Functional (Breadmaking) and Biochemical Properties of Wheat Flour Components. VIII. Starch[1]

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ABSTRACT

Fractionation and reconstitution studies have shown that the starch tailings fraction, although contributing to water absorption and dough feel, is not essential for optimum loaf volume. In this study, reconstituted prime starches from three hard red winter wheats, three hard red spring wheats, one soft white wheat, and one soft red winter wheat, all baked with a constant gluten and a constant water-solubles fraction, had essentially equal loaf-volume and crumb characteristics. Prime starch of durum wheat was significantly lower and four club wheat prime starches were significantly higher in loaf volume than that of the control starch from hard red winter wheat. Apparently, the club wheat starches were superior to the others because of genetic rather than environmental differences. Starches from rye and barley nearly equalled wheat starch in breadmaking; corn, milo, oat, rice, and potato starches were inferior. A small-granule starch isolated from a hard winter wheat flour had breadmaking characteristics that nearly equalled those of the control flour, suggesting that granule size did not govern the breadmaking potential of a starch. Corn, milo, and rice starches, which gelatinized at a temperature higher than that required for wheat starch, had poor breadmaking characteristics. But oat, potato, and durum wheat starches, which gelatinized at the same temperature as wheat starch, also had poor breadmaking characteristics. Starches gelatinized at much higher temperatures in dough than in a 4% starch-water slurry.

Starch in a bread dough, according to Sandstedt (1), (a) dilutes the gluten to a desired consistency, (b) furnishes sugar through amylase action, (c) provides a surface suitable for a strong union with the gluten, (d) becomes flexible during partial gelatinization, thereby permitting further stretching of the gas-cell film, and (e) takes water from the gluten by gelatinization, thereby causing the film to set and become rigid. Most cereal chemists probably would agree with these functions.

Rotsch (2) prepared bread from dough in which gluten and starch were replaced by other substances. However, he did not find a suitable substitute for wheat starch. Jongh (3) found that 0.05 to 1.00% glyceryl monosterate enhanced aggregation of starch granules (in gluten-free doughs) and formation of plastic structures; he suggested that starch is an important element of dough structure, and that gluten acts as a binder of starch granules.

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Harris (4) and Sandstedt (1) have shown that rice, corn, waxy corn, and potato starches do not have the baking quality of wheat starch. On the basis of these data, Medcalf and Gilles (5) concluded that wheat starch was generally superior in baking quality to starches from other plant species.

Researchers disagree about the relative breadmaking quality of starches from different wheat varieties. Harris and Sibbitt (6,7) and Sandstedt (1) found that starches from different varieties varied widely in baking quality. However, Finney (8) and Hoseney et al. (9) found no differences in the breadmaking quality of starches isolated from hard wheats that varied widely in breadmaking quality. Pence et al. (10) found no differences in starches from wheats of a single class but noted some differences between classes. Apparently, much of the disagreement stems from different breadmaking techniques, from variations in starch damage from milling, and whether the water-soluble fraction was reconstituted.

So far research has not explained the relation of granule size and gelatinization temperature of starch to breadmaking performance. Grewe and Bailey (11) found no significant correlation between granule size and loaf volume. Ponte et al. (12), working with air-classified flours, found granule size and starch damage negatively correlated with the breadmaking quality of starches, but they could not identify the factor primarily responsible for the negative response.

The purpose of our study was to determine if wheat starch is unique in its breadmaking performance, to determine if starches from various wheat classes vary in baking quality, and to relate granule size and gelatinization temperature to breadmaking performance.

MATERIALS AND METHODS

Flours

A hard red winter wheat flour (Regional Baking Standard, RBS) was milled from a composite of several wheat varieties that were harvested at many locations throughout the Southern and Central Great Plains in 1967. Two additional hard red winter wheat flours (Kharkof and Wanser) were milled from composites of samples harvested in the Pacific Northwest in 1967. Other wheat flours, together with wheat-harvest locations, included: hard red spring (Thatcher, Selkirk, and Lee), milled from composites of wheat samples, Northern Great Plains; durum (Wells), Fargo, N. Dak.; soft red winter (Seneca), Wooster, Ohio; and club (Omar, Moro, Elgin, and Elmar) and soft white (Nugaines), milled from composites of wheat samples, the Pacific Northwest in 1967.

