High α-Amylase Flours: Effect of pH, Acid, and Salt on Paste Characteristics

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ABSTRACT

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Falling number and amylograph viscosity results demonstrated the beneficial effect of reduced pH in conjunction with salt on the pastes of high α-amylase flours. A salt concentration of 1.88% distinctly counteracted the detrimental effect of increased α-amylase levels of 108, 218, and 540 SKB units/100 g of flour. At pH 4.2, the liquefying action of α-amylase was considerably retarded. The peak viscosity of pastes increased considerably as the pH was adjusted to 4.2 with either lactic or hydrochloric acid and a concentration of 1.56% salt in the flour-water slurry.

Paste characteristics of a flour depend largely on α-amylase content. The detrimental effect of sprouting in wheat on paste characteristics and baking has been documented (Kozmin 1933, Huber 1978, Ibrahim and D'Appolonia 1979, Kulp et al 1983, Lorenz et al 1983), and acidification as a means to inactivate α-amylase in wheat flour has received some attention (Fuller et al 1970, Meredith 1970, Palla and Verrier 1974, Dorfer and Koball 1980).

The protective effect of sodium chloride on the integrity of starch granules during gelatinization was reported by Ganz (1965). Noll (1985) observed that salt had no significant effect on the falling number values which, according to that author, was in agreement with the findings of Meredith (1970).

Little information is available on paste characteristics of high α-amylase flours in relation to salt level at different pH levels adjusted with organic or mineral acids. The present study investigated the effects of salt concentration, slurry pH, and type of acid used on the paste characteristics of normal and high α-amylase flours.

MATERIALS AND METHODS

Extensively grown bread wheat cultivar WL 1562, conditioned to 15.5% moisture, was milled to 72% extraction with the pneumatic Buhler laboratory mill (MLU 202). The flour contained 10.1% protein (N × 5.7), showed a diastatic activity of 220 mg of maltose/10 g (AACC 1976), and a color grade of 1.9 (Henry Simon cereal laboratory method 4.04 Edition 0276). Sprouted wheat was prepared in the laboratory by increasing the moisture content to 42% and germinating at 20°C for five days, followed by drying at 50°C and grinding to a fine powder in the Falling Number AB Kamas mill (0.8-mm sieve). Assay for α-amylase according to Perten (1966) showed an activity of 108 Sandstedt, Kneen, and Blish (SKB) units/g. High α-amylase blends of flours were prepared by incorporating the sprouted wheat powder with normal flour of the same variety. The maltose values of those blends were: 5.7, 6.8, and 8.9%, corresponding to α-amylase levels of 108, 216, and 540 SKB units/100 g of flour, respectively. In some tests, 20–40 SKB units/100 g of flour were also used.

Adjusting pH

Acetic, lactic, hydrochloric, and phosphoric acids (analytical reagent grade) at 0.1 *N* were used to adjust the pH of the slurries to 5.0 and 4.2. Lactic acid was refluxed, cooled, and used for preparing the 0.1 *N* solution.

Falling number was determined according to the ICC method (1976). Amylograph paste viscosity of normal flour was determined by using 60 g of flour in 450 ml of distilled water. For high α-amylase flours, the sample weight was increased to 100 g in 450 ml of water to obtain meaningful scale readings in the test. The flour-water suspension was thoroughly mixed before transfer to the amylograph bowl.

Effect of Salt

A typical plain bread dough consists of a flour-water system (100 g of flour + 60 ml of water) in which the amount of salt per 100 g of flour normally varies from 1.5 to 2.5%. On a dough weight basis, the amount of salt corresponds to 0.94% and 1.56%, respectively. The salt in dough is present mainly in the water phase. The effect of 0.0, 0.94, and 1.56% salt on the falling number and amylograph paste characteristics was determined.

