COMPARISON OF RESIDUAL SUGAR AND FIRMING CHARACTERISTICS OF WHITE PAN BREADS MADE BY SPONGE DOUGH AND SHORT-TIME DOUGH PROCESSES

by

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GENERAL INTRODUCTION

The sponge dough process is the most popular baking method used today by the U. S. baking industry, especially by the large wholesale bakers, in the manufacture of white pan bread, which is the major product of American bakeries. The popularity of the sponge dough process is due to the greater processing tolerance of the procedure and to the flavor, texture and longer shelf life of the bread (Pyler 1973; Dubois 1981). The short-time dough processes are used by retail bakers and food service operators to avoid night and early morning work and to reduce labor costs. These methods are not common to large bakers due to the poorer processing tolerance of the procedure and to the poorer flavor, texture and shelf life of the bread (Ponte and Reed 1982).

Generally, the firming rate of the bread made by the sponge dough process is said to be slower than the one made by short-time dough process. The difference in firming rate between these two different baking processes is said to be influenced by the differences of bread formula and fermentation time. However, no study has apparently been done so far to obtain conclusive data.

Therefore, this study was undertaken to measure more precisely the firming characteristics of white pan breads made by the sponge dough process and short-time dough processes as well as the swelling properties of the bread crumb starch.

Short-time dough bread was made with two mixing procedures: conventional and high-speed. The high-speed mixing process has been popular in England and is referred to as the Chorleywood bread process (Elton 1965; Chamberlain 1978). Though British bread differs considerably in formulation from American white pan bread (Ponte 1978), the formulation of American white pan bread was used in this study for an accurate comparison of firming characteristics of bread crumb made by conventional mixing method and high-speed mixing methods. Formulation of the

doughs made by these different baking methods was identical, except for yeast and oxidant (potassium bromate), to permit a direct comparison of the processes. Also, the influence of specific volume and bread moisture losses on bread crumb firmness measurements was minimized for the same reason.

Prior to the comparative bread firming study, residual sugar distribution of white pan breads made by these different baking methods was studied. The resulting data were helpful in establishing formulations for the bread produced by the different methods. Little work has been published on residual bread sugar distribution. This residual sugar study was separated from the firming study to simplify this thesis, though these two topics are related as noted.

Thus, the purposes of this study are summarized as follows:

1. To compare the residual sugar distribution of white pan bread crumb made by the sponge dough process, and the short-time dough process made by both conventional and high-speed mixing methods.

2. To compare the firming characteristics of white pan bread crumb made by the sponge dough process, and the short-time dough process made by both conventional and high-speed mixing methds.

LITERATURE REVIEW

Residual Bread Sugars and Their Effect on Crumb Firmness

Different sugar types and amounts in the bread formulation influence yeast fermentation, thus altering the fermentation products produced during dough fermentation and residual sugars in the final loaf. This will significantly affect bread flavor and texture. For this reason it is important to trace individual sugars during breadmaking as a function of the baking method. Little work has been done in this area.

Early investigators have studied the effect of sugars on bread firming, showing that sugars have only a small improving effect on bread firming (Edelmann et al. 1950; Barham and Johnson 1951; Bohn 1954). No recent study has been done to relate sugar usage to the keeping properties of bread. Some work has been done to trace individual sugars during the baking process in relation to yeast action (Koch et al. 1954; Piekarz 1963; Tang et al. 1972; Ponte and Reed 1982).

Under the anaerobic conditions prevailing in a dough, yeast ferments sugars to ethanol and carbon dioxide. These sugars are the monosaccharides, glucose and fructose, and the disaccharides, sucrose and maltose. Lactose is not fermented by baker's yeast. Starches and dextrins are not fermented by yeast but may serve as sources of fermentable sugers if they are hydrolyzed by amylases (Ponte and Reed 1982).

Koch et al. (1954) reported that yeast ferments glucose preferentially, followed by fructose and maltose. Ponte and Reed (1982) showed that in the sponge dough process where both glucose and fructose were present in the dough, glucose was more rapidly fermented and maltose levels were low (0.7 to 0.9), if no maltose was added as a part of the sweetener system. They also studied the residual bread

sugars in laboratory-produced sponge dough bread made with several different sweetener types.

Koch et al. (1954) traced glucose, fructose and maltose in a straight dough process. When 5% sucrose and 3% yeast were used in the formula, glucose was fermented rapidly, fructose was fermented slower than glucose, and maltose increased gradually with time. Then 0.14% glucose, 0.79% fructose and 1.50% maltose were left in the final loaf.

Tang et al. (1972) traced the sugars in a sponge dough process, made with 5% sucrose and 2.5 yeast. In the sponge, native glucose and fructose were fermented rapidly. None were left in the sponge after two hours fermentation. Maltose increased to 1.3% after two hours fermentation, then decreased rapidly to 0.1% at four hours. In the dough, glucose, fructose and maltose decreased faster in this order and 0.7% glucose, 1.2% fructose and 0.2% maltose were left in the final loaf. Similar results were obtained by Koch et al. (1954).

Piekartz (1963) traced the sugars in a liquid pre-ferment process. When corn syrup (3.9% maltose and 4.1% glucose) was used in the formula, glucose was rapidly fermented throught the fermentation period. Maltose was fermented slowly in the pre-ferment. In the dough, the level of maltose actually increased because the rate of maltose formation from starch was greater than rate of fermentation. There, the final bread contained hardly any glucose but almost 4% maltose.

Bread Staling

Bread staling, according to a widely accepted definition by Bechtel et al. (1953), is "a term which indicates decreasing consumer acceptance of bakery products by changes in the crumb other than those resulting from action of spoilage organisms."

Bread staling involves changes in both crumb and crust. Crumb staling is a

more complex and physiochemical phenomena than that of crust staling. Dry and crisp crust in its fresh state becomes soft and leathery upon staling, due to moisure migration from the crumb and the air to the crust. On the other hand, crumb staling can occur without loss of moisture (Boussingault 1852).

Bice and Geddes (1953) listed a number of changes as characteristics of crumb staling: (1) changed taste and aroma, (2) increased hardness of crumb, (3) increased capacitance of crumb, (4) increased crumbliness of crumb, (5) increased starch crystallization of crumb, (6) decreased absorptive capacity of crumb, (7) decreased susceptibility of crumb to beta-amylase, and (8) decreased soluble starch content.

Crumb staling has commonly been measured as a function of changes in crumb firming (Lineback 1984). However, a recent study (Dragsdorf and Varriano-Marston 1980) reported that starch crystallinity and bread firming are not synonymous, when alpha-amylase is utilized as a dough supplement.

Though crumb starch is considered to play the major role in crumb staling, many other factors such as protein, pentosans, flour lipids, moisture migration between starch and gluten, the ratio of starch to protein and baking ingredients have to be considered as shown in several studies (Willhoft 1973; Zobel 1973; Maga 1975; Kim and D'Appolonia 1977a-e).

Effect of Processing Method on Bread Staling

It is very difficult to discuss only the effect of processing method on bread staling because the formulation, operational steps and certain product characteristics have to be considered along with the processing method. However, Kulp (1979) reported that freshness was retained longer in bread made by the continuous mixing process, sponge dough process and brew process, straight dough process and

the short-time dough process, in that order. This seems to correspond with general thinking within the baking industry.

D'Appolonia (1984) explained the effect of the longer fermentation process on staling as follows: as a consequence of yeast fermentation, the gluten undergoes changes, the net overall effect being referred to as maturation or conditioning--such as changes in the gluten structure may well affect the degree of softness in the bread crumb as well as the rate of crumb firming.

The limited enzymatic activity in the short-time process may also affect the rate of crumb firming. The crumb structure of the bread prepared by the continuous mixing process is quite different from that produced by the conventional process, which may affect the rate of crumb firming.

Generally, it is said that the high-speed mixing process produces bread that is firmer and stales faster than that made by conventional processes, but no precise academic study appears to have been done to confirm this observation. Also, little work has been done so far to compare the effect of processing method on bread.

Role of Starch in Bread staling

As bread stales, the amount of soluble starch decreases (Katz 1930). Linndet (1902) named this decrease in the solubility of starch "retrogradation." Schoch and French (1947) reported that the decrease in soluble starch during staling of bread was due to "progressive spontaneous aggregation" of amylopectin and that amylose had no significant role in crumb firming, since it was insoluble and was already retrograded during baking and cooling of the bread. Also, Kim and D'Appolonia (1977c and 1977d) showed that the soluble starch was predominantly amylopectin and that the amylose content decreased largely during the first day with only small changes occurring after that. Ghiasi et al. (1979) reported that

the major starch component in soluble starch was degraded amylopectin that had shorter average chain length and higher A-chain to B-chain ratio than normal wheat amylopectin, which was probably due to the action of amylases during baking.

Cornford et al. (1964) studied the relationships between elastic modulus, time, and temperature in bread crumb and found that bread staling is basically characterized by retrogradation of starch in the crumb. The basic mechanism was instantaneous nucleation followed by rod-like growth of crystals. Axford (1967); Mciver (1968); and Colwell (9169) showed similar results by using differential thermal analysis (DTA). Later, differential scanning calorimetry (DSC) was found by Fearn and Russell (1982) to be more precise for study in this area. Katz (1928) found that as bread staled, the x-ray diffraction pattern of bread crumb changed from V-pattern which indicates starch is in an amorphous state, to B-pattern which is typical of starch in its crystalline state.

