

# Springiness of Pancake and Its Relation to Binding of Prime Starch to Tailings in Stored Wheat Flour

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## ABSTRACT

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Wheat flours were stored at room temperature (15–25°C), 40, 60, 80, and 100°C for various times. The baking performance of these flours was then evaluated in terms of the springiness of pancakes (recovery from crushing). Baking performance improved with increased storage time at each temperature. Brabender Amylograph tests of the flours indicated that the onset temperature in viscosity decreased with increased storage time at each temperature. When the flours were fractionated by acetic

acid (pH 3.5) with mortar and pestle, recoveries of the water-solubles and gluten fractions were unchanged, but recoveries of prime starch and tailings fractions changed remarkably with increased storage time. On the other hand, those changes were not observed when flours were fractionated with a Waring blender. The binding of prime starch to tailings was correlated significantly with baking performance.

Seguchi and Matsuki (1977) provided quantitative evidence that pancakes baked with fresh wheat flour have poor textures. Chlorination or heat-treatment (120°C for 2 hr) of wheat flour improved the texture, adding springiness and reducing gumminess (Seguchi and Matsuki 1977, Seguchi 1990a). The increased springiness of pancakes is an important quality property. However, because of health concerns, the use of chlorinated wheat flour is limited, the heated flour has a slight burnt smell and color and yields cakes low in volume, due to denaturation of proteins. The search for other methods to improve flour continues. The breadmaking quality of freshly milled flour tends to improve with time, depending on the nature of the flour and storage conditions (Zeleney 1954). A number of studies have reported on the factors affecting the successful long-term storage of wheat flour for breadmaking and cake baking (Kozmin 1935, Fisher et al 1937, McCalla et al 1939, Shellenberger 1939, Jones and Gersdorff 1941, Fifield and Robertson 1959, Pomeranz et al 1968, Yoneyama et al 1970, Loney and Meredith 1974, Johnson and Hosney 1980, Bothast et al 1981, and Takeda 1986). Bennett and Coppock (1957) pointed out that the main changes occurring in flour during storage involve: 1) moisture content, 2) capacity to absorb water, 3) dough elasticity and extensibility, and 4) microbiological deterioration. Age-related changes in water binding capacity (WBC) and in the batter properties of freshly milled flours parallel improvements in their cake baking qualities (Shelke et al 1992a,b). However, the mechanism responsible is not well understood. Seguchi (1993) reported that starch granules isolated from aged wheat flour were hydrophobic, and the amount of starch granule surface protein was three to four times higher than in the control. These phenomena are similar to chlorinated (Seguchi and Matsuki 1977, Seguchi 1990b) or heat-treated wheat flour (Seguchi 1984). Chen and Schofield (1996) reported the effects of short-term storage on levels of free reduced glutathione (GSH), free oxidized glutathione (GSSG), protein glutathione mixed disulfides (PSSG), and breadmaking performance.

In the present study, wheat flours were stored under various conditions (times and temperatures), and their baking qualities were evaluated in terms of the springiness of pancakes (recovery from crushing). Using acetic acid (pH 3.5), the flours were fractionated into water-solubles, gluten, tailings, and prime starch. The interaction between the prime starch and tailings fractions was investigated. Furthermore, it was ascertained whether the interaction between prime starch and tailings correlated with baking quality.

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## MATERIALS AND METHODS

### Wheat Flour

The wheat flour used was “K Alps” which is made from Western White wheat by Nitto Flour Milling Co. (Tokyo). Protein and ash contents of the wheat flour were 8.2 and 0.38%, respectively, at 13.2% mb. Fresh flour was put into vinyl bags and stored at –20°C until used.

### Wheat Flour Storage

Wheat flour (0.5 kg) was poured into an iron pan (25 × 34 × 3 cm) to a depth of 1.0 cm, and left in a computer-controlled drying oven (DV 41, Yamato Co., Tokyo) or incubator (Eyela Low Temp. Incubator LTI-600 SD, Rikakikai Co., Tokyo). Storage included 233 days at room temperature (15–20°C), 189 days at 40°C, 24 days at 60°C, nine days at 80°C, and 10 hr at 100°C. Storage flours were stored at –20°C until used. Moisture of samples was determined by the method of Tsutsumi and Nagahara (1961). Flour treatments were performed in duplicate.

