

Effect of Holding Temperature on the Structures of Mung Bean Starch Gels and Noodles

N. Ohwada,¹ K. Ishibashi,^{1,2} and K. Hironaka¹

ABSTRACT

Cereal Chem. 79(5):732–736

The effect of storage temperatures (−10, +1, and +10°C) on the structural organization of mung bean starch gels and noodles was studied by acid hydrolysis, X-ray diffractometry, and gel-permeation chromatography. The gels showed higher susceptibility to acid compared with the noodles as shown by the rate constants of the first stage of hydrolysis ($k = 5.37\text{--}12.17 \times 10^{-2}/\text{day}$ and $k = 4.19\text{--}4.61 \times 10^{-2}/\text{day}$ for gels and noodles, respectively). Acid hydrolysis showed no difference in the amount of resistant residues of both gels (42–46%) and noodles (44–45%), except for gels (38%) stored at −10°C. The acid-resistant residues

of both the gels and noodles had a B-type X-ray diffraction pattern (major reflections at $2\theta = 19, 24, \text{ and } 25^\circ$). The acid-resistant residues of the unstored sample and those stored at −10°C for both gels and noodles contained chains with DP 46–54 and after debranching yielded two peaks with DP 29–39 and DP 15–19. The acid-resistant residues of gels and noodles stored at +1 and +10°C contained chains with DP 35–37 and after debranching showed two chain populations with DP 31–33 and DP 14–19. These results indicate the greater participation of amylopectin in the retrogradation process occurring during storage at +1 and +10°C.

Gel and noodle systems are important for the utilization of starches. Numerous studies have dealt with the elucidation of the structures of gels (Matsukura et al 1983; Jane and Robyt 1984; Miles et al 1985; Matsunaga and Kainuma 1986; Mestres et al 1988) and noodles (Takahashi et al 1987; Mestres et al 1988; Singh et al 1989). Starch gels were described as complex composites in which swollen gelatinized granules are embedded in an interpenetrating amylose-gel matrix (Miles et al 1985). On the other hand, noodles (specifically from mung bean starch) were described as a ramified 3D network held together by short segments of strongly retrograded amylose that melts at temperatures above the boiling point of water (Mestres et al 1988b; Xu et al 1993).

The formation of gels and noodles involves heating and cooling steps where the basic processes of gelation and retrogradation are involved. In the manufacture of starch noodles, retrogradation is achieved by holding at temperatures (−18 to 5°C) for a certain period of time (12–24 hr) (Galvez et al 1994). Previous studies on the elucidation of starch noodle structures used commercially available products and did not specify the process variables involved.

The purpose of this study was to determine the effect of at least one process variable (holding temperature) on the structures of gels and noodles from mung bean starch.

MATERIALS AND METHODS

Isolation of Starch

Mung bean seeds from Shaanxi province, China, were purchased through a local importer. Starch was isolated from the seeds according to the method of Schoch and Maywald (1968) except for a change in sieve sizes and washing with 0.1% NaOH to remove protein and other contaminants (Lii and Chang 1981). The properties of isolated starch were reported elsewhere (Sabiniano 1995).

Preparation of Gels

A 5% (w/v, dry basis) mung bean starch suspension was heated in a boiling water bath for 10 min with constant stirring. The final temperature of the cooked solution was 92°C. The cooked solution was carefully distributed in petri dishes (42 × 20 mm, 15 g/dish), covered, sealed, and then steamed for 20 min to ensure

complete gelatinization. The gels were allowed to cool to 20°C before storage at −10, +1, and +10°C for 24 hr. After storage, the samples were thawed at 25°C for 1 hr before dehydration with ethanol and acetone. Control samples were dehydrated with ethanol and acetone 2 hr after standing at room temperature (20°C).

Preparation of Noodles

Noodles were prepared according to the method of Lii and Chang (1981). Starch paste (5%) was mixed with raw starch (95%) to form a dough with a smooth, glossy surface. The dough (54% moisture) was extruded through a syringe (25 mL) into a water bath (90–95°C). The noodles were taken out of the water as soon as they floated and were immediately rinsed with cold tap water. The noodles were left in the tap water for 2 hr and then hung on a pole, followed by storage at −10, +1, and +10°C for 24 hr. The noodles stored at 1°C were thawed in cold water for 2 hr before drying in a forced-draft cabinet dryer at 40°C overnight. The noodles stored at −10 and +10°C were dried directly because thawing was not necessary. Control samples were dried without storage.