Alpha-amylases from cereal, fungal, and bacterial sources decrease the rate of bread firming (Miller et al. 1953; Pyler 1969). Zobel and Senti (1959) found that crystallinity of breads containing the enzyme was greater after three days storage than the control bread without enzyme, although the former bread was softer than the latter. This indicates firming and crystallinity were not synonymous. These workers suggested that the increased softness was attributed to the crystalline regions having greater freedom to move after cleavage of bonds by the enzyme in the amorphous regions, resulting in a decrease in rigidity. However, more regions or chains were able to align and associate, thus increasing the crystallinity. Dragsdorf and Varriano-Marston (1989) showed similar results.

Shoch's explanation (1965) for the role of starch in staling has been most widely accepted so far. According to him, wheat starch granules undergo restricted swelling during baking due to the limited amount of water present as the more soluble amylose dissolves and diffuses into the surrounding water. As selling

continues, the amylose solution becomes so concentrated in the small amount of interstitial water between the granules that, after the loaf has cooled, this amylose retrogrades to an insoluble gel structure which does not undergo further changes. Amylopectin can still retrograde during storage in the following manner. The outer branches of the amylopectin, which has expanded in the limited-water system to some extent, can gradually align and associate to yield a more rigid structure.

Minor modification of this study was done by Lineback (1984). He explained that portions of the amylose and amylopectin chains extend beyond the boundary of the granule, i.e., making the granule appear like a "hairy" billiard ball. These chains can associate or align (retrograde) with other carbohydrate chains in the interstices between granules and with those protruding in appropriate orientation from the granule boundary when they are in sufficiently close proximity. A similar explanation was provided by Matsukura et al. (1983).

Effect of Surfactants on Bread Staling

At present, surfactants are the most effective and widely used anti-staling agent. The study of surfactants as related to staling started when Schoch and Wiliams (1944) reported that amylose forms a water insoluble precipitate with fatty acids. Several workers suggested that surfactants retard staling because they attach to the surface of the starch granule and therefore, prevent amylose from diffusing out (Lehman 1942; Whistler and Hilbert 1944; Strandine et al. 1951; Bourne et al. 1960; Jough 1961). It was indicated by Hanes (1937) and Mikus et al. (1946) that the structure of amylose-fatty acid complexes consists of bundles of helices packed in a hexagonal fashion.

Banks and Greenwood (1971) reported that amylose can exist in helix form in the presence of a complexing agent, and the helical complex is stabilized by both

intramolecular hydrogen bonding and hydrophobic bonding between the amylose and complex agent, i.e., a hydrocarbon chain of fatty acids or surfactants. Katz (1930) showed that the X-ray diffraction spectrum of helical amylose complex had the V-Pattern, which indicated pasted starch.

Osman et al. (1961) reported that all amylose complexes with surfactants gave the same X-raty diffraction pattern as the V-pattern of amylose-fatty acid complexes, and they found no apparent relationship between complex formation with the amylose and anti-firming effects on the bread crumb. DeStefanis et al. (1976) found that surfactants form a complex during baking not only with amylose but also with amylopectin. Osman and Dix (1960) showed that surfactants can dramatically influence maximum viscosity temperature and gel strength of starch.

Krog (1971) reported that monoglycerids with chain length C12 to C18 had better complexing effects with amylose among various surfactants. Lagendijk and Pennings (1970) showed similar results. Riisom et al. (1984) showed that unsaturated monoglyceride with cis-configuration was better than that with trans-configuration in amylose complexing ability. Ghiasi et al. (1982a and 1983) reported that saturated monoglycerides (monostearin) and sodium stearoyl-lactylate (SSL) both formed strong complexes with amylose from 60 C to 80 C. Several studies have been done recently with amylose complexes in relation to thermal stability (Kuginuma and Donovan 1981; Stute and Konieczy-Janda 1983; Eliasson et al. 1984).

The degradation of amylose by amylolytic enzymes is known to be decreased by formation of the amylose-lipid comlex (Lonkhoysen and Blankestijn 1976; Kim and Robinson 1979; Holm et al. 1983; Eliasson et al. 1984). It has been reported that SSL improved bread quality, especially when a foreign flour was supplemented to the wheat flour (Tsen and Tang 1971; Tsen et al. 1971; tsen and Hoover 1971). Tenny

and Schmidt (1968) reported that the SSL provides the dough with tolerance to withstand production and formulation variables. SSL also makes the gluten more extensible and stronger by binding with the gluten, and forms complexes with starch that retard gelatinization during baking and delays retrogradation after baking.

Several actions of monoglyceride in bread baking systems were discussed by Coppock (1954). According to him, the mechanisms of monoglycerides were as follows: (1) dispersion of fat through the dough, (2) retention of soluble starch in the granules, (3) retardation of gelatinization, (4) supplying more moisture to the gluten, and (5) retention of moisture initially by gluten.

Relation of Swelling Behavior of Bread Crumb Starch to Gelatinization and to Bread Staling

The most widely accepted definition of gelatinization is that of Seib (1971): "Gelatiniztaion is the irreversible rupture of the native, secondary bond forces in the crystalline regions of a starch granule."

A starch-in-water suspension, when subjected to heating, absorbs a small amount of water, losing its birefringence when it reaches a crucial temperature. At this point, some granules swell rapidly and irreversible, losing their birefringement characteristics (Seib 1971). This process is known as gelatinization. Therefore, the loss of birefringence is a widely accepted indication of gelatinization (Leach 1965). Collison (1968) reported that larger granules lose birefringence at a lower temperature than similar granules.

Starch granules continue to swell as the temperature is increased beyond the gelatinization temperature, to several hundred times the original volume. Simultaneously, soluble materials leach out of the granule and some of the granules rupture completely. By this process, the viscosity and soluble material in the aqueous phase increase (Seib 1971).

Gelatinization starts in the region of the granule where the associative forces are the weakest (amorphous region); the strength of the associative bonds in this region varies among the different granules belonging to the same botanical type. This is the reason why gelatinization takes place over a range of temperature rather than a single temperature (Leach 1975).

According to Collison and Elton (1961), granules of wheat starch were found to retain their identity until a temperature of 95°C, and on further heating in an autoclave at 105°C, the identity of granules was completely lost.

Schoch (1965) reported that formation of amylose gels in the aqueous phase due to leaching of amylose from swollen granules contributes to initial firmness, since such gels retrograde very quickly after the bread comes out of the oven. The staling process is attributed to crystallization (retrogradation) of amylopectin within the swollen granules. With monoglycerides or similar surfactants present, the leaching of amylose is prevented because the surfactants form an insoluble complex with amylose within the starch granules (Krog and Davis 1984). Ghiasi et al. (1982b) demonstrated that amylose-surfactant complex is formed within the starch granules before gelatinizatin takes place. Ghiasi et al. (1982a) reported that SSL and saturated distilled MG effectively stopped leaching of amylose from the swollen granules.

Krog (1973) reported that the pasting temperature of wheat starch is considerably increased in the presence of effective amylose complexing agents. Riisom et al. (1984) showed that all monoglycerides increased the viscosity in comparison to control when amylopectin curves of fresh bread crumb was determined. The amylograph viscosity of bread crumb reflects the starch gelatinization taking place during baking in such a way that the degree of starch swelling in the amylograph is inversely related to the amount of starch swelling that occurs during baking (Krog and Davis 1984).

CHAPTER I. Residual Sugar Analysis of White Pan Bread Made by the Sponge Dough and Short-Time Dough Processes.

INTRODUCTION

Early workers suggested that the sugar content in the formula does not affect the firmness of the bread (Edelman et al. 1950; Barham and Johnson 1951; Bohn 1954). These results were based on the sponge dough process. Whether or not sugar content in the formula affects firmness of bread made by other baking methods has not been investigated. Therefore, residual bread sugar content should be known when the firmness of bread made by different baking methods is studied. Also, there is little or no information concerning residual sugars in short-time dough process white pan bread made by conventional mixing or high-speed mixing methods. Several studies have been done to trace fermentable sugars throughout the baking procedure of sponge dough (Koch et al. 1954) and liquid pre-ferment processes (Piekarz 1963).

Therefore, residual sugar analysis was done prior to the comparative firming characteristics study to obtain information on residual sugar of white pan bread made by sponge dough and short-time dough processes, with both conventional and high-speed mixing methods. We used a high performance liquid chromatography (HPLC) method, which seems to have not yet been used for the quantification of residual sugars in bread crumb. HPLC was used to estimate fructose, glucose, sucrose and maltose contained in bread crumb when sucrose in the formula was varied from 1% to 8%.

The dough temperature and the fermentation time were precisely adjusted for each baking experiment, since these experimental conditions will affect the residual sugar content in the final loaf of bread.

MATERIALS AND METHODS

Flour

The flour used was bleached bread flour from Ross Milling Co. Laboratory

analysis showed this flour to contain 13.7% moisture, 11.9% protein and 0.48% ash (dry basis). The farinograph showed: 61.4% water absorption, and 6.5 min peak time. The amyograph peak viscosity was 580 B.U. and the falling number was 206, indicating a typical commercial malt level.

Baking Formula

The formula given in Table 1 was used. The formula is based on the reports by Dubois (1981) and Kulp and Dubois (1982) in which the general formulas for different baking methods in the U.S.A. were shown. Small modifications were done to the basic formula in order to maintain optimum breadmaking conditions for each method, except for yeast, to permit a more accurate comparison of the processes. The modified formulas are still considered to be quite typical of that used by the U.S. baking industry.

Instant dry yeast (Fermipan, Delft, Holland) was used to keep yeast activity equal for each baking experiment because fresh compressed yeast changes in activity as each day passes, even when stored in a refrigerator.

