Relationship Between Physicochemical Properties of Starches and White Salted Noodle Quality in Japanese Wheat Flours

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ABSTRACT

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This study describes the effect of starch properties of Japanese wheat flours on the quality of white salted noodles (WSN). Starch was isolated from 24 flours of 17 Japanese cultivars and amylose content was determined along with pasting properties by Rapid Visco Analyser (RVA), thermal properties by differential scanning calorimetry (DSC), and the distribution of amylopectin chain length by high-performance anion exchange chromatography (HPAEC). Twenty flours were used to prepare WSN. As expected, 5–6% lower amylose content was associated with good WSN quality (higher scores in softness, elasticity, and smoothness). RVA analysis indicated that the pasting temperature had the greatest influence on WSN quality, while breakdown and setback showed slight effects on WSN quality. DSC results showed that lower endothermal enthalpy (ΔH) in the amylose-lipid complex was associated with good WSN quality. Chain-length distribution of amylopectin by HPAEC was not an important factor in relation to WSN quality.

Most domestic wheat in Japan is used for the production of white salted noodles (WSN) called udon. Starch properties are widely recognized as the most important determinant for the quality of Japanese WSN. Oda et al (1980) and Toyokawa et al (1989) demonstrated that lower amylose content was preferable in WSN manufacturing. High-swelling starch is beneficial to WSN quality (Crosbie 1991; Konik et al 1993). Starch pasting properties determined by amylograph and Rapid Visco Analyser (RVA) provide useful information for predicting WSN quality. High peak viscosity (Crosbie 1991; Konik and Miskelly 1992; Panozzo and McCormick 1993), low pasting temperature (Oda et al 1980; Endo et al 1988), and high breakdown (Oda et al 1980, Konik and Miskelly 1992) were associated with superior WSN quality. The work of Batey et al (1997) suggested that a decreased number of branches in amylopectin molecules resulted in good WSN quality. In recent years, a wheat breeding program in Japan has been established to develop cultivars with reduced amylose content for high quality WSN. In Japan, Chikugoizumi and Nishihonami are the newly released representative cultivars with low amylose content. Miura and Tanii (1994) and Sasaki and Matsuki (1998) studied the starch properties in several Japanese wheat cultivars preferable for WSN. However, they conducted no sensory evaluation of WSN.

This study was designed to determine the physicochemical properties of starches from Japanese wheat cultivars, including Chikugoizumi and Nishihonami. We analyzed amylose content, pasting properties by RVA, thermal properties by differential scanning calorimetry (DSC), and the distributions of amylopectin chain length by high-performance anion exchange chromatography (HPAEC). Furthermore, a sensory evaluation of WSN was made to clarify the influence of starch properties on WSN quality.

MATERIALS AND METHODS

Wheat Samples

Seventeen Japanese wheat cultivars were used in this study. Wheat cultivars (except Chihokukomugi, which is adapted to Hokkaido Island) were planted in the experimental farm at the Kyushu National Agricultural Experiment Station at Chikugo, Fukuoka. The 1996-97 experiment was performed using 15 wheat cultivars. Fourteen wheat cultivars were sown on 20 November 1996, and harvested on 28 May 1997, whereas sowing and harvesting dates were 20 November 1996, and 3 June 1997, respectively, for Norin No. 61. The 1997-98 experiment was performed to determine the influence of sowing and harvesting dates using four wheat cultivars. For standard harvest, sowing and harvesting dates were 19 November 1997, and 19 May 1998, respectively. For early harvest, sowing and harvesting dates were 5 November 1997, and 14 May 1998, respectively. The cultivar Chihokukomugi harvested in 1997 was obtained from the Hokkaido Food Agency. Wheat samples were washed and tempered before milling on a Buhler experimental mill to produce 60% extraction flour. Starch from each flour sample was isolated by the method of Oda et al (1980). Flour (50 g) and water (30 mL) were mixed to form a dough ball. The dough ball was left in cold distilled water for 60 min and hand-kneaded under water until the washings were clear. The starch washings were combined and passed through a 45-µm sieve. The filtrate (starch suspension) was allowed to stand for 3 hr. The supernatant was discarded, and the remaining starch pellet was washed successively with water twice and then with ethanol, then air-dried.

