and A is the absorbance of reducing sugar produced from total starch fraction at the initial time.

Model for retrogradation kinetics

The Avrami model was employed to describe the kinetics of starch recrystallization of cooked rice with various sodium salts and chlorides. The model (10) can be expressed as:

$$\theta = \frac{(E_L - E_t)}{(E_L - E_O)} = \exp(-k \cdot t^n)$$

where Θ is the fraction of uncrystallized starch at time t, E_0 and E_t are the degradation extent of starch at times 0 and t, respectively. E_L is the limiting degradation extent, k is the rate constant, and n is the Avrami exponent. The rate constants for rice starch were obtained from linear regression of retrogradation data as:

$$\log\left(-\ln\frac{(E_L - E_t)}{(E_L - E_O)}\right) = \log k + n\log t$$

Pasting properties

Pasting profiles were obtained using a rapid visco analyser (RVA-3D, Newport Scientific, Warriwood, Australia). The freeze-dried rice starch flour (2.58 g, db) was suspended in distilled water and adjusted to a total weight of 28 g. The samples were equilibrated at 50°C for 1 min and then heated at a rate of 6°C/min to 95°C and maintained at that temperature for 5 min before cooling to 50°C at a rate of 6°C/min. A constant spindle speed of 160 rpm was used. From the resulting pasting curve, the pasting temperature (°C), peak time (min), peak viscosity (RVU), breakdown (RVU), final viscosity (RVU), and set-back (RVU) were calculated as previously described method (11).

Statistical analysis

An analysis of variance (ANOVA) was performed, and the differences among the samples were determined by Duncan's multiple range test using the Statistical Analysis System. $p<0.05$ was considered significantly.

RESULTS AND DISCUSSION

Effect of sodium salts and chlorides on the degree of gelatinization of retrograded rice starch after reheating

The retrograded rice starch was prepared to examine the effect of sodium salts and chlorides on regelatinization when the retrograded starch was heated. Namely, the rice starch gelatinized to 91.2% using 2% (w/v) starch slurry. This gelatinized starch was retrograded by the adjusted water content to 65% (w/v) and stored at 4°C for 2 days. Thus, 67.6% of the gelatinized starch was retrograded (Fig. 1). After reheating, the degree of gelatinization of the retrograded rice starch with salts and chlorides of various concentrations were shown in Table 1. The degree of gelatinization of the retrograded rice starch sample increased after reheating. The degree of gelatinization of the starch that did not have any salts or chlorides added also increased after reheating. All retrograded rice starch gels containing salts showed higher gelatinization compared to the starch without salt. Among samples containing different sodium salts, the samples with Na_3PO_4 showed the highest increment of the gelatinization. Also, the degrees of gelatinization of samples increased as the concentration of salts increased. Additionally, the effect of sodium phosphate on promoting gelatinization of rice starch was the most predominant among all of the added sodium salts. This effect may be the result of the different chemical structures of the salts. The degree of gelatinization with the addition of chlorides was increased after reheating, too. All retrograded rice starch gels containing chlorides showed higher gelatinization compared to the starch without salt, and samples containing $CaCl_2$ had significantly higher gelatinization among the chlorides samples.

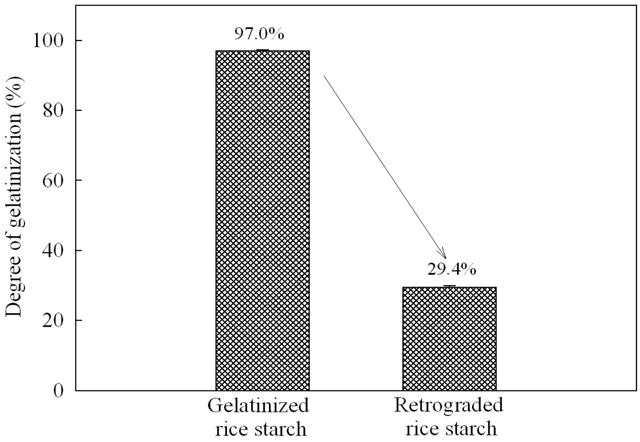

Fig. 1. Preparation of the retrograded rice starch from the gelatinized rice starch.