### Brabender Amylograph Tests

Brabender Amylograph tests were performed according to Approved Method 22-10 (AACC 1995). Wheat flour (65 g, 14% mb) and 460 mL of water were mixed and subjected to the Brabender Amylograph over a temperature range of 20–96°C. The onset temperature was determined when the viscosity of the flour-water suspension reached 100 BU.

### Pancake Baking Test

The pancake baking test was performed as described previously (Seguchi and Matsuki 1997, Seguchi 1990a). Flour (100 g), powdered sugar (20 g), sodium bicarbonate (1.6 g), sodium acid pyrophosphate (2.3 g), and water (110 mL) were put into a Kitchen Aid mixer (model K45, Hobart Mfg. Co., Troy, OH) and mixed with a flat beater at 112 rpm for 30 sec. The flour batter (200 g) was transferred into an iron pan (12-cm dia. and 2.5-cm depth) and baked in a drying oven (model DS-63, Yamato Scientific Co., Tokyo, Japan) at 170–180°C for 13 min (first for 10 min and then for a further 3 min after turning). After cooling for 1 min at room temperature, weight (g) and volume (cm<sup>3</sup>) of the pancake were measured. Volume was measured by rapeseed displacement (Method 10-10B, AACC 1995). Duplicate bakings were made and a third pancake was baked if the volume difference was >2%. Five minutes after baking was completed (internal temperature of the pancake was ≈54°C), the pancake was pressed under a 5.19-kg weight (plunger 12-cm dia.) for 30 sec (45.9 g/cm<sup>3</sup> of pancake) and the recovered volume was measured immediately. The springiness (recovery from crushing) of the pancake was expressed as recovered pancake volume (cm<sup>3</sup>)/original pancake volume (cm<sup>3</sup>) ×

100 (%). The pancake was further cross-sectioned vertically and the halves placed one upon the other and photographed.

### Fractionation of Wheat Flour by Acetic Acid (pH 3.5)

Flour was fractionated by the method of Sollars (1958). The homogenization step was performed by using a Waring blender (Excel Auto Homogenizer, Nihon Seiki Seisakusho Co., Tokyo, Japan) and a mortar and pestle (ANM-150 type, Nittokagaku Co., Japan) with 120 and 70 rpm, respectively (Seguchi et al 1997). Flour (50 g) was mixed with 150 mL of water and homogenized for 20 min at room temperature. After centrifugation at  $1,700 \times g$  for 20 min at room temperature, the supernatant was freeze-dried (water-solubles fraction). The pellet was homogenized in 125 mL of 0.136*N* acetic acid solution (pH 3.5) and centrifuged. The resulting pellet was further homogenized in 75 mL of 0.0283*N* acetic acid solution (pH 3.5) and centrifuged. After centrifugation, the two supernatants were combined and freeze-dried (gluten fraction). The pellet was homogenized in 150 mL of water and the pH was adjusted to 5.0 with 5*N* NaOH solution. After centrifugation, two layers of pellet appeared: the upper yellowish and viscous layer was the tailings fraction, while the white layer in the bottom was the prime starch fraction. Both fractions were freeze-dried. Protein content was determined as  $N \times 5.7$ . Starch, ash, and lipid contents were determined by the method of McCready et al (1950) and Approved Methods 08-01 and 30-26 (AACC 1995). A modified fractionation technique was employed to separate each fraction without disrupting the weak forces of interaction occurring in the flour-water suspension (Seguchi et al 1997). A mortar and pestle were used in the homogenation step. Table I shows the

results of flour fractionation by the mortar and pestle and the blender. The greatest difference was in the recovery of the tailings and prime starch fractions. When the mortar and pestle was used, the recovery of prime starch was decreased, and the recovery of tailings fractions was increased relative to when the blender was used. The prime starch could not be completely separated from the tailings by centrifugation ( $1,700 \times g$ , 20 min). The protein contents in the prime starch and tailings fractions obtained using the mortar and pestle were slightly higher than those obtained using the blender (Table I).