Starch Properties

The apparent amylose content of the flour was determined in duplicate by an iodine-staining procedure (Juliano 1971). DSC measurement was performed in an analyzer (DSC-7, Perkin-Elmer Co., Norwalk, CT) equipped with a 1020 TA workstation. Starch (≈3 mg, dwb) was introduced into an aluminum sample pan. Distilled water was then added to give a starch concentration of 30% (dwb, w/w) and the pan was hermetically sealed. An empty pan was used as the reference. The samples were heated from 30 to 130°C at 10°C/min. The DSC experiments were performed at least in triplicate. RVA paste viscosity was determined using the RVA-3D (Newport Scientific Pty. Ltd., Australia). Each starch was added to 25 mL of distilled water to create a 10% starch suspension. The starch suspension was kept at 50°C for 1 min, heated to 95°C at 13.2°C/min, kept at 95°C for 2.7 min, then cooled to 50°C at 11.6°C/min and kept at 50°C for 2 min. The RVA experiments were performed in triplicate or duplicate. For the separation of released maltosaccharides, HPAEC was conducted (BioLC Dionex Co., CA) using pulsed amperometric detection and a 4- × 250-mm CarboPac PA1 column. Each starch was debranched with *Pseudomonas amyloderamosa* isoamylase as described previously (Noda et al 1995). The sample solution was eluted at 1 mL/min with a linear gradient of 500 m*M* sodium acetate in 150 m*M* NaOH using the method of Koizumi et al (1991). HPAEC analysis was performed in duplicate. The area of each peak of linear chains up to DP 30 was determined using Hitachi chromato-integrator D-2500. Based on the area percen-

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tage of each peak of the amylopectin chain length (DP 6–30), the ratio of the content of shorter chains (DP 6–12) to the sum of all fractions of DP 6–30 was calculated.

Preparation of WSN and Sensory Evaluation

Japanese WSN were prepared by the modified procedures based on the standard Japanese methods (Anonymous 1985). For the samples with low amylose content (<22%), the WSN were boiled for 18 min; those with high amylose content (>22%) were boiled for 20 min. A trained panel of 16 members performed a sensory evaluation of WSN. This assessment included three parameters of WSN quality, softness, elasticity, and smoothness. The cultivar Norin No. 61 cultivated in Gunma prefecture was used as a standard sample. The sample noodles were evaluated against a noodle prepared from a standard sample. The standard sample was allocated scores of 7.0, 17.5, and 10.5 for softness, elasticity, and smoothness, respectively. The higher the score, the better.

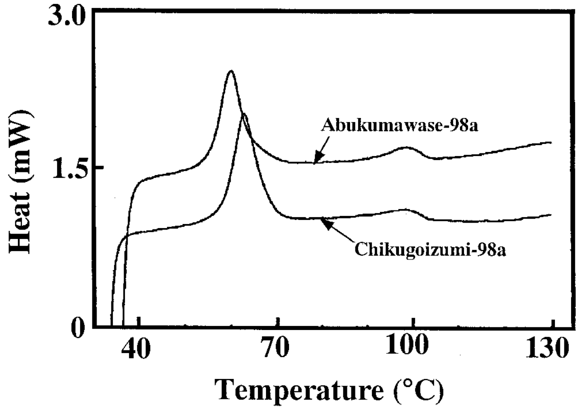

Fig. 1. Thermograms from differential scanning calorimetry (DSC) of representative wheat starches (Chikugoizumi-98a and Abukumawase-98a).

Statistical Analysis

All possible correlations among nine parameters of starch properties of 24 starch samples were calculated. Furthermore, the correlations between starch properties and all parameters of WSN quality were calculated to evaluate the influence of starch properties on WSN quality. Calculations were done using Microsoft Excel 5.0 for Macintosh.

RESULTS AND DISCUSSION

Amylose Content

Amylose contents were 20.6–26.6% (Table I). As expected, amylose content was lower (20.6–21.6%) in Chikugoizumi and Nishihonami, which have been recently released to improve the eating quality of Japanese WSN. In contrast, Norin No. 61, Shiroganekomugi, and Abukumawase, which were formerly released for Japanese WSN, exhibited a higher amylose content (25.8–26.6%). From the 1997-98 experiment, the effect of sowing and harvesting dates on amylose content was not important (data not shown).