Chemical Analysis

Total carbohydrate was determined using the phenol-sulfuric acid method (Dubois et al 1956). Reducing power was determined by the Park-Johnson method as modified by Hizukuri et al (1981). Glucose was used as the reference standard in the determination of both total carbohydrate and reducing power.

X-ray Diffraction

X-ray diffraction patterns were recorded on an X-ray diffractometer (Shimadzu GX-2). The X-rays were $K\alpha$ radiation achieved by bombardment of the copper target at 35 kV and 7.5 mA. Diffractograms were registered at $2\theta = 0\text{--}40^\circ$ at a scan rate of $2^\circ/\text{min}$. Gel samples were adjusted to 65% moisture, while noodle samples were hydrated to 100% moisture and equilibrated for at least 2 hr before analysis.

Mild Acid Hydrolysis

Gels and noodles were ground in a food mill to a particle size of <500 μm . Mild acid hydrolysis was performed with the ratio of 1.67 g starch to 100 mL of 1M HCl at 35°C (Robin et al 1974; Mestres et al 1988b) over a 40-day period for gels and a 43-day period for noodles. Each sample was gently shaken daily, and an aliquot (0.1 mL) of a digest was taken at various times and made to 10-mL volume with water. After centrifugation, triplicate aliquots (1.0 mL each) of the supernatant were assayed for total carbohydrate. At the end of the hydrolysis period, the mixture was centrifuged, the supernatant discarded, and the residue rinsed with

¹ Department of Bioresource Science, Obihiro University of Agriculture and Veterinary Medicine, Obihiro 080-8555 Japan.

² Corresponding author. Phone: +81-155-49-5571. Fax: +81-155-49-5577. E-mail: ken@obihiro.ac.jp.

deionized water. The washing and centrifugation steps were repeated four times, and the residue was dried at 35°C under vacuum. The dried residues were analyzed by X-ray diffractometry and gel-permeation chromatography (GPC).

GPC

Relative molecular weight distributions were estimated by GPC according to the procedure of Mestres et al (1988a) and Xu and Seib (1993). GPC was done on a 26 × 100 mm HW-50S column (Toyopearl, Tosoh Corp., Tokyo). The excluded and total volumes of the column were calibrated using Blue Dextran 2000 and D-glucose, respectively. Duplicate chromatograms were essentially the same. The acid resistant residues (10 mg) were dissolved in 0.5 mL of 2M aqueous KOH. Each solution was diluted with water (9.5 mL) and filtered through a 0.45-μm syringe filter. An aliquot (2.5 mL) of the mixture was immediately injected into the column. Components were eluted with 0.1M aqueous KOH at a flow rate of 12 mL/hr in the descending direction. Fractions (5 mL/tube) were collected and analyzed for total carbohydrate and reducing power, from which degrees of polymerization (DP) were calculated.

Debranching with Isoamylase

Debranching of resistant residues by isoamylase was done essentially as in Xu and Seib (1993). A resistant residue (10 mg) was dissolved in 2M aqueous KOH (0.5 mL) and the solution was neutralized with 2M HCl. Dimethyl sulfoxide (2 mL), water (2 mL), and 10 mM acetate buffer (5 mL, pH 3.8) were added, followed immediately by isoamylase (328 units). The mixture was incubated at 45°C for 24 hr and the reaction was stopped by heating in a boiling water bath for 10 min. After centrifugation, the supernatant was filtered through a 0.45-μm syringe filter. An aliquot (2.5 mL) of the filtrate was injected onto the same column

and under the same conditions used for the resistant residues. Likewise, the degrees of polymerization of the identified peaks were determined.