The oil binding ability of the prime starch was tested as described previously (Seguchi 1984).

### Statistical Analysis

Statistical analysis was conducted using analysis of variance (ANOVA). Significant calculated mean values were compared using Duncan's multiple range test at  $\alpha = 0.05$  level of significance.

## RESULTS AND DISCUSSION

### Pancake Baking Performance of Stored Wheat Flours

Seguchi (1990a) reported that the springiness of a pancake could be improved by using flour previously heated at 120°C for 5 hr. A reduction in this temperature will require lengthening the storage time, but to what extent? It is known that chemical reactions proceed at double rate when the temperature of the reaction mixture is increased by 10°C (Pauling 1963). Based on this experiment using 120°C for 5 hr, the calculated storage times at

TABLE I  
Comparison of Acetic Acid Fractionations (14% mb) of Wheat Flour by Mortar and Pestle and Waring Blender Methods

Fraction	Yield	Protein	Lipid	Starch	Ash
Mortar and pestle					
Wheat flour	100	8.37	0.60	80.3	0.50
Water-solubles	3.8	25.44	0.59	25.3	5.70
Gluten	8.7	65.85	3.45	3.7	0.80
Prime starch	40.8	4.72	0.26	94.4	0.24
Tailings	42.3	0.38	0.50	87.4	0.18
Recovery	95.5				
Waring blender					
Wheat flour	100	8.37	0.60	80.3	0.50
Water-solubles	4.5	22.8	0.24	21.0	5.40
Gluten	7.5	61.56	2.68	3.9	0.97
Prime starch	18.4	3.74	0.40	78.1	0.28
Tailings	64.0	0.19	0.25	87.6	0.16
Recovery	94.4				

TABLE II  
Effect of Flour Storage Time and Temperature on Pancake Quality

Heat Treatment	Moisture Content (%)	Specific Volume (cm <sup>3</sup> /g) <sup>a</sup>			
		Original	After Pressing	Springiness (% recovery from crushing)	
Control	11.2	2.21 (0.05) a	1.55 (0.06) g-i	70.0	(3.0) a
100°C, 10 hr	6.61	1.92 (0.01) d-f	1.89 (0.01) a	98.0	(0.0) i-k
80°C					
2 days	4.26	1.98 (0.03) b-d	1.69 (0.07) b-f	85.4	(2.3) d
4 days	1.40	1.97 (0.01) c-e	1.78 (0.03) ab	90.6	(1.8) f-k
9 days	0.00	1.44 (0.01) j	1.45 (0.03) j	101	(1.5) k
60°C					
7 days	2.98	2.06 (0.08) bc	1.72 (0.04) b-e	83.3	(1.7) c-e
24 days	0.00	1.75 (0.00) hi	1.75 (0.00) b-d	100	(0.0) jk
40°C					
47 days	6.39	2.08 (0.07) b	1.60 (0.01) e-h	76.9	(2.5) b
189 days	5.79	1.49 (0.00) j	1.44 (0.00) j	96.6	(0.0) h-k
Room temperature					
130 days	12.58	1.88 (0.03) f-h	1.66 (0.04) bc	88.3	(0.9) g-k
233 days	12.82	1.83 (0.01) d-g	1.76 (0.01) b-g	96.2	(3.9) e

<sup>a</sup> Values represent means of four replicates and standard deviation in parentheses. Means followed by different letters in the same column are significantly different at  $P = 0.05$  according to Duncan's multiple range test.