Sponge Dough Procedure

In the sponge dough method, the major fermentative action takes place in a pre-ferment, which is referred to as a sponge. Normally, more than one-half of the total dough flour is subjected to the physical, chemical and biological action of an active yeast fermentation (Pyler 1973b). A normal sponge will expand in volume by a factor of 4 or 5 during fermentation (Cotton and Ponte 1973).

A Hobart mixer, Model A-200 (Hobart Mfg. Co., Troy, Ohio) was used for mixing the sponge and dough.

The procedure was as follows:

1. Weigh the sponge and dough ingredients separately.

2. Mix sponge for 3 min. at speed 1 (120 rpm). Sponge temperature was 76±1°F (24-25°C). Yeast was suspended in the water before mixing.
3. Place mixed sponge in lightly greased fermentation bowl and place in fermentation cabinet, adjusted to 85°F (29°C) and 86% relative humidity (R.H.). Allow to ferment for 4 hours to reach the proper degree of maturity or ripeness that is indicated by perceptible drop in the sponge, usually called the break.
4. After 4 hours, place dough ingredients in mixing bowl and mix for 30 sec. at speed 1.
5. Place fermented sponge into mixer bowl and mix for 30 sec. at speed 1, then shift mixer to speed 2 (240 rpm) and mix the dough for 5 min. to obtain optimum development. The dough temperature after mixing was 81± 1°F (27-28°C).
6. Place the dough in the fermentation cabinet maintained at 85°F (29°C) and 86% R.H. for the 30 min. rest, then scale dough pieces to 539 grams.
7. Round each dough piece separately by hand.
8. Rest the dough pieces at 76°F (24°C) and 75% R.H., covering the dough pieces with a nylon sheet, for an intermediate proof period of 20 min.
9. Mould the dough piece with Oshikiri Moulder, Model MS (Oshikiri Machinery LTD., Tokyo, Japan) adjusted to: top roller, 12; dough feeder, 4; guide rail, 25; plate height, 3.5; plate pressure, 2; maximum clearance scale, maximum; return gap scale, 1/16; pressure knob, 1.5.
10. Pan the dough piece and proof to height (1.5 cm above pan) at 105°F (41°C) and 92% R.H. (60±2 min).
11. Bake at 425°F (218°C) for 20 min in Reed Reel Oven (Bakers Engineering & Equipment Co., Kansas City, Kansas).

12. Cool on the steel rack for one hour at 76°F (24°C) and 75% R.H.
13. Wrap the loaf twice in a moisture proof plastic bag by sucking the internal air without deforming the loaf shape.
14. Place the loaf on the steel rack for 24 hours at 76°F (24°C) and 75% R. H. At this time, samples are taken for moisture determination and sugar extraction.

Short-Time Dough Process

Short-time doughs are often used when it is important to reduce the overall time required for bread processing. Short-time doughs may yield bread in about 2 hours, as opposed to 7-8 hours for conventional sponge doughs. A decrease in fermentation time calls for an increase in yeast concentration and a drastic increase in proof time (Ponte and Reed 1982).

Two mixing methods, i.e., conventional mixing and high-speed mixing were used. Hobart mixer, Model A-200 (Hobart Mfg. Co., Troy, Ohio) was used for conventional mixing method. Mono high-speed mixer, Model 35F (Mono Bakery Equipment INC., Malvern, PA.), with a rotation speed of 475 rpm and a propeller length of 33.0 cm was used for the high-speed mixing method.

This procedure was as follows:

1. Weigh the ingredients. Yeast was suspended in the water before mixing.
2a. In the conventional mixer, mix the dough for 30 sec. at speed 1, then shift mixer to speed 2 and mix the dough for 6 min. to get optimum development. The dough temperature after mixing was 81 1°F (27-28°C).
2b. In the high-speed mixer, mix the dough for 30 sec. and after scraping down ingredients still attached to the internal face of the mixer, mix the dough for 3 min. to obtain optimum development. The dough temperature after mixing was 81 1°F (27-28°C).

3. Place the mixed doughs in lightly greased fermentation bowls placed in a fermenatation cabinet at 85°F (29°C) and 86% R.H. for a rest period of 15 min., then scale dough pieces to 539 grams.
4. Round each dough piece separately by hand.
5. Rest the dough piece at 76°F (24°C) and 75% R.H., covering the dough piece with a nylon sheet, for an intermediate proof period of 10 min.
6. Mould the dough piece with the Oshikiri Moulder, Model MS adjusted the same as sponge dough procedure except for plate height, 3.0.
7. Pan the dough piece and proof to height (1.5 cm above pan) at 105°F (41°C) and 92% R.H. (70±2 min for conventional mixing method, 75±2 min for high speed mixing method).
8. The remaining steps were the same as for the sponge dough procedure, 11 to 14.

Moisture Determination

Moisture was determined in bread samples according to AACC method 44-15A (American Association of Cereal Chemists 1983).

Extraction of Residual Sugars From Bread Crumb

There are several methods to extract sugars from food materials. For the sugar extraction from bread crumb, methanol-water solvent system, ethanol-water solvent system and methanolo-chloroform-water solvent systems can be applied. Suitable solvents for the free sugars are the lower alcohols, espcially methanol (Thompson and Wolfrom 1962). In sugar extraction from bread crumb or cereal materials, an ethanol-water solvent system is frequently used (Koch et al. 1954; Tang et al. 1972; Palmer and Brandes 1974;Cerning-Beroard 1975; Tanaka et al. 1975; Birch and Green 1978), since glucose is more soluble in ethanol than in methanol.

Also, solubility of fructose and sucrose is greater in methanol that in ethanol and methanol is a fairly poisonous solvent. Methanol-chloroform-water solvent system has the advantage that the sample is also effectively defatted, since the lipids go into the chloroform phase (Ponte et al. 1969).

Since the experimental bread contained a surfactant (SSL), the methanol-water phase could not be separated from the cholorofrom phase in the methanol-chloroform-water solvent system. Therefore, the ethanol-water solvent system was used for sugar extraction from bread crumb.

Fifty grams of bread crumb were placed in a 500 ml flask and 250 ml of 80% ethanol were added. After shaking the flask intensely for 3 min., it was placed in a water bath at 60°C with moderate shaking for 60 min. After the mixture was filtered roughly with vacuum through a Whatman No. 2 filter paper, it was filtered again carefuly though Watman No. 5 filter paper. For complete extraction, the filtered residue was washed several times with a small amount of 80% ethanol.

The filtrate was evaporated to about 15 ml in a rotary vacuum evaporator at a bath temperature of 50°C, then placed in a centrifuge tube. The inside of a flask used in evaporation was washed several times with a small amount of distilled water and the water was taken into the same centrifuge tube. Then the solution was centrifuged at 10,000 rpm for 5 min. The supernantant was carefully removed without disturbing the bread crumb residue in the bottom of the centrifuge tube, and diluted up to 25 ml in a volumetric flask.

The sample solution was frozen immediately in a freezer until liquid chromatography analysis. The frozen sample was thawed at room termperature (c.a. 25°C) just before chromatographic analysis.

Liquid Chromatography

Equipment

The following equipment was used: Varian (Pala Alto, CA) high performance liquid chromatograph (Model 5000 with 10 ml sample loop valve injector), Varian Aerograph refractive index detector (cell volume, 6 ul; minimum detectability, refractive index units), Houston Instrument (Austin, Texas) Omniscribe TM Recorder (100mV full scale, chart speed variable), Alltech (Arlington Heights, IL) analytical column (length 30 cm, 4.6 mm I.D.). The column packing was Alltech Bondapack NH_2, particle size 10 u. To protect the analytical column a Universal Guard Column, length 4 cm, 4 mm I.D., packed with Alltech pellicular (40 u) amino packing material was used.

Sugar Standards

Sugars used were of the highest purity available for Fisher Scientific Co. (Fairlawn, NJ). No impurities were ever detected during the analyses. Standard solutions were prepared in water.

Experimental Conditions

As a result of considerable pre-experiments to determine the most favorable conditions for chromatographic analysis, the following experimental conditons were used: eluant, 85/15, acetonytolyle/water; flow rate, 1.0 ml/min for the analysis of glucose and fructose, and 1.5 ml/min for the analysis of sucrose and maltose; temperature, 25°C; injection, 10 ul; detector, refractometer, x2; chart speed of recorder 0.5 cm/min.

Two different flow rates were used in order to obtain a peak of appropriate

width for each sugar for accurate calculation of peak area. Flow rate gradient was tried to obtain calculation of peak area at the time of analysis, but the base line of the chromatogram was too noisy for accurate calculation of the peak areas. Also, by using the flow rate gradient, it became very difficult to stabilize the base line of the chromatogram for further analyses.

The experimental conditions for HPLC are summarized in Table 2.

Statistical Method

The least square method (Snedecor and Cochran 1980) was used to obtain a regression formula which showed the relation between the concentration of each sugar solution and the peak area obtained by the chromatogram, as shown below. The correlation value was calculated also as shown below (Snedecor and Cochran 1980) to determine the degree of accuracy of the obtained regression formula. Correlation value was expressed as r.

Regression formula: $y = bx$

y: concentration of each sugar solution (%)

x: peak area of each sugar chromatogram (mm^2)

r: correlation value ($0<r<1$)

$$b = \frac{\Sigma XiYi}{\Sigma Xi^2} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

$$r = \frac{\Sigma XiYi}{\sqrt{\Sigma Xi^2 \Sigma Yi^2}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

Table 1. Formula Used for Baking[a]

Ingredients	Sponge Dough Process			Short-Time Dough Process
	Sponge	Dough	Total	
Flour	70	30	100	100
Water	40	23	63	63
Yeast[b]	2.5	--	63	3.5
Yeast Food[c]	0.5	--	0.5	0.5
Salt	--	2.0	2.0	2.0
Nonfat dry Milk	--	2.0	2.0	2.0
Shorteningd	--	2.5	2.5	2.5
SSL[e]	--	0.5	0.5	0.5
Sucrose	--	Variable	Variable	Variable

[a]Ingredients, % based on flour weight.