Analytical Procedures

Protein and moisture were determined as described in AACC Approved Methods (13). The 10-g. baking procedure described by Shogren et al. (14) was used. The potassium bromate requirement of RBS, 30 p.p.m., was used in all baking studies. The standard deviation for the average of duplicate loaf volumes was 1.75 cc.

Fraction Procedures

Each wheat flour was fractionated into gluten, starch, and water-solubles as described by Hoseney et al. (15). In addition, each starch was separated manually into prime and tailings fractions.

A small-granule wheat starch was prepared from the RBS tailings fraction as described by Yamazaki (16). The tailings fraction was dispersed with water in a Waring Blendor, sieved over a 325-mesh screen, and the thrus centrifuged at 1,000 X g. That procedure was repeated until the starch and tailings gel were separated.

Starch fractions were obtained from corn, milo, barley, rye, oats, and rice by a simple wet-milling procedure. The grain was steeped in distilled water for 30 hr. at 4°C., then ground in a Hobart coffee mill, and sieved over a flour cloth. The overs were suspended in water, ground, and sieved; that procedure was repeated until no additional milky starch suspension was obtained. Thrus of the flour cloth were combined and centrifuged at 1,000 X g. The supernatant water was discarded, and the nonstarchy components were skimmed off the prime starch. That procedure was repeated until the starch appeared pure. Potato starch was isolated by the same procedure, except that a Waring Blendor was used instead of the Hobart mill.

All fractions were dried by lyophilization. The starch fractions, to avoid being damaged (17), were hydrated to about 11% moisture before being reconstituted. No evidence of starch damage in terms of increased water absorption or lower loaf volume was found in reconstituted flours.

Gelatinization Temperature

The gelatinization temperature of each starch was determined by heating a 4% aqueous slurry in a water bath. After heating to a selected temperature, each slurry was held at that temperature for 15 min., and a sample was taken for microscopic examination. After establishing the temperature of initial gelatinization, the bath temperature was then raised by suitable increments and that procedure was repeated until the temperature of 100% gelatinization was established. That technique yielded shorter gelatinization ranges than normally reported in the literature. Each heated sample was examined under a polarizing microscope to determine the percentage of granules retaining birefringence. The percentage of gelatinized starch granules was plotted against temperature. The temperature required to gelatinize 50% of the granules was obtained by interpolation of each plot.

The gelatinization of starch in dough was determined by mixing, to optimum consistency, a reconstituted dough containing the starch being tested. The dough was molded around the bulb of a thermometer, which was inserted in a large test tube (3 X 17 cm.) equipped with an air condenser. The test tube was then placed in a water bath and was held for 15 min. after an equilibrium temperature was attained. A series of doughs was heated to temperatures that covered the

TABLE I. BAKING DATA FOR RECONSTITUTED FLOURS (12.8% PROTEIN) CONTAINING GLUTEN, WATER-SOLUBLES, AND VARIOUS STARCH FRACTIONS

Starch Fraction	Mixing Time min.	Absorption %	Loaf Volume cc.
Unfractionated flour	4	66.0	80
Total	2-3/4	65.0	80
Prime and tailings (80/20)	2-5/8	65.0	80
Prime	2-3/4	61.0	80
Tailings	2-5/8	93.0	43

gelatinization range. Each dough was removed manually, dispersed in a minimum of water, and sieved through a 100-mesh screen. The thrus of the screen were centrifuged at 1,000 X g. The water and top layer of tailings and protein were discarded, and the starch was examined microscopically.

RESULTS AND DISCUSSION

Baking Results

The RBS flour had a loaf volume of 80 cc. (10-g. method, Table I). Fractionation of the flour into crude gluten, starch, and water-solubles, followed by their lyophilization and reconstitution, yielded a reconstituted flour that yielded a loaf volume comparable to that of the original flour. Reconstitution of the prime and tailings starch fractions at their original ratio (80% prime and 20% tailings) with crude gluten and water-solubles gave a reconstituted flour which had a loaf volume equal to that of the original flour. Replacing the total starch fraction with only prime starch gave a reconstituted flour that contained no tailings fraction, and that had a loaf volume equal to that of the original unfractionated flour, but the absorption was significantly lower. Replacing the total starch fraction with the tailings starch gave a reconstituted flour that contained no prime starch and had an extremely low loaf volume (43 cc.); the absorption was 43% higher than that of the control. Thus, the tailings fraction materially affected dough absorption and feel but had no apparent effect on loaf volume.