RESULTS AND DISCUSSION

Acid Hydrolysis of Mung Bean Starch Gels and Noodles

A two-stage hydrolysis was evident in the solubilization profiles of the gels and noodles (Figs. 1A and 2A). The acid-resistant residues were 38–46% for the gels after 40 days and 44–45% for the noodle samples after 43 days. Plotting the hydrolysis data (X) as $\log_{10}[100/(100-X)]$ vs. time (Figs. 1B and 2B) (Robin et al 1974) clearly showed the two-stage hydrolysis pattern. The faster stage corresponds to the hydrolysis of the more amorphous parts while the second stage corresponds to the hydrolysis of the crystalline material which is slowly degraded (Kainuma and French 1971; Robin et al 1974; Biliaderis et al 1981b).

TABLE I
Hydrolysis Rate Constants of Gels and Noodles
in 1M HCl at 35°C^a

Sample	Hydrolysis Rate Constant ($k \times 10^{-2}/\text{day}$) ^b			
	Not Stored	Storage Temp. (°C)		
		-10	+1	+10
5% Starch gels	7.33	12.17	5.37	6.91
	(0.944) ^c	(0.871)	(0.897)	(0.926)
Noodles	4.61	4.31	4.19	4.28
	(0.864)	(0.919)	(0.942)	(0.917)

^a Hydrolysis periods were 40 days for gels and 43 days for noodles.

^b Apparent rate constant k for the first stage of hydrolysis curve, $\log_{10}[100/(100 - X)]$ vs. time, calculated from $k = (2.303/t) \log_{10}[100/(100 - X)]$.

^c Numbers in parenthesis give correlation coefficient of the corresponding linear regression of the experimental data; all were significant at $P < 0.01$.

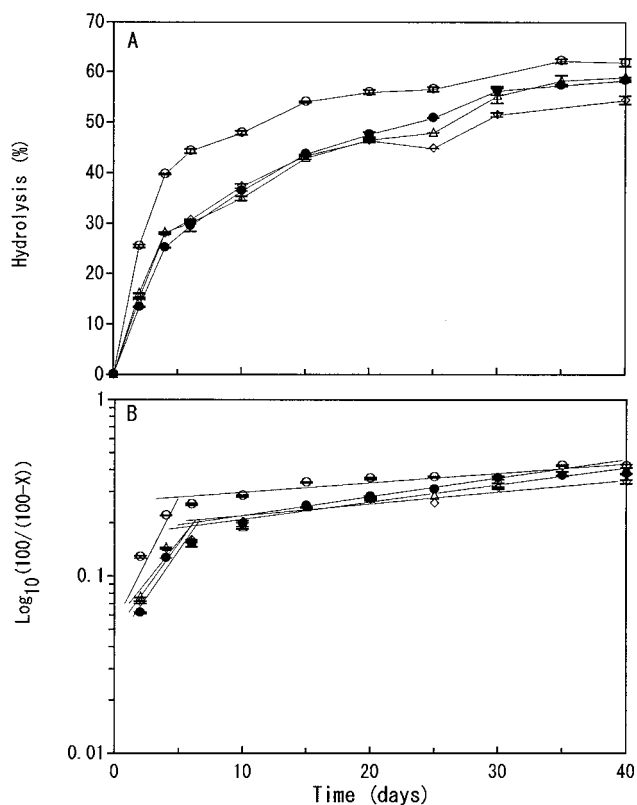


Fig. 1. Hydrolysis of mung bean starch in 1M HCl at 35°C. A, % hydrolysis (X) vs. time. B, $\log_{10}[100/(100 - X)]$ vs. time. (●) Control; (○) stored at -10°C for 24 hr; Δ stored at +1°C for 24 hr; (◇) stored at +10°C for 24 hr. Error bars indicate standard deviations ($n = 2$).