[b]Though yeast % is expressed as fresh yeast. Instant Active Dry Yeast (IADY) was used in the actual experiment in the following manner: IADY % = 0.4 X Fresh Yeast %.

[c]Arkady, Archer Daniels Midland Co., Decatur, IL.

[d]Non-emulsified shortening, Archer Daniels Midland, Co.

[e]Sodium stearoyl-2-lactylate, C. J. Patterson Co., Kansas City, MO.

Diagram 1. Procedure for Residual Sugar Extraction from Bread Crumb.

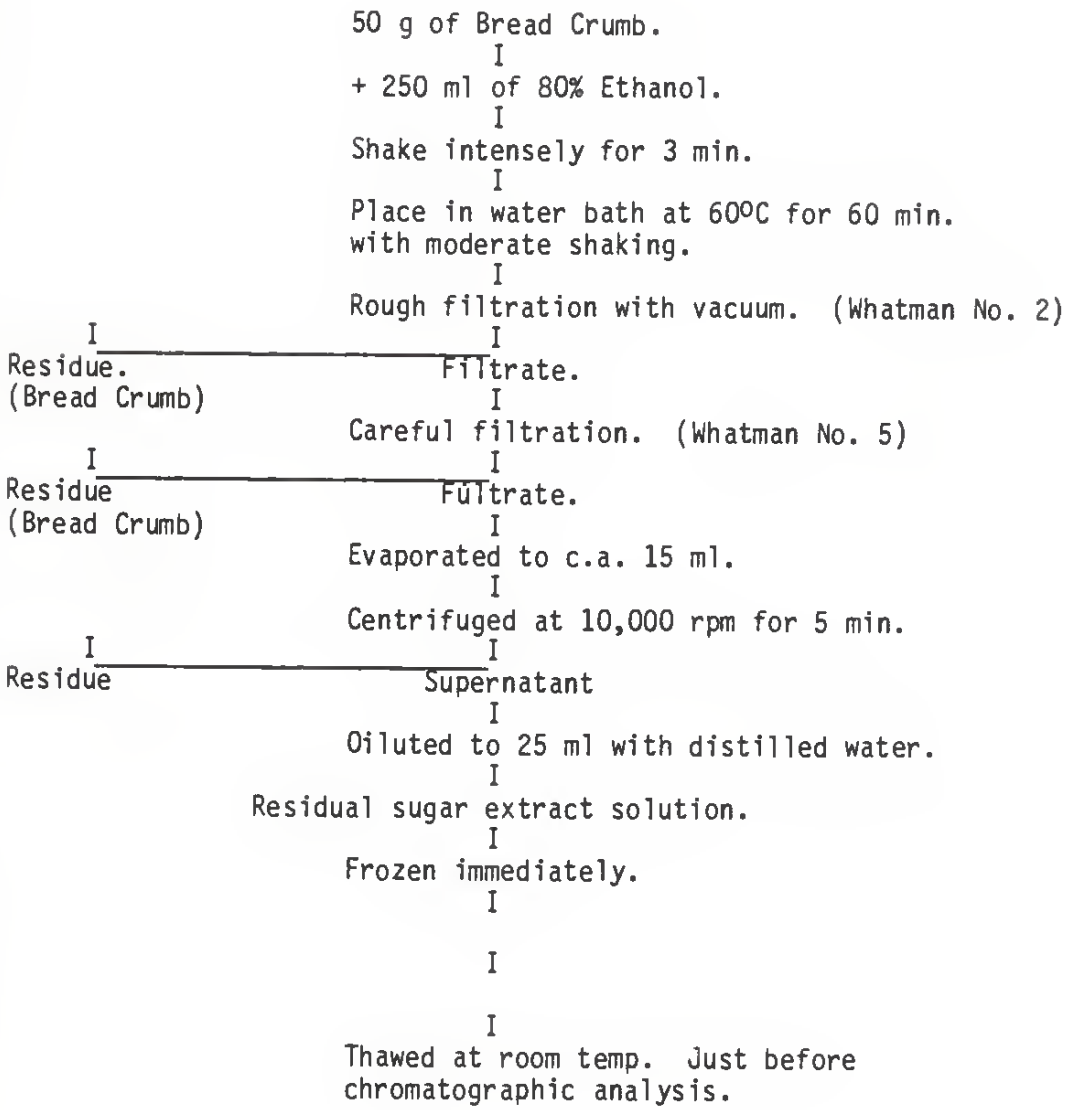


Table 2. Experimental Conditions for High Performance Liquid Chromatography.

Columm	:	Alltech Column C-6000.
Packing	:	Alltech Bondapak NH_2 (10 u).
Eluant	:	85/15, CH_3CN/H_2O.
Flow Rate	:	1.0 ml/min for Glucose & Fructose
		1.5 ml/min for Sucrose & Maltose.
Temperature	:	25°C.
Injection	:	10 ul.
Oetector	:	Refractometer X2.
Chart Speed	:	0.5 cm/min.

RESULTS AND DISCUSSION

Chromatographic Separation

After deciding the chromatograpic conditions, the following factors were tested; ratio of eluant (CH_3CN:H_2O); flow rate; refractive index range; chart speed. The best conditions were then chosen, but two flow rates were used as mentioned before.

Figure 1 shows the chromatographic separation of 3% fructose, glucose, sucrose and maltose at a flow rate of 1.0 ml/min. Fructose and glucose were clearly separated and the peak areas could be easily calculated. THe peaks of sucrose and maltose appeared wider. The tail of the maltose peak especially drifted so much that it disturbed the proper calculation of peak area. When concentration of sucrose and maltose solutions were less than 1%, the peak areas were difficult to calculate.

Figure 2 shows the chromatographic separation of 3% of the same sugars at a flow rate 1.5 ml/min. Fructose and glucose were not clearly separated. On the other hand, resolution of sucrose and maltose peaks were much improved, allowing accurate calculation of peak areas.

Therefore, fructose and glucose analysis was done at a flow rate of 1.0 ml/min.

Chromatograms of extracted sugar solutions from sponge dough bread and short-time dough bread with both conventional mixing and high-speed mixing methods when 7% sucrose was used in the formula are shown in Figure 3 to Figure 8.

Fructose and glucose were separated fairly well at 1.0 ml/min flow rate. No sucrose was identified in any of the sugar extracts. The maltose peak area was sharp enough to be calculated at 1.5 ml/min flow rate.

The lactose peak was identified through every sugar extract, but its area could not be calculated because this peak (F) was always attached to some unknown peak (G) and because the lactose peak (F) was not well separated from the maltose peak (E) in sugar extracts from short-time dough breads.

Lactose which is derived from nonfat dry milk in the bread formula is not fermented by baker's yeast, thus it remains in the final loaf in the same amount as in the formula (Ponte and Reed 1982). Therefore, lactose was neglected in this chromatographic analysis.

Several unknown peaks were observed. These peaks were considered not to be significantly important in this study.

Standard Curve

Standard solutions of fructose, glucose, sucrose and maltose were accurately prepared with distilled water, in concentrations form 1% to 5% in increments of 1%, utilizing 100 ml volumetric flask. each standard solutions was injected twice and two peak areas were calculated for each standard solution. Then the two values were duplicated for regression formula calculation.

Standard curves and calculated regression formulas with correlation values are shown in Figure 9 to Figure 12. Each correlation of the regression line showed a fairly high value which indicates the accuracy of these regression formulas.

Residual Sugar Content of Sponge Dough and Short-Time Dough Bread

Sucrose content in the formula was varied from 1% to 8%, in increments of 1%. Each variable was test-baked twice, and each dough yielded two loaves. Then 25 g of crumb from each of the two loaves from a dough were combined to provide a total of 50 g crumb for each residual sugar extraction. Thus, two separate extracts were

prepared for each sucrose variation in the formula. Each extract was analyzed twice by liquid chromatography. The calculated peak areas of four liquid chromatographic analyses for each sucrose variation were then averaged.

Figure 13 graphically summarized the analytical data obtained from the white pan bread made by the sponge dough process.

Fructose increased linearly as sucrose used in the formula increased. Glucose increased slowly when less than 3% of sucrose was used in the formula, but then glucose increased more rapidly when sucrose in the formula was greater than 3%. Residual glucose was always lower than fructose. On the other hand, maltose appeared almost constant, at around 0.25% regardless of the various amounts of sucrose used in the formula.

In the dough system, glucose is derived from sucrose and crumb starch. Therefore, the total amount of glucoe produced in the dough system is higher than the total amount of fructose. But this result showed fructose in the final loaf to be higher in amount than glucose. This simply indicates that yeast ferments glucose faster than fructose, which agrees with previous studies (Bohn 1954; Kock et al. 1954; Piekarz 1963; Tang et al. 1972; Ponte and Reed 1982).

In the dough system, maltose is only derived from starch, therefore formula sucrose showed no effect on the amount of maltose produced form starch. If yeast ferments the maltose at a constant rate in the dough system when various amount of sucrose are used in the formula, the residual maltose content should be identical. These results satisfy this expectation very well.

Yeast requires a certain amount of glucose for its metabolism. After yeast is satisfied, glucose will accumulate. That is probably the reason why glucose increase was slower at the lower sucrose usage level in the formula.