RESULTS AND DISCUSSION

The falling number (FN) values of the normal flour with an initial slurry pH of 5.9 steadily increased as the concentration of salt was increased from 0.31 to 1.88% (Fig. 1). A similar trend, although less pronounced, was observed at pH 5.0. Without salt in the pH 5.0 slurry, adjustment with hydrochloric, orthophosphoric, acetic, or lactic acid decreased the FN of 645 sec to 483, 461, 539, or 475 sec, respectively. A drastic reduction occurred in the FN values at pH 4.2, most notably in the case of hydrochloric acid.

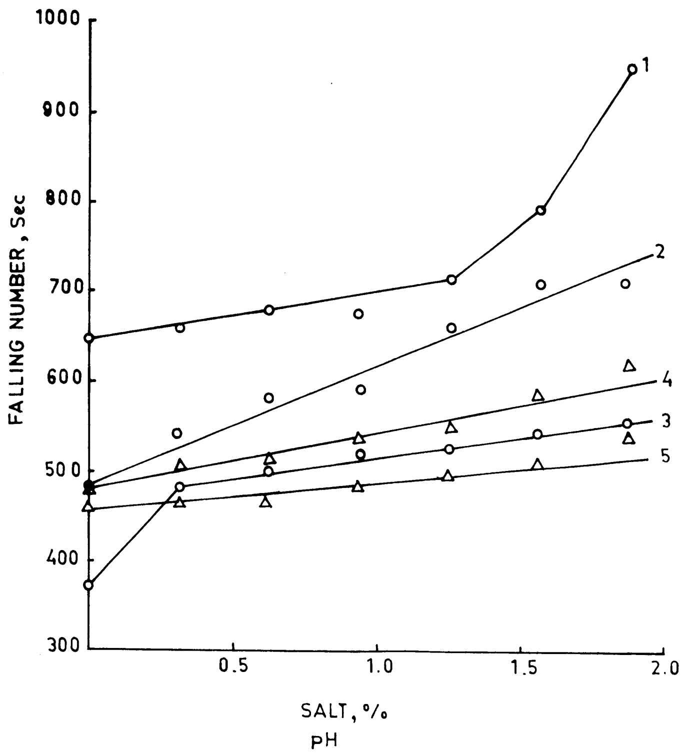

Fig. 1. Effect of pH, acid, and salt concentrations on the falling number values of normal flour. HCl (-o—o-) or lactic acid (-Δ—Δ-) used at pH levels 5.9 (**1**), 5.0 (**2** and **4**), and 4.2 (**3** and **5**).

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Effects of pH, Acid, and Salt on the Falling Number of High α-Amylase Flours

As the level of α-amylase contributed by the sprouted wheat increased, the FN values decreased from 645 sec for normal flour to 70 sec with 540 SKB units/100 g of flour (Table I). A negligible change in the FN values of the 108 SKB units/100 g of flour occurred as the pH of the slurry was decreased to 5.0 using any of the mineral or organic acids. However, the effect of salt on FN was quite pronounced even at 0.31% concentration in the pH 5.0 slurry (Fig. 2). As the salt concentration in the slurry was increased, a greater increase in FN values occurred at pH 4.2 than at pH 5.0. The range of FN values at pH 5.9 and 5.0 with 0.94 and 1.25% salt seemed to fall within the range considered desirable for breadmaking. The effect of mineral as well as lactic acid on FN values was about the same.

A drastic decrease in FN values from 645 sec with the normal flour to 88 sec with 216 SKB flour at pH 5.9 was observed. Decreasing the pH to 4.2 using either hydrochloric or lactic acid increased the FN values to 149 and 146 sec, respectively (Fig. 3). A greater effect on FN values was observed with a combination of decreased pH and salt concentrations of 0.94 and 1.56%. The effect on FN values of mineral acids and lactic acid in pH 4.2 slurries with 0.94 and 1.25% salt was significant.

The FN value of the 540 SKB units/100 g of normal flour at pH 5.9 was 70 sec. At pH 5.0, the FN values increased minimally by the addition of salt. A much greater change occurred at pH 4.2 with the flour-water slurry (Fig. 4); this is associated with greater inactivation and the protective effect of salt on starch (Ganz 1965).