Pasting Properties

Pasting properties were determined by RVA, the peak viscosity was 267–348 RVU (Table I). The 1996-97 experiment indicated that starches extracted from the high-amylose cultivars, Norin No. 61 and Shiroganekomugi, exhibited relatively lower peak viscosity (306–307 RVU) compared with those from the low amylose cultivars, Chikugoizumi and Nishihonami (330–338 RVU). Breakdown and setback were 44–82 and 107–139 RVU, respectively. All starches extracted from Chikugoizumi exhibited lower setback values (107–116 RVU). Therefore, Chikugoizumi starches appeared to be difficult to retrograde. There was large variation in pasting temperature (68.2–86.0°C) among starch samples. Norin No. 61, Shiroganekomugi, and Abukumawase starches showed somewhat higher pasting temperatures (82.7–86.0°C). The 1997-98 RVA data proved that earlier sowing and harvesting obviously enhanced the values of peak viscosity and pasting temperature.

TABLE I
Amylose Content and Pasting Properties of Wheat Starches

		Rapid Visco Analyser (RVA) Properties[a]			
Sample[b]	Amylose Content (%)	Peak Viscosity (RVU)	Breakdown (RVU)	Setback (RVU)	Pasting Temperature (°C)
Saikai No. 175-97	20.6	321	48	109	68.2
Saikai No. 176-97	23.6	341	59	132	80.8
Saikai No. 177-97	23.1	317	63	124	78.3
Saikai No. 178-97	23.3	331	67	125	69.0
Saikai No. 179-97	23.8	326	52	124	80.8
Saikai No. 182-97	23.3	348	55	127	80.3
Saikai No. 183-97	23.7	344	58	128	69.0
Saikai No. 184-97	22.1	344	52	110	69.1
Nishihonami-97	21.6	338	55	139	79.9
Chikugoizumi-97	21.6	330	53	116	68.9
Kinuiroha-97	23.2	336	56	125	69.0
Iwainodaichi-97	23.2	323	59	129	77.1
Nishinokaori-97	24.5	323	52	131	81.1
Shiroganekomugi-97	26.6	306	58	134	82.7
Norin No. 61-97	25.8	307	61	122	82.8
Chihokukomugi-97	24.8	324	82	131	70.3
Saikai No. 179-98a	22.5	301	51	119	80.8
Chikugoizumi-98a	20.6	284	60	108	69.1
Iwainodaichi-98a	23.6	301	63	117	77.9
Abukumawase-98a	25.8	267	46	108	84.8
Saikai No. 179-98b	23.6	326	55	138	84.1
Chikugoizumi-98b	20.7	305	49	107	71.0
Iwainodaichi-98b	23.7	325	44	127	83.1
Abukumawase-98b	26.3	294	45	129	86.0
Mean ± SD	23.4 ± 1.7	319 ± 20	55 ± 8	123 ± 10	76.8 ± 6.3

[a] Values are means of at least two determinations.

[b] 97 = harvested in 1997, 98 = harvested in 1998, 98a = sown on 19 November 1997 and harvested on 19 May 1998, 98b = sown on 5 November 1997 and harvested on 14 May 1998.

Thermal Properties

Typical DSC thermograms of wheat starches are presented in Fig. 1. They show a large endothermal peak at a lower temperature and a second endothermal peak at a higher temperature. The two peaks may be caused by the starch gelatinization and the dissociation of the amylose-lipid complex, respectively. Starch gelatinization properties were recorded as peak temperature (T_p) and energy of enthalpy (ΔH). The ΔH was determined in the amylose-lipid complex region. The DSC thermal properties are listed in Table II.

Starch gelatinization properties indicated that the T_p of all the wheat samples was 59.1–63.4°C and the ΔH was 10.5–13.2 J/g. Starches extracted from the low amylose cultivars, Chikugoizumi and Nishihonami, showed relatively higher T_p values (61.5–63.4°C) than those from the high amylose cultivars, Norin No. 61, Shiroganekomugi, and Abukumawase (59.1–60.1°C). Earlier sowing and harvesting dates tended to decrease the values of T_p for the 1997-98 experiment. It was suggested that starches extracted from wheat grown at a lower temperature have lower gelatinization temperatures. According to Shi et al (1994), gelatinization temperature in wheat was clearly lower as environmental temperature decreased during grain filling. Therefore, our results for T_p support the data of Shi et al (1994) because earlier sowing and harvesting represent lower temperature during grain filling. As for the thermal properties in the second peak, which is caused by the amylose-lipid complex, ΔH was 1.3–1.9 J/g. ΔH was higher (1.7–1.9 J/g) in the high amylose cultivars, Norin No. 61, Shiroganekomugi, and Abukumawase. According to Qian et al (1998), the ΔH for the amylose-lipid complex was 1.2 J/g for commercial wheat starch, which is almost in agreement with our data.

