Influence of Amylose Content on Properties of Wheat Starch and Breadmaking Quality of Starch and Gluten Blends

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ABSTRACT

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The effects of amylose content on thermal properties of starches, dough rheology, and bread staling were investigated using starch of waxy and regular wheat genotypes. As the amylose content of starch blends decreased from 24 to 0%, the gelatinization enthalpy increased from 10.5 to 15.3 J/g and retrogradation enthalpy after 96 hr of storage at 4°C decreased from 2.2 to 0 J/g. Mixograph water absorption of starch and gluten blends increased as the amylose content decreased. Generally, lower rheofermentometer dough height, higher gas production, and a lower gas retention coefficient were observed in starch and gluten blends with 12 or 18% amylose content compared with the regular starch and gluten blend. Bread baked from starch and gluten blends exhibited a more porous crumb structure with increased loaf volume as amylose content in the starch decreased. Bread from starch and gluten blends with amylose content of 19.2–21.6% exhibited similar crumb structure to that of bread with regular wheat starch which contained 24% amylose. Crumb moisture content was similar at 5 hr after baking but higher in bread with waxy starch than in bread without waxy starch after seven days of storage at 4°C. Bread with 10% waxy wheat starch exhibited lower crumb hardness values compared with bread without waxy wheat starch. Higher retrogradation enthalpy values were observed in breads containing waxy wheat starch (4.56 J/g at 18% amylose and 5.43 J/g at 12% amylose) compared with breads containing regular wheat starch (3.82 J/g at 24% amylose).

Functional properties of starch have considerable effects on the quality of wheat-based food products. The role of the starch component in bread quality including bread staling is being studied extensively. Starch retrogradation assayed with X-ray spectra is one of the primary observations to quantify bread staling (Dragsdorf and Varriano-Marston 1980). Schoch and French (1947) and Kim and D'Appolonia (1977) reported that the spontaneous aggregation of amylopectin results in the staling of bread during storage. The significance of the amylose-to-amylopectin ratio in bread staling was studied using waxy cornstarch or waxy barley starch, primarily due to the absence of waxy wheat starch. Ghiasi et al (1984) reported that adding waxy barley starch to high-protein wheat flour results in softer bread than bread containing regular barley starch added to high-protein wheat flour. Also, bread made from wheat flour with sugary, waxy cornstarch exhibits a softer crumb compared with bread baked from wheat flour with regular wheat starch (Zallie et al 1984). However, these studies provide insufficient information about the role of starch in bread staling, especially the influence of amylose-to-amylopectin ratio on the starch retrogradation and bread staling mechanism independent of the protein interference in flour.

Recently, waxy wheat was developed through hybridization or mutation of wheat lines carrying null alleles at any of three loci (*wx*-A1, *wx*-B1, and *wx*-D1) which encode granule-bound starch synthase. Therefore, it is now possible to use waxy wheat starch as a substitute for waxy barley starch or waxy corn starch to study the significance of the amylose-to-amylopectin ratio in bread staling. To determine the influence of the amylose-to-amylopectin ratio on retrogradation of starch and bread staling during storage independent of other components, it is necessary to prepare starch and gluten to formulate adjusted starch and gluten blends for breadmaking. The objectives of our research were to determine thermal properties of isolated wheat starches with various amylose contents, to observe the changes in dough rheology and gas formation in dough during fermentation as a function of starch amylose content and to evaluate the effects of amylose content on starch retrogradation in bread crumb and bread staling.

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MATERIALS AND METHODS

Materials

Soft white spring wheat cv. Alpowa; hard white spring wheat cv. Klasic; an advanced breeding line of hard white spring wheat, WA 7778; and two unnamed advanced breeding lines of waxy wheat from Northwest Breeding Company (Pullman, WA), referred to as waxy I and waxy II, were used for this study. Wheat was milled to flour of 60% extraction on a Buhler experimental mill according to Approved Method 26-31 (AACC 2000). Flours were fractionated into gluten, solubles, tailings starch, and prime starch according to the method of Czuchajowska and Pomeranz (1993c). Gluten was further purified by washing with running tap water, then lyophilizing and ground using a Udy cyclone mill fitted with a perforated screen with 0.25-mm openings. Prime starches fractionated from 100 g of flour (db) were purified by washing with 500 mL of distilled water three times. Purified prime starches were air-dried at 24°C for three days and ground using a Udy cyclone mill fitted with a perforated screen with 0.25-mm openings. Moisture content of both gluten and prime starch were equilibrated to ≈10% before blending together.