100, 80, 60, 40, and 20°C would be 20 hr, 4 days, 14 days, 54 days, and 214 days, respectively. However, in practice, it was necessary to extend the storage time to obtain flour with further improved baking qualities. It is generally true that the rate of reaction increases with increasing temperature and that a plot of  $\log k$  vs.  $1/T$  yields a linear relation over a significant range (in accordance with the Arrhenius equation), however this was not always true. The plot can show curvature and sometimes distinct breaks, reflecting changes in the reaction mechanism of the system. Beyond certain temperatures, the rate of an enzyme-activated reaction always decreases with increasing temperature, due to thermal degradation of the enzyme. Baking results are shown in Table II. To achieve a high degree of springiness, flour heated at room temperature (20–25°C), 40, 60, 80, and 100°C, needed to be stored for 233 days, 189 days, 24 days, 9 days, and 10 hr, respectively. Figure 1 shows that control pancake had a more dense cake-cell structure (5.19 kg), while pancakes made from flour stored at room temperature for 233 days were not crushed and recovered their original volume. It was concluded that the change in springiness of the pancakes was a result of flour storage (Table II). Flour heated at a lower temperatures needed to be stored longer. The specific volume of control pancakes was 2.21 cm<sup>3</sup>/g, which gradually decreased with flour storage time (Table II). However, the springiness is a more important quality in pancakes than specific volume.

#### Effects of Storage Time on Amylograms

Figure 2 shows the amylograms of wheat flours stored at 80°C for two, four, and nine days. The onset temperature in viscosity is gradually decreased with increased storage time. Maximum viscosity is increased with increased storage time, except at nine days, by which time, depolymerization of starch had probably occurred (Loney and Meredith 1974). Table III shows the onset temperature in viscosity of various stored flours. The onset temperatures are

all lower than that of the control (85.2°C) and decreased with increased storage time. These results are similar to those of chlorinated wheat flour (Seguchi and Matsuki 1977, Seguchi 1990b) and heat-treated (120°C for 5 hr) wheat flour (Seguchi 1984, 1990a). They obtained hydrophobic starch granules from the chlorinated and heat-treated flours. A decrease in onset temperature by chlorination or heat-treatment would be related to the hydrophobicity of the starch granules. Starch granules in stored flour were also hydrophobic (Seguchi 1993), possibly as a result of interaction with other fractions such as tailings, producing larger particles in the flour suspension. Hydrophobicity of the starch granule was caused by change of starch granule surface protein (Seguchi and Matsuki 1977, Seguchi 1984, Seguchi 1993). Such interactions would be further strengthened at higher temperatures. A larger particle would increase the viscosity at lower temperature and decrease onset temperature.

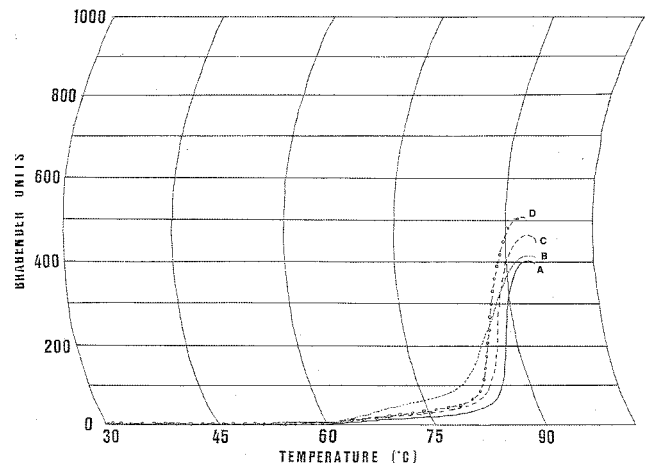
**TABLE III**  
Onset Temperature in Amylograph Viscosity of Wheat Flour Stored at Different Conditions

Treatment	Onset Temperature (°C) at 100 BU
Control	85.2
100°C	
10 hr	80.7
80°C	
2 days	83.6
4 days	82.5
9 days	79.7
60°C	
7 days	84.2
24 days	82.5
40°C	
47 days	84.0
Room temperature	
233 days	76.2
25°C	
202 days	76.4

