Alpha-Amylase in Field-Sprouted Wheats: Its Distribution and Effect on Japanese-Type Sponge Cake and Related Physical and Chemical Tests

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ABSTRACT

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To clarify the effect of field sprouting on quality, we determined α-amylase activity (0–4.13 dextrinizing units [DU] per gram) in soft white winter wheat composites with typical levels of field sprouting (0–36.2%) and in their mill fractions, and we studied its effects on the Japanese type of sponge cake and in related tests. Average yields of the corresponding mill fractions of seven wheat composites were patent flour, 45%; midpatent flour, 10%; clear flour, 15%; bran, 25.8%; shorts, 3.2%; and red dog, 1.0%. Ash and protein contents of the fractions were typical. α-Amylase activity was relatively low for 45% patent, midpatent, and clear flours and relatively high for bran, shorts, and red dog. When α-amylase activity in DU per gram of each mill fraction was calculated as DU per gram of wheat, based on yield, activity increased linearly in each mill fraction with increasing wheat α-amylase. When expressed as percent of wheat DU, bran accounted for 42% of the α-amylase activity, patent flour for 32%, shorts for 9%, clear flour for 8%, midpatent flour for 7%, and red dog for 2%. Sponge cake volume increased from 1,280 cc for the control to 1,315 cc for the flour milled from wheat containing 0.35 DU/g. Thereafter, volume decreased rapidly to 908 cc as DU per gram of wheat increased to 4.13. At least 0.2 DU/g of wheat (about 2.5% sprouted wheat) should be a doubly safe level that would have no adverse effect on sponge cake quality. Sponge cake volume, percent of sprouted wheat, amylograph viscosity, falling number, and gas production were all functions of the α-amylase activity of wheat or flour. Different levels of field sprouting should not be simulated by supplementing unsprouted wheat with a highly sprouted one, especially not with a highly malted barley.

The expression "sprout-damaged wheat" implies that any level of sprouted wheat is undesirable; yet, 0.2–0.5% of 100% highly sprouted (malted) wheat is commonly used as a flour improver in breadmaking. Some believe that a few tenths of one percent of sprouted wheat significantly and adversely affect cake quality, particularly sponge cake made in Japan. The belief is at least partly based on certain physical and chemical tests that are sensitive to trace amounts of α-amylase produced during the sprouting of wheat. To verify or clarify the sprouted-wheat question, we determined α-amylase activity in field-sprouted soft white winter wheats and their mill fractions and studied its effect on the Japanese type of sponge cake, amylograph viscosity, falling number, and gas production.

MATERIALS AND METHODS

Wheat Samples

Seven composites of soft white winter varieties of wheat from the 1978 crop in eastern Washington were obtained from the Western Wheat Quality Laboratory, Pullman, WA. The composites contained 0–36.2% field-sprouted wheat and 0.03–4.13 dextrinizing units (DU) of α-amylase activity per gram (Table I). Two other soft white winter wheats, 1978 crop, from Centennial Mills, Portland, OR, contained 0 and 5.5% sprouted wheat and 0.04 and 0.23 DU of α-amylase activity per gram, respectively. They were used only in studies of the relation of percent sprouted wheat, falling number, amylograph viscosity, and gas production to α-amylase activity. Percent sprouted wheat was determined by the Federal Grain Inspection Service, Colfax, WA.

Experimental Milling

Each wheat was tempered to 14.0% moisture for 24 hr, then experimentally milled on six stands of Allis rolls to give five break, one sizing, two tailing, one low grade, and nine middling streams. Yield of each fraction was calculated as percent of total products.

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Reference to a company or product does not imply approval or recommendation by the USDA to the exclusion of others that may be suitable.

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Moisture, Protein, Ash, and α-Amylase

Moisture, protein, and ash contents were determined by AACC approved methods 44-15A, 46-11, and 08-01, respectively. α-Amylase activity (DU per gram) was determined by the method of Mathewson and Pomeranz (1979).