Chemical Analyses

Moisture content of flour, prime starch, and gluten was determined by oven drying for 1 hr at 130°C (AACC Approved Method 44-15A). Ash content was determined by combustion for 16 hr at 580°C (AACC Approved Method 08-01). Protein content (N × 5.7) of flour and flour fractions were determined instrumentally (Leco Corp., St. Joseph, MI) with a thermoconductivity detector. Amylose content of prime starch was determined according to the iodometric method described by Morrison and Laignelet (1983).

Thermal Properties of Starches

Gelatinization and retrogradation characteristics of starch (waxy, regular from WA 7778, and blends of waxy and regular starches) and bread crumb were determined using differential scanning calorimetry (DSC) (Pyris1, Perkin-Elmer Corp., Norwalk, CT). An indium standard was used for temperature and enthalpy calibration. Starch or lyophilized bread crumb (10 mg) and 20 μL of distilled water were placed in a stainless steel capsule, sealed, and allowed to equilibrate for 24 hr at 24°C. The sample was then heated in the calorimeter from 20 to 180°C at 10°C/min. A capsule with an inert material (aluminum oxide) and water (1:2 ratio) served as the reference. Onset temperature and peak temperature were determined for each endotherm using data processing software (Pyris Manager). The transition enthalpy of starch gelatinization and retrogradation was calculated from the peak area and expressed as J/g of dry matter. Regular starch and blends with waxy starch were gelatinized in the DSC capsule as described for the determination of gelatinization properties and stored for 24, 48, and 96 hr at 4°C to determine retrogradation of starch. The DSC capsules were rescanned at each storage time to determine retrogradation properties of starch.

Rheological Properties and Baking Performance of Starch and Gluten Blends

Starch and gluten blends with selected amylose content were prepared by mixing 16 g (db) of gluten from cv. Klasic and 84 g (db) of prime starch blends. Prime starch blends were prepared by mixing various ratios of prime starches from Alpowa and two waxy wheat lines to adjust the amylose content of the prime starch blends from 12 to 24%. Optimum mixing time and water absorption of blends of starch and gluten with or without bread formula (sugar, salt, shortening) were determined using a 10-g mixograph (National Mfg., Lincoln, NE) according to Approved Method 54-40A (AACC 2000).

Rheofermentometer (Tripette & Renaud, Paris) dough development and gas retention of starch and gluten blends were determined using the procedure of Czuchajowska and Pomeranz (1993a,b). Starch and gluten blends (100 g, 14% mb) were mixed to a full formula bread dough with 6 g of sugar, 4 g of nonfat dry milk, 1.5 g of salt, 3 g of shortening, 1.8 g of yeast, 5 mL of malt solution, and water. Water absorption of starch and gluten dough was reduced by 5 mL for the dough with regular starch and by 3 mL for doughs with both regular and waxy starch from the mixograph absorption to improve handling properties of dough. Bread dough of starch and gluten blends was also prepared without malt in the formula to avoid excess hydrolysis of waxy starch and overproduction of gas during the fermentation. After mixing to optimum mixing time as determined from the mixograph test, the dough was placed in a preconditioned (30°C) fermentation chamber for 15 min. After 15 min, the chamber was sealed and dough height, gas production, and gas retention were measured every 3 min for 2 hr and 24 min.

Bread was baked from starch and gluten blends according to the optimized method of Finney (1984). Bread loaf volume was recorded by rapeseed displacement in a graduated chamber. Moisture content and hardness of bread crumb taken from the center portion of bread were determined 5 hr after baking at 24°C, and at seven days after storage at 4°C. Moisture content of bread crumb was determined by oven drying at 105°C for 24 hr. Hardness of bread crumb was evaluated with a compression test using a texture analyzer (TA-XT2, Stable Micro System, Haslemeres, England). A slice of bread 2 cm thick was cut from the center portion of the bread. The slice was placed on a flat metal plate and compressed to 25% of its thickness at a speed of 1.0 mm/sec using a plastic plunger (2.5 cm diameter) with a flat surface. A piece of crumb from another center cut of bread was lyophilized and ground to powder using a Udy cyclone mill fitted with a perforated screen with 0.25-mm openings for determination of starch retrogradation.

Statistical Analysis

All tests were performed in duplicate. Least significant difference (LSD) and analysis of variance (ANOVA) were performed using the Statistical Analysis System (SAS Institute, Cary, NC). Significance was defined at 5% ($P < 0.05$).