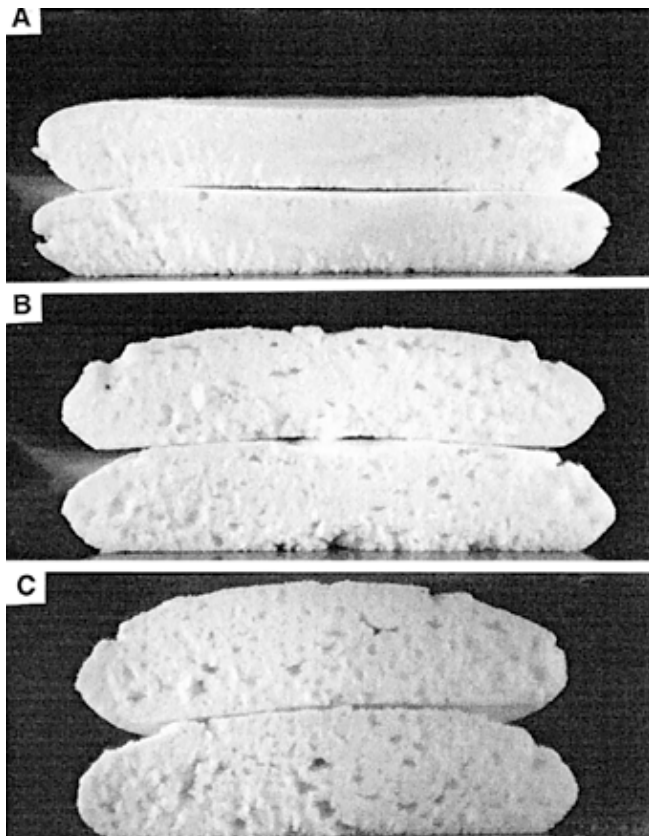
**TABLE IV**  
Correlation Coefficients of Springiness (%) in Pancake and Percent of Flour Fractions<sup>a</sup>

Fraction	Correlation Coefficients
Water solubles	-0.8920 ( <i>P</i> = 0.042)
Gluten	-0.7492 ( <i>P</i> = 0.145)
Tailings	+0.9821 ( <i>P</i> = 0.003)
Prime starch	-0.9836 ( <i>P</i> = 0.003)

<sup>a</sup> *n* = 5.



**Fig. 2.** Effect of storage time of wheat flours on Brabender amylograph onset temperature and maximum viscosity. Stored for 0 (A), 2 (C), 4 (D), and 9 (B) days.



**Fig. 1.** Compressed and recovered pancakes made from flour stored at room temperature for 0 (A), 88 (B), and 233 (C) days.

### Effect of Time on Flour Fractions During Storage

Wheat flour stored at room temperature for 30, 60, 90, 120, and 150 days were subjected to acetic acid (pH 3.5) fractionation. Figure 3 shows the effect of time on water-solubles, gluten, tailings, and prime starch fractionated using the blender. None showed clear changes during storage. On the other hand, using the mortar and pestle, the prime starch and tailings fractions showed significant changes during storage (Fig. 4). The prime starch fraction decreased and the tailings fraction increased with increased storage time. The prime starch fraction became gradually more difficult to separate from the tailings fraction with time. The two fractions did not separate at all after 150 days. Figure 5A and B shows the separated prime starch and tailings fractions from control flour. Figure 5C shows the binding mass of the same two fractions from flour stored at room temperature for 150 days. Starch granules and binding mass of prime starch with tailings

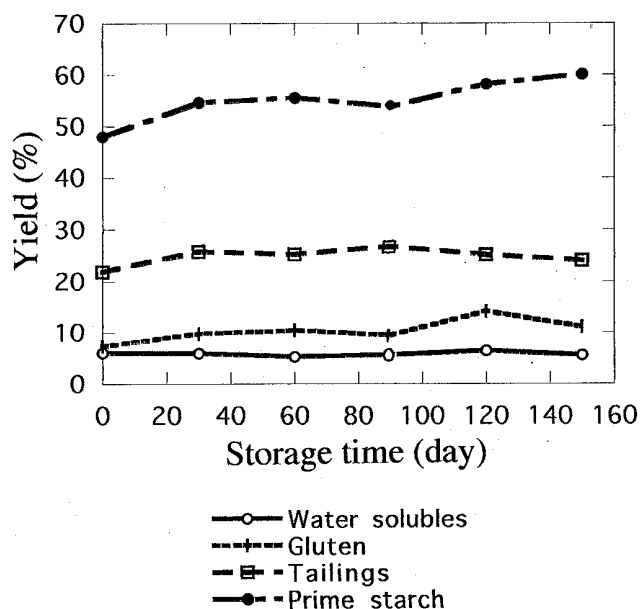


Fig. 3. Effect of flour storage time at room temperature on flour fractions determined using the Waring blender.