Amylopectin Chain Length

Typical distribution patterns of wheat amylopectin (DP 6–30) are presented in Fig. 2. All amylopectins examined peaked at DP 11

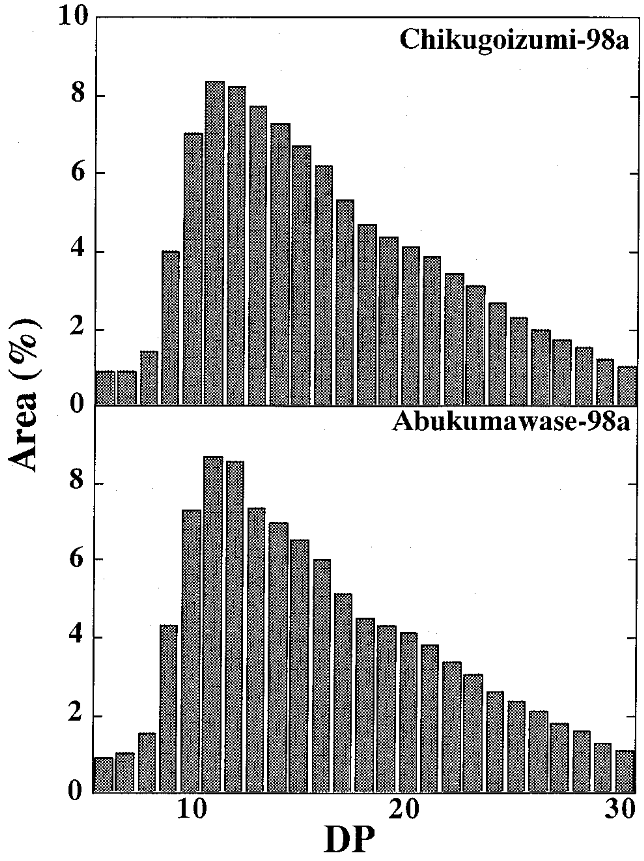

Fig. 2. Chain-length distributions (DP 6–30) of representative wheat amylopectins (Chikugoizumi-98a and Abukumawase-98a). Total peak area of each specimen was taken as 100%.

TABLE II
Thermal Properties from Differential Scanning Calorimetry (DSC) and Amylopectin Chain Length by High-Performance Anion Exchange Chromatography (HPAEC) of Wheat Starches

Sample[a]	DSC Properties[b]			Amylopectin Chain Length[c]
	Starch Gelatinization		Amylose Lipid Complex	
	T_p (°C)	ΔH (J/g)	ΔH (J/g)	
Saikai No. 175-97	61.1 ± 0.2	11.9 ± 0.2	1.5 ± 0.1	0.318
Saikai No. 176-97	60.4 ± 0.3	11.6 ± 0.2	1.6 ± 0.1	0.320
Saikai No. 177-97	60.5 ± 0.2	11.7 ± 0.1	1.5 ± 0.0	0.319
Saikai No. 178-97	60.1 ± 0.2	11.8 ± 0.1	1.3 ± 0.1	0.323
Saikai No. 179-97	59.4 ± 0.1	11.5 ± 0.2	1.3 ± 0.1	0.322
Saikai No. 182-97	60.1 ± 0.3	11.1 ± 0.1	1.6 ± 0.1	0.320
Saikai No. 183-97	60.1 ± 0.1	11.2 ± 0.2	1.5 ± 0.1	0.320
Saikai No. 184-97	61.9 ± 0.1	12.2 ± 0.3	1.3 ± 0.2	0.319
Nishihonami-97	62.6 ± 0.1	12.3 ± 0.1	1.5 ± 0.1	0.319
Chikugoizumi-97	62.1 ± 0.1	12.3 ± 0.2	1.4 ± 0.2	0.322
Kinuiroha-97	60.3 ± 0.1	11.6 ± 0.2	1.3 ± 0.1	0.319
Iwainodaichi-97	60.6 ± 0.1	11.7 ± 0.1	1.6 ± 0.1	0.320
Nishinokaori-97	59.1 ± 0.3	10.5 ± 0.2	1.5 ± 0.2	0.323
Shiroganekomugi-97	60.0 ± 0.2	11.1 ± 0.0	1.7 ± 0.2	0.321
Norin No. 61-97	59.4 ± 0.2	11.0 ± 0.2	1.7 ± 0.1	0.322
Chihokukomugi-97	60.7 ± 0.1	11.7 ± 0.2	1.4 ± 0.3	0.320
Saikai No. 179-98a	60.5 ± 0.1	12.4 ± 0.4	1.4 ± 0.2	0.320
Chikugoizumi-98a	63.4 ± 0.4	13.2 ± 0.3	1.3 ± 0.1	0.308
Iwainodaichi-98a	62.0 ± 0.1	12.7 ± 0.2	1.6 ± 0.1	0.322
Abukumawase-98a	60.1 ± 0.2	12.3 ± 0.3	1.7 ± 0.1	0.322
Saikai No. 179-98b	60.1 ± 0.2	12.0 ± 0.2	1.6 ± 0.2	0.323
Chikugoizumi-98b	61.5 ± 0.3	13.1 ± 0.2	1.5 ± 0.1	0.318
Iwainodaichi-98b	61.0 ± 0.1	12.0 ± 0.2	1.6 ± 0.1	0.320
Abukumawase-98b	59.1 ± 0.1	12.0 ± 0.2	1.9 ± 0.1	0.328
Mean ± SD	60.5 ± 1.1	11.9 ± 0.6	1.5 ± 0.2	0.320 ± 0.003