Gelatinization increment of the retrograded rice starch after reheating

The effects of various sodium salts and chlorides on gelatinization of the retrograded rice starch after the reheating is shown in Fig. 2. The gelatinization increment after heating for the samples without added salts was 38.0%. The gelatinization increment of samples containing salts and chlorides were higher than that of starch without salt sample when the samples were reheated. As the addition concentration was increased when the samples were reheated, the gelatinization increment increased over 40%. The gelatinization increment of sample adding sodium phosphate was 52.2% after reheating with comparing to starch without salt sample. The samples adding chlorides showed similarly trend to the sam-

Table 1. Effect of sodium salts and chlorides on the degree of gelatinization in the retrograded starch after reheating

Samples			Concentrations (%)			
			0.05	0.10	0.50	1.00
Sodium salts	Cation	Anion				
Retrograded starch	–	–	$29.4\pm0.5^{e1)}$	29.4 ± 0.5^{e}	29.4 ± 0.5^{d}	29.4 ± 0.5^{e}
No addition	–	–	67.4 ± 0.3^{d}	67.4 ± 0.3^{d}	67.4 ± 0.3^{c}	67.4 ± 0.3^{d}
NaCl	Na^+	Cl^-	69.4 ± 0.7^{b}	70.4 ± 0.5^{b}	72.1 ± 0.5^{b}	77.3 ± 0.4^{c}
CH_3COONa	Na^+	CH_3COO^-	68.4 ± 0.3^{c}	69.2 ± 0.1^{c}	71.2 ± 0.4^{b}	77.2 ± 0.8^{c}
Na_3PO_4	Na^+	PO_4^{3-}	70.5 ± 0.6^{a}	71.4 ± 0.5^{a}	74.1 ± 0.1^{a}	81.6 ± 0.3^{a}
Chlorides	Cation	Anion				
Retrograded starch	–	–	29.4 ± 0.5^{e}	29.4 ± 0.5^{e}	29.4 ± 0.5^{d}	29.4 ± 0.5^{e}
No addition	–	–	67.4 ± 0.3^{d}	67.4 ± 0.3^{d}	67.4 ± 0.3^{c}	67.4 ± 0.3^{d}
NaCl	Na^+	Cl^-	69.4 ± 0.7^{b}	70.4 ± 0.5^{b}	72.1 ± 0.5^{b}	77.3 ± 0.4^{c}
KCl	K^+	Cl^-	68.9 ± 0.5^{b}	70.4 ± 0.3^{b}	72.2 ± 0.9^{b}	77.9 ± 0.4^{c}
$CaCl_2$	Ca^{2+}	Cl^{2-}	69.8 ± 0.3^{ab}	71.2 ± 0.4^{a}	73.7 ± 0.9^{a}	80.2 ± 0.5^{b}
$MgCl_2$	Mg^{2+}	Cl^{2-}	69.8 ± 0.4^{ab}	70.8 ± 0.5^{ab}	73.6 ± 0.9^{a}	80.0 ± 0.5^{b}

1) Different superscripts in a column are significant difference at $p<0.05$ by Duncan's multiple comparisons.