Starches from the spring and soft red winter wheats, when reconstituted and baked into bread, had loaf volumes that essentially were comparable to that of the RBS prime starch (Table II). The durum prime starch, when reconstituted, had a significantly lower loaf volume and a slightly higher water absorption than those of RBS prime starch.

Each of the prime starches from the club wheat varieties (Omar, Moro, Elgin, and Elmar), when reconstituted with gluten and water-solubles from the RBS at the

TABLE II. BAKING DATA FOR RECONSTITUTED FLOURS (12.8% PROTEIN) CONTAINING GLUTEN AND WATER-SOLUBLES FROM RBS AND STARCH FROM VARIOUS SOURCES

Source of Prime Starch	Wheat Type	Mixing Time min.	Ab-sorption %	Loaf Volume cc.
RBS	HRW	2-3/4	61.0	80
Thatcher	HRS	2-1/2	61.0	79
Selkirk	HRS	2-1/4	61.0	81
Lee	HRS	2-3/4	61.0	79
Seneca	SRW	3-1/8	61.0	79
Wells	Durum	2-3/8	63.0	74
Omar	Club	2-3/4	61.0	85
Moro	Club	2-5/8	61.0	83
Elgin	Club	2-3/4	61.0	84
Elmar	Club	2-3/4	61.0	83
Kharkof	HRW	3-1/8	61.0	80
Wanser	HRW	2-3/4	60.0	78
Nugaines	Soft white	2-3/4	60.0	79

TABLE III. BAKING DATA FOR RECONSTITUTED FLOURS (12.8% PROTEIN) CONTAINING GLUTEN AND WATER-SOLUBLES FROM RBS AND STARCH FROM VARIOUS SOURCES

Source of Starch	Mixing Time min.	Absorption %	Loaf Volume cc.
RBS prime	2-3/4	61.0	80
Corn	3-3/4	75.0	48
Milo	2-3/4	68.0	54
Oat	2-5/8	70.0	58
Barley	2-1/2	61.0	78
Rye	3-1/8	61.0	77
Rice	1-7/8	73.0	68
Potato	3-3/4	73.0	60
Small-granule wheat	1-5/8	68.0	77

protein content of the RBS, had loaf volumes (Table II) that were about 5% higher than those of the flours reconstituted with RBS prime starch. Thus, prime starch from club wheats appeared to be superior, for breadmaking purposes, to those from other classes of wheat.

Were the club wheats superior because of their genetic background or the environment under which they were grown? The two hard red winter wheats (Kharkof and Wanser) and one soft white wheat (Nugaines) were grown under nearly the same conditions as were the club samples. Starches isolated from those samples and reconstituted by the previously described technique gave loaf volumes that were comparable to that of the RBS starch. Thus, starches from club wheats apparently were genetically superior to starches from other wheat classes.

To learn more about the role of starch in breadmaking, starches were isolated from several nonwheat sources including corn, milo, oats, barley, rye, rice, and potatoes. Of those starches, only rye and barley, when reconstituted with crude gluten and water-solubles from RBS, gave bread loaf volumes that were nearly equal to those of the controls (Table III). Reconstituted loaves containing corn, milo, oat, rice, and potato starches all had high water absorption, low loaf volume, and pale, unappetizing color (except for potato starch, which was golden brown). Reconstituting the nonwheat prime starches with wheat tailings (80% prime, 20% tailings) gave essentially the same results as when using 100% nonwheat prime starch.

The starches differed noticeably in granule size (Fig. 1). Wheat, rye, and barley starches had approximately the same granule size; potato starch granules were much larger, those of corn and milo slightly smaller, and oat and rice granules much smaller than those of wheat starch. To determine whether the small-granule size of oat and rice starches was related to their poor baking characteristics, a sample of wheat flour (RBS) was fractionated (Fig. 2) according to Yamazaki's procedure (16). Small-granule wheat starch (Fig. 1), when reconstituted with gluten and water-solubles, had a loaf volume (Table III) only slightly less than that of the control flour. Thus, loaf volume does not appear to be a function of granule size.