Japanese-Type Sponge Cake

Sponge cakes, made from each 45% patent flour, were prepared by the formula and procedure described by Nagao et al (1976), except that each batch of batter for two cakes was 2.2 times the amount required for one. Batter for each cake contained 100 g of flour (sifted four times); 100 g of baker's special-fine sifted sugar; 100 g of Fleischmann's pasteurized frozen whole eggs (FL-28), which contained small amounts of corn syrup, dextrin, and salt; and 28 or 40 g of water (including optional flavors). The Hobart mixer (model K5-A) was equipped with a 5-qt bowl; a wire whip for creaming sugar, whole eggs, and water; a flat beater for mixing flour and creamed mixture; and speed settings from 1 to 10 (40–240 rpm). Hand mixing of the flour into the creamed mixture was replaced with mechanical mixing in the Hobart[3] by gently immersing flour in the creamed mixture with a flat beater for 16 sec at 40 rpm, then for 3.5–4 sec at 240 rpm. The mixer was operated by a GraLab Universal Timer set at 20 sec, so that the setting change was made while the mixer was running. Scaled amounts of ingredients (328–340 g) were baked at 180°C for 30 min. After a cake was cooled for 1 hr, its volume was determined by rapeseed displacement. Duplicate cakes were made on each of two or three days. A difference of 38 cc between averages of four determinations was statistically significant at $P = 0.05$.

Gas Production, Falling Number, and Amylograph Viscosity

Gas production in gasograph units of 10 g of 45% patent flour was tested by fermenting for 3 hr with 3.5% compressed yeast according to the method of Rubenthaler et al (1980). The gas production value for control flour was subtracted from the value of each flour milled from field-sprouted wheats. The falling numbers provided by the Western Wheat Quality Laboratory had been determined according to AACC approved method 56-81B. Amylograph peak viscosity of 910 BU was obtained with a modification of AACC approved method 22-10 on a slurry of 66.5 g of 45% patent control flour and 460 ml of distilled water. In determinations of amylograph peak viscosities, 0.7 g of each 45% patent flour milled from field-sprouted wheat replaced 0.7 g of the control flour. Before flour was added to the amylograph bowl, it was slurried in 300 ml of water in a flask that was rinsed with 160 ml

[3]Natsuaki and Finney. Unpublished data.

of water. Initial temperature was 25°C. Time to reach peak viscosity was 43–44 min.

TABLE I
Yield, α-Amylase Activity, and Ash and Protein Contents of Fractions Milled from Field-Sprouted Soft White Winter Wheats Harvested in Washington in 1978[a]

Wheat[b] and Fractions	Yield (%)	α-Amylase (DU/g)[c]	Ash (%)	Protein (%)
0% Sprouted Nugaines	···	0.03	1.44	8.7
Patent flour	45	···	0.33	7.2
Midpatent (10% cut)	10	···	0.41	6.3
Clear flour	17.07	···	0.52	8.4
Bran	23.23	···	4.48	11.9
Shorts	3.83	···	2.82	14.1
Red dog	0.87	···	2.22	12.0
Total	100.00			
3.6% Sprouted Nugaines	···	0.35	1.36	8.7
Patent flour	45	0.18	0.32	6.7
Midpatent (10% cut)	10	0.15	0.37	7.2
Clear flour	13.98	0.21	0.48	8.3
Bran	26.94	0.69	3.77	12.0
Shorts	2.91	2.08	2.27	14.1
Red dog	1.15	1.55	1.70	11.7
Total	99.98			
11% Sprouted NLHW	···	0.98	1.44	9.6
Patent flour	45	0.48	0.31	7.8
Midpatent (10% cut)	10	0.65	0.38	6.4
Clear flour	15.45	0.61	0.49	9.2
Bran	25.44	1.51	4.24	13.4
Shorts	3.16	3.57	2.71	15.4
Red dog	0.93	2.73	1.91	12.9
Total	99.98			
31.5% Sprouted SWWW	···	2.13	1.32	9.0
Patent flour	45	1.57	0.32	7.1
Midpatent (10% cut)	10	1.48	0.34	6.7
Clear flour	14.75	1.23	0.45	8.7
Bran	26.17	3.49	3.80	12.8
Shorts	3.17	6.26	1.98	14.1
Red dog	0.90	4.68	1.52	12.4
Total	99.99			
30% Sprouted SWWW	···	2.13	1.46	7.3
Patent flour	45	1.69	0.33	5.2
Midpatent (10% cut)	10	1.08	0.36	5.8
Clear flour	13.97	1.03	0.47	6.9
Bran	27.78	3.60	4.05	10.7
Shorts	2.54	6.58	2.33	12.4
Red dog	0.69	6.84	1.66	10.7
Total	99.98			
30% Sprouted Nugaines	···	3.06	1.49	8.1
Patent flour	45	2.18	0.33	6.2
Midpatent (10% cut)	10	2.09	0.39	5.4
Clear flour	15.64	1.45	0.48	7.5
Bran	24.95	5.18	4.51	11.9
Shorts	3.34	8.33	2.89	14.3
Red dog	1.08	6.74	1.62	11.2
Total	100.01			
36.2% Sprouted SWWW	···	4.13	1.34	9.6
Patent flour	45	3.01	0.34	7.7
Midpatent (10% cut)	10	2.87	0.37	7.6
Clear flour	14.21	2.06	0.49	9.5
Bran	26.44	6.79	3.80	13.4
Shorts	3.31	9.08	2.04	15.3
Red dog	1.02	9.43	1.57	13.9
Total	99.98			