[a] 97 = harvested in 1997, 98 = harvested in 1998, 98a = sown on 19 November 1997 and harvested on 19 May 1998, 98b = sown on 5 November 1997 and harvested on 14 May 1998.

[b] Mean ± SD; values are means of at least three replicate determinations.

[c] Peak area ratio of DP 6–12. Values are means of at least two determinations.

TABLE III
Correlation Between Starch Properties for Wheat Starches[a]

	Amylose Content	Peak Viscosity	Breakdown	Setback	Pasting Temp.	T_p (starch gelatinization)	ΔH (starch gelatinization)	ΔH (amylose lipid complex)
Amylose content								
Peak viscosity	–0.24							
Breakdown	0.10	0.18						
Setback	0.46*	0.45*	0.27					
Pasting temperature	0.64**	–0.31	–0.33	0.44*				
T_p (starch gelatinization)	–0.74**	–0.04	0.08	–0.42*	–0.50**			
ΔH (starch gelatinization)	–0.57**	–0.44*	–0.14	–0.57**	–0.27	0.75**		
ΔH (amylose lipid complex)	0.57**	–0.36	–0.36	0.26	0.75**	–0.36	–0.18	
Peak area ratio of DP 6–12	0.64**	0.10	–0.14	0.41*	0.44*	–0.70**	–0.45*	0.42*

[a] ** and *= $P < 0.01$ and 0.05, respectively; $n = 24$.

TABLE IV
Sensory Scoring Values of Japanese White Salted Noodle

Sample[a]	Softness	Elasticity	Smoothness
Saikai No. 175-97	7.6	20.0	12.2
Saikai No. 176-97	7.5	18.8	11.2
Saikai No. 177-97	7.5	19.5	11.7
Saikai No. 178-97	7.4	18.6	11.2
Saikai No. 179-97	7.4	19.8	11.9
Saikai No. 182-97	7.3	19.3	11.9
Saikai No. 183-97	7.2	18.8	11.7
Saikai No. 184-97	7.4	21.5	13.1
Nishihonami-97	7.5	19.4	11.4
Chikugoizumi-97	7.8	21.0	12.2
Kinuiroha-97	7.5	20.3	12.0
Iwainodaichi-97	7.4	19.3	12.0
Nishinokaori-97	nd[b]	nd	nd
Shiroganekomugi-97	7.1	17.0	10.3
Norin No. 61-97	7.1	18.1	11.0
Chihokukomugi-97	6.9	20.4	12.0
Saikai No. 179-98a	7.4	19.6	12.0
Chikugoizumi-98a	7.6	19.7	11.9
Iwainodaichi-98a	7.4	18.7	11.6
Abukumawase-98a	6.8	17.1	10.4
Saikai No. 179-98b	nd	nd	nd
Chikugoizumi-98b	nd	nd	nd
Iwainodaichi-98b	7.2	17.9	11.1
Abukumawase-98b	nd	nd	nd
Mean ± SD	7.4 ± 0.2	19.2 ± 1.2	11.6 ± 0.6

[a] 97 = harvested in 1997, 98 = harvested in 1998, 98a = sown on 19 November 1997 and harvested on 19 May 1998, 98b = sown on 5 November 1997 and harvested on 14 May 1998.
[b] Not determined.