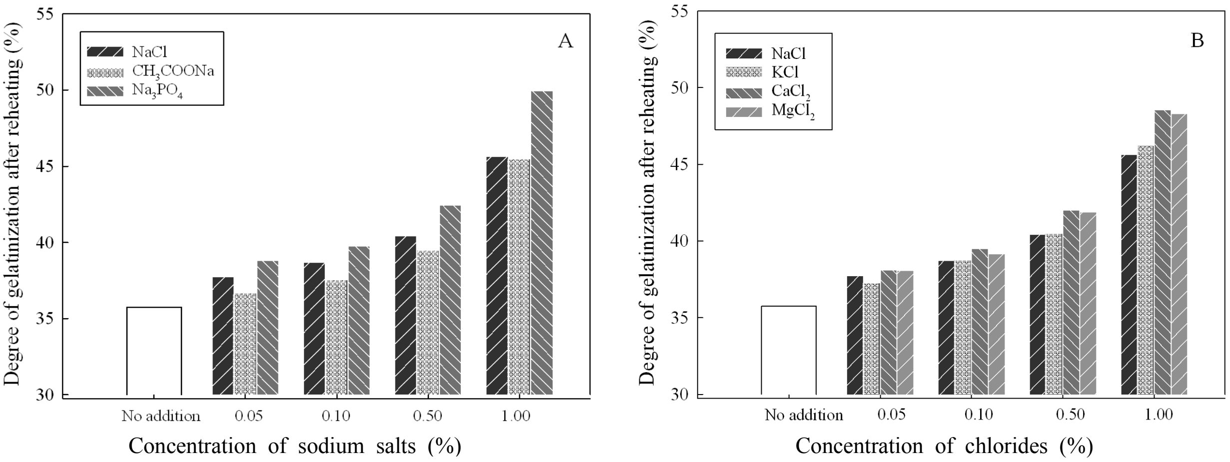

Fig. 2. Effect of several of sodium salts (A) and chlorides (B) on the increment of degree of gelatinization in the retrograded rice starch after reheating.

ples with sodium salts but the degree of gelatinization increment was lower than those of samples with sodium salts. This result supported that the effect of sodium phosphate on gelatinization promoting of rice starch was the most predominant among the added sodium salts, too.

Pasting properties of the retrograded rice starch with sodium salts and chlorides after reheating

The RVA pasting properties of retrograded rice starch before and after reheating with various sodium salts and chlorides are displayed in Table 2. The RVA peak viscosity of the retrograded rice starch (starch without salt) showed the high set back, which is an indicator for the extent of starch retrogradation (12), among the samples. Reheating treatment of the retrograded rice starch by adding various sodium salts and chlorides resulted in reduction of peak viscosity, break down, and set back. The

Table 2. Effect of sodium salts and chlorides on RVA parameters of the reheated retrograded rice starch