[a]Chemical data are expressed on a 14% moisture basis.
[b]NLHW = Nugaines-Luke-Hyslop wheat composite, SWWW = soft white winter wheat.
[c]Dextrinizing units per gram of wheat or fraction.

RESULTS AND DISCUSSION

Yield, Ash, and Protein of Mill Fractions

Average yields of the mill fractions from the seven wheats (Table I) were patent flour, 45%; midpatent flour, 10%; clear flour, 15%; bran, 25.8%; shorts, 3.2%; and red dog, 1.0%. Ash and protein contents of the fractions were typical.

α-Amylase Activity of Mill Fractions

α-Amylase activity was relatively low for 45% patent, midpatent, and clear flours and relatively high for bran, shorts, and red dog (Table I). α-Amylase activity in 45% patent flour was about 50% of the wheat activity when it was 1 DU or less and about 75% of the wheat activity when it was about 2 DU or greater. The α-amylase activity of clear flour was greater than that of 45% patent when the wheat activity was less than or equal to about 1 DU/g; activity of clear flour was less than that of 45% patent when wheat activity was equal to or greater than about 2 DU/g and had deeply penetrated the endosperm.

When the α-amylase activity of each fraction, expressed as DU per gram of the fraction (Table I), was multiplied by the corresponding percent yield, the calculated activity per gram of wheat increased linearly in each mill fraction with increasing wheat α-amylase (Fig. 1). The sum of the activities of the fractions equals that of the corresponding wheat. When expressed as percent of wheat α-amylase (Fig. 2), bran accounted for 42% of the α-amylase activity in the wheat, patent flour for 32% (high because of having the highest milling yield), shorts for 9% (low because of low yield), clear flour for 8%, midpatent flour for 7%, and red dog for 2% (very low because of having the lowest yield). For wheats with α-amylase activities less than about 1 DU/g, bran, shorts, and red dog fractions had higher and 45% patent, 10% midpatent, and clear flours had lower levels of the enzyme than did the corresponding fractions from wheats with α-amylase activities greater than 1 DU/g.

Related Test Values vs Wheat α-Amylase Activity

The determination of percent sprouted wheat, in the absence of a more suitable test, is a highly subjective method used in trade

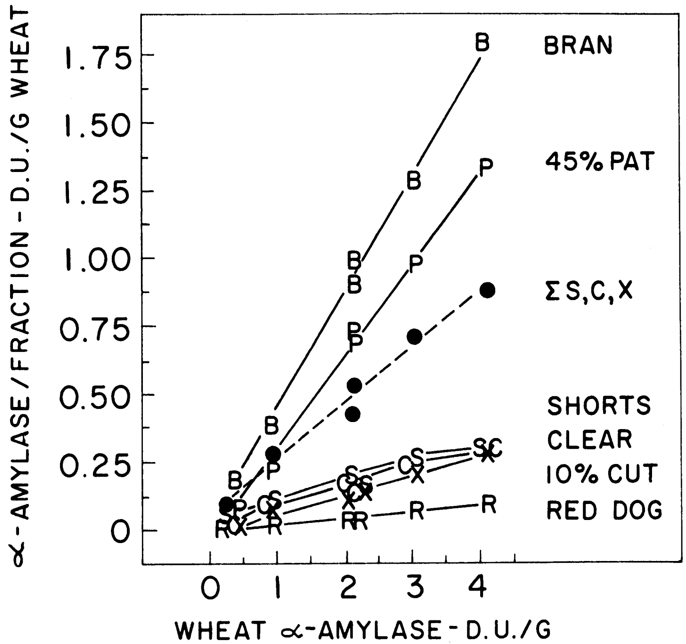

Fig. 1. α-Amylase activities of the mill fractions (F), in dextrinizing units (DU) per gram of field-sprouted wheats (F × percent yield), plotted vs wheat α-amylase activities. Sum (Σ) of the shorts (**S**), clear (**C**), and 10% cut (**X**, also called midpatent) shows the amount of α-amylase accounted for by those fractions.

