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Gelatinization Properties of Heat-Moisture Treated Potato and Sweetpotato Starches

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Abstract

Gelatinization properties of heat-mositure treated potato and sweet potato starches were investigated. Water-binding capacity of starch was increased by heat-moisture treatment, which was more pronounced in sweet potato starch. Blue value was not affected by the treatment. Amylograph viscosities were decreased by heat-mositure treatment, which was more pronounced in potato starch. Critical concentration of NaOH for gelatinization of starch increased as moisture level increased. Gel volume of starch upon KSCN gelatinization was higher in potato starch. Gelatinized starches showed Binghamapseudoplastic behavior. Consistency index and yield stress were drastically decreased upon heat-moisture treatment.

Introduction

Potato and sweet potato are the major starch sources in Korea. However, studies on the starch of Korean potato and sweet potato are scarce.[1] Shin and Ahn[2] recently reported some properties of moist and dry sweet potato starches.

It is well known[3-7] that heat-moisture treatment significantly affects the starch properties. In general, the swelling power and crystallinity of starch decreas by heat-moisture treatment. Donovan *et al.*[7] employed differential scanning calorimeter (DSC) to examine the properties of heat-moisture treated wheat and potato starches. Their results indicated that the treated samples showed a broadening of the gelatinization temperature range and a shifting of the endothermal transition toward higher temperatures, compared to the untreated starches.

The purpose of this study was to investigate the gelatinization properties of Korean potato and sweet potato starches.

Materials and Methods

Materials

Commercial potato and sweet potato starches were washed with distilled water twice, air-dried and passed through a 100-mesh sieve.

Heat-moisture treatment

The method of heat-moisture treatment was essentially that of Sair.[8] Starch was suspended in water, centrifuged and air-dried to give 18,21 and 24% moisture contents. Starch samples in glass jars were placed in an air oven at 100°C for 16hr. After cooling, the jars were opened, and the starch samples air-dried and passed through a 100-mesh sieve.

Physico-chemical properties

Water-binding capacity and blue value were determined by the methods of Medcalf and Gilles[9] and Gilbert and Spragg,[10] respectively.

Gelatinization properties

Hot-paste viscosities were analyzed using a Brabender/visco/Amylograph. Starch concentration used was 6%(d.b.).

Viscosity development of starch samples in aqueous sodium hydroxide solution was followed with a Brookfield viscometer (model LVF).[11] Gelatinization of starch in KSCN solution was measured at 25°C as described by Lindqvist.[12]

Rheological properties of gelatinized starch solution

Starch suspension (6%, d.b.) was heated at 95°C for 30min and cooled to 30°C in an ice water.

Rheological properties were analyzed using a Brabender rotational viscometer (model Viscotron, measuring system E_{17}) at 10-210*rpm*. Rheological parameters at 30-70°C were calculated from the following Herschel-Bulkley equation:[13]

$$\tau = KD^n + \tau_y \quad \cdots\cdots\cdots\cdots\cdots(1)$$

where K is consistency index (Pa S^{-n}); n is flow behavior index(−); τ is yield stress (*Pa*); τ is shear stress (*Pa*); and D is shear rate(s^{-n}).

τ and D were calculated from experimental data as follows:

$$\tau = B \cdot S \cdot Y \quad \cdots\cdots\cdots\cdots\cdots(2)$$

$$D = N \cdot X \quad \cdots\cdots\cdots\cdots\cdots(3)$$

where S is torque; N is rotational speed (*rpm*); and B,X and Y are correction factors.

n and K were obtained from a graph of log (τ-τ_o) vs. log D.[14] τ_y was calculated by Casson equation:[15]

$$\sqrt{\tau} = Kc\sqrt{D} + \sqrt{Zy} \quad \cdots\cdots\cdots\cdots\cdots(4)$$

All calcutations were carried out by Apple II computer.

Results and Discussion

Physico-chemical properties

Water-binding capacity and blue value of heat-moisture treated potato and sweet potato starches are given in Table 1. The water-binding capacity of untreated potato starch was lower than that of the untreated sweet potato starch. The heat-moisture treatment caused only a small increase in the water-binding capacity of potato starch, which agreed with the results of Kulp and Lorenz.[3] However, considerable increase in the water-binding capacity was observed for sweet potato starch. The water-binding capacities of starches were increased by heat-moisture treatment, which was more pronounced in sweet starch.

Blue value of potato starch was higher than that of sweet potato starch (Table 1). The heat-moisture treatment did not affect the blue value of the starches.