TABLE V
Correlation Between Starch Properties and Sensory White Salted Noodle Quality[a]

Starch Properties	Softness	Elasticity	Smoothness
Amylose content	–0.82**	–0.68**	–0.69**
Peak viscosity	0.33	0.46*	0.45*
Breakdown	–0.18	0.13	0.04
Setback	–0.17	–0.24	–0.32
Pasting temperature	–0.43*	–0.68**	–0.64**
T_p (starch gelatinization)	0.51*	0.41	0.37
ΔH (starch gelatinization)	0.35	0.26	0.24
ΔH (amylose lipid complex)	–0.46*	–0.72**	–0.66**
Peak area ratio of DP 6–12	–0.32	–0.22	–0.24

[a] ** and *=$P < 0.01$ and 0.05, respectively; $n = 20$.

or 12 and had shoulders at ≈DP 19. This is in agreement with the report of Shibanuma et al (1996), who studied the distributions of amylopectins from four wheat cultivars by HPAEC. The peak area ratio of DP 6–12 to DP 6–30 was 0.308 to 0.328 (Table II). Thus, the differences fin the unit-chain distributions of amylopectin among various wheat samples were not large.

Correlation Between the Parameters of Starch Properties

All possible correlations among the nine parameters of 24 wheat starch samples are listed in Table III. It is generally accepted that higher amylose content is the major factor contributing to lower peak viscosity and higher setback. For example, previous research indicated that amylose content was negatively correlated with peak viscosity (Collado and Corke 1997; Collado et al 1999; Black et al 2000). Additionally, Katayama et al (1999) observed a positive correlation between amylose content and setback for many kinds of sweet potato starch samples. In our research, there was a positive correlation between amylose content and setback ($r = 0.46$), while there was no correlation between amylose content and peak viscosity. The amylose content was positively correlated with pasting temperature ($r = 0.64$). This is agrees with the results of Katayama et al (1999), who observed a positive correlation between amylose content and pasting temperature using sweet potato starches. In contrast, there was no correlation between amylose content and pasting temperature for starch samples from 133 wheat landraces (Black et al 2000). Currently, one of the main factors affecting starch gelatinization properties is the molecular structure of starch. Waxy starch tends to have higher T_p and ΔH values in starch gelatinization than nonwaxy starch (Yasui et al 1996; Fujita et al 1989, 1993, 1998). Sasaki and Matsuki (1998) indicated that starch with lower amylose content showed higher values of T_p and ΔH for 12 wheat starch samples. Negative correlations between amylose content and two DSC parameters of starch gelatinization, T_p ($r = –0.74$) and ΔH ($r = –0.57$), were also detected in our present data. However, results have been obtained in which the amylose-amylopectin ratio did not affect the DSC parameters of starch gelatinization (Noda et al 1993, 1998; Kim et al 1995). From our previous results (Noda et al 1998), the content of amylopectin short chains was more important than the amylose-amylopectin ratio in accounting for DSC gelatinization properties for sweet potato and buckwheat. Our present data also indicated that the content of amylopectin short chains (DP 6–12) was negatively correlated with T_p ($r = –0.70$) and ΔH ($r = –0.45$) in starch gelatinization for 24 wheat starch samples. However, a significant positive correlation ($r = 0.64$) existed between amylose content and the content of amylopectin short chains (DP 6–12). Therefore, starch with higher amylose content had higher content of amylopectin short chains. To clarify the contribution of starch molecular properties to DSC parameters, further studies using wheat starches with lower amylose content and higher content of amylopectin short chains would be needed. The pasting temperature was positively correlated with ΔH in the amylose-lipid complex ($r = 0.75$). This means that a higher content of amylose-lipid complex would reduce the swelling potential of starch, which holds for previous data that amylose-lipid complex inhibited the swelling power of starch (Eliasson 1985).

WSN Quality

Japanese WSN made from various wheat flours are evaluated in Table IV. Low values of softness (6.8–7.1), elasticity (17.0–18.1), and smoothness (10.3–11.0) were observed in cultivars with high amylose content (Norin No. 61, Shiroganekomugi, and Abukumawase). As expected, WSN made from these cultivars appeared to exhibit undesirable properties.

