Effect of Ingredients on Continuous Bread-Crumb Pasting Characteristics[1]

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ABSTRACT

A laboratory model Wallace and Tiernan continuous baking unit was used to investigate the effect of ingredients on bread-crumb pasting characteristics. Effects of broth time and developer speed on the crumb also were examined. Besides visual examination of the crumb, the Brabender amylograph was used to measure the pasting properties of the different bread crumbs. The initial temperature at which a rise was noted in the amylograph curve increased at high sugar levels, while the peak height at 95°C. decreased. This decrease was noted also with high levels of nonfat dry skim milk. Peak height was higher for the bread crumbs containing less water in the bread formula. High and low levels of yeast resulted in high and low peak heights, respectively. Different amounts of oxidation or shortening did not affect the peak height of the bread crumb appreciably. An increase in the peak height of the crumb was noted as the broth time was increased.

The effect of different additives on the pasting properties of wheat starch has been discussed recently by D'Appolonia (1). In addition, this worker studied the effect of ingredients commonly used in bread production on starch gelatinization properties as measured by the amylograph.

The present study was a continuation of previous work (1) in an attempt to further elucidate the role of various baking ingredients on starch pasting properties.

Whereas the initial investigation (1) was conducted directly on starch slurries, emphasis in the present study was placed on the effect of the baking ingredients on the pasting properties of the bread crumb. Although constituents other than starch are present in the crumb and changes have occurred in the starch during baking, it was felt that useful information could be obtained by investigating the pasting properties of the bread crumbs.

MATERIALS AND METHODS

Flour Source

A composite lot of hard red spring wheat flour milled on a pilot Miag mill was used for the bread-baking. The flour contained 14.0% protein (14% m.b.) and gave a farinograph peak time of 5.5 min. and farinograph absorption of 66.0% (14% m.b.).

Bread-Baking

A Wallace and Tiernan Laboratory model continuous baking unit (Baker Process Co., Belleville, N. J.) was used to produce the continuous bread (2). The baking formula used for the control loaf, with percentage of ingredients based on flour weight,was as follows:

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Flour	5,000 g.	Yeast food	0.5%
Sugar	8.0%	Yeast	2.75%
Salt	2.25%	Water	69.0%
Milk	2.0%	Potassium bromate	60 p.p.m.
Shortening	3.25%	Potassium iodate	12 p.p.m.

The method itself used for the bread production has been described previously (2). The optimum developer speed for the flour utilized was 130 r.p.m.

Variation in Baking Formula and Procedure

To ascertain the effect of the baking ingredients on the pasting properties of the starch in the crumb of the bread, several experiments were conducted. Each ingredient or variable was studied individually while keeping the remainder of the formula and procedure constant. Table I shows the level of each ingredient investigated as well as the different broth times and developer speeds.

Evaluation of Bread Crumb by Brabender Amylograph

Two hours after removal of the bread from the oven, the crumb was separated from the crust, freeze-dried, and ground on a Wiley mill to pass a 60-mesh sieve. Sixty grams (d.b.) of the freeze-dried bread crumb was slurried in 350 ml. distilled water with a Waring Blendor and then transferred to the amylograph bowl. An additional 100 ml. of distilled water was used to rinse the Blendor, and this also was transferred to the bowl.

The bread-crumb slurry was heated uniformly from 25° to 95°C., held at 95°C. for 15 min., and then cooled uniformly for 30 min. to 50°C. The measurements obtained were pasting temperature, peak height at 95°C., peak height at 95°C. after 15 min. hold, and peak height at 50°C.

Analysis of Individual Free Sugars in Bread Crumb

A Technicon Sugar AutoAnalyzer was used to measure the various amounts of sucrose, maltose, lactose, fructose, and glucose in the bread crumb. The procedure utilized has been described previously (3) with the exception of the gradient elution system and colorimetric reaction. Method I and the cysteine sulfuric acid reagent of Hough et al. (4) were employed.