RESULTS AND DISCUSSION

Characteristics of Wheat Flours and Starches

The flour protein content of soft white spring wheat cv. Alpowa was 8.5%, whereas the protein content of hard white spring wheat cv. Klasic was 15.9%. Protein content of the waxy wheat flours was 16.8% in waxy I and 15.2% in waxy II. Alpowa was grown in Pullman, WA, a relatively high rainfall area, while Klasic was grown in a dry land area (Lind, WA). The two waxy wheat lines were grown in a semiarid location (Brawley, CA) under irrigation and heavy use of fertilizer. The high protein content of Klasic and the two waxy wheat lines probably resulted from dry climatic conditions or a generous application of fertilizer. Prime starches isolated from regular and waxy wheat flours exhibited protein content <0.33% and ash content <0.05%, indicating that the prime starches were relatively pure. Amylose content of prime starch, as determined by the iodine colorimetric method, was 24% in regular starches and 0% in waxy starches.

The DSC endothermic curves of waxy, regular, and blends of waxy and regular starches are presented in Fig. 1. Regular starch exhibited a sharp and narrow gelatinization peak, whereas the waxy starch exhibited a broader and flatter gelatinization peak. The onset tem-

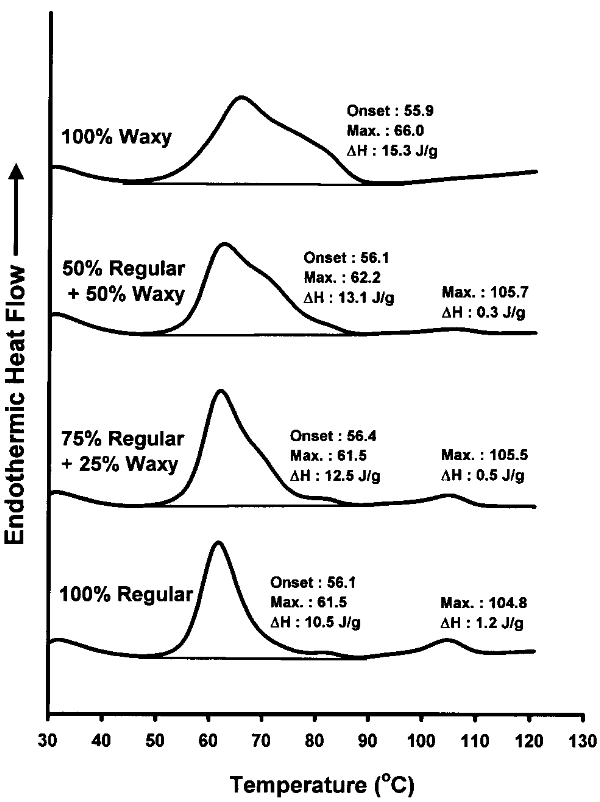

Fig. 1. Gelatinization characteristics determined using differential scanning calorimetry of waxy wheat starch, regular wheat starch, and blends of waxy and regular wheat starches.

TABLE I
Retrogradation Characteristics of Regular Wheat Starch and Blends with Waxy Wheat Starch During Storage at 4°C[a]

	100% Regular			75% Regular + 25% Waxy			50% Regular + 50% Waxy			100% Waxy		
Storage Time (hr)	T_o (°C)	T_p (°C)	ΔH_g (J/g)	T_o (°C)	T_p (°C)	ΔH_g (J/g)	T_o (°C)	T_p (°C)	ΔH_g (J/g)	T_o (°C)	T_p (°C)	ΔH_g (J/g)
24	48.2a	54.6a	0.04c	40.7a	54.7a	0.21c	nd	nd	nd	nd	nd	nd
48	41.2b	52.6ab	0.86b	41.5a	53.6a	0.86b	42.6a	52.3a	0.43b	nd	nd	nd
96	41.0b	51.8b	2.20a	39.4a	49.5b	1.81a	41.8a	52.2a	1.40a	nd	nd	nd

[a] Values followed by the same letter in the same column are not significantly different ($P < 0.05$). T_o, T_p, ΔH_g = onset and peak temperature, and transition enthalphy; nd = not detected.

peratures of starch gelatinization of waxy and regular wheat starches were 56.1 and 55.9°C, respectively. The peak temperature of starch gelatinization was 61.5°C for regular wheat starch and 66.0°C for the waxy wheat starch, respectively. The gelatinization enthalpy for regular wheat starch was 10.5 and 15.3 J/g for the waxy wheat starch, suggesting that waxy starch requires greater energy input for gelatinization. There is a higher proportion of crystallinity in waxy wheat starch granules than in regular wheat starch granules because amylopectin primarily forms a crystalline structure in starch granules. Accordingly, waxy wheat starch requires higher gelatinization peak temperature and endothermic enthalpy compared with regular wheat starch. Fujita et al (1998) also reported that waxy wheat starch requires a higher gelatinization temperature and a higher gelatinization enthalpy due to its higher crystallinity compared with regular starch. Waxy wheat starch exhibited no endothermic peak for the melting of amylose-lipid complex, whereas melting of amylose-lipid complex occurred at ≈105°C in regular wheat starch.