Amylograms

Amylograms of potato and sweet potato starches are shown in Fig. 1. The hot paste of potato starch was unstable as observed by the viscosity drop after 15 min at 92°C, while that of sweet potato starch was quite stable (Table 2). These results were agreed with the previous reports.[13,16,17]

The hot and cold paste viscosities of both starches decreased with each increment of moisture (Table 2). Treatment lowered the 92°C consistency of hot paste but increased the paste stability during subsequent cooking. The initial pasting temperatures also increased by the treatment. It was worthy to note that the treated potato starches at moisture levels of 21 and 24% did not show appreciable increase in viscosities.

Alkali gelatinization

Viscosity development patterns of potato and sweet potato starches in aqueous NaOH solution are shown in Fig. 2. Potato starch gelatinized at lower alkali concentration than sweet potato. It was assumed that the gelatinization was completed when the viscosity reached plateau. The critical alkali concentrations for the

Table 1. Some physico-chemical properties of potato and sweet potato starches

Starch		Ash (%)	Protein (N×6.25) (%)	Water binding (%)	Blue value
Potato					
Untreated		0.17	0.25	73.8	0.412
Heat-moisture	18%	—	—	74.1	0.408
	21%	—	—	74.3	0.416
	24%	—	—	80.0	0.408
Sweet potato					
Untreated		0.12	0.27	77.2	0.360
Heat-moisture	18%	—	—	78.8	0.375
	21%	—	—	91.8	0.360
	24%	—	—	103.1	0.360

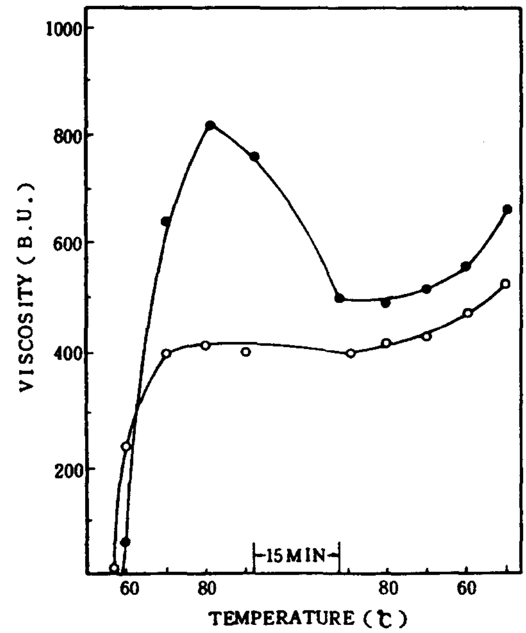

Fig. 1. Amylogram of potato (▲) and sweet potato (•) starches (6%, d.b.)

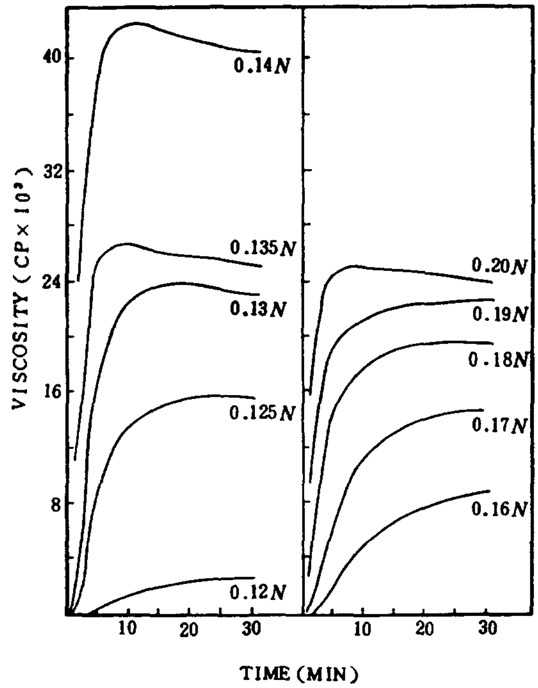

Fig. 2. Viscosity development vs. times of potato (left) and sweet potato (right) starches at various concentrations of NaOH

gelatinization of potato and sweet potato starches were 0.125 and 0.19*N*, respectively.