Amylograph Paste Viscosity

Salt as well as pH affected the pasting temperature of the flours (Table II). As the salt concentration in the pH 5.85 normal flour slurry was increased to 1.56%, pasting temperature increased from 62.5 to 65.5° C. By decreasing the pH to 5.0, pasting temperature of the slurry without salt increased by 1.5 to 3.0° C depending upon the acid used. The pasting temperature of the pH 4.2 slurry without salt decreased by 1.0 to 2.5° C. The peak viscosities were significantly increased by the addition of 0.94 and 1.56% salt to the slurry at varied pH.

The initial peak viscosity of 740 Brabender units (BU) with normal flour was decreased by 9.5, 10.0, 7.4, and 74% when adjusted to pH 5.0 using hydrochloric, orthophosphoric, acetic, or lactic acids, respectively. A considerable increase in peak viscosity of pH 4.2 paste occurred despite its greater acidity (Fig. 5). Salt at that pH of the slurry had a significant effect on the peak viscosity of the paste. The temperature at the peak viscosity generally declined in pastes at pH 5.0 and 4.2 in the presence of 0.94% salt. The decline varied from 0.5 to 2.0° C as compared to the control pastes without salt.

The effects of pH and salt concentrations on the average peak viscosity of flour were highly significant ($P < 0.01$). Average peak

TABLE I
Effect of Sprouted Wheat Supplementation on the Falling Number of Sound Wheat Flour

Sprouted Wheat (g/100 g)	α-Amylase (SKB/100 g)	Maltose Value (%)	FN[a] (sec)
0.0	0	2.2	645
0.2	20	3.8	306
0.4	40	4.6	225
1.0	108	5.7	176
2.0	216	6.8	88
5.0	540	8.9	70

[a]Falling number.

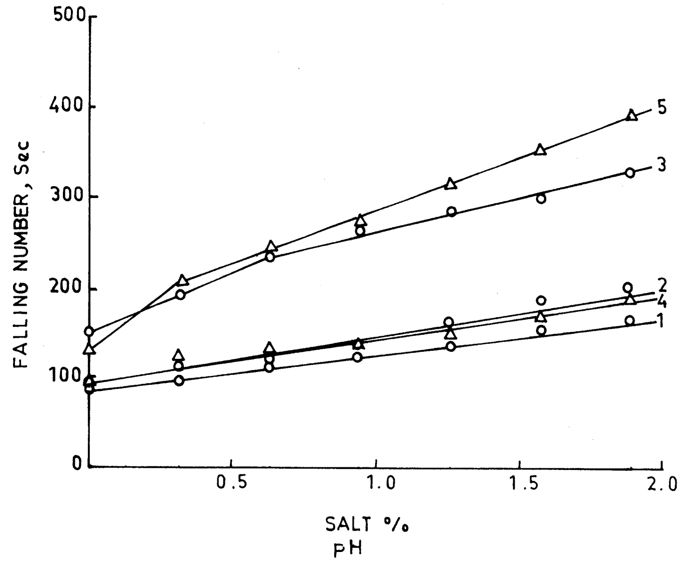

Fig. 3. Effect of pH, acid, and salt concentrations on the falling number values of 216 SKB units/100 g of α-amylase flour. HCl (-o—o-) or lactic acid (-△—△-) used at pH levels 5.9 (**1**), 5.0 (**2** and **4**), and 4.2 (**3** and **5**).