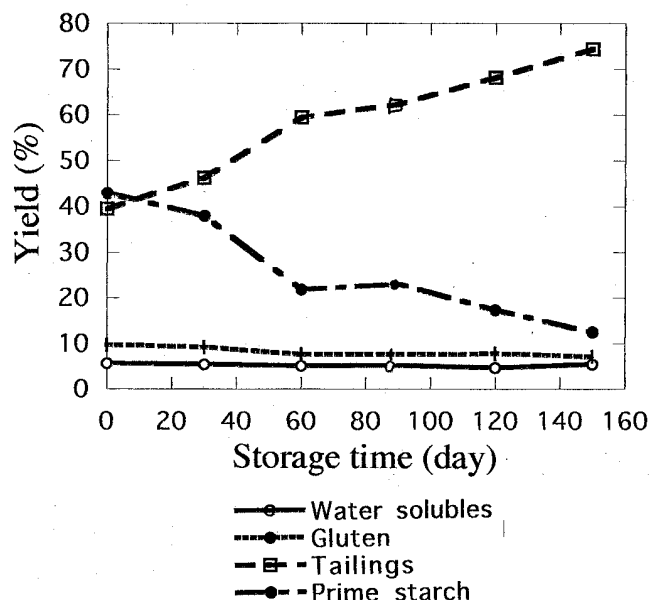


Fig. 4. Effect of flour storage time at room temperature on flour fractionated by mortar and pestle.

fractions separated from the stored flour using the blender and the mortar and pestle method, respectively, showed strong oil-binding ability (Fig. 6A and B). We speculate that the main binding force between prime starch and tailings in stored flour was due to hydrophobic interactions. Seguchi (1990b, 1993) reported increased protein levels on the surface of hydrophobic starch granules obtained from both chlorinated and stored flour. Protein levels would be related to the binding of prime starch with tailings. Figure 7 shows the effect of time on protein content in a mixture of prime starch and tailings. The protein content in the mixture obtained by the mortar and pestle method gradually increased with time. The correlation coefficients of the protein in a mixture of prime starch and tailings and of protein and tailings fraction (Fig. 4) were  $-0.9474$  ( $P = 0.001$ ) and  $+0.9541$  ( $P = 0.001$ ), respectively, suggesting that the protein in the mixture acts as a binder.

Wheat flours stored at 40, 60, 80, and 100°C for various times were fractionated using the mortar and pestle into water-solubles, gluten, tailings, and prime starch. The effect of time on the four fractions is shown in Fig. 8A–D. Over time, the prime starch and tailings fractions became difficult to separate at all storage temperatures, eventually these fractions could not be separated. These results were the same as those obtained at room temperature.