Sodium salts and chlorides	Concentration (%)	Pasting temperatures (°C)	Peak time (min)	Viscosity (RVU)				
				Peak viscosity	Holding strength	Final viscosity	Break down	Set back
Retrograded cooked rice	-	$49.5^{a1)}$	5.1^{a}	465.5^{a}	194.0^{c}	359.0^{b}	272.5^{a}	165.0^{a}
NaCl	0.05	49.0^{a}	4.6^{b}	389.0^{c}	180.0^{d}	325.0^{d}	209.0^{b}	145.0^{b}
	0.10	49.5^{a}	4.5^{b}	443.0^{b}	224.0^{a}	369.5^{a}	219.0^{b}	145.5^{b}
	0.50	49.9^{a}	4.5^{b}	384.0^{d}	191.0^{c}	334.5^{c}	193.0^{c}	143.5^{b}
	1.00	49.7^{a}	4.4^{b}	389.5^{c}	164.0^{e}	281.5^{e}	225.5^{b}	117.5^{c}
CH_3COONa	0.05	49.5^{a}	5.2^{a}	484.5^{a}	211.0^{b}	385.0^{bc}	273.5^{a}	174.0^{a}
	0.10	49.8^{a}	5.1^{ab}	451.5^{bc}	232.5^{a}	406.5^{a}	219.0^{b}	174.0^{c}
	0.50	50.0^{a}	5.1^{ab}	420.0^{d}	213.5^{b}	387.0^{b}	206.5^{bc}	173.5^{b}
	1.00	49.4^{a}	5.1^{b}	442.0^{c}	213.0^{b}	386.5^{bc}	229.0^{b}	173.5^{b}
Na_3PO_4	0.05	49.9^{a}	4.4^{b}	482.0^{a}	199.5^{b}	392.5^{a}	282.5^{a}	193.0^{a}
	0.10	49.4^{a}	4.2^{b}	452.5^{c}	199.0^{b}	385.0^{b}	253.5^{c}	186.0^{b}
	0.50	49.8^{a}	4.1^{c}	321.5^{d}	167.5^{c}	308.5^{e}	154.0^{d}	141.0^{d}
	1.00	49.9^{a}	4.1^{c}	237.0^{e}	118.0^{d}	215.5^{f}	119.0^{e}	97.5^{e}
KCl	0.05	49.7^{a}	5.0^{a}	401.0^{bc}	194.5^{a}	351.5^{abc}	206.5^{b}	157.0^{b}
	0.10	49.7^{a}	4.7^{b}	384.0^{c}	167.0^{b}	325.0^{cd}	217.0^{b}	158.0^{b}
	0.50	49.8^{a}	4.7^{b}	418.0^{b}	202.5^{a}	346.5^{bcd}	215.5^{b}	144.0^{c}
	1.00	49.7^{a}	4.6^{b}	388.5^{bc}	189.0^{a}	319.5^{d}	199.5^{b}	130.5^{d}
$CaCl_2$	0.05	49.4^{a}	5.0^{a}	459.5^{a}	193.5^{b}	345.5^{c}	266.0^{a}	152.0^{b}
	0.10	49.7^{a}	4.9^{ab}	403.0^{b}	190.0^{b}	335.0^{d}	213.0^{b}	145.0^{bc}
	0.50	49.5^{a}	4.9^{ab}	368.0^{d}	181.0^{c}	321.5^{e}	187.0^{b}	140.5^{c}
	1.00	49.3^{a}	4.9^{ab}	397.5^{b}	192.0^{b}	330.5^{d}	205.5^{d}	138.5^{c}
$MgCl_2$	0.05	49.5^{a}	5.1^{a}	468.0^{b}	206.0^{c}	373.0^{b}	262.0^{a}	167.0^{a}
	0.10	49.9^{a}	5.0^{a}	495.5^{a}	232.5^{a}	399.0^{a}	263.0^{a}	166.5^{a}
	0.50	49.7^{a}	5.0^{a}	426.5^{c}	221.0^{b}	372.0^{b}	205.5^{b}	151.0^{b}
	1.00	49.7^{a}	5.0^{a}	398.0^{d}	220.5^{b}	369.0^{b}	177.5^{c}	148.5^{b}

[1)] Different superscripts in a column are significant difference at $p<0.05$ by Duncan’s multiple comparisons.

decrease in peak viscosity, break down, and setback were more pronounced with increasing salt and chloride concentrations. The peak viscosity, break down, and set back of the reheated samples showed the lowest values in the samples with 0.50% and 1.00% Na_3PO_4. The set back, also had the lowest value in the samples containing Na_3PO_4.

Effect of sodium salts and chlorides on retrogradation and its rate of preparing retrograded cooked rice

The degree of retrogradation of the cooked rice with sodium salts and chlorides is shown in Fig. 3. Sodium salts and chlorides were added to a rice sample which was cooked at the initial heat process to see whether sodium salts and chlorides have an effect on the retrogradation of cooked rice samples for storage. So, different sodium salts and chlorides were added to each sample at the initial process, and all showed different degrees of retrogradation. When the retrograded cooked rice samples were reheated, all the samples containing sodium salts and chlorides showed lower retrogradation than that of starch without salt. The sodium salts and chlorides had a significant ($p<0.05$) influence on retrogradation of cooked rice. These results agree with the reports of other investigators (10). These observations suggest that hydration and swelling of rice starch granules were gently affected by the salts and chlorides,