The onset temperatures of gelatinization for blends of waxy and regular wheat starches were similar at a range of 56.1 to 56.4°C. Adding up to 50% waxy wheat starch to regular starch did not significantly affect the peak temperature of starch gelatinization. On the other hand, the gelatinization enthalpies increased from 10.5 J/g in regular wheat starch to 12.5 J/g in the blend with 25% waxy wheat starch and to 13.1 J/g in the blend with 50% waxy wheat starch.

Retrogradation Characteristics of Blends of Waxy and Regular Wheat Starch

Retrogradation properties of waxy, regular, and blends of waxy and regular wheat starch during 96 hr of storage are summarized in Table I. Onset temperature for melting retrograded regular starch was 48.2°C with 24 hr of storage at 4°C, and decreased to 41.2°C with 48 hr of storage at 4°C. On the other hand, no significant changes in onset temperature for melting retrograded starch were observed in starch blends with 25% waxy wheat starch as storage time increased from 24 to 96 hr. Peak temperature for melting retrograded starch decreased as storage time increased in regular wheat starch and starch blends with 25% waxy wheat starch. No retrogradation of starch was observed in the starch blend with 50% waxy wheat starch (66% moisture) stored for 24 hr at 4°C or in waxy wheat starch stored for up to 96 hr at 4°C. Both onset temperature and peak temperature for melting retrograded starch in regular starch and blends of waxy and regular wheat starch were lower than those for gelatinization, indicating that there is less crystallization in retrograded starch compared with native wheat starch.

Transition enthalpy for retrograded regular wheat starch significantly increased from 0.04 J/g at 24 hr to 2.20 J/g at 96 hr of storage. Transition enthalpy of retrograded starch blends with 25 or 50% waxy wheat starch also increased as storage time increased. However, transition enthalpy for starch retrogradation was much lower as the proportion of waxy wheat starch in the blend was increased. Hayakawa et al (1997) reported that over a three-week storage period, waxy wheat starch exhibited very little increase in melting enthalpy of retrograded starch, whereas regular wheat starch exhibited twice the retrogradation enthalpy.

Rheological Properties of Dough Prepared from Starch and Gluten Blends

Mixograms of starch and gluten blends where the starch portion consisted of either regular wheat starch or of blends of waxy and regular wheat starch are presented in Fig. 2. Regardless of differences in starch composition, three mixograms of starch and gluten blends without breadbaking formula were similar in pattern, dough resistance, and stability, and showed optimum mixing at ≈10.5 min. With the breadbaking formula, mixograph mixing time of starch and gluten blends was shortened to ≈7 min and dough resistance to

TABLE II
Rheofermentometer Parameters of Starch and Gluten Blends[a]

Starch	Maximum Dough Height (mm)	Gas Formation (mL)	Gas Retention Coeffecient (%)
With Malt			
Alpowa (100%)	63.2a	1,515.5a	90.0a
Alpowa +			
25% Waxy I	63.0a	1,548.5a	89.0ab
50% Waxy I	58.3b	1,561.0a	88.4ab
Alpowa +			
25% Waxy II	56.3b	1,539.5a	88.0ab
50% Waxy II	45.7c	1,600.5a	86.6b
Without Malt			
Alpowa (100%)	54.8bc	1,378.5b	92.0a
Alpowa +			
25% Waxy I	59.7ab	1,427.5ab	91.5a
50% Waxy I	66.6a	1,472.5a	88.7b
Alpowa +			
25% Waxy II	55.2bc	1,449.5ab	89.7b
50% Waxy II	51.2c	1,411.0ab	89.8b

[a] Gluten from cv. Klasic. Starches were blends of regular and waxy starches. Values within malt treatment followed by the same letter in the same column are not significantly different ($P < 0.05$).