The critical concentration of NaOH for gelatinization of the both starches increased by heat-moisture treatment

Table 2. Amylograph viscosities of heat-moisture treated potato and sweet potato starches

Starch		Initial pasting temperature (°C)	Peak Viscosity (B.U.)	At 92°C (B.U.)	After 15min at (B.U.)	on cooling to 50°C (B.U.)
Potato						
Untreated		65.0	820	740	510	630
Heat-moisture	18%	92.0	—	10	30	65
	21%[a]	—	—	—	—	—
	24%[a]	—	—	—	—	—
Sweet potato						
Untreated		72.5	410	410	400	540
Heat-moisture	18%	83.0	—[b]	50	215	260
	21%	86.0	—[b]	25	125	260
	24%	89.0	—[b]	15	90	140

[a]No viscosity increases were observed.
[b]No peak was observed.

Table 3. Critical sodium hydroxide concentration for gelatinization of potato and sweet potato starches

Starch		Concentration (*meq* NaOH/*g*)
Potato		
Untreated		2.08
Heat-moisture	18%	3.16
	21%	3.67
	24%	4.00
Sweet potato		
Untreated		3.16
Heat-moisture	18%	3.67
	21%	4.00
	24%	4.17

(Table 3). The critical alkali concentrations for the treated potato starch at 18 and 21% moisture levels were the same to those for untreated and treated (18% H_2O) sweet potato starch, respectively. At the same critical alkali concentration the viscosity of the treated potato starch at 18% moisture level was four times higher than that of sweet potato starch at the same moisture level. It was reported[18] that viscosity of starch in NaOH solution was affected by such factors as amylose content, granule structure and molecular structure of starch, but correlations among them are complex and somewhat unknown.

Gel volume of potato and sweet potato starches treated with KSCN is tabulated in Table 4. Potato starch showed a maximum gel volume at 5.5*M* KSCN, while sweet potato starch at 6.0*M*. The gel volume of both starches decreased by heat-moisture treatment, which was more pronounced as moisture level increased. However, no significant differences of gel volumes between treated potato and sweet potato starches were noticed. Lindqvist[12] reported that gel formation of starch in KSCN solution can only take place if amylose has first leached out of the starch granules and that amylopectin is the predominant gel forming component of starch. It is known[19] that one of the changes occurring during heat-moisture treatment of potato starch is the conversion of a fraction of amorphous amylose to a less soluble helical form. Therefore, it seems that the maximum gel volumes of treated starches occurred at a higher concentration than untreated starches (Table 4) may be due to the structural changes of amylose fraction by heat-moisture treatment.

Rheology of gelatinized starch solution

A plot of sheat stress against shear rate of gelatinized potato and sweet potato starches is shown in Fig. 3. At the same shear rate, the shear stress of potato starch was higher than that of sweet potato starch. However, the treated starches showed an opposite trend. The same patterns were also observed at various measuring temperatures of 50,60 and 70°C (data are not shown).

Rheological parameters calculated from the data of Fig. 3 are given in Table 5. Untreated potato and sweet potato starches had yield stress at all measuring

Table 4. Gel volume of 0.3*g* starch treated with various concentrations of 50*ml* KSCN after 24hr at 25°C

Starch		Gel volume (*ml*) as KSCN concentration (*M*)														
		2.0	2.5	3.0	3.5	4.0	4.5	5.0	5.5	6.0	6.5	7.0	7.5	8.0	8.5	9.0
Potato																
Untreated		18.0	21.9	22.5	23.2	25.0	28.9	30.8	31.0	30.5	29.3	24.2	–	–	–	–
Heat-moisture	18%	–	–	–	–	–	11.2	11.5	12.1	13.2	15.1	16.8	15.5	13.8	12.2	10.5
	21%	–	–	–	–	–	10.0	10.5	11.0	11.5	14.8	15.5	15.8	14.8	13.7	12.8
	24%	–	–	–	–	–	9.5	9.8	10.3	11.0	12.0	14.5	15.0	14.1	13.2	12.5
Sweet potato																
Untreated		11.0	15.0	16.0	16.5	17.0	17.5	18.0	18.5	19.9	18.0	16.0	–	–	–	–
Heat-moisture	18%	–	–	–	–	–	11.0	11.5	12.2	13.0	14.5	16.0	15.0	14.0	12.3	11.0
	21%	–	–	–	–	–	10.8	11.0	11.8	12.8	13.8	15.5	15.0	13.8	12.7	11.5
	24%	–	–	–	–	–	8.5	8.8	9.4	10.3	11.8	12.5	14.5	13.5	12.5	11.8