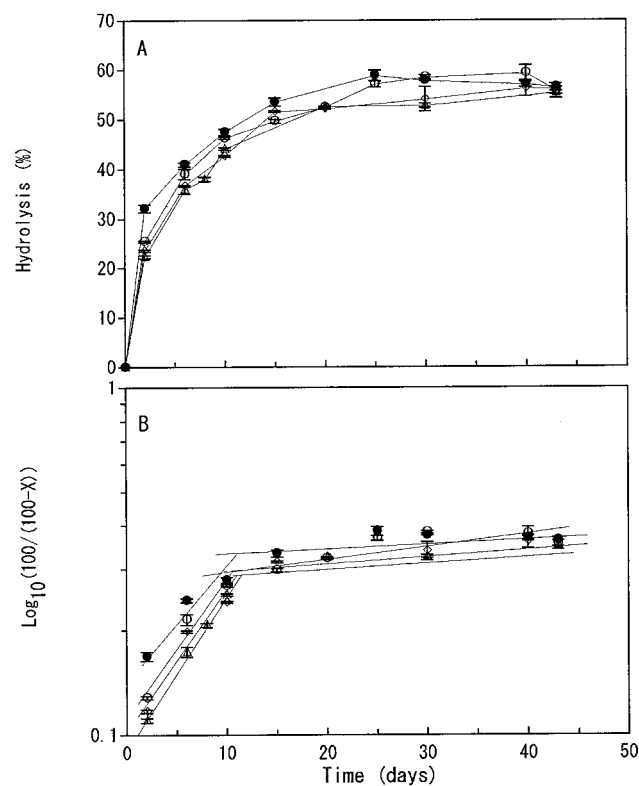


Fig. 2. Hydrolysis of mung bean starch noodles in 1M HCl at 35°C. A, % hydrolysis (X) vs. time. B, $\log_{10}[100/(100 - X)]$ vs. time. (●) Control; (○) stored at -10°C for 24 hr; Δ stored at +1°C for 24 hr; (◇) stored at +10°C for 24 hr. Error bars indicate standard deviations ($n = 2$).

The first stage required eight days (30–45% hydrolysis) for the gels and 10 days (42–47% hydrolysis) for the noodles but the second stage did not show much difference in terms of rate. The rate constants of hydrolysis (Table I) show that the gel samples ($k = 5.37\text{--}12.17 \times 10^{-2}/\text{day}$) were hydrolyzed faster than the noodles ($k = 4.19\text{--}4.61 \times 10^{-2}/\text{day}$). These results indicate different molecular organization within each sample. When starch is gelatinized and stored at a low temperature, starch molecules reassociate but in weaker molecular and structural forms than in the native molecules (White et al 1989). Matsukura et al (1983) also noted that retrograded starches were much more susceptible to acid than raw starches, indicating that they are less crystalline than the raw starch.

Two factors for the resistance of crystalline portions against acidic attack were proposed. First, the dense packing of starch chains within the crystalline regions make it difficult for the H_3O^+ ions to penetrate. Second, for hydrolysis to occur, it would require the glucosidic unit to undergo a change in conformation from a chair to a half-chair, which requires a very high energy of activation and therefore would have a very low probability (Kainuma and French 1971). The crystalline regions were more resistant to acidic and enzymatic hydrolysis due to the formation of compact double helices between chains in adjacent molecules of amylose or between adjacent clusters of chains from a single amylopectin molecule or from neighboring amylopectin molecules (Manners 1985).

Gel samples stored at -10°C for 24 hr showed greater susceptibility to acid attack ($k = 12.17 \times 10^{-2}/\text{day}$) followed by the

control ($k = 7.33 \times 10^{-2}/\text{day}$) and then by the gel stored at $+10^\circ\text{C}$ ($k = 6.91 \times 10^{-2}/\text{day}$). The least susceptibility to acid hydrolysis was exhibited by the gel stored at $+1^\circ\text{C}$ ($k = 5.37 \times 10^{-2}/\text{day}$). With regard to the noodles, all samples did not differ significantly in the rate of hydrolysis, but the stored samples had k values ($k = 4.199\text{--}4.31 \times 10^{-2}/\text{day}$) lower than the control ($k = 4.61 \times 10^{-2}/\text{day}$). These results indicate the effect of storage temperature on properties of the starch gels and noodles. In gels, storage at -10°C for 24 hr, made the gel more susceptible to acid hydrolysis than the control and storage at $+1^\circ\text{C}$ and $+10^\circ\text{C}$. This could be due to