When these data are converted to a dry solids basis, they very much agree with the results reported by Ponte and Reed (1982) who used thin layer chromatography

for residual sugar quantification. The data also agree with the results shown by Tang et al (1972) who used paper chromatography for sugar analysis. Since high performance liquid chromatography is faster and more accurate than other chromatographic methods, these results suggest that liquid chromatographic analysis has some advantages for sugar qualification or quantification in bread systems.

Figure 14 graphically summarized the analytical data obtained from white pan bread made by the short-time dough process with conventional mixer use.

Fructose increased linearly as sucrose increased in the formula. Glucose showed a slightly lower increasing rate in the region of lower sucrose usage in the formula, but it increased faster in the region of higher sucrose use. This tendency is the same as that obtained from the sponge dough process. Both fructose and glucose were slightly higher in amount than those sugars found in sponge dough bread at each sucrose level in formula. It was especially higher in the region of lower level of formula sucrose, though those sugars were similar at the higher formula sucrose levels.

Maltose was found to be higher (c.a. 1.5) in amount than that found in sponge dough bread (c.a. 0.25%). Koch et al (1954) and Tang et al (1972) explained that maltose is produced from starch by the action of amylases produced by yeast and native in the flour, during the earlier stage of dough fermentatin. Maltose increases in dough as long as monosaccharides are available for yeast fermentation. Therefore,in the short-time dough process, maltose remains at a higher level in the final loaf compared with sponge dough bread.

In this result maltose seemed to increase very slightly as sucrose increased in the formula. Maltose fermentation by yeast might be restricted by higher concentration of sugars in the dough, for some reason.

Residual monosaccharides in sponge dough and short-time breads were similar at the higher sucrose levels probably because of a balance between fermentation time and

yeast level. This indicates that the sweetness of the bread made by sponge dough and short-time dough processes can be controlled to a similar level.

Figure 15 graphically summarizes the analytical data obtained from the white pan bread made by the short-time dough process with use of the high speed mixer.

The amount of each residual sugar and the tendency of an increase of each residual sugar were very similar to the results obtained from the short-time dough process using a conventional mixer. However, each residual sugar content was very slightly lower than that of bread from conventional mixing process, probably because approximately 5 min longer final proof time was required in high-speed mixing method (c.a. 75 min final proof time) than for conventional mixing method (c.a. 70 min final proof time).

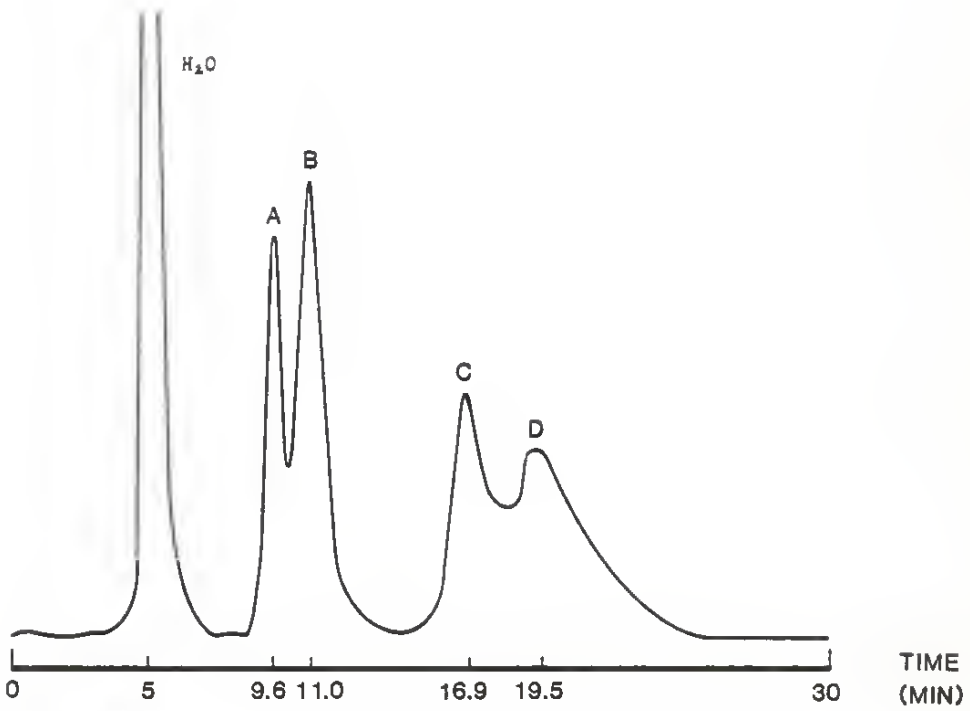
This fact indicates that high-speed mixing of the dough does not affect the residual sugar content in the final loaf, that is, high-speed mixing does not affect the yeast fermentation.

Table 3 summarizes moisture contents of white pan breads made by sponge dough and short-time dough processes at both 1% and 8% sucrose level in the formula. Each moisture value is the data averaged from each of two loaves from two different doughs.

This result shows that there is no significant difference in the bread moisture between processing methods and among various sugar content in the formula. Therefore, it can be said that the breads used for chromatographic analysis had the same moisture content. Thus, the results obtained from three different processes can be compared on the basis of bread crumb weight.

Figure 1. Chromatographic Separation of 3% each of (A) Fructose, (B) Glucose, (C) Sucrose, and (D) Maltose at 1.0 ml/min Flow Rate.

Figure 2. Chromatographic Separation of 3% each (A) Fructose, (B) Glucose, (C) Sucrose, and (D) Maltose at 1.5 ml/min.


H₂O
A
B
C
D
0
5
9.6
11.0
16.9
19.5
30
TIME
(MIN)

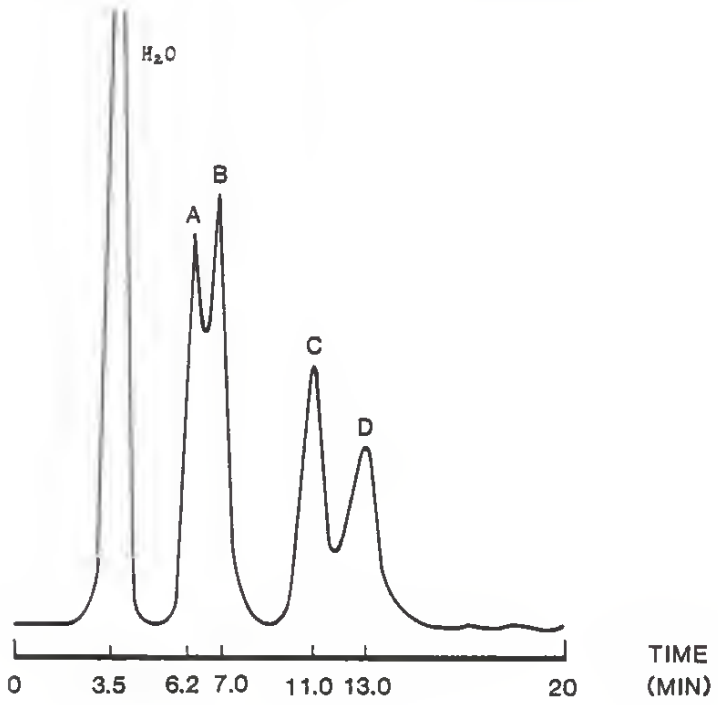
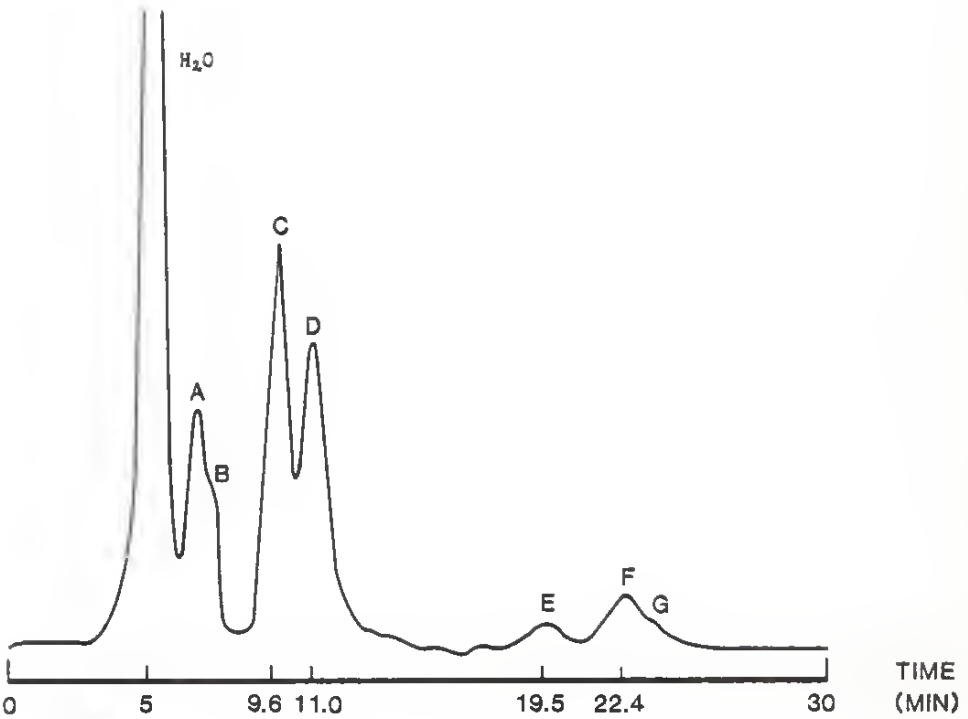

H₂O
A
B
C
D
0
3.5
6.2
7.0
11.0
13.0
20
TIME
(MIN)

Figure 3. Chromatogram of Sugar Extract from Sponge Dough Bread, When 7% Sucrose was Used in the Formula, at 1.0 ml/min Flow Rate.