TABLE I. LEVELS OF INGREDIENTS AND VARIABLES STUDIED

Sugar %	Salt %	Nonfat Dry Skim Milk %	Shortening %	Yeast %	Absorption %	Oxidation Bromate:Iodate p.p.m.:p.p.m.	Broth Time hr.	Developer Speed r.p.m.
0	0	0	0	1	63	0:0	0.75	100
2	1.25	1	1.25	2.75	66	60:48	1.50	130
4	2.25	2	3.25	5	69	60:0	2.50	160
6	3.25	4	5.25		72	180:48	3.50	190
8		6			75	0:12	4.50	220
12						180:12		250
16						60:12		
20								

RESULTS AND DISCUSSION

Effect of Ingredients, Broth Time, and Developer Speed on Bread Produced: Sugar (Sucrose)

As the amount of sugar was increased from 8%, which represented the control loaf, the crust color became darker while the crumb color became grayish and the grain more open. As the sugar level was decreased from 8 to 0% there was a reduction in loaf volume, a caving-in of the side walls, an increase in paleness of the crust, and a more dense crumb. As the sugar level was decreased, the dough at the extrusion became stiffer.

Each ingredient was studied individually while all other factors were maintained constant. Some of the adverse effects noted in some of the bread could have been eliminated by altering certain conditions or varying other ingredients. This was not done, however, because of the intent of the study.

Salt (Sodium Chloride)

As the amount of salt was decreased from the control loaf of 2.25% the dough at the extruder became quite slack and showed the properties of overdevelopment. At the high salt level, the dough appeared firm and underdeveloped during extrusion. At the low level of salt or in the absence of salt, the bread produced had high side walls, increased loaf volume, and a very open, coarse, yellowish gray crumb. The crumb of the bread with the higher salt level was quite close and white in appearance.

Nonfat Dry Skim Milk

Levels of nonfat dry skim milk below the control loaf of 2% produced bread of acceptable internal and external appearance. The main effect was a paler crust color. The bread crumb, however, was uniform, close, and white in appearance. Bread containing milk levels higher than the control was of inferior quality. The crust color was excessively dark and the crumb was open and yellowish in appearance.

Shortening

The shortening used for the baking was a liquid shortening obtained from Procter and Gamble (PG7N).

Low levels of shortening in the bread or the absence of it resulted in a flat, dark top crust, and reduced volume. The dough showed the properties of overdevelopment during extrusion. Without shortening, the bread crumb was dense and grayish in color. The highest level of shortening utilized produced bread similar in appearance to the control.

Yeast

The bread produced using 1% yeast in the formula had a low loaf volume and an inferior grain and texture. The crumb was very compact and heavy. The use of 5% yeast resulted in bread with larger loaf volume compared to the control and an open, aerated crumb.

Absorption

No extreme differences were noted in the external or internal appearance of bread produced at the different absorption levels investigated. Loaves containing the high absorption did produce a grayish crumb color. Peak time, which is defined as the time in seconds required to reach the peak on the continuous unit recorder, increased with the higher absorption levels, indicating that a higher developer speed should have been used for these loaves.

TABLE II. EFFECT OF SUGAR (SUCROSE) ON BREAD-CRUMB PASTING PROPERTIES

Sugar Level %	Pasting Temperature °C.	Peak Height at 95° C. B. U.	15-min. Height B. U.	Height at 50° C. B. U.
0	82.0	300	350	740
4	82.0	410	520	950
6	83.0	400	490	920
8 (Control)	83.5	320	430	850
12	83.5	270	340	730
16	84.0	210	280	590
20	86.5	150	210	470

Oxidation

Bread containing high or low levels of oxidation showed properties of under- or overdevelopment, respectively. Some of the faults observed would have been eliminated by altering the developer speed; however, as mentioned previously, this was not the intent of the study.

Broth Time and Developer Speed

One of the major effects of broth time on the bread produced was on the crust color. Short and long broth times resulted in dark and pale crust color, respectively. The longer broth times also produced a white crumb color and a closer grain as compared to the control. The main effect of developer speed was on the external appearance of the bread.