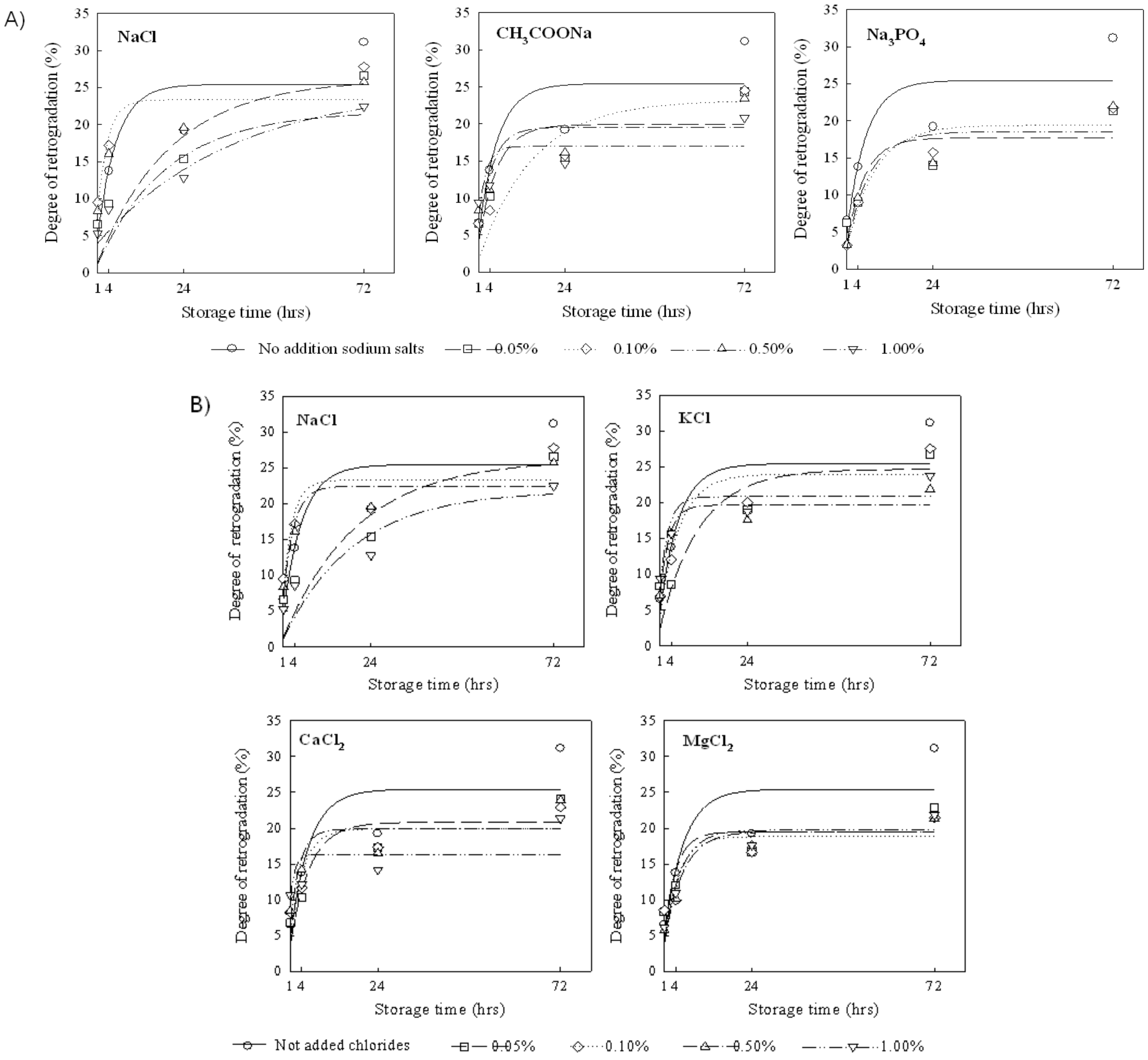

Fig. 3. Degree of retrogradation of retrograded cooked rice with different sodium salts (A), chlorides (B), and concentration during storage.