channels to predict biochemical changes, including the production of α-amylase activity, that take place during the sprouting of wheat. At high levels, α-amylase activity can impair the baked products. Wheat α-amylase activity was used as the independent variable in Fig. 3 because 1) α-amylase activity now can be determined quickly, accurately, and objectively, 2) α-amylase activity is a better index of the biochemical change than is percent sprouted wheat, 3) the sprouting of wheat is simply a physical change that accompanies the biochemical changes, and 4) all related tests, including percent sprouted wheat, can be compared with wheat α-amylase activity as the common denominator.

Percent sprouted wheat increased with increasing wheat DU up to about 2 DU and then increased at a much slower rate with further increases in wheat DU (Fig. 3A). Thus, percentages of sprouted wheat of 30 or more did not satisfactorily reflect wheat α-amylase activities produced during sprouting.

Gas production was a consistent function of wheat α-amylase activity, although rate of change of gas production per 1 DU decreased with increasing wheat DU (Fig. 3B).

Falling number decreased from 400 (control) to 140 for the wheat containing only 0.35 DU/g of α-amylase activity, approached 100 at 1 DU/g, and reached a minimum of about 65 at 2 DU/g (Fig. 3C). Falling number affords little differentiation between wheats with α-amylase activities of about 0.5 to more than 4 DU/g.

Amylograph peak viscosity was decreased significantly by trace amounts of α-amylase. For example, the wheat that contained 0.35 DU/g yielded a 45% patent flour that contained 0.18 DU/g (Table I, 3.6% sprouted). Thus, 0.7 g of the patent flour contained 0.126 DU. Expressed on a total flour basis, that is 0.126 DU/66.5 g or 0.0019 DU/g of total flour. That small level of α-amylase corresponded to a patent flour viscosity of 850 BU, which was 60 BU less than that of the control (910 BU).

Sponge Cake Volume vs Wheat α-Amylase Activity

The volume of sponge cakes made with 40% water increased from 1,280 cc for the control to 1,315 cc for the 45% patent flour milled from wheat containing 0.35 DU/g (Fig. 4). Crumb grains and other cake properties were normal (Fig. 5, top and 2nd row). Thereafter, volume decreased rapidly to 908 cc for 4.13 DU/g of wheat (Figs. 4–6). Thus, an α-amylase activity of *at least* 0.2 DU/g of wheat (about 2.5% sprouted wheat) should be a *doubly safe* level that would have no adverse effect on sponge cake quality.

Sponge cakes made with the reduced absorption of 28% (Figs. 4–6) demonstrated that great reduction of the adverse effects of α-amylase in Japanese-type sponge cakes is possible, although probably not economical.

Sponge Cake Volume vs Related Tests

The relations between cake volume and percent sprouted wheat (Fig. 7A) and between cake volume and gas production of flours from field-sprouted wheats (Fig. 7B) were similar to the relation between cake volume and α-amylase activity in wheat (Fig. 4).

Wheat with a falling number of 140 yielded a sponge cake volume equal to that of the control (Fig. 7C). As falling number decreased below 140, cake volume decreased sharply.