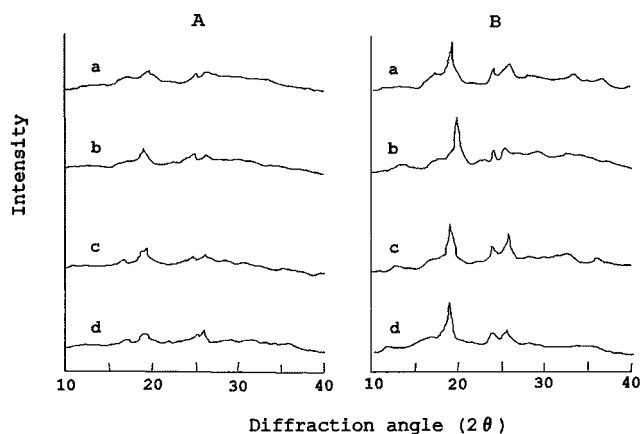


Fig. 3. X-ray diffraction patterns of mung bean starch gels (A) before and (B) after acid hydrolysis. a–d, respectively: control, -10°C (24 hr), $+1^\circ\text{C}$ (24 hr), $+10^\circ\text{C}$ (24 hr).

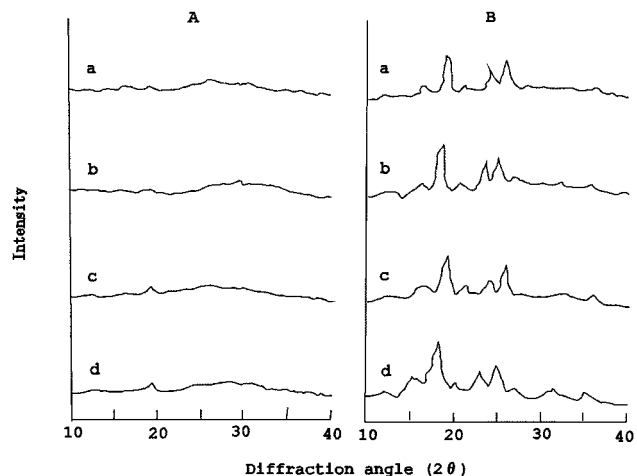


Fig. 4. X-ray diffraction patterns of mung bean starch noodles (A) before and (B) after acid hydrolysis. a–d, respectively: control, -10°C (24 hr), $+1^\circ\text{C}$ (24 hr), $+10^\circ\text{C}$ (24 hr).

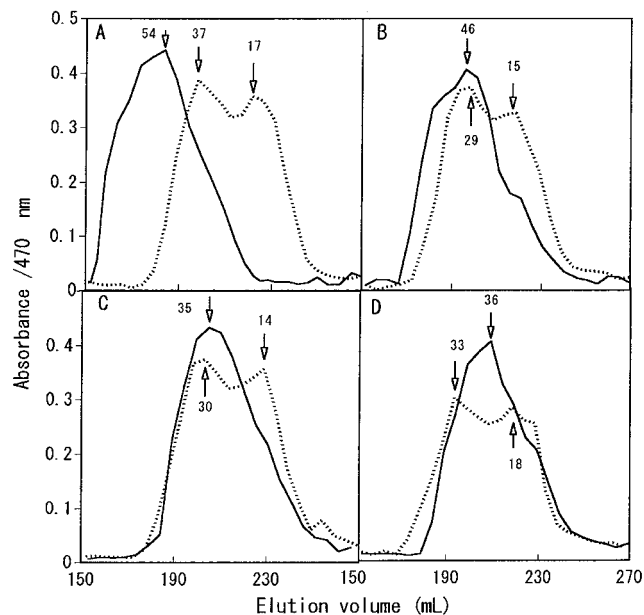


Fig. 5. Elution profiles of 5% mung bean starch gels resistant to 1M HCl at 35°C before (—) and after (---) debranching with isoamylase on a Toyopearl HW-50S column (2.6×100 cm) eluted with 0.1M KOH at a flow rate of 12 mL/hr at 20°C . A, control; B, stored at -10°C for 24hr; C, stored at $+1^\circ\text{C}$ for 24hr; D, stored at $+10^\circ\text{C}$ for 24hr. Arrows show degree of polymerization (DP).