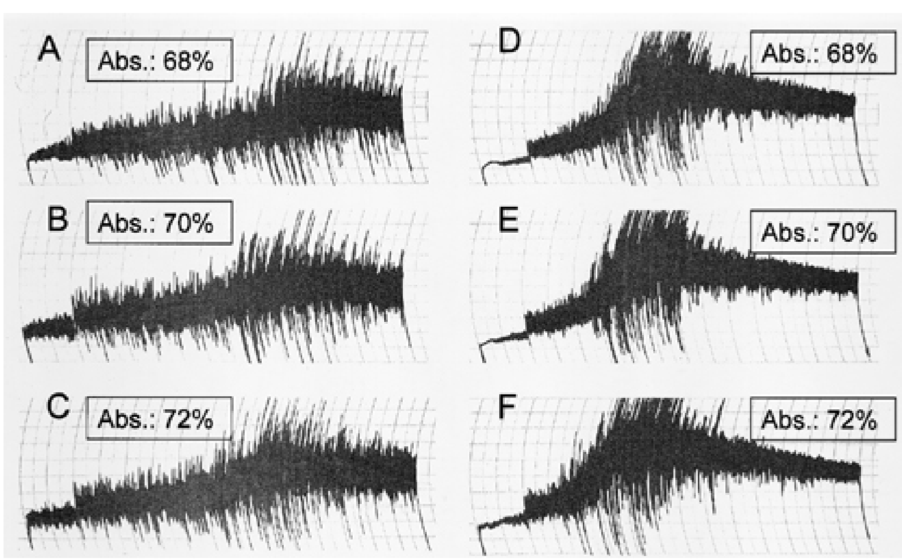

Fig. 2. Mixograms of starch and gluten blends with various starch compositions. A, B, and C, without bread formula (sugar, salt, shortening). D, E, and F, with baking formula. A and D contain 100% regular starch; B and E contain 75:25 regular and waxy I starch; C and F contain 50:50 regular and waxy I starch.

mixing was increased. However, there were no differences in mixing time or mixograph pattern of starch and gluten blends with different starch compositions. Mixograph patterns of starch and gluten blends where the starch was prepared by mixing regular wheat starch and waxy II wheat starch were similar to those of starch and gluten blends with waxy I wheat starch. These results indicate that mixing characteristics of starch and gluten blends mainly depend on gluten characteristics and are little affected by starch component.

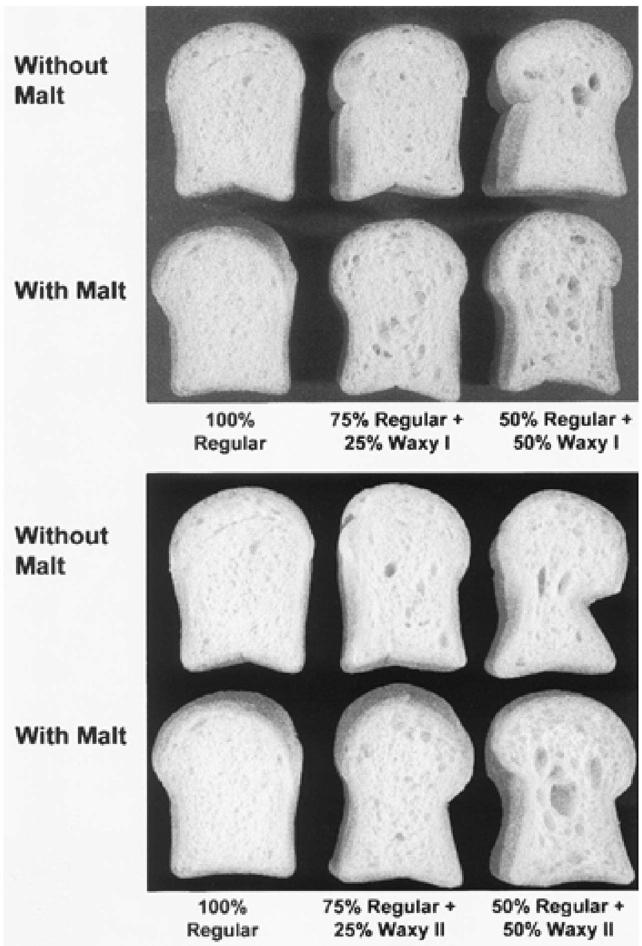

Fig. 3. Bread baked from starch and gluten blends with 25 or 50% waxy wheat starch.

The mixograph water absorption of starch and gluten blends, with or without addition of baking ingredients, increased from 68 to 72% as the proportion of waxy starch increased from 0 to 50%. The increase in water absorption indicates that waxy wheat starches absorb and retain more water during mixing than regular wheat starch. Mixograph water absorption of starch and gluten blends was not affected by the incorporation of all of the breadmaking ingredients.