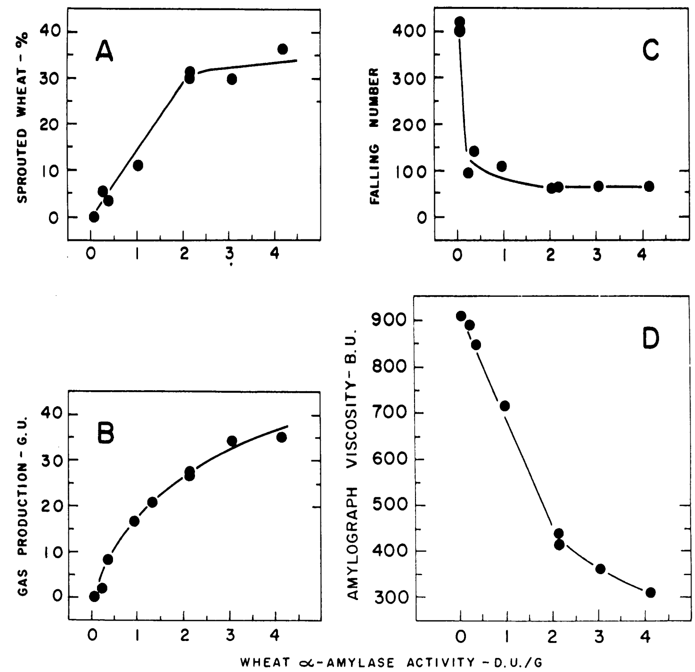

Fig. 3. Percent field-sprouted wheat, falling numbers of field-sprouted wheats, and gas productions and amylograph viscosities of 45% patent flours milled from field-sprouted wheats plotted vs wheat α-amylase activities. **GU** = gasograph units, **DU** = dextrinizing units.

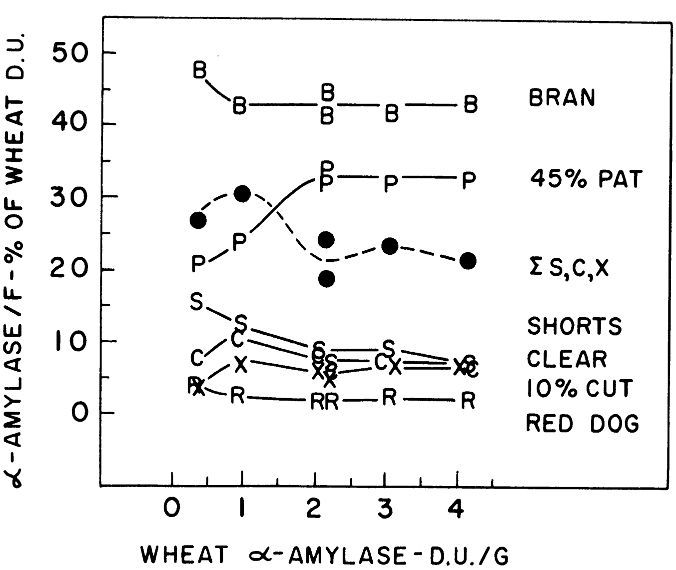

Fig. 2. α-Amylase activities of the mill fractions (**F**) as percent of wheat α-amylase activity, both in dextrinizing units (**DU**) per gram of field-sprouted wheat, plotted against wheat α-amylase activities. Sum (Σ) of the shorts (**S**), clear (**C**), and 10% cut (**X**, also called midpatent) shows the amount of α-amylase accounted for by those fractions.

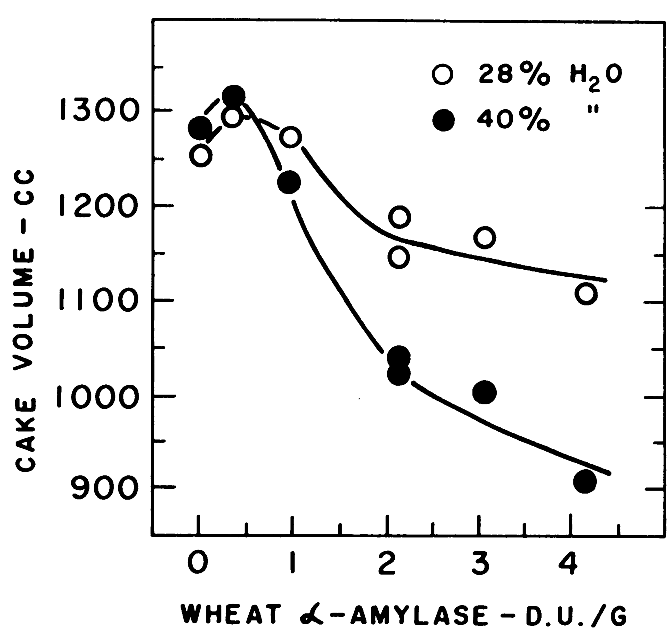

Fig. 4. Changes in volume of Japanese-type sponge cakes (28 and 40% water absorptions) baked from 45% patent flours milled from field-sprouted wheats that varied greatly in α-amylase activities expressed as dextrinizing units (**DU**) per gram.

An amylograph viscosity of at least 100 BU less than that of the control flour (910 BU) is associated with normal quality in cakes made with 40% water (Fig. 7D).