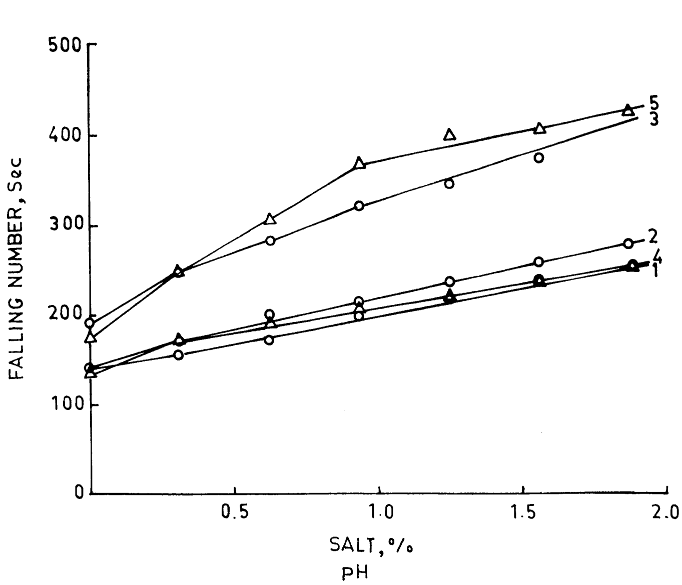

Fig. 2. Effect of pH, acid, and salt concentrations on the falling number values of 108 SKB units/100 g of α-amylase flour. HCl (-o—o-) or lactic acid (-△—△-) used at pH levels 5.9 (**1**), 5.0 (**2** and **4**), and 4.2 (**3** and **5**).

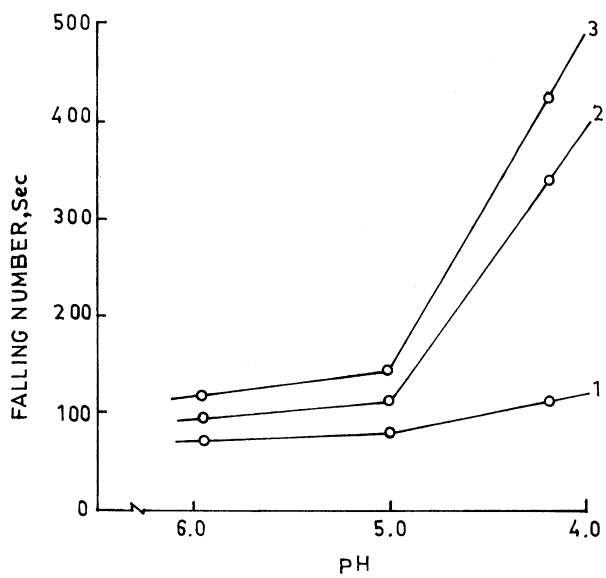

Fig. 4. Effects of pH and salt on the falling number values of 540 SKB units/100 g of α-amylase flour. Curve **1** = 0.0% salt, **2** = 0.94% salt, and **3** = 1.56% salt.

viscosity values for pH 5.85, 5.0, and 4.2 slurries were 900, 965, and 1,043 BU, as compared to 811, 960, and 1,018 BU for 0.0, 0.94, and 1.56% salt concentrations, respectively. Differences in peak viscosity resulting from the acids used for adjusting the pH were not significant. The effect of salt concentration on the paste viscosity at 95° C was statistically significant ($P < 0.01$). By and large, the pH effect on paste viscosities at 95° C was not significant.

High α-Amylase flour pastes

The amylograph test showed nil paste viscosity for the 108 SKB units/100 g α-amylase flour (60 g + 450 ml of water) at the initial pH of 5.85 and at pH 5.0 (Table III). A nominal indication of 15 and 5 BU viscosity was observed when the pH was adjusted to 4.2 with hydrochloric and lactic acids, respectively. In slurries of pH 5.85 and 5.0, incorporation of 0.94 and 1.56% salt also made no difference, and little increase in the amylograph curve from baseline (0 BU) was observed. The pH 4.2 pastes with the addition of salt developed measurable viscosities. A collated study of results in Tables II and III revealed that the pasting temperature of the higher α-amylase flour at pH 4.2 as compared to normal flour was not changed significantly when pH was adjusted with either acetic or orthophosphoric acids. The increase in paste viscosity resulting from the 1.56% salt level compared to 0.94% and using hydrochloric, orthophosphoric, acetic, and lactic acids for adjusting pH to 4.2, was 50.7, 47.4, 77.1, and 34.1%, respectively. Maximum paste viscosity of 430 BU under these conditions was caused by lactic acid treatment. The increase in viscosity was more consistent in the case of mineral acids.