Rheofermentometer parameters of starch and gluten blends with or without malt are summarized in Table II. With malt, the maximum dough height of blends decreased from 63.2 to 58.3 mm for waxy I wheat starch and from 63.2 to 45.7 mm for waxy II wheat starch as the proportion of waxy wheat starch ratio in blends was increased from 0 to 50%. Gas formation of doughs prepared from starch and gluten blends during fermentation generally increased as the proportion of waxy wheat starch was increased. However, the gas retention coefficient decreased from 90.0 to 88.4% for waxy I wheat starch and from 90.0 to 86.6% for waxy II wheat starch with the addition of 50% waxy starch to the blends. Increased gas formation in starch and gluten blends after incorporation of waxy wheat starch could be due to higher water absorption of the blends during dough mixing and higher proportion of amylopectin, providing fermentable sugars during fermentation by the action of amylase from malt. Decrease in dough height and gas retention of starch and gluten blends by incorporation of waxy wheat starch resulted from the collapse of dough structure during fermentation, as observed visually during the test. The structure of dough with added waxy wheat starch may be weakened by increased hydrolysis of amylopectin and the accompanying action of yeast to produce CO_2.

When malt was not added, the maximum dough height of blends with regular starch or 25% waxy starches decreased compared with dough prepared with malt, while the maximum dough height of blends with 50% waxy wheat starches increased. The collapse of dough without malt during fermentation was reduced compared with dough with added malt. Without malt, the dough produced a smaller amount of gas, but the gas was better retained than in dough prepared with malt. The maximum dough height of starch and gluten blends increased significantly, from 54.8 to 66.6 mm, with the incorporation of 50% waxy I wheat starch, and decreased to 51.2 mm with the incorporation of 50% waxy II starch. Increasing the amylopectin content of starch and gluten blends by adding waxy wheat starch resulted in increased gas formation and decreased gas retention regardless of the addition of malt to the formula. The changes in rheofermentometer parameters of starch and gluten blends by adding waxy wheat starch without malt in the formula may be due

TABLE III
Loaf Volume, Moisture Content, and Hardness of Bread Baked from Starch and Gluten Blends[a]

		5 hr After Baking		7 Days After Baking	
Starch	**Bread Volume (mL)**	**Moisture (%)**	**Hardness (N)**	**Moisture (%)**	**Hardness (N)**
With Malt					
Alpowa (100%)	725c	42a	1.94a	34b	8.55a
Alpowa +					
25 % Waxy I	780b	39b	1.06b	38a	8.36a
50 % Waxy I	795b	44a	0.52c	40a	6.92b
Alpowa +					
25 % Waxy II	795b	43a	1.23b	39a	8.24ab
50 % Waxy II	820a	44a	0.57c	39a	8.23ab
Without Malt					
Alpowa (100%)	730c	42a	2.41a	29c	8.45a
Alpowa +					
25 % Waxy I	748b	43a	1.41b	38b	7.66a
50 % Waxy I	760b	44a	1.22b	40a	8.17a
Alpowa +					
25 % Waxy II	760b	43a	1.15bc	40a	7.88a
50 % Waxy II	788a	44a	0.92c	39ab	7.20a

[a] Gluten was from cv. Klasic; starches were blends of regular and waxy starches. Values within malt treatment followed by the same letter in the same column are not significantly different ($P < 0.05$).

to the increased water absorption of the starch and gluten blends during dough mixing, and also to the increased proportion of amylopectin in the starch.

Bread Baked from Starch and Gluten Blends

Breads baked with or without malt from starch and gluten blends with selected amylose content are presented in Fig. 3. The volume of breads prepared from regular wheat starch and gluten with or without malt was ≈730 mL. The volume of breads prepared with malt increased to >780 mL with the incorporation of 25% waxy starch and to >795 mL with the incorporation of 50% waxy wheat starch (Table III). Breads prepared from starch and gluten blends with the incorporation of waxy wheat starches without malt were much smaller than the corresponding breads prepared with malt.

The crumb structure of bread became more open as the waxy wheat starch ratio was increased. Bread baked with malt exhibited a more open crumb structure than bread baked without malt. Amylose molecules play an important role for the formation of bread crumb structure and prevent the collapse of the baked bread on cooling. Therefore, decreasing the proportion of amylose by the addition of waxy wheat starch in the starch and gluten blends resulted in a more open-structured bread crumb. Including malt in the starch and gluten blends with added waxy wheat starch further opened the crumb structure because waxy starch is more easily attacked by α-amylase from malt than is regular starch.