A,B,G, : Unknown
C : Fructose
D : Glucose
E : Maltose
F : Lactose

Figure 4. Chromatogram of Sugar Extact from Sponge Dough Bread, When 7% Sucrose was Used in the Formula, at 1.5 ml/min Flow Rate.

A,B,G, : Unknown
C : Fructose
D : Glucose
E : Maltose
F : Lactose


H_2O
A
B
C
D
E
F
G
0
5
9.6
11.0
19.5
22.4
30
TIME
(MIN)

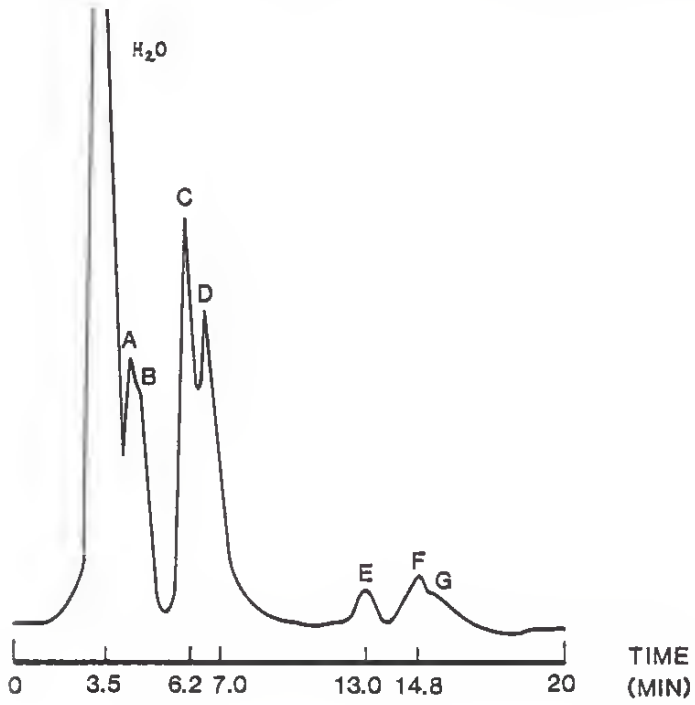
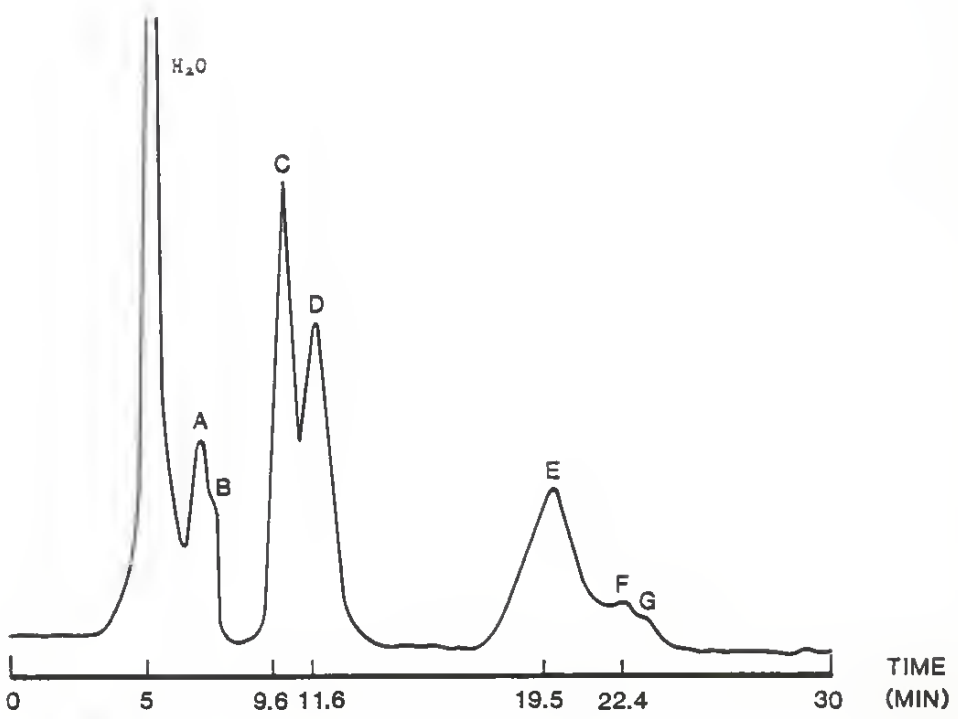

H_2O
A
B
C
D
E
F
G
0
3.5
6.2
7.0
13.0
14.8
20
TIME
(MIN)

Figure 5. Chromatogram of Sugar Extract from Short-Time, Conventional Mixing Bread, When 7% Sucrose was Used, at 1.0 ml/min Flow Rate.

A,B,G : Unknown
C : Fructose
D : Glucose
E : Maltose
F : Lactose

Figure 6. Chromatogram of Sugar Extract from Short-Time, Conventional Mixing Bread, When 7% Sucrose Was Used, at 1.5 ml/min Flow Rate.

A,B,G, : Unknown
C : Fructose
D : Glucose
E : Maltose
F : Lactose


H₂O
C
D
A
B
E
F
G
0
5
9.6
11.6
19.5
22.4
30
TIME
(MIN)

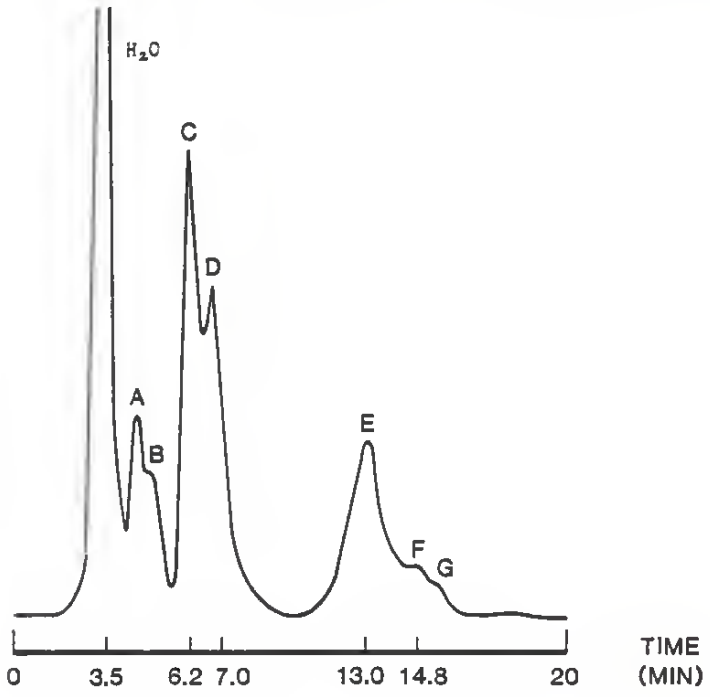
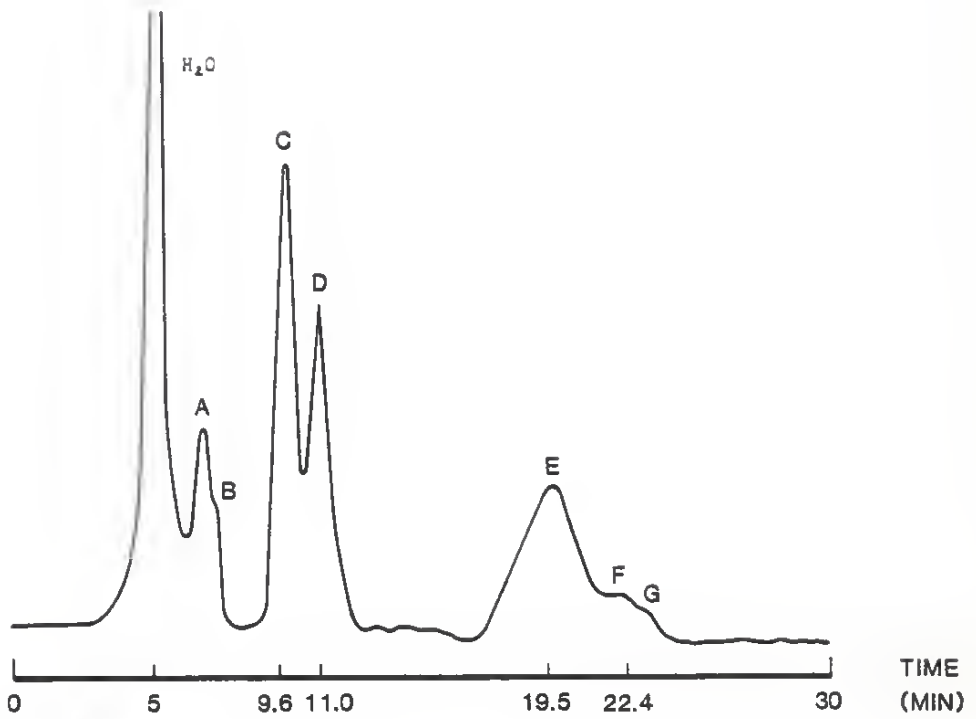

H₂O
C
D
A
B
E
F
G
0
3.5
6.2
7.0
13.0
14.8
20
TIME
(MIN)

Figure 7. Chromatogram of Sugar Extract from Short-Time, High-Speed Mixing Bread, When 7% Sucrose was Used, at 1.0 ml/min Flow Rate.