Amylograph viscosity, falling number, sprouted wheat, and gas production are indexes of sponge cake volume and all are functions of the α-amylase activity of wheat or flour.

Adverse Effects of α-Amylase Supplements

When a nonsprouted control 45% patent flour was supplemented with barley malt of very high α-amylase activity (52 DU/g), its potential to make sponge cake (Fig. 8, left) was more adversely affected than that of the same control flour supplemented to the same level of enzyme activity with a flour (2.12 DU/g) milled from

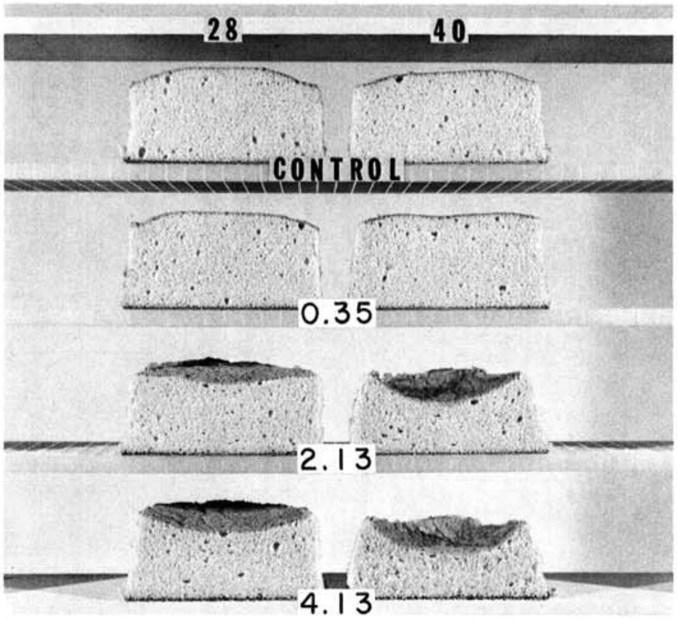

Fig. 5. Japanese-type sponge cakes (28 and 40% water absorptions) baked from 45% patent flours milled from field-sprouted wheats that contained 0–4.13 dextrinizing units of α-amylase activity per gram.

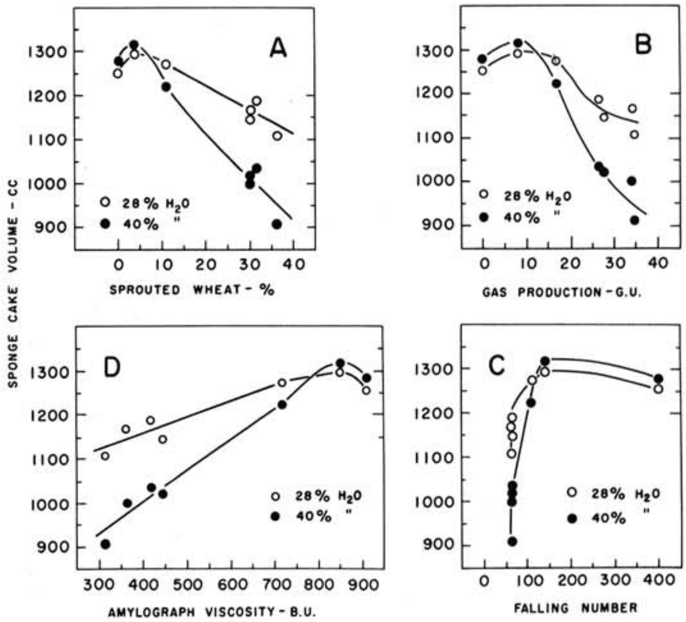

Fig. 7. Volumes of Japanese-type sponge cakes (28 and 40% water absorptions) baked from 45% patent flours milled from field-sprouted wheats plotted vs amylograph viscosities and gas productions of the flours, falling numbers of the wheats, and percent sprouted wheat. **GU** = gasograph units.