Changes in crumb moisture and hardness of bread baked from the starch and gluten blends after 5 hr of baking and seven days of storage at 4°C are summarized in Table III. Moisture content of bread 5 hr after baking was not significantly influenced by incorporation of waxy starch or malt at 39–44% in bread baked with malt and 42–44% in bread without malt. Bread baked with the starch and gluten blends with waxy wheat starch exhibited lower crumb hardness values compared with bread baked from the regular wheat starch and gluten blends, regardless of malt. The decrease in crumb hardness may be due to the porous crumb structure and the softening of the crumb when waxy wheat starch was added into the bread formula.

During seven days of storage, there were significant decreases in crumb moisture content and large increases in hardness of bread crumb. Seven days after baking, bread baked with added waxy wheat starches exhibited much higher crumb moisture content. Bread baked without malt exhibited trends similar to those of bread baked with malt in crumb moisture content. However, hardness of bread crumb was not significantly different among breads with selected starch compositions seven days after baking.

Retrogradation characteristics of starch in the crumb of bread prepared from starch and gluten blends during seven days of storage are summarized in Table IV. Bread stored for seven days at 4°C generally exhibited lower peak temperatures for the melting of retrograded starch than bread after 5 hr of baking, regardless of the use of malt in the bread. No difference in peak temperature for the transition of retrograded starch one day after baking was observed between breads baked with regular wheat starches or blends of waxy and regular wheat starch. Transition enthalpy of starch retrogradation in bread crumb was greater in bread stored for seven days at 4°C than in bread stored for one day at 24°C. The transition enthalpy for starch retrogradation was higher in bread with added waxy starches than in bread baked from regular starch and gluten blends, regardless of the use of malt or storage time. This result is contradictory to the retrogradation characteristics of blends of regular and waxy wheat starches, as determined using DSC (Table I), where the transition enthalpy of starch retrogradation decreased as the proportion of waxy wheat starch was increased. The difference in starch retrogradation between bread and starch may be due to the difference in moisture content around starch molecules during storage. While a 1:2 ratio of starch to water in the starch gel was maintained in the DSC capsule, the moisture content of bread

TABLE IV
Retrogradation Characteristics[a] of Bread Baked from Starch and Gluten Blends[b]

Starch	T_o (°C)	T_p (°C)	ΔH (J/g)
With Malt			
1 day after baking			
Alpowa (100%)	46.27a	53.17a	3.22c
Alpowa +			
25% Waxy	46.01a	52.77a	3.79bc
50% Waxy	45.54ab	52.17a	3.92b
7 days after baking			
Alpowa (100%)	44.86bc	52.51a	3.82bc
Alpowa +			
25% Waxy	44.63bc	50.81b	4.06b
50% Waxy	44.39c	50.67b	5.43a
Without Malt			
1 day after baking			
Alpowa (100%)	45.61b	52.65a	3.20d
Alpowa +			
25% Waxy	45.84b	52.57a	3.67c
50% Waxy	46.70a	52.92a	4.19b
7 days after Baking			
Alpowa (100%)	44.89c	51.61c	3.83c
Alpowa +			
25% Waxy	45.82b	52.08b	4.40b
50% Waxy	45.82b	51.77bc	5.10a

[a] Differential scanning calorimetry parameters: T_o, T_p, ΔH_g = onset and peak temperature, and transition enthalphy.

[b] Gluten was from cv. Klasic; starches were blends of regular and waxy starches. Values within malt treatment followed by the same letter in the same column are not significantly different ($P < 0.05$).

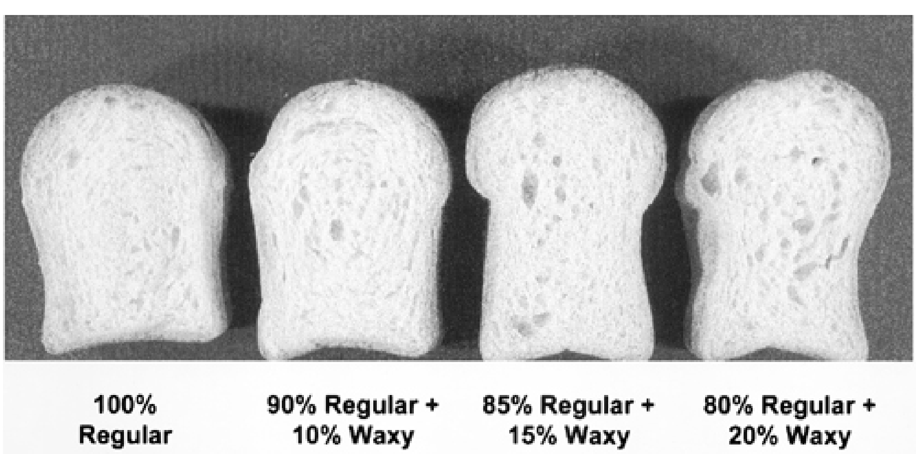

Fig. 4. Bread baked from starch and gluten blends with 10, 15, and 20% waxy I wheat starch.

TABLE V
Loaf Volume, Moisture Content, and Hardness of Bread Baked from Starch and Gluten Blends[a]

Starch	Bread Volume (mL)	5 hr After Baking		7 Days After Baking	
		Moisture (%)	Hardness (N)	Moisture (%)	Hardness (N)
Alpowa (100%)	725b	42a	1.94a	34c	8.55a
Alpowa +					
10 % Waxy I	828a	41a	1.04b	39a	7.31b
15 % Waxy I	838a	43a	1.14b	39a	7.94ab
20 % Waxy I	840a	44a	1.09b	36b	7.57ab

[a] Gluten from cv. Klasic. Starches were blends of regular and waxy starches. Values followed by the same letter in the same column are not significantly different ($P < 0.05$).

crumb was <44% after baking. In the limited moisture system of bread crumb, retrogradation of amylopectin molecules may occur faster than in the high moisture starch gel system. Zeleznak and Hoseney (1986) also reported that amylopectin retrogradation is dependent on the amount of water present. Furthermore, the transition enthalpy of starch retrogradation in bread crumb, as determined using DSC, might not be a suitable indicator of staling of bread containing starch with variable amylose content.

Bread was also baked from starch and gluten blends with malt, where the regular starch was blended with 10–20% waxy wheat starch. Bread volume, changes in crumb moisture, and changes in crumb hardness of bread baked from starch and gluten blends at 5 hr after baking and seven days of storage at 4°C are listed in Table V. The volume of bread prepared from regular starch and gluten was 725 mL. The volume of bread consistently increased to >828 mL with incorporation of waxy wheat starch. Increasing starch amylopectin content did not have a significant effect on crumb moisture content. Bread baked from starch and gluten blends with increased amylopectin content exhibited lower crumb hardness values compared with bread baked from regular wheat starch and gluten blends. During seven days of storage at 4°C, there were large decreases in crumb moisture content and large increases in crumb hardness of bread. Nevertheless, bread baked with waxy wheat starches exhibited significantly higher crumb moisture content ($P < 0.05$). Bread baked with 10% waxy starch was softer than bread baked with regular wheat starch. The crumb structure of bread baked from starch and gluten blends with incorporation of 10–20% waxy wheat starch is presented in Fig. 4. Compared with bread baked with 25 or 50% waxy wheat starch (Fig. 3), bread baked with 10–20% waxy wheat starch exhibited a less open bread crumb structure with fewer large pores. Crumb structure of bread baked from starch and gluten blends with added waxy starch was similar to that of bread baked from regular wheat starch and gluten blends, especially with 10 or 15% waxy wheat starch incorporation.

CONCLUSIONS

Increasing the proportion of amylopectin molecules in starch blends by adding waxy wheat starch delayed the retrogradation of starch paste. Increasing the waxy wheat starch proportion of dough prepared with gluten blends resulted in increased mixograph water absorption. Increased gas formation and decreased gas retention also were observed as the proportion of waxy wheat starch in bread formulations was increased. Bread prepared from 25 or 50% waxy wheat starch and gluten blends exhibited greater bread volume, softer crumb, and more porous crumb structure than bread baked from blends of regular wheat starch and gluten. Including malt in the blends with added waxy wheat starch further opened up the crumb structure. Bread prepared from 25 or 50% waxy wheat starch and gluten blends exhibited a higher level of starch retrogradation in crumb than bread baked from blends of regular wheat starch and gluten. Bread prepared from less than 20% waxy wheat starch and gluten blends exhibited crumb structure equivalent to that of bread containing regular wheat starch but retained higher moisture content of crumb during storage. Crumb hardness of bread prepared from 10% waxy starch and gluten blends was significantly softer than that of bread with regular wheat starch, even after seven days of storage. Incorporation of waxy wheat starch could be helpful for retaining moist crumb of bread during storage after baking without developing open crumb structure, and potentially extend the acceptable shelf life of bread.

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