Table 3. Effect of sodium salts and chlorides on retrogradation rate of retrograded cooked rice after reheating

Concentration (%)	Sodium salts							
	Not added (starch without salt)		NaCl		CH_3COONa		Na_3PO_4	
	n	k	n	k	n	k	n	k
0.05	0.46	0.82	0.41	0.59	0.34	0.56	0.34	0.48
0.10	0.46	0.82	0.31	0.79	0.39	0.55	0.51	0.49
0.50	0.46	0.82	0.32	0.73	0.30	0.58	0.49	0.48
1.00	0.46	0.82	0.39	0.47	0.22	0.52	0.50	0.35
	Chlorides							
Concentration (%)	Not added (starch without salt)		KCl		$CaCl_2$		$MgCl_2$	
	n	k	n	k	n	k	n	k
0.05	0.46	0.82	0.39	0.65	0.37	0.59	0.31	0.61
0.10	0.46	0.82	0.42	0.72	0.30	0.59	0.30	0.56
0.50	0.46	0.82	0.29	0.61	0.28	0.62	0.41	0.58
1.00	0.46	0.82	0.26	0.68	0.19	0.53	0.35	0.55

which caused the decrease of available water for gelatinization. Therefore, the samples containing salts and chlorides showed retrogradation lower than that of the starch without salt. Among all the samples, the sample of retrograded cooked rice containing Na_3PO_4 showed the lowest retrogradation after reheating. The effect of sodium salts and chlorides on the retrogradation rate of cooked rice after reheating is shown in Table 3. The rate of retrogradation decreased with the addition of sodium salts and chlorides for cooked rice at all concentrations. The rate constant of starch without salt sample showed the highest value (k; 0.82). The rate constant of retrogradation with sodium salts was decreased as their concentration was increased. These results showed similar trends with the cooked rice samples containing chlorides. Among the sodium salt samples, the cooked rice containing Na_3PO_4 showed the lowest retrogradation rate after reheating at all concentrations. Particularly, the concentration of 1% Na_3PO_4 had a retrogradation rate constant of 0.35. The result was consistent with the effect of phosphate on the firming rate of cooked rice (13,14). Also, it appears that the anions had a bigger effect on the retrogradation rate of cooked rice after reheating than the cations. The low retrogradation kinetics of sample containing Na_3PO_4 are influenced by molecular structure, granule morphology, and starch phosporylation (15).

Gelatinization increment of the retrograded cooked rice with salts and chlorides after reheating

The effect of sodium salts and chlorides on gelatinization increment of the cooked rice after reheating is shown in Fig. 4. The gelatinization value of the retrograded cooked rice without salts and chlorides after reheating was 38.7%. Samples containing sodium salts and chlorides had a gelatinization increment over 43%, regardless of sodium salt and chloride concentrations. The gelatinization increment of samples containing sodium salts and chlorides increased as their concentration increased. In samples containing chlorides, $MgCl_2$ had the highest gelatinization increment by 59.3%, which was 20.6% higher than those of starch without salt. Na_3PO_4 had the highest gelatinization increment among all samples with 22.6%. The results of the gelatinization were dependent on the type of salt ion (16); i.e., the anions have an effect on penetration. Thus, the higher external electrolyte concentration caused the smaller effect of electrolyte exclusion (17). Therefore, the swelling of the rice starch granules are generally affected by the anionic salts, which have an effect on increase of gelatinization caused by broken hydrogen bonds (16-19).