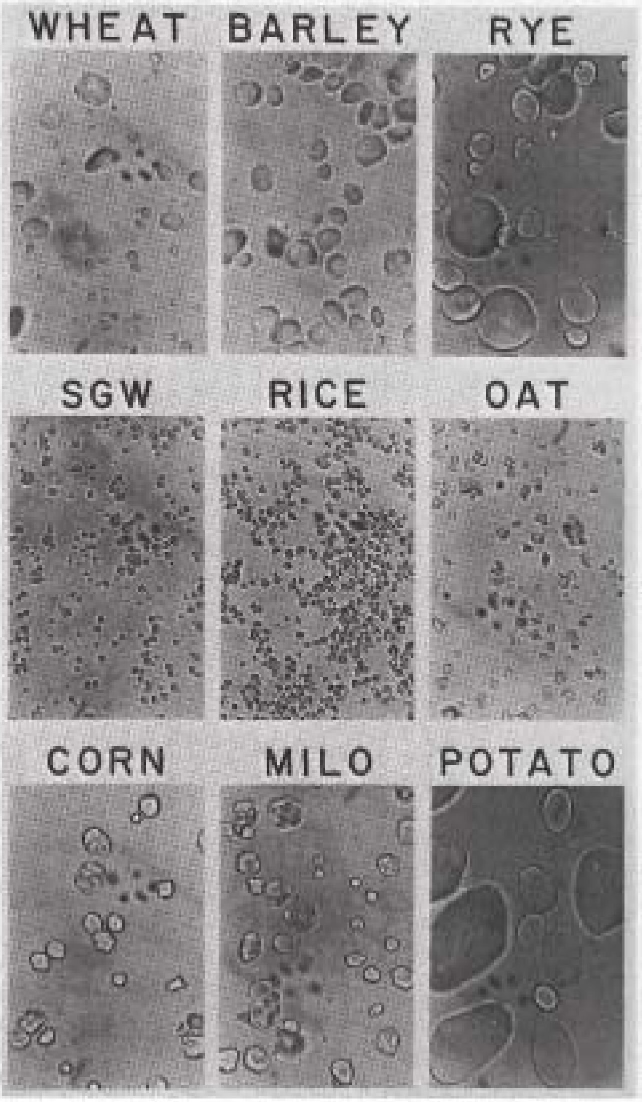

Fig. 1. Photomicrographs of prime starches isolated from wheat, barley, rye, rice, oats, corn, milo, and potatoes, along with a small-granule wheat starch isolated from the tailings fraction (400:1).

The high absorption of the dough containing the small-granule starch probably was related to the starch's increased surface area, or a higher percentage of damaged starch granules in that fraction.

TABLE IV. GELATINIZATION TEMPERATURE RANGE AND TEMPERATURE OF 50% GELATINIZATION OF VARIOUS STARCHES (4% AQUEOUS SLURRY)

Source of Starch	Gelatinization Start °C.	 End °C.	 50% °C.
RBS	54	59	55
Omar	53	59	55
Wells	45	60	53
Corn	65	73	68
Milo	63	68	67
Oat	53	59	55
Barley	56	61	60
Rye	49	56	51
Rice	69	75	71
Potato	50	60	55
Small-granule wheat	54	59	56

Gelatinization

Starches also varied in gelatinization temperature (Table IV). Milo, corn, and rice gelatinized at much higher temperaures than did the other starches. Gelatinization curves were essentially the same for all wheat starches, except for durum, which gelatinized over a greater temperature range than the other wheat starches. The lower initial gelatinization temperature for durum starch was in agreement with results reported by Medcalf and Gilles (18). Potato starch also had a greater gelatinization range than the other starches.

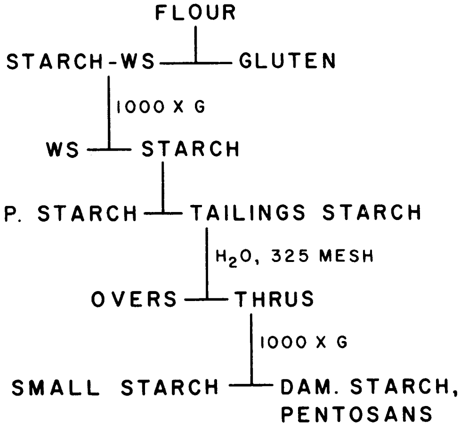

Fig. 2. Scheme for isolating a small-granule wheat starch.