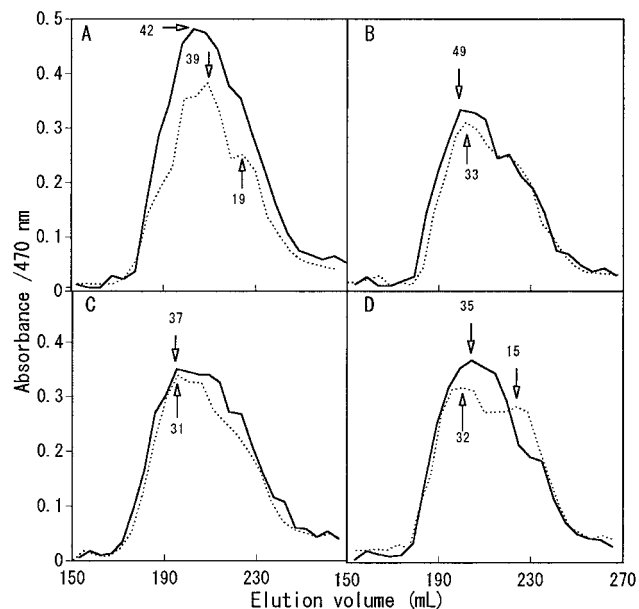


Fig. 6. Elution profiles of residues of mung bean starch noodles resistant to 1M HCl at 35°C before (—) and after (---) debranching with isoamylase on a Toyopearl HW-50S column (2.6×100 cm) eluted with 0.1M KOH at a flow rate of 12mL/hr at 20°C . A, control; B, stored at -10°C for 24hr; C, stored at $+1^\circ\text{C}$ for 24hr; D, stored at $+10^\circ\text{C}$ for 24hr. Arrows show degree of polymerization (DP).

the spongy texture of the gels stored at -10°C . Ferrero et al (1993) reported that spongy structures were observed with freezing rates <10 mm/hr and could be attributed to the water release (desolvation) caused by slow freezing and formation of large ice crystals, which leads to the formation of high-amylose concentration zones with the thickening of the fibrillar structure. Although it would be expected that crystallization of amylose and amylopectin would favor the formation of more resistant residues (i.e., higher susceptibility to acid attack), the reassociation was not as extensive as that which occurred at $+1^{\circ}\text{C}$, $+10^{\circ}\text{C}$, and room temperature (20°C). This could be explained by the fact that at freezing temperature, water is less available and decreases the mobility of starch molecules to reassociate. The control exhibited some degree of susceptibility to acid attack because the mere gelation process is an indication that some extent of starch reassociation occurred (Matsukura et al 1983; Miles et al 1985; Doublier et al 1987).

For the noodle samples, the effect of storage temperature on the rate of hydrolysis was not clearly shown because the values were very close to each other. Nevertheless, it was evident that storage made the gels more resistant to acid hydrolysis. Storage of the noodles at -10°C also produced a spongy texture but did not make the noodle susceptible to acid attack as the gel stored at -10°C for 24 hr. This difference could be due to the retrogradation that already occurred when the noodles were left in tap water for ≈ 2 hr during preparation, such that the effect of storage at -10°C , was more on dehydration, causing the spongy texture.

X-ray Diffraction of Gels and Noodles

Mung bean starch gels, whether unstored (control) or stored at -10 , $+1$ and $+10^{\circ}\text{C}$, showed weak X-ray diffraction patterns (Fig. 3). However, after acid hydrolysis, the residues produced the sharp X-ray diffractions of the B-type (major reflections at $2\theta = 19$, 24 , and 25°) characteristic of retrograded starches. The same trend was observed for the starch noodles with the acid-treated noodles producing sharper peaks than the acid-hydrolyzed gels (Fig. 4). These results also indicate the preferential hydrolysis of the amorphous portion (Colonna et al 1981) and suggests that the noodles were composed of a more orderly structure. Wu and Sarko (1978) suggested that reordering of the crystallites might take place during acid hydrolysis by displacement of the water molecules in the crystallite cavities by double-helices. This reordering of chain segments gives more crystalline structure with a sharper X-ray pattern (Kainuma and French 1971).