Increasing the flour-water ratio (100 g of flour + 450 ml of water) showed a measurable paste viscosity of 108 SKB units/100 g of flour (Table IV). Adjusting the pH to 5.0 with hydrochloric, orthophosphoric, acetic, and lactic acids produced pastes of 120, 115, 95, and 110 BU, respectively, in the absence of salt. Corresponding values of 300, 260, 155, and 400 BU were obtained with pH 4.2 flour slurries without salt (Fig. 6). There was a tremendous increase in the paste viscosities of pH 4.2 slurries in the presence of 0.94 to 1.56% salt. The increase was more noticeable in the slurries where lactic acid was used to adjust the pH. The paste viscosity of 400 BU without salt in the pH 4.2 slurry increased by 6.71 and more than sevenfold on the addition of 0.94 and 1.56% salt, respectively. Such high increases in the viscosities of higher α-amylase flour pastes by a combination of pH and salt have technological implications for manipulating the gel structure of starch by modulating the adverse effect of higher α-amylase in the flour.

Both FN and amylograph tests have shown that one of the ways to minimize the detrimental effect of excessive α-amylase in flour is to adjust the pH and salt in the dough system. The FN test

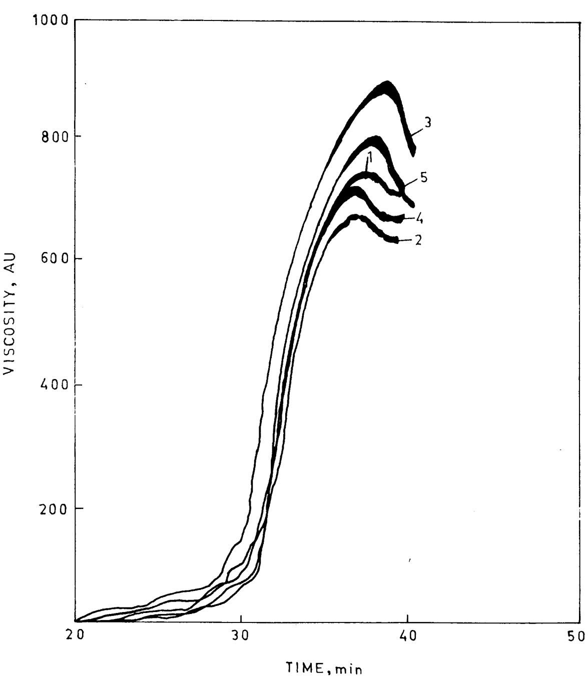

Fig. 5. Effect of pH and acids on the amylograms of WL 1562 normal flour. HCl was used at pH 5.85 (**1**), 5.00 (**2**), or 4.20 (**3**). Lactic acid was used at pH 5.00 (**4**) or 4.20 (**5**).

TABLE II
Effect of pH, Acids, and Salt on Paste Characteristics of Normal Flour (60 g of Flour + 450 ml of water)

Acid	pH	Salt (%)	PT[a] (°C)	PV[b] (BU)	Increase in PV[c] (%)	PVT[d] (°C)	V[e] at 95°C (BU)	Increase in V[c] (%)
None (control)	5.85	0.00	62.5	740	···	90.8	700	···
	5.85	0.94	64.5	940	27.0	90.8	780	11.4
	5.85	1.56	65.5	1020	37.8	91.0	845	20.7
Hydrochloric	5.0	0.00	65.0	670	···	90.8	640	···
	5.0	0.94	65.5	1060	58.2	89.0	850	32.8
	5.0	1.56	66.5	1130	68.7	90.8	880	37.5
	4.2	0.00	60.0	890	···	90.0	770	···
	4.2	0.94	65.5	1125	26.5	90.5	920	19.5
	4.2	1.56	66.5	1175	32.0	90.8	940	22.1
Orthophosphoric	5.0	0.00	65.5	665	···	90.0	630	···
	5.0	0.94	65.5	1050	57.9	89.5	840	33.3
	5.0	1.56	66.0	1170	75.9	90.5	920	46.0
	4.2	0.00	61.0	860	···	90.5	750	···
	4.2	0.94	65.0	1125	30.8	89.5	860	14.7
	4.2	1.56	66.0	1165	35.5	90.5	920	22.7
Acetic	5.0	0.00	64.5	685	···	91.5	640	···
	5.0	0.94	64.5	1085	58.4	89.5	855	33.6
	5.0	1.56	66.0	1150	67.9	90.5	920	43.8
	4.4	0.00	61.5	750	···	91.5	690	···
	4.4	0.94	64.5	1105	47.3	89.8	855	23.9
	4.4	1.56	66.0	1200	60.0	90.8	935	35.5
Lactic	5.0	0.00	64.0	715	···	90.5	660	···
	5.0	0.94	64.5	1040	45.5	89.0	840	27.3
	5.0	1.56	66.0	1155	61.5	91.0	910	37.9
	4.2	0.00	61.0	800	···	90.5	680	···
	4.2	0.94	64.5	1135	41.9	89.0	850	25.0
	4.2	1.56	66.0	1180	47.5	91.0	880	29.4