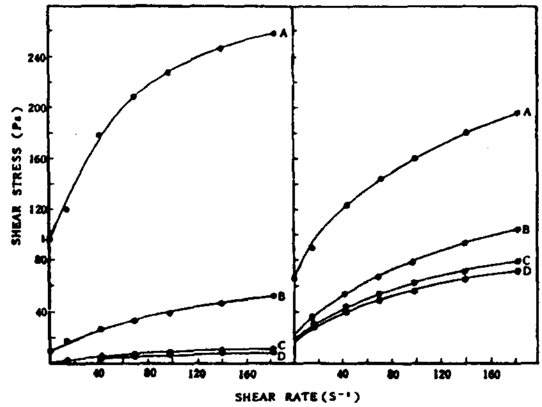

Fig. 3. Shear stress vs. shear rate of gelatinized potato (left) and sweet potato (right) starches measured at 30°C
A = Untreated; B = 18% H_2O-treated; C = 21% H_2O-treated; D = 24% H_2O-treated

temperatures. The shear stress of potato starch was drastically decreased by treatment and it was negligible at 24% moisture level. The treatment also decreased the shear stress of sweet potato starch, which was not as drastic as the potato starch. The flow behavior index was less than 1 in all cases(Table 5). The flow behavior index of the potato starch was decreased by treatment at moisture levels of 21 and 24%; however, that of the sweet potato starch remained constant. The data in Table 5 therefore indicate that all but potato starch treated at 24% moisture level were Bingham pseudoplastic flow. The potato starch treated at 24% moisture had no yield stress with flow behavior index of 1, which showed that it was Newtonian flow.

Consistency index of potato starch was lower than that of sweet potato starch(Table 5). The temperature dependence of the consistency index followed an Arrhenius equation. Apparent activation energies of untreated potato and sweet potato starches at 30-50°C were 4.09 and 3.39 *kcal/mole*, respectively. However, apparent activation energies at 50-70°C of both starches were 1.40 *kcal/mole*. The apparent activation energies of treated potato and sweet potato starches at all moisture levels were 3.58 and 1.40 *kcal/mole*, respectively.

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Table 5. Effect of measuring temperatures on rheological properties of gelatinized starch(6%)

temperature (°C)	Heat-moisture treatment	Potato starch			Sweet potato starch		
		K	n	y	K	n	y
30	None	4.31	0.72	96.79	4.66	0.66	65.37
	18%	1.38	0.66	9.00	2.96	0.64	20.69
	21%	0.14	0.83	0.55	2.18	0.64	19.57
	24%	0.06	0.91	0.11	1.82	0.66	16.65
50	None	2.83	0.76	76.24	3.29	0.65	39.95
	18%	1.03	0.66	7.08	2.58	0.63	21.32
	21%	0.10	0.85	0.50	1.92	0.65	17.09
	24%	0.05	0.96	0.04	1.58	0.66	12.88
60	None	2.66	0.77	68.69	2.85	0.68	29.80
	18%	0.72	0.69	4.74	2.31	0.64	17.00
	21%	0.08	0.93	0.07	1.77	0.65	15.81
	24%	0.03	0.98	0.01	1.60	0.65	14.19
70	None	2.51	0.76	59.59	2.88	0.66	34.82
	18%	0.69	0.69	5.73	2.26	0.64	20.36
	21%	0.07	0.89	0.07	1.66	0.66	15.86
	24%	0.03	0.97	0.01	1.36	0.67	11.31

K: Consistency index ($Pa \cdot s^{n}$) n: Flow behavior index, y: Yield stress (*Pa*)

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수분 열처리한 감자 및 고구마전분의 호화 특성

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**농수산물 유통공사 종합식품연구원

감자 및 고구마 전분의 수분-열처리에 따른 호화특성을 비교하였다. 수분-열처리에 의하여 전분의 물결합능력은 증가하였으며 그 정도는 고구마전분이 더 현저하였다. 전분의 blue value는 수분-열처리에 의하여 영향을 받지 않았다. 아밀로그라프의 점도는 수분-열처리에 의하여 크게 감소하였으며, 최고 점도는 나타나지 않았다. 가성소다에 의한 전분의 호화는 감자가 고구마전분보다 쉬웠으며, 수분-열처리에 의하여 호화에 필요한 알칼리의 농도는 증가하였다. KSCN에 의한 전분겔의 부피는 감자가 고구마전분보다 높았다. 감자 및 고구마 호화전분은 항복응력을 갖는 의가소성 유체의 성질을 보였으며, 수분-열처리에 의하여 점조도지수 및 항복응력이 크게 감소하였다.