GPC of Gel and Noodle Residues Resistant to Acid Hydrolysis

The elution profiles of the residues of mung bean starch gels and noodles resistant to acid hydrolysis showed almost the same patterns with single peaks (Figs. 5 and 6). It could be noted that the control samples and the ones stored at -10°C for 24 hr showed peaks with higher DP (42–54) than those stored at $+1^{\circ}\text{C}$ and $+10^{\circ}\text{C}$ (DP 29–39) while those stored at $+1^{\circ}\text{C}$ and $+10^{\circ}\text{C}$ did not change so much (DP 31–33). However, in almost all samples, debranching also yielded minor peaks with DP 14–19. The ranges of DP values obtained in this study were close to that of acid-hydrolyzed maize starch gels with DP 47 before debranching and DP 14 and 41 after debranching (Mestres et al 1988a); acid-hydrolyzed mung bean starch vermicelli with DP 33 before debranching and the appearance of DP 14 after debranching (Mestres et al 1988b); mung bean starch noodles with DP 35 and DP 25 before and after debranching, respectively (Xu and Seib 1993); retrograded normal corn starches with DP 58 before debranching and DP 58–60 and DP 19 after debranching (Matsukura et al 1983). The differences in DP values before and after debranching indicate the presence of branched points in the resistant residues (Xu and Seib 1993).

It has been mentioned that in a gelatinized starch paste, amylose gelation occurs faster than amylopectin crystallization (Miles et al 1985; Mestres et al 1988b). In control samples where retro-

gradation essentially took place at 20°C , the rate of retrogradation was slower than at lower temperatures ($+1$ and $+10^{\circ}\text{C}$). White et al (1989) reported that crystallinity occurred faster and to a greater extent as the storage temperature was decreased. In freezing temperatures such as -10°C , retrogradation is retarded because water becomes less available for the amylose-amylopectin molecules to reassociate. Thus, the greater change in the DP values of the control samples and those stored at -10°C for 24 hr before and after debranching indicates that more of the amylopectin chains had been involved in the retrogradation process. In the noodles and gels stored at $+1$ and $+10^{\circ}\text{C}$, retrogradation was faster and involved only a few of the amylopectin chains; thus, the small change in DP upon debranching. Those amylopectin chains were mainly from the linear external chains of DP 15–20 and a few of DP 30 linked together with $\alpha(1-6)$ linkages (Ring et al 1987). In mung bean starch vermicelli, the acid-resistant crystallites were amylose-based, but a peak of DP 14 was also found and considered to be the remaining fragments of branched-short chains of amylopectin (Mestres et al (1988b)). These results suggest that the amylopectin chains involved in the acid-resistant crystallites could be the ones described by Matsukura et al (1983) and Matsunaga et al (1986). They proposed several possible structures to protect the amylopectin chains and shorter chain amylose of DP 40–60 against acid treatment describing a) modes of double-standed chains with two units of amylopectin existing side by side in the same molecule forming a parallel double-helix structure; b) a unit chain of amylopectin forming an antiparallel double-helix structure with another unit chain of different amylopectin molecules; c) an amylose chain forming by itself a double-helix structure side-by-side with the double-helix structure of amylopectin; d) one half of an amylose chain forming a parallel double-helix structure with a unit chain of amylopectin and the other half an antiparallel double-helix structure with another unit chain of amylopectin; e) the combined structures as described in c) and d) with one amylose chain forming the double-helix structure with two unit chains of amylopectin and by itself.