Effect of Ingredients, Broth Time, and Developer Speed on Bread Crumb Amylograms and Free Sugars: Sugar (Sucrose)

Table II shows the effect of various levels of sugar in the bread formula on the pasting properties of the bread crumb. As the sugar level was increased, the pasting temperature also increased. The peak heights, as indicated by the values obtained at 95°C., the 15-min. hold period, and the height at 50°C.,increased from 0% sugar to 4% sugar, but decreased thereafter.

It can be speculated that the lower the peak height for the bread-crumb amylograms, the greater the amount of starch gelatinization that has taken place during bread-baking. It would appear that the higher levels of added sugar aided starch gelatinization during baking. However, a higher peak height for the 0 level of sugar would have been expected.

Measurement of the individual free sugars, maltose, lactose, fructose, and glucose, in the bread crumbs containing the different added levels of sugars in the formula showed that fructose and glucose underwent the major changes (Table III). Only small variations were noted in the amounts of maltose with the different levels of added sugar. Values for a peak obtained from the sugar analysis chromatogram which was eluted in the same position as the sucrose standard and is designated as

TABLE III. EFFECT OF SUCROSE LEVEL IN BREAD FORMULA ON FREE SUGARS IN CRUMB[a]

Sugar Level %	Unknown[b] %	Maltose %	Lactose %	Fructose %	Glucose %
0	0.14	2.86	1.05	0.09	0.13
4	0.22	2.71	0.85	0.31	0.13
8 (Control)	0.22	2.38	0.83	2.15	0.56
12	0.20	2.31	1.04	3.39	1.13
16	0.21	2.31	0.88	4.99	2.37

[a]Values expressed on a dry basis.
[b]Values determined using the sucrose standard curve.

an unknown in Table II were essentially constant. The values for this unknown were determined using the sucrose standard curve. Work is currently underway to determine whether this sugar is in fact sucrose or some other compound. It has been reported (5,6) and generally accepted that sucrose is hydrolyzed almost immediately, upon mixing by the invertase enzyme, into glucose and fructose. Work by Lee and Liau (7), using radioactive tracers, however, has indicated that some residual sucrose was present in their crumb extract. Evidence was also obtained by these workers indicating that glucose and fructose derived from the sucrose could undergo degradation as well as polymerization to disaccharides and oligosaccharides, during the baking of bread. The increase in the amounts of fructose and glucose in the bread crumbs with the increase in added sugar may have contributed to the amylogram results obtained.

Previous results in this laboratory (1) revealed that as the sugar content was increased in a starch slurry, the peak height during gelatinization as measured by the amylograph also increased. It is difficult to attempt an explanation of the data obtained using a starch slurry with the results using bread crumb. One additional factor must be kept in mind. All samples of bread crumb analyzed with the amylograph were weighed on a constant weight basis. Variations in the amount of starch due to the various levels of sugar or other ingredients were not considered so that the amount of starch per given weight of bread crumb did vary and could have affected the results.

Figure 1 shows the amylograph curves obtained for the crumbs containing 0, 4, 8, 12, and 20% sugar in the bread formula. In addition to the information given in Table II, this figure illustrates that a difference also occurs during the cooling of the curve with the different sugar levels.

Salt (Sodium Chloride)

Little difference was noted in the peak height of the bread crumb amylograms containing the levels of salt studied. There was, however, an increase in pasting temperature as the salt level was increased, a result which has been reported previously with starch gelatinization in the presence of salt (1).

Nonfat Dry Skim Milk

With increases in the amount of nonfat dry skim milk in the baking formula, a pattern in the amylograph curves similar to that obtained with the increase in sugar levels resulted (Table IV). As was the case with the sugar it would appear that the higher levels of milk resulted in more starch gelatinization during the baking.