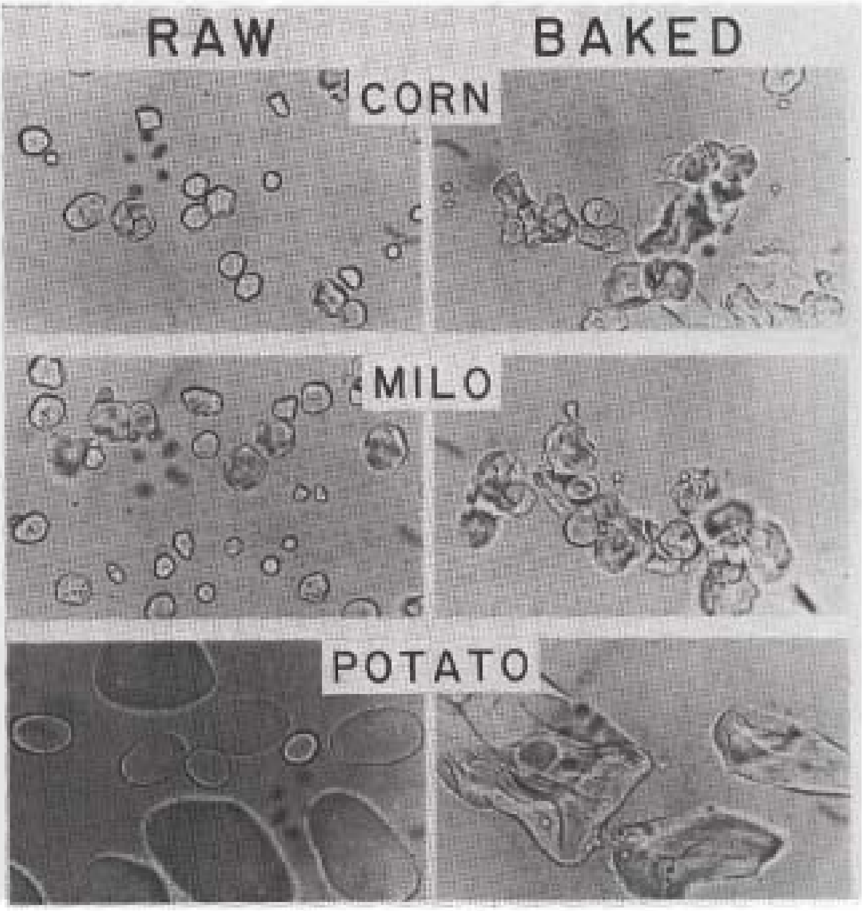

Fig. 3. Photomicrographs of wheat, barley, and rye prime starches (raw) and the same starches (baked) that were isolated from reconstituted loaves of bread (400:1).

The baked starches that gelatinized at higher temperatures (corn, milo, and rice) were only partially swollen and distorted during baking (Figs. 3, 4, and 5). Many of the granules retained birefringence even though the temperature in the loaf of bread was known to approach 100°C. (19). Thus corn, milo, and rice starches resisted gelatinization under the limited water conditions in a dough. The effect of limited water on gelatinization temperature of wheat starch is illustrated in Fig. 6.

Corn, milo, and rice starches had poor baking characteristics and relatively high