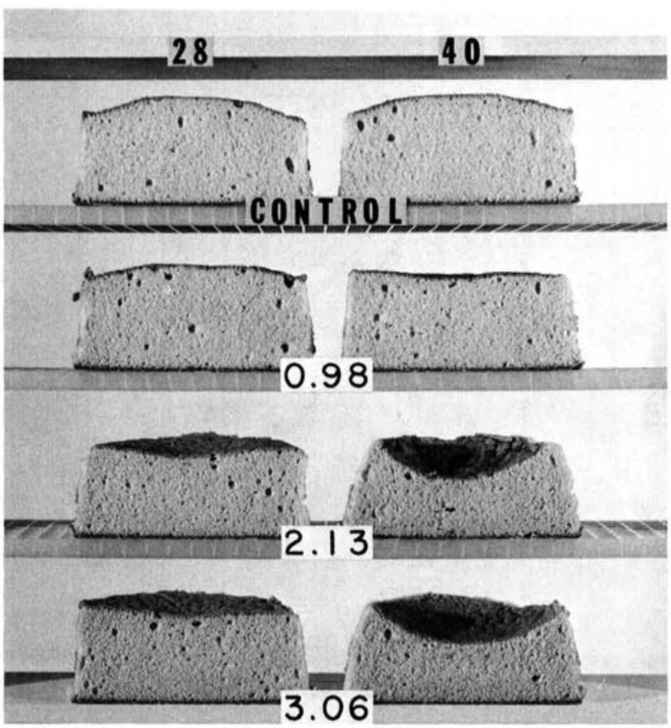

Fig. 6. Japanese-type sponge cakes (28 and 40% water absorptions) baked from 45% patent flours milled from field-sprouted wheats that contained 0–3.06 dextrinizing units of α-amylase activity per gram.

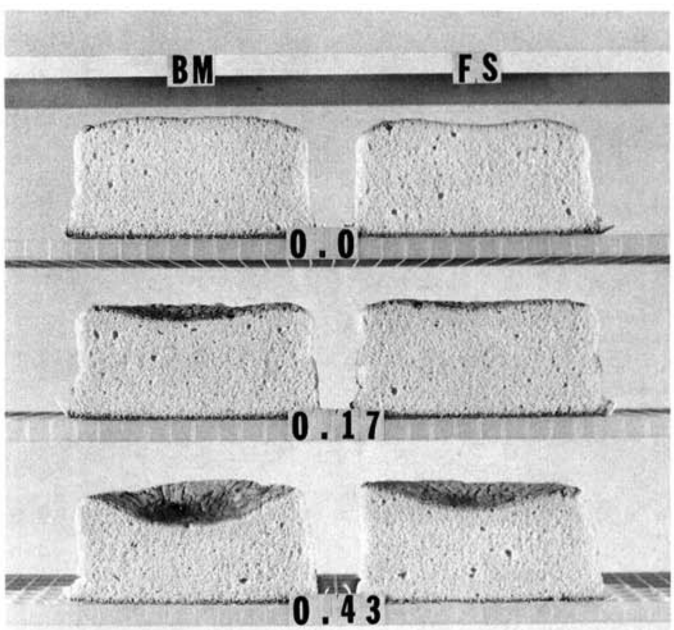

Fig. 8. Japanese-type sponge cakes (36% water absorption) baked from 45% patent flour that contained supplements (0, 0.17, and 0.43 dextrinizing units [DU] per gram) of barley malt (**BM**, 52 DU/g) and of flour (2.12 DU/g) from field-sprouted (**FS**) wheat (3 DU/g).

a field-sprouted wheat that contained only 3 DU/g (Fig. 8, right). Cake made from patent flour that contained 0.48 DU/g and was milled from a field-sprouted wheat containing 0.98 DU/g (Table I, 11% sprouted) was less adversely affected (Fig. 6, 2nd row, right) than was cake made from the control flour supplemented to 0.43 DU/g with the flour from field-sprouted wheat containing 3 DU/g (Fig. 8, bottom right). A similar but less striking comparison can be made between sponge cakes baked from flours containing 0.17 DU/g (Fig. 8) and cake baked from the flour (0.18 DU/g) milled from field-sprouted wheat containing 0.35 DU/g (Fig. 5, 2nd row, right). Thus, different levels of field sprouting should not be simulated by supplementing unsprouted wheat with a highly sprouted one, especially not with a highly malted barley.

Biochemical changes that occur in lightly sprouted grain differ quantitatively and probably qualitatively from those that occur in highly sprouted grain. For instance, the ratio of amylolytic to proteolytic enzymes may change as the grain is sprouted to increasingly advanced levels. Even the formation of new or disappearance of old compounds, including those with enzymatic activities, might occur in highly sprouted grain. Consequently, one should not assume that adding equal amounts of α-amylase from lightly and highly sprouted grains will have the same overall effects on functional properties, including performance of batters in cakemaking.

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