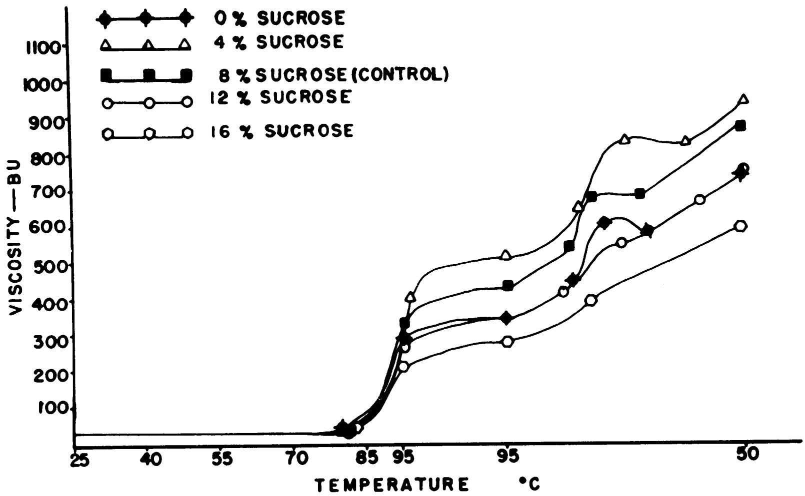

Fig. 1. Effect of different sucrose levels in the baking formula on bread-crumb amylograms.

TABLE IV. EFFECT OF NONFAT DRY SKIM MILK ON BREAD-CRUMB PASTING PROPERTIES

Milk Level %	Pasting Temperature °C.	Peak Height at 95° C. B. U.	15-min. Height B. U.	Height at 50° C. B. U.
0	82.0	390	460	880
1	83.0	370	460	880
2 (Control)	83.5	320	430	850
4	83.5	300	390	790
6	85.0	260	340	770

Shortening and Oxidation

No large differences were noted in the pasting properties of the bread crumb containing the different levels of shortening or different amounts of oxidation. It has been reported (1) that in the presence of high levels of potassium bromate or potassium iodate as compared to the amount used in bread, an increase in the peak viscosity of starch resulted. Due to chemical reactions involved in baking or because of the small amounts of oxidation used, this effect was not noted. The highest level of shortening used (5.25%) did increase pasting temperature and reduce peak height slightly.

Yeast

The amount of yeast used in the bread formula had a pronounced effect on the pasting properties of the starch in the bread crumb. With the low level of yeast the peak height at 95°C., the 15-min. hold height, and the height at 50°C. were lower than the control crumb, whereas the high level of yeast produced the reverse results (Table V). The low yeast level caused less fermentation, with the net result being that more sugars were available at the baking stage. A greater degree of fermentation and conversion of sugars took place with the high yeast level, thereby

TABLE V. EFFECT OF YEAST ON BREAD-CRUMB PASTING PROPERTIES

Yeast Level %	Pasting Temperature °C.	Peak Height at 95° C. B. U.	15-min. Height B. U.	Height at 50° C. B. U.
1	83.5	230	300	630
2.75 (Control)	83.5	320	430	850
5	81.5	460	580	1,100

TABLE VI. EFFECT OF ABSORPTION ON BREAD-CRUMB PASTING PROPERTIES

Absorption Level %	Pasting Temperature °C.	Peak Height at 95° C. B. U.	15-min. Height B. U.	Height at 50° C. B. U.
63.0	83.5	390	475	910
66.0	83.5	370	460	880
69.0 (Control)	83.5	340	450	880
72.0	82.5	330	410	800
75.0	82.0	300	380	770

TABLE VII. EFFECT OF BROTH TIME ON BREAD-CRUMB PASTING PROPERTIES

Broth Time hr.	Pasting Temperature °C.	Peak Height at 95° C. B. U.	15-min. Height B. U.	Height at 50° C. B. U.
0.75	83.5	280	320	690
1.50	83.5	260	300	670
2.50 (Control)	83.5	330	420	850
3.50	83.0	480	600	1,020
4.50	83.5	440	600	1,040

leaving less residual sugars during the baking. Measurement of the individual free sugars in the bread crumbs containing the different amounts of yeast revealed that higher amounts of glucose and fructose were present in the crumbs containing the 1% yeast when compared to the control crumb, whereas lower amounts were present in the 5% yeast-containing crumb. The results obtained with the yeast studies would therefore be in agreement with the sugar and milk studies.