[a] Pasting temperature.
[b] Peak viscosity (in Brabender units).
[c] As compared to viscosity without salt at each pH.
[d] Peak temperature.
[e] Viscosity at 95°C.

TABLE III
Effect of pH, Acids, and Salt on the Paste Characteristics of High α-Amylase (108 SKB) Flour (60 g of Flour + 450 ml of water)

Acid	pH	Salt (%)	PT[a] (°C)	PV[b] (BU)	PVT[c] (°C)	V[d] (BU)
None (control)	5.85	0.0–1.56	···	0	···	0
Hydrochloric	4.2	0.00	63.5	15	72.0	0
	4.2	0.94	69.0	365	88.0	200
	4.2	1.56	72.0	550	90.0	375
Orthophosphoric	4.2	0.00	···	0	···	0
	4.2	0.94	69.0	380	88.0	200
	4.2	1.56	73.5	560	89.5	375
Lactic	4.2	0.00	64.5	5	67.5	0
	4.2	0.94	71.0	425	89.0	275
	4.2	1.56	74.5	570	89.0	400
Acetic	4.4	0.00	···	0	···	0
	4.4	0.94	70.5	350	89.0	195
	4.4	1.56	73.5	620	89.5	430

[a] Pasting temperature.
[b] Peak viscosity (in Brabender units).
[c] Peak viscosity temperature.
[d] Viscosity at 95°C.

(Hagberg 1960, Perten 1964) has been accepted for grading of wheat for α-amylase activity. Factors influencing the routine FN test have been examined by several workers (Perten 1967, Tipples 1971, Tara and Bains 1976). For controlling the α-amylase supplements for normal wheat flour, the amylograph is extensively used by the baking industry. The protective effect of sodium chloride on the integrity of starch granules resulting in increased gelatinization temperature was reported by Ganz (1965) using 2.5% salt in the amylograph test, which far exceeded salt content of bread doughs. The test uses a controlled temperature increase of 1.5° C/min during the cooking cycle of flour-water slurry in the amylograph bowl. However, the flour-water ratio in this test deviates considerably from the flour-water proportion characterizing a bread dough. The α-amylase dextrinizing action in the test continues over a longer time than in the FN test, in which the flour-water ratio is perceptibly higher than that used in the amylograph test. The time required for flour starch gelatinization in the FN test more closely approximates conditions of baking in the oven compared to the amylograph system. A flour with a rating of 108 SKB units/100 g produced a minimal viscosity level of 65 BU, which was inordinately increased at pH 4.2 and further increased with 0.94 and 1.56% salt in the slurry. This effect was more marked under those conditions causing greater inactivation of the enzyme in a more dilute system as compared to the values of FN test at the same pH and salt concentrations. The amounts of salt used by Meredith (1970) and Noll (1985) in the FN and amylograph tests were considerably below those used by the present authors simulating salt contents in bread doughs. Differences in the paste viscosities of Australian wheats have been related to their α-amylase status as reported by Moss (1967). Poor relationship between the FN values and amylograph results for English and Australian wheats was reported by Hutchinson (1966). Finney (1985) related α-amylase activity with the FN number values of 12 varieties of U.S. wheats. The higher amylograph viscosity of flour at pH 4.2, especially of sprouted wheat blends, was attributed to the greater inactivation of the enzyme in a more dilute system as compared to the more concentrated flour-water slurry used in the FN test.