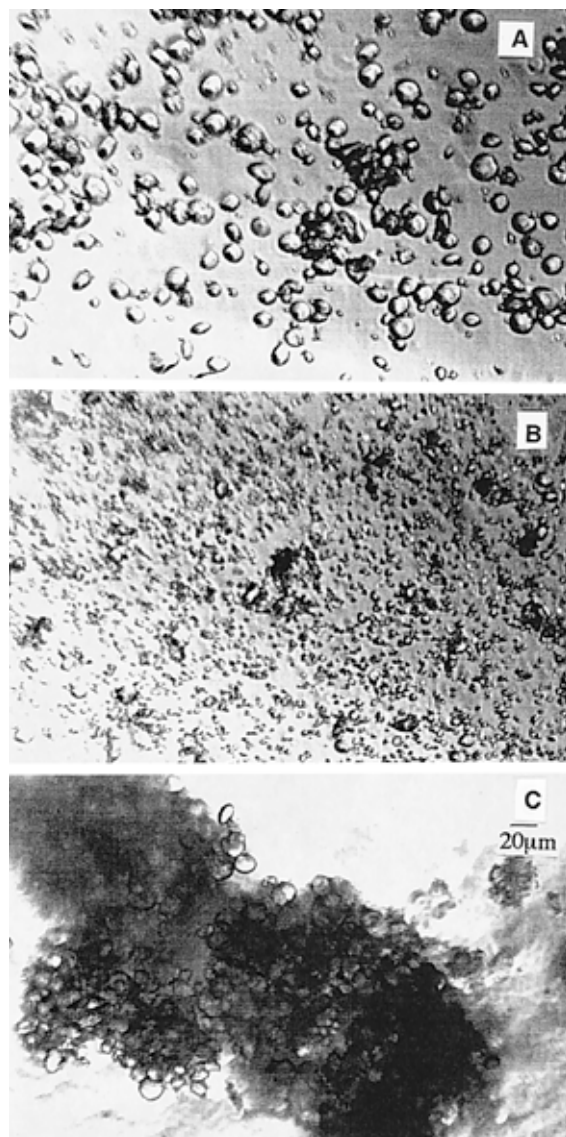


Fig. 5. Microphotographs of prime starch (A) and tailings (B) fractions of control flour and of the fraction containing prime starch bound to tailings (C) of flour stored at room temperature for 150 days. Fractionated by mortar and pestle.

### Correlation Coefficients of Springiness

Table IV shows the correlation coefficients of springiness (recovery %) of pancake and the percentage of water-solubles, gluten, tailings, and prime starch in stored flours. The prime starch fraction correlated negatively and the tailings fraction correlated positively with springiness of pancake. As shown in Fig. 4 and Fig. 8 A-D, the amount of prime starch in the tailings fraction increased with storage time. The binding of prime starch to tailings by hydrophobic interaction correlated significantly with baking performance.

### CONCLUSIONS

We concluded that storage of flour (a balance between time and temperature) yielded the same improvement in baking performance as chlorination and heat-treatment at 120°C for 5 hr. Frac-

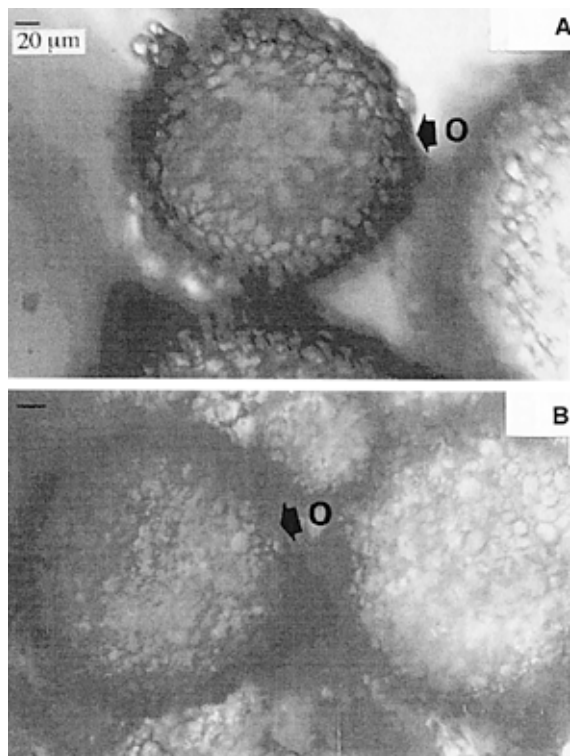


Fig. 6. Microphotographs of water, oil droplet (O), and adhesive prime starch fraction (A) fractionated by blender, and binding mass (B) of the prime starch and tailings fractions of flour stored at room temperature for 150 days fractionated by mortar and pestle.