A,B,G, : Unknown
C : Fructose
D : Glucose
E : Maltose
F : Lactose

Figure 8. Chromatogram of Sugar Extract form Short-Time, High-Speed Mixing Bread, When 7% Sucrose was Used, at 1.5 ml/min Flow Rate.

A,B,G, : Unknown
C : Fructose
D : Glucose
E : Maltose
F : Lactose


H₂O
C
D
A
B
E
F
G
0
5
9.6
11.0
19.5
22.4
30
TIME
(MIN)

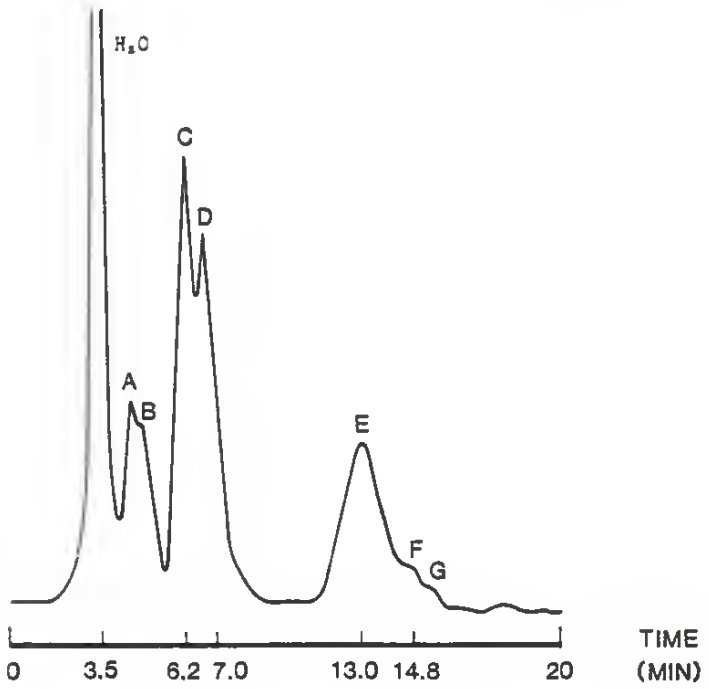

H₂O
C
D
A
B
E
F
G
0
3.5
6.2
7.0
13.0
14.8
20
TIME
(MIN)

Figure 9. Standard Curve for Determintion of Fructose (%) by Peak Area (mm^2).

The regression line : $y = 1.021 \times 10^{-2x}$

The correlation : $r = 0.9998$

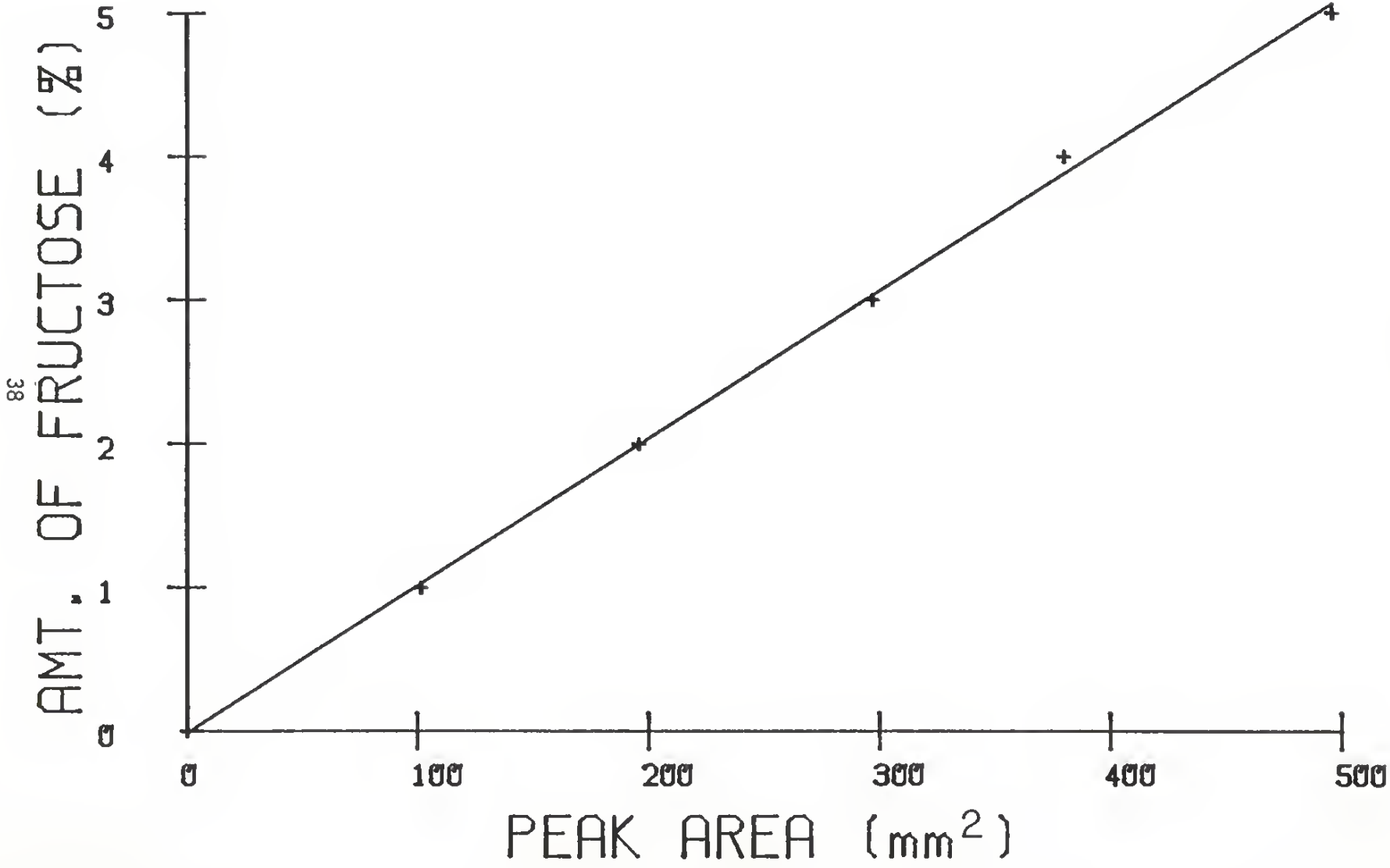

AMT. OF FRUCTOSE (%)
0
1
2
3
4
5
0
100
200
300
400
500
PEAK AREA (mm2)

Figure 10. Standard Curve for Determinatin of Glucose (%) by Peak Area (MM^2).

The regression line : $y = 6.663 \times 10^{-3x}$

The correlation : $r = 0.9999$

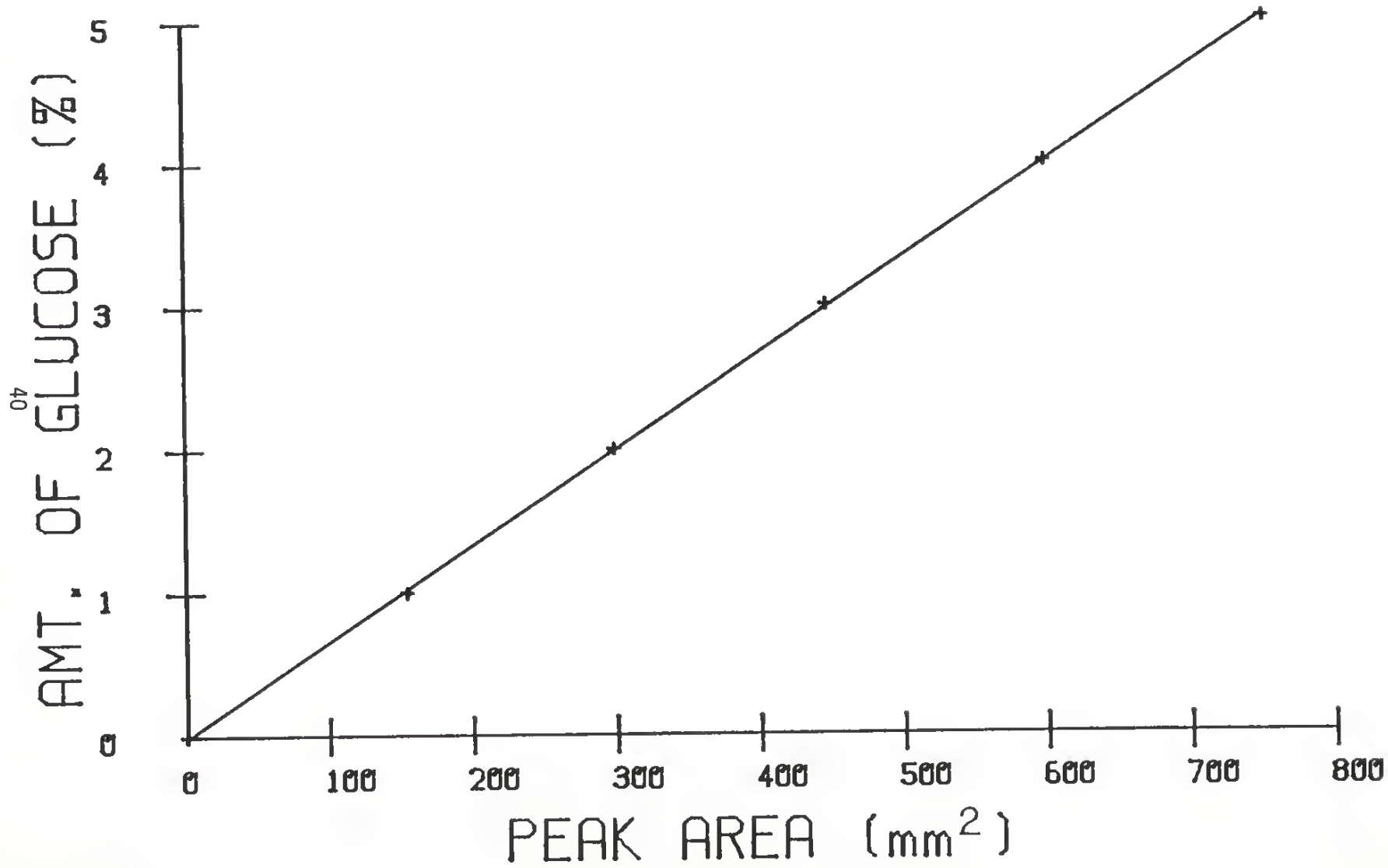

AMT. OF GLUCOSE (%)
40
5
4
3
2
1
0
0
100
200
300
400
500
600
700
800
PEAK AREA (mm2)

Figure 11. Standard Curve for Determination of Sucrose (%) by Peak Area (mm^2).