TABLE IV
Effect of pH, Acids, and Salt on Paste Characteristics of High α-Amylase (108 SKB units/100 g) Flour (100 g of flour + 450 ml of water)

Acid	pH	Salt (%)	PT[a] (°C)	PV[b] (BU)	Increase in PV[c] (Times)	PVT[d] (°C)	V[e] (BU)
None (control)	5.85	0.00	62.5	65	···	68.5	0
	5.85	0.94	63.0	260	4.00	71.0	0
	5.85	1.56	63.5	370	5.69	72.0	0
Hydrochloric	5.0	0.00	58.5	120	···	65.0	0
	5.0	0.94	63.0	360	3.0	71.0	5
	5.0	1.56	63.5	550	4.6	73.5	80
	4.2	0.00	58.5	300	···	65.2	0
	4.2	0.94	62.2	1155	3.85	84.8	480
	4.2	1.56	63.5	1690	5.63	87.0	680
Orthophosphoric	5.0	0.00	59.5	115	···	67.5	0
	5.0	0.94	63.0	350	3.04	71.2	10
	5.0	1.56	63.8	535	4.65	72.8	60
	4.2	0.00	58.0	260	···	67.0	0
	4.2	0.94	62.5	995	3.83	84.8	585
	4.2	1.56	63.5	1600	6.15	86.5	600
Acetic	5.0	0.00	60.0	95	···	66.8	0
	5.0	0.94	63.5	335	3.52	72.0	0
	5.0	1.56	64.0	535	5.62	73.0	70
	4.4	0.00	59.0	155	···	66.0	0
	4.4	0.94	62.2	1195	7.71	84.8	470
	4.4	1.56	64.0	1865	12.03	87.5	1100
Lactic	5.0	0.00	59.5	110	···	65.5	0
	5.0	0.94	63.0	370	3.36	71.0	5
	5.0	1.56	64.5	520	4.73	74.5	80
	4.2	0.00	58.0	400	···	68.2	5
	4.2	0.94	61.5	2685	6.71	86.0	875
	4.2	1.56	63.0	>2800	>7.00	···	···

[a] Pasting temperature.
[b] Peak viscosity (in Brabender units).
[c] As compared to viscosity without salt at each pH.
[d] Peak viscosity temperature.
[e] Viscosity at 95° C.

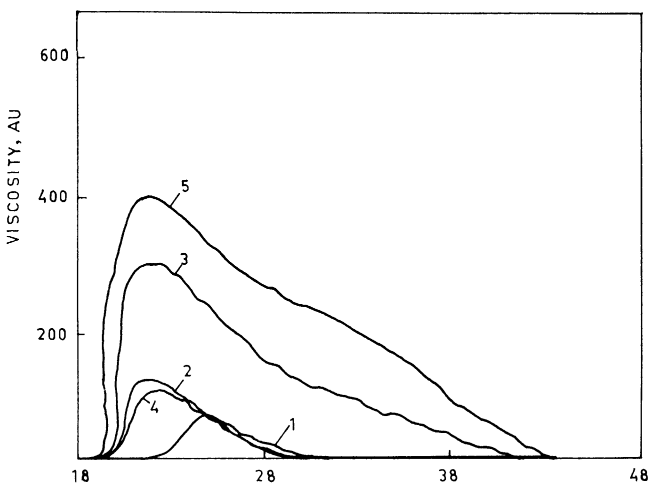

Fig. 6. Effect of pH and acids on the amylograms of high α-amylase (108 SKB units/100 g) flour (100 g + 450 ml of water). HCl was used at pH 5.8 (**1**), 5.00 (**2**), or 4.20 (**3**). Lactic acid was used at pH 5.00 (**4**) or 4.20 (**5**).

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