The pasting properties of the retrograded cooked rice with sodium salts and chlorides after reheating

The detailed parameters of the pasting properties of the retrograded cooked rice with sodium salts and chlorides after reheating are shown in Table 4. The peak viscosity of starch without salt sample showed the highest value compared to the samples containing sodium salts and chlorides. The set back, which is an indicator of extent of starch retrogradation, had the highest value in the starch without salt sample. Overall, the set back value decreased as the concentration of added sodium salts and chlorides in cooked rice increased. Among the all sodium salts and chlorides, $CaCl_2$ had the lowest set back value, which was a different result from the rice starch samples. These differences are likely the result of different component systems. Rice starch is a mono component system whereas cooked rice is a poly component system. Also, in the cooked rice containing $CaCl_2$, it appears that calcium chloride forms an ionic crosslink that bonds more tightly between the neighboring chains of starch molecules in gelatinization than other samples. Therefore, it might be expected to show the lowest set-

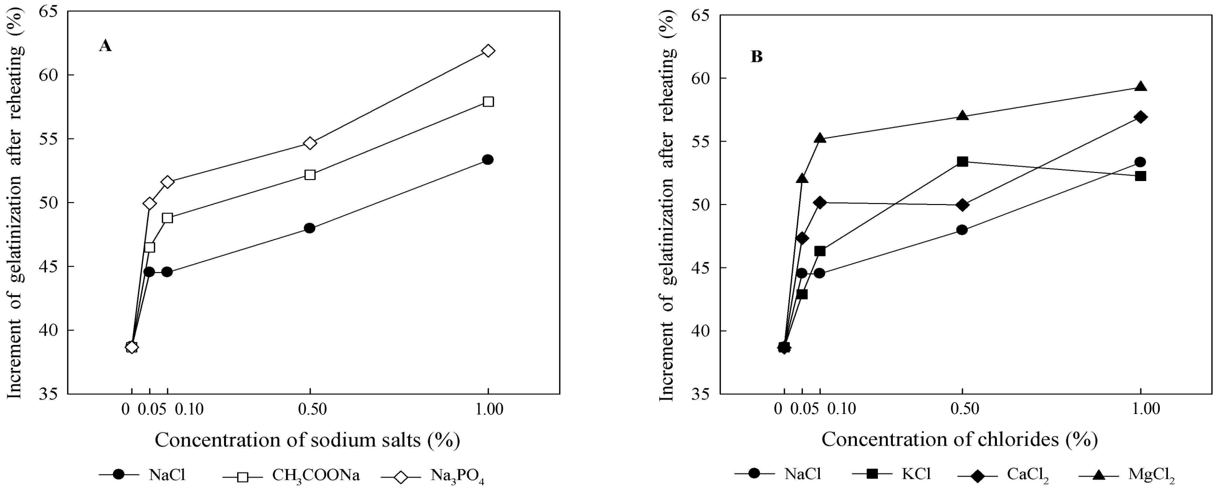

Fig. 4. Effect of various sodium salts (A) and chlorides (B) on gelatinization increment of the retrograded cooked rice after reheating with different concentration.

Table 4. Effect of sodium salts and chlorides on RVA parameters of the reheated retrograded cooked rice