The regression line : $y = 1.543 \times 10^{-2x}$

The correlation : $r = 0.9998$

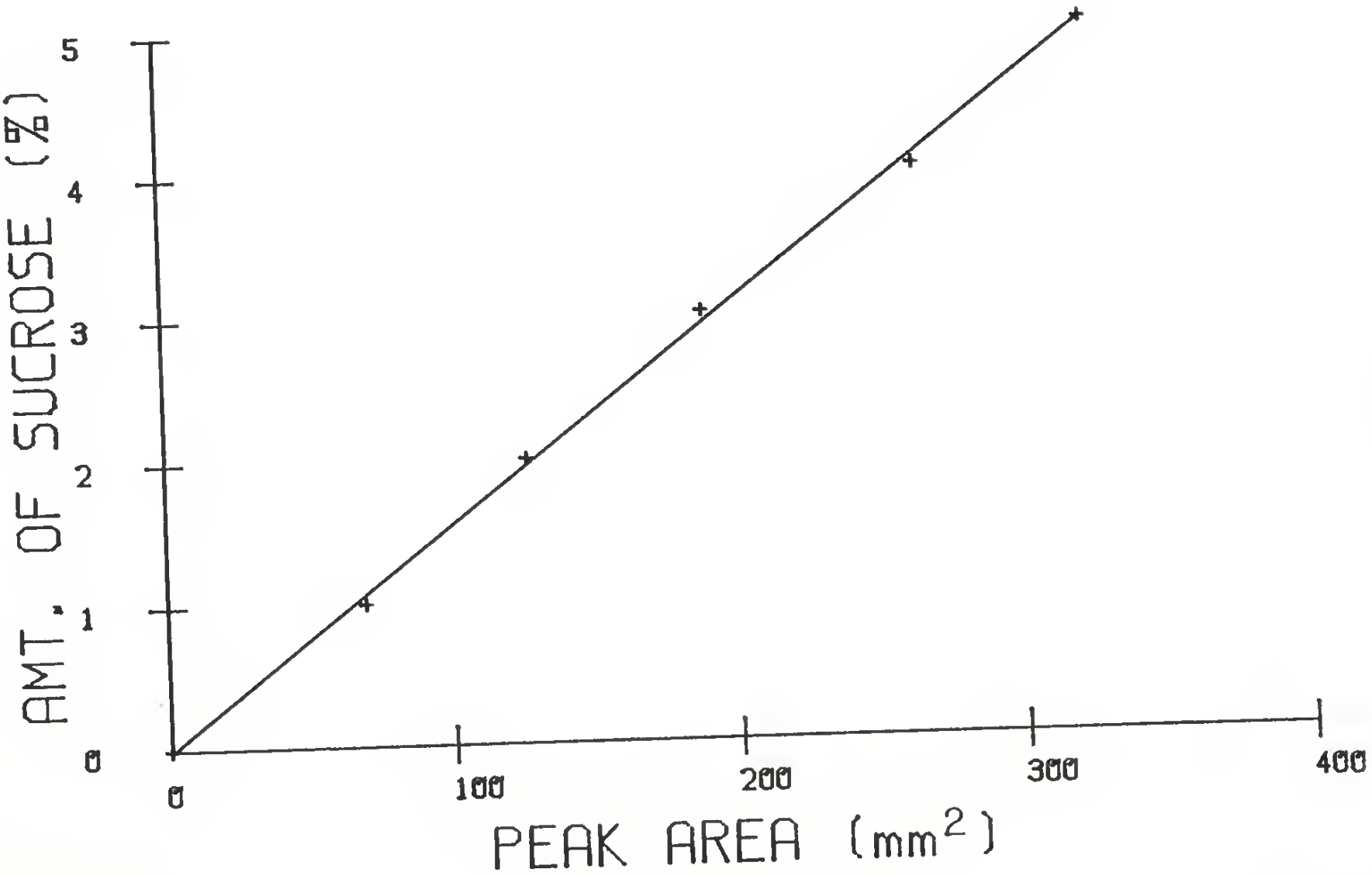

AMT. OF SUCROSE (%)
0
1
2
3
4
5
0
100
200
300
400
PEAK AREA (mm2)

Figure 12. Standard Curve for Determination of Maltose (%) by Peak Area (mm^2).

The regression line : $y = 1.491 \times 10^{-2} X$

The correlation : $r = 0.9999$

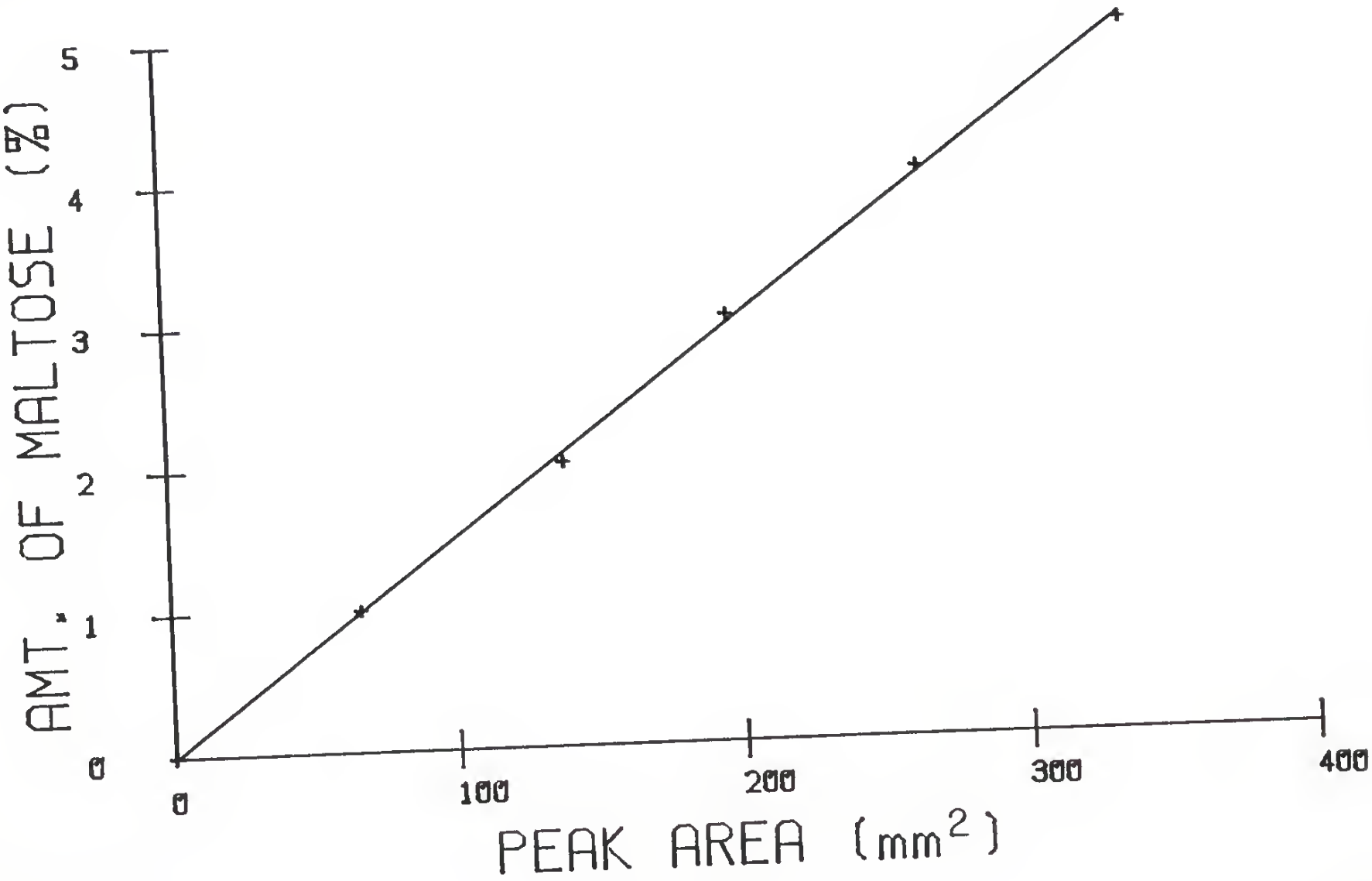

AMT. OF MALTOSE (%)
0
1
2
3
4
5
0
100
200
300
400
PEAK AREA (mm²)

Figure 13. Amount of Residual Sugars Found in Sponge Dough Bread, When Amount of Sucrose Was Varied in the Formula

A : Fructose
B : Glucose
C : Maltose