Absorption

During bread-baking it is known that gelatinization of the starch takes place but that the extent of gelatinization is restricted because of the limited amount of water available. Table VI shows data for the pasting properties of the bread crumbs obtained using different amounts of water in the bread formula. As the baking absorption increased, the amylogram viscosity decreased. These results would indicate that as the water content in the baking formula was increased more gelatinization of the starch took place during baking. Figure 2 shows graphically the effect of different baking absorptions on the bread-crumb amylograms.

Broth Time and Developer Speed

Broth time is the time in hours that the yeast, yeast food, sugar, salt, milk, and

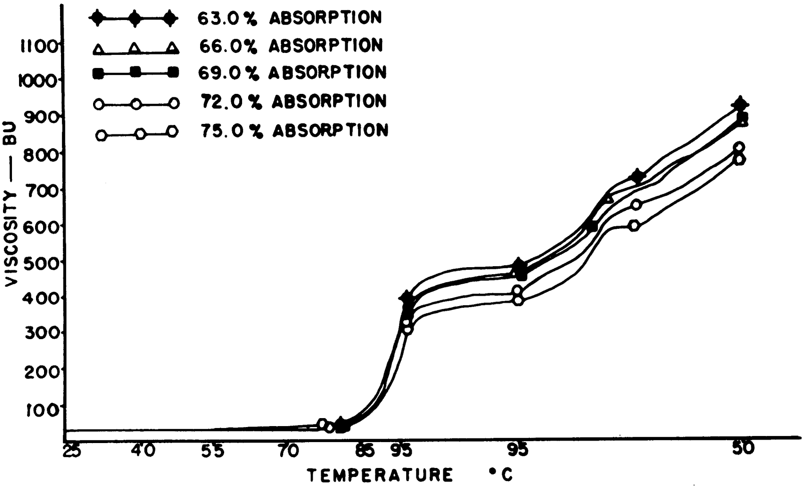

Fig. 2. Effect of different absorption levels in the baking formula on bread.

TABLE VIII. EFFECT OF BROTH TIME ON FREE SUGARS IN CRUMB[a]

Broth Time hr.	Unknown[b] %	Maltose %	Lactose %	Fructose %	Glucose %
0.75	0.16	2.71	0.93	3.05	1.25
1.50	0.20	2.53	1.05	2.79	0.93
2.50 (Control)	0.23	2.49	0.84	2.24	0.53
3.50	0.24	2.51	0.91	1.27	0.25
4.50	0.31	2.88	1.06	1.14	0.16

[a]Values expressed on a dry basis.

[b]Values determined using the sucrose standard curve.

water are allowed to agitate prior to incorporation of the flour at the premix stage. This factor had a definite effect on the gelatinization properties of the bread crumb.

A low peak height or viscosity occurred in the bread crumb with the short broth time, whereas the reverse took place with the long broth times (Table VII). These results would be in agreement with those obtained with the yeast studies. A short broth time would reduce the amount of fermentation thereby leaving more sugars available at the baking stage. A long broth time, however, would result in less sugars at the baking stage. Measurement of the individual free sugars (Table VIII) indicates that fructose and glucose contents decreased while the sugar listed as unknown in Table VIII which was eluted in the same position as sucrose as mentioned previously increased as the broth time increased.

The pasting properties of the bread crumb made using the different developer speeds were essentially unchanged.

The results of this investigation have indicated that certain ingredients used in bread production will affect the gelatinization of starch that takes place during baking.

Sugar, nonfat dry skim milk, and ingredients or factors directly involved in fermentation such as yeast and broth time all showed a pronounced effect.

The baking absorption, as was expected, also had an effect on the extent of starch gelatinization occurring during baking.

Because of the multiplicity of reactions and interreactions that occur during the baking process as well as the presence of biochemical constituents other than starch, it is difficult to give a precise explanation of the results obtained in this study.

The use of conventional bread also may have provided additional interesting information.

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