Additives	Concentration (%)	Pasting temperatures (°C)	Peak time (min)	Viscosity (RVU)				
				Peak viscosity	Holding strength	Final viscosity	Break down	Set back
Retrograded cooked rice		$49.6^{a1)}$	3.4^{bc}	283.0^{a}	79.0^{a}	156.0^{a}	204.0^{a}	77.0^{a}
NaCl	0.05	49.6^{a}	3.6^{bc}	229.5^{c}	82.0^{a}	148.0^{a}	147.5^{b}	66.0^{c}
	0.10	49.4^{a}	2.9^{c}	262.5^{b}	78.0^{a}	149.5^{a}	184.5^{a}	71.5^{b}
	0.50	49.6^{a}	2.8^{c}	268.5^{ab}	85.5^{a}	151.0^{a}	183.0^{a}	65.5^{c}
	1.00	49.0^{a}	4.3^{ab}	185.5^{d}	81.5^{a}	138.0^{b}	104.0^{c}	56.5^{d}
CH_3COONa	0.05	49.1^{a}	3.2^{b}	244.0^{c}	82.5^{bc}	145.0^{b}	161.5^{b}	62.5^{b}
	0.10	49.6^{a}	2.4^{c}	283.5^{b}	82.0^{bc}	145.5^{b}	201.5^{a}	63.5^{b}
	0.50	48.7^{a}	2.4^{c}	312.0^{a}	86.0^{b}	145.5^{b}	226.0^{a}	59.5^{bc}
	1.00	48.7^{a}	2.4^{c}	303.0^{ab}	82.0^{bc}	138.5^{c}	221.0^{a}	56.5^{c}
Na_3PO_4	0.05	49.0^{a}	2.5^{b}	295.0^{bc}	83.0^{a}	148.0^{b}	212.0^{b}	65.0^{c}
	0.10	49.6^{a}	2.0^{c}	288.5^{bc}	73.0^{b}	135.0^{c}	215.5^{b}	62.0^{d}
	0.50	49.2^{a}	1.3^{e}	326.5^{ab}	64.5^{c}	135.0^{c}	262.0^{a}	70.5^{b}
	1.00	49.5^{a}	0.9^{f}	280.0^{c}	57.0^{d}	133.5^{c}	223.0^{b}	76.5^{a}
KCl	0.05	49.3^{ab}	2.6^{b}	299.5^{a}	88.5^{abc}	165.0^{a}	211.0^{a}	76.5^{a}
	0.10	49.6^{a}	2.3^{c}	262.5^{bc}	82.0^{bc}	149.0^{c}	180.5^{b}	67.0^{b}
	0.50	49.7^{a}	2.1^{d}	231.5^{d}	79.0^{c}	143.5^{c}	152.5^{c}	64.5^{b}
	1.00	48.9^{b}	2.1^{d}	223.5^{d}	94.0^{a}	142.5^{c}	129.5^{c}	48.5^{c}
$CaCl_2$	0.05	49.3^{a}	4.2^{a}	210.0^{b}	77.5^{a}	142.0^{b}	132.5^{b}	64.5^{b}
	0.10	49.3^{a}	4.6^{a}	196.5^{bc}	75.5^{ab}	134.0^{c}	121.0^{bc}	58.5^{c}
	0.50	49.1^{a}	4.0^{a}	173.0^{cd}	71.0^{bc}	119.5^{d}	102.0^{c}	48.5^{c}
	1.00	49.6^{a}	3.5^{a}	163.0^{d}	67.5^{c}	104.5^{e}	95.5^{c}	37.0^{c}
$MgCl_2$	0.05	49.7^{a}	3.0^{a}	221.0^{d}	80.5^{a}	143.0^{b}	140.5^{c}	62.5^{b}
	0.10	49.7^{a}	2.4^{b}	259.5^{bc}	81.0^{a}	141.0^{bc}	178.5^{b}	60.0^{bc}
	0.50	49.6^{a}	2.4^{b}	270.5^{bc}	82.0^{a}	143.0^{b}	188.5^{ab}	61.0^{bc}
	1.00	48.9^{b}	2.4^{b}	251.5^{c}	76.5^{a}	124.5^{d}	175.0^{b}	48.0^{d}

1) Different superscripts in a column are significant difference at $p<0.05$ by Duncan's multiple comparisons.

back (20).

CONCLUSION

Our results showed the effect of sodium salts and chlorides on the reheating behavior of the retrograded rice starch and the cooked rice. Sodium salts and chlorides had a pronounced influence on the reheating behavior of the retrograded rice starch and the cooked rice. The increment of gelatinization of samples containing Na_3PO_4 after reheating was the highest value. Also, the increment of gelatinization showed an increasing trend as the Na_3PO_4 concentration increased. The retrogradation rate of the cooked rice containing sodium salts and chlorides showed a lower value than that of starch without salt. This result was supported by the result of pasting properties. Among the samples, sample containing Na_3PO_4 had the most positive effect of gelatinization increment and retarding for the retrogradation of rice starch and cooked rice. Also, anions seem to be more important than that of cation on reheating behavior of the retrograded rice starch and the cooked rice. Using the appropriate salts, it should be possible to improve the qualities of ready-to-eat starch food after reheating.

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