Correlation Between WSN Quality and Starch Properties

The correlations between starch properties and four parameters of WSN quality are presented in Table V. Currently, one of the main factors for WSN quality is amylose content (Oda et al 1980; Toyokawa et al 1989). In this study, as expected, significant negative correlations were detected between amylose content and all parameters of WSN quality: softness (r = –0.82), elasticity (r = –0.68), and smoothness (r = –0.69). Starch pasting properties determined by amylograph and RVA have been used to predict WSN quality. Previous research has indicated a relationship between peak viscosity and WSN quality (Crosbie 1991; Konik and Miskelly 1992; Panozzo and McCormick 1993). We also observed correlations between peak viscosity and two parameters of WSN quality, elasticity (r = 0.46) and smoothness (r = 0.45). However, the other parameter, softness, was not correlated with peak viscosity. Pasting temperature was negatively correlated with all parameters of WSN quality: softness (r = –0.43), elasticity (r = –0.68), and smoothness (r = –0.64). Oda et al (1980) and Endo et al (1988) also found that the starch from Australian Standard White, which possessed favorable characteristics for making WSN, showed somewhat lower pasting temperature than those from other wheat cultivars ranking standard class for making WSN. In contrast, breakdown and setback were not correlated with all parameters of WSN quality. Konik and Miskelly (1992) found no relationship between setback and WSN quality but significant positive correlations between breakdown and three parameters of WSN quality: softness, elasticity, and eating quality. Our RVA data demonstrated that pasting temperature is more suitable to estimate WSN quality than peak viscosity. T_p and ΔH in starch gelatinization had no effects on WSN except that the positive correlation of T_p with softness was significant (r = 0.51). On the contrary, significant negative correlations were observed between ΔH values in the amylose-lipid complex and all WSN quality parameters: softness (r = –0.46), elasticity (r = –0.72), and smoothness (r = –0.66). The increased level of amylose-lipid complex presumably increased the firmness and loss of elasticity, resulting in poor quality WSN. This is the first report to show the relationship between ΔH values in amylose-lipid complex and WSN quality. Little information is available on the contribution of amylopectin structure to WSN quality except for the report of Batey et al (1997). In this study, the distributions of amylopectin chain length determined by HPAEC had no influence on WSN quality. Distributions of amylopectin chain length spanned a relatively narrow range; therefore, further studies would be needed to obtain a precise relationship between amylopectin chain length and WSN quality. Our investigation clearly demonstrated that, in addition to RVA, DSC is useful in predicting WSN quality in wheat flours.

CONCLUSIONS

In the present study, we evaluated the starch properties that influence WSN quality using 24 samples of Japanese wheat flours. Besides amylose content and RVA properties, DSC results were responsible for WSN quality. Significantly, ΔH in the amylose-lipid complex was negatively correlated with individual parameters of WSN quality. By contrast, the distributions of amylopectin chain length measured by HPAEC had no effects on WSN quality. Our results may provide useful information for wheat breeders and users.

LITERATURE CITED

Anonymous. 1985. Quality assessment for wheat-sensory tests for noodles. (In Japanese) Ministry of Agriculture, Forestry and Fisheries. National Food Research Institute: Tokyo.

Batey, I. L., Gras, P. W., and Curtin, B. M. 1997. Contribution of the chemical structure of wheat starch to Japanese noodle quality. J. Sci. Food Agric. 74:503-508.

Black, C. K., Panozzo, J. F., Wright, C. L., and Lim, P. C. 2000. Survey of white salted noodle quality characteristics in wheat landraces. Cereal Chem. 77:468-472.

Collado, L. S., and Corke, H. 1997. Properties of starch noodles as affected by sweet potato genotype. Cereal Chem. 74:182-187.

Collado, L. S., Mabesa, R. C., and Corke, H. 1999. Genetic variation in the physical properties of sweet potato starch. J. Agric. Food Chem. 47:4195-4201.

Crosbie, G. B. 1991. The relationship between starch swelling properties, pasta viscosity and boiled noodle quality in wheat flours. J. Cereal Sci. 13:145-150.

Eliasson, A. C. 1985. Starch gelatinization in the presence of emulsifiers. Starch 37:411-415.

Endo, S., Karibe, S., Okada, K., and Nagao, S. 1988. Factors affecting gelatinization properties of wheat starch. (In Japanese) Nippon Shokuhin Kogyo Gakkaishi 35:7-14.

Fujita, S., Donghui L., Sugimoto, Y., Inouchi, N., and Fuwa, H. 1989. Some properties of starch from foxtail millet (*Setaria italica* BEAUV.). Agric. Biol. Chem. 53:1163-1165.

Fujita, S., Morita, T., and Fujiyama, G. 1993. The study of melting temperature and enthalpy of starch from rice, barley, wheat, foxtail- and proso-millets. Starch 45:436-441.

Fujita, S., Yamamoto, H., Sugimoto, Y., Morita, N., and Yamamori, M. 1998. Thermal and crystalline properties of waxy wheat (*Triticum aestivum*) starch. J. Cereal Sci. 27:1-5.

Juliano, B. O. 1971. A simplified assay for milled-rice amylose. Cereal Foods World 16:334-338.

Katayama, K., Komaki, K., Tamiya, S., and Takayanagi, K. 1999. Varietal and annual variations in pasting properties of sweet potato starch. Breed. Sci. 49:173-178.

Kim, Y. S., Wiesenborn, D. P., Orr, P. H., and Grant, L. A. 1995. Screening potato starch for novel properties using differential scanning calorimetry. J. Food Sci. 60:1060-1065.

Koizumi, K., Fukuda, M., and Hizukuri, S. 1991. Estimation of distributions of chain length of amylopectins by high-performance liquid chromatography with pulsed amperometric detection. J. Chromatogr. 585:233-238.

Konik, C. M., and Miskelly, D. M. 1992. Contribution of starch and non-starch parameters to the eating quality of Japanese white salted noodles. J. Sci. Food Agric. 58:403-406.

Konik, C. M., Miskelly, D. M., and Gras, P. W. 1993. Starch swelling power, grain hardness and protein: Relationship to sensory properties of Japanese noodles. Starch 45:139-144.

Miura, H., and Tanii, S. 1994. Endosperm starch properties in several wheat cultivars preferred for Japanese noodles. Euphytica 72:171-175.

Noda, T., Takahata, Y., and Nagata, T. 1993. Factors relating to digestibility of raw starch by amylase. J. Jpn. Soc. Starch Sci. 40:271-276.

Noda, T., Takahata, Y., and Sato, T. 1995. Distributions of the amylopectin chain length of sweet potatoes differing in stages of development, tissue zone and variety. J. Jpn. Soc. Food Sci. Technol. 42:200-206.

Noda, T., Takahata, Y., Sato, T., Suda, I., Morishita, T., Ishiguro, K., and Yamakawa, O. 1998. Relationships between chain length distribution of amylopectin and gelatinization properties within the same botanical origin for sweet potato and buckwheat. Carbohydr. Polym. 37:153-158.

Oda, M., Yasuda, S., Okazaki, S., Yamauchi, Y., and Yokoyama, Y. 1980. A method of flour quality assessment for Japanese noodles. Cereal Chem. 57:253-254.

Panozzo, J. F., and McCormick, K. M. 1993. The rapid viscoanalyzer as a method of testing for noodle quality in a wheat breeding programme. J. Cereal Sci. 17:25-32.

Qian, J., Rayas-Duarte, P., and Grant, L. 1998. Partial characterization of buckwheat (*Fagopyrum esculentum*) starch. Cereal Chem. 75:365-373.

Sasaki, T., and Matsuki, J. 1998. Effect of wheat starch structure on swelling power. Cereal Chem. 75:525-529.

Shi, Y. C., Seib, P. A., and Bernardin, J. E. 1994. Effects of temperature during grain-filling on starches from six wheat cultivars. Cereal Chem. 71:369-383.

Shibanuma, K., Takeda, Y., and Hizukuri. S. 1996. Molecular and pasting properties of some wheat starches. Carbohydr. Polym. 29:253-261.

Toyokawa, H., Rubenthaler, G. L., Powers, J. R., and Schanus, E. G. 1989. Japanese noodle qualities. Starch components. Cereal Chem. 66:387-391.

Yasui, T., Matsuki, J., Sasaki, T., and Yamamori, M. 1996. Amylose and lipid contents, amylopectin structure, and gelatinization properties of waxy wheat (*Triticum aestivum*) starch. J. Cereal Sci. 24:131-137.

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