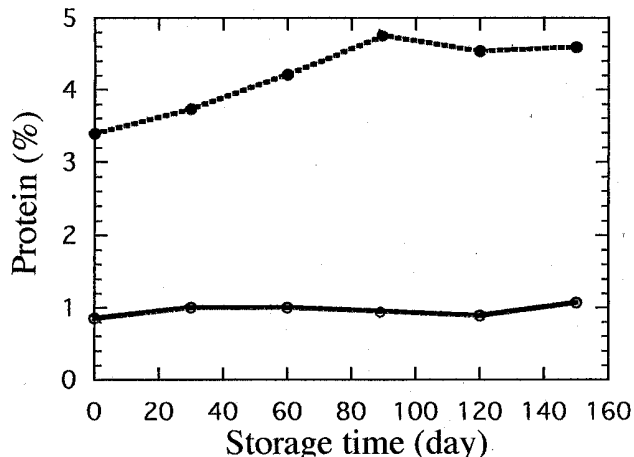


Fig. 7. Changes in protein content in a mixture of prime starch and tailings in flour stored at room temperature. Mixtures were fractionated by blender (broken line) and mortar and pestle (solid line).

tionation indicated that separation of the prime starch and tailings fractions gradually decreased with increased storage time. The temperature of viscosity onset decreased with increasing storage time. The storage conditions under which such masses were produced correlated closely with those for improved baking performance (springiness).

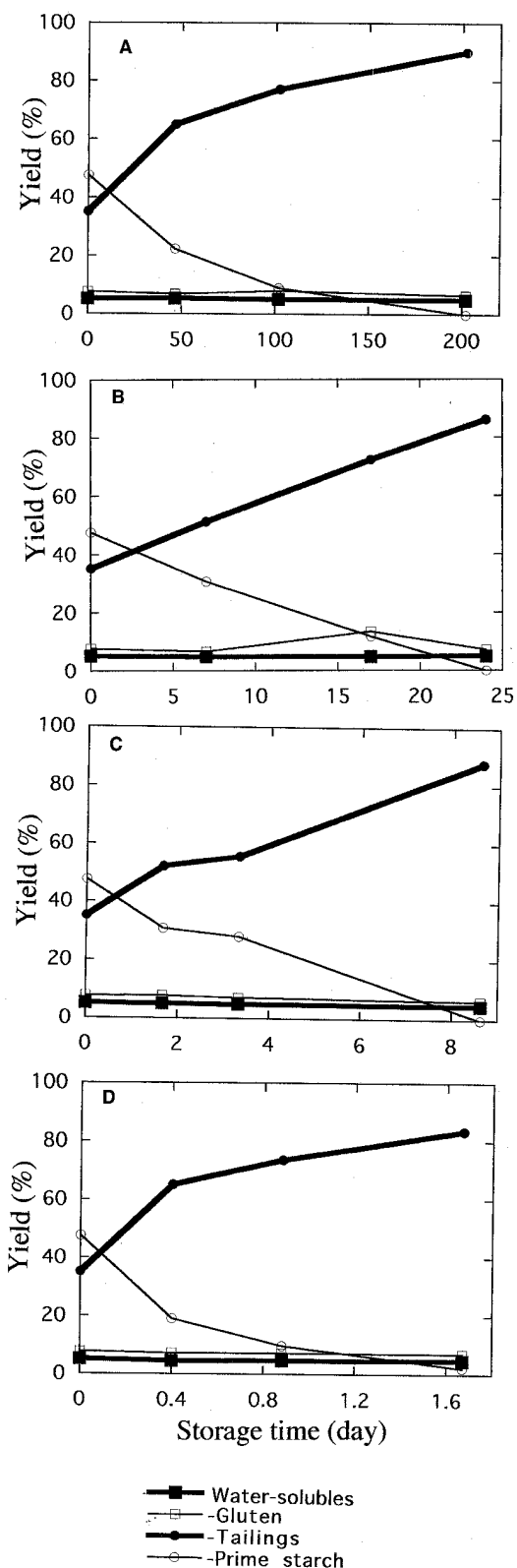


Fig. 8. Effect of storage temperature on water solubles, gluten, prime starch and tailings fractions of flours, fractionated by acetic acid (pH 3.5) using the mortar and pestle method. A, 40°C; B, 60°C; C, 80°C; D, 100°C.

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