LITERATURE CITED

- Biliaderis, C. G., Grant, R. D., and Vose, J. R. 1981b. Structural characterization of legume starches. II. Studies on acid-treated starches. *Cereal Chem.* 58:502-507.
- Colonna, P., Buleon, A., and Mercier, C. 1981. *Pisum sativum* and *Vicia faba* carbohydrates: Structural studies of starches. *J. Food Sci.* 46:88-93.
- Doublier, J. L., Llamas, G., and Le Meur, M. 1987. A rheological investigation of cereal starch pastes and gels. Effect of pasting procedures. *Carbohydr. Polym.* 7:251-275.
- Dubois, M., Gilles, K. A., Hamilton, J. K., Rebers, P. A., and Smith, F. 1956. Colorimetric method for determination of sugars and related substances. *Anal. Chem.* 28:350-356.
- Ferrero, C., Martino, M. N., and Zaritzky, N. E. 1993. Effect of freezing rate and xanthan gum on the properties of corn starch and wheat flour pastes. *Int. J. Food Sci. Technol.* 28:481-498.
- Galvez, F. C. F., Resurreccion, A. V. A., and Ware, G. O. 1994. Process variables, gelatinized starch and moisture effects on physical properties of mung bean noodles. *J. Food Sci.* 59:378-386.
- Hizukuri, S., Takeda, Y., and Yasuda, M. 1981. Multi-branched nature of amylose and the action of debranching enzymes. *Carbohydr. Res.* 94:205-213.
- Jane, J. L., and Robyt, J. F. 1984. Structure studies of amylose-V complexes and retrograded amylose by action of alpha amylases and a new method for preparing amyloextrins. *Carbohydr. Res.* 132:105-118.
- Juliano, B. O. 1984. Rice starch: Production, properties and uses. Page 507 in: *Starch Chemistry and Technology*. R. L. Whistler, J. N. BeMiller, and E. F. Paschall, eds. Academic Press: London.
- Kainuma, K., and French, D. 1971. Nageli amyloextrin and its relationship to starch granule structure. I. Preparation and properties of amyloextrins from various starch types. *Biopolymers* 10:1673-1680.
- Lii, C. Y., and Chang, S. M. 1981. Characterization of red bean (*Phaseolus radiatus* var. Aurea) starch and its noodle quality. *J. Food Sci.* 46:78-81.

- Matsukura, U., Matsunaga, A., and Kainuma, K. 1983. Structural studies on retrograded normal and waxy corn starches. *J. Jpn. Soc. Starch Sci.* 30:106-113.
- Matsunaga, A., and Kainuma, K. 1986. Studies on the retrogradation of starch in starchy foods. 3. Effect of the addition of sucrose fatty acid ester on the retrogradation of starch. *Starch* 38:1-6.
- Mestres, C., Colonna, P., and Buleon, A. 1988a. Gelation and crystallization of maize starch after pasting, drum-drying or extrusion cooking. *J. Cereal Sci.* 7:123-134.
- Mestres, C., Colonna, P., and Buleon, A. 1988b. Characteristics of starch networks within rice flour noodles and mung bean starch vermicelli. *J. Food Sci.* 53:1809-1812.
- Miles, M. J., Morris, V. J., Orford, P. D., and Ring, S. G. 1985. The roles of amylose and amylopectin in the gelation and retrogradation of starch. *Carbohydr. Res.* 135:271-281.
- Ring, S. G., Colonna, P., I'Anson, K. J., Kalichevsky, M. T., Miles, M. J., Morris, V. J., and Orford, P. D. 1987. The gelation and crystallisation of amylopectin. *Carbohydr. Res.* 162:277-293.
- Robin, J. P., Mercier, C., Charbonniere, R., and Guilbot, A. 1974. Lintnerized starches. Gel filtration and enzymatic studies of insoluble residues from prolonged acid treatment of potato starch. *Cereal Chem.* 51:389-406.
- Sabiniano, N. S. 1995. Molecular associations in mung bean starch gels and noodles. MS thesis. University of Agricultural and Veterinary Medicine: Obihiro, Japan.
- Schoch, T. J., and Maywald, E. C. 1968. Preparation and properties of various legume starches. *Cereal Chem.* 45:564-573.
- Singh, U., Voraputhaporn, W., Rao, P. V., and Jambunathan, R. 1989. Physicochemical characteristics of pigeon pea and mung bean starches and their noodle quality. *J. Food Sci.* 54:1293-1297.
- Takahashi, S., Hirao, K., Kobayashi, R., Kawabata, A., and Nakamura, M. 1987. Properties and cooking quality of starches. 8. The degree of gelatinization and texture during the preparation of harusame noodles. *J. Jpn. Soc. Starch Sci.* 34:21-30.
- White, P. J., Abbas, I. R., and Johnson, L. A. 1989. Freeze-thaw stability and refrigerated-storage retrogradation of starches. *Starch* 41:176-180.
- Wu, H. C. H., and Sarko, A. 1978. The double-helical molecular structure of crystalline β -amylose. *Carbohydr. Res.* 61:7-25.
- Xu, A., and Seib, P. A. 1993. Structure of tapioca pearls compared to starch noodles from mung beans. *Cereal Chem.* 70:463-470.

[Received September 13, 2001. Accepted April 22, 2002.]