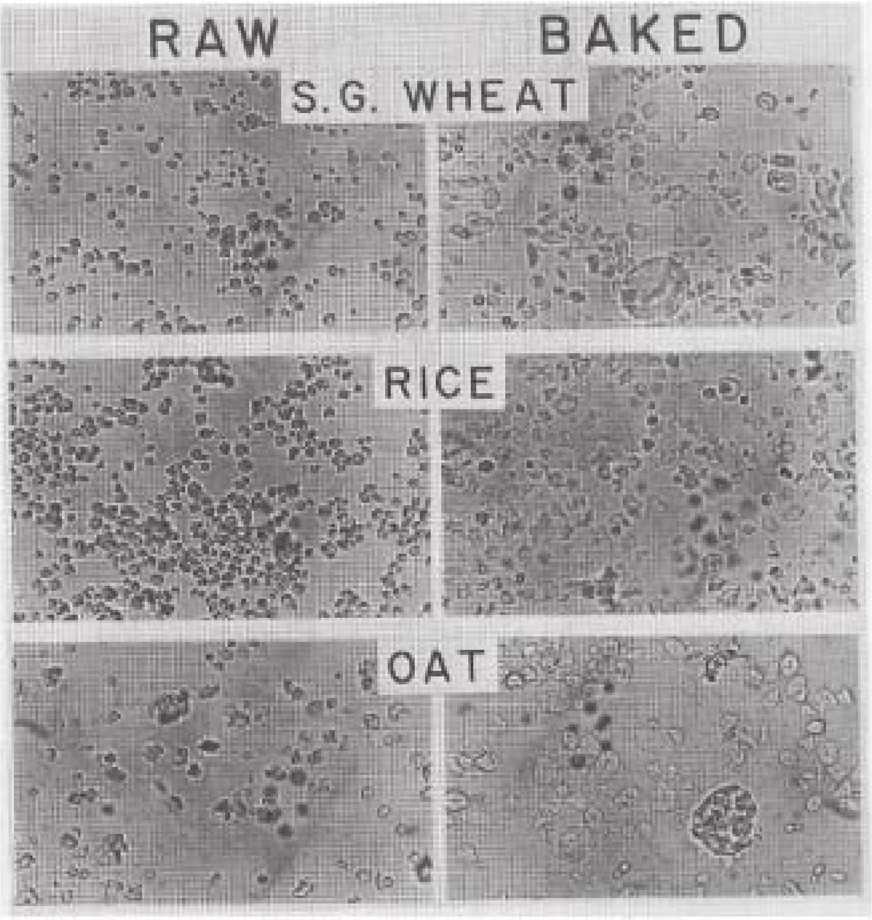

Fig. 4. Photomicrographs of small-granule wheat, rice, and oat prime starches (raw) and the same starches (baked) that were isolated from reconstituted loaves of bread (400:1).

gelatinization temperatures. However, oat, potato, and durum wheat starches also had poor baking characteristics, even though their gelatinization temperatures were relatively low and essentially equal to those of the hard wheat starches. In addition, the superior-baking, club wheat starches gelatinized at the same temperature as the other wheat starches. Because neither starch-granule size nor gelatinization temperature accounted for the bread-baking potential of a starch, we concluded that some other unidentified characteristic is of utmost importance.

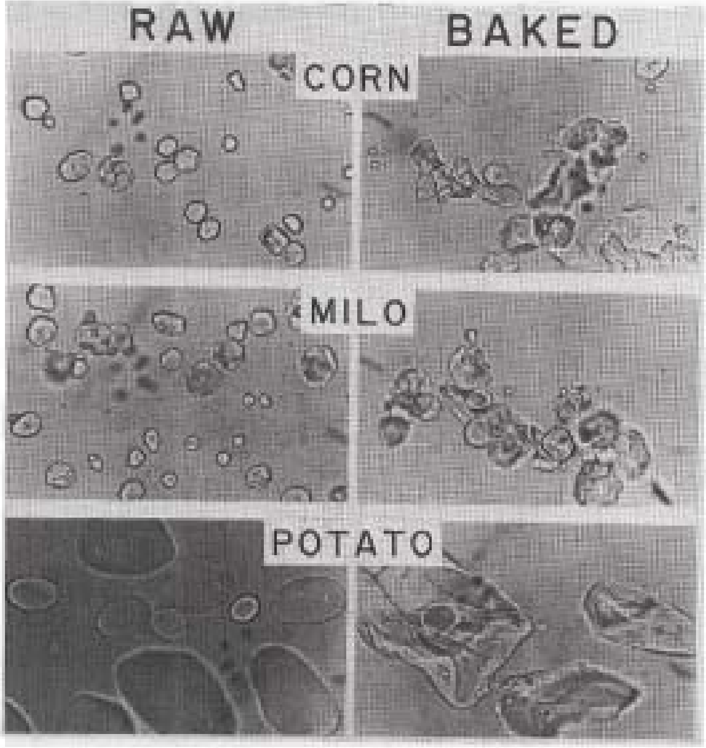

Fig. 5. Photomicrographs of corn, milo, and potato prime starches (raw) and the same starches (baked) that were isolated from reconstituted loaves of bread (400:1).

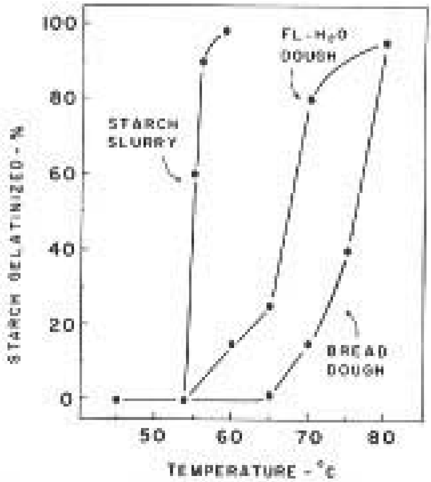

Fig. 6. Gelatinization curves for a 4% aqueous wheat-starch slurry, a flour-water dough, and a bread dough containing all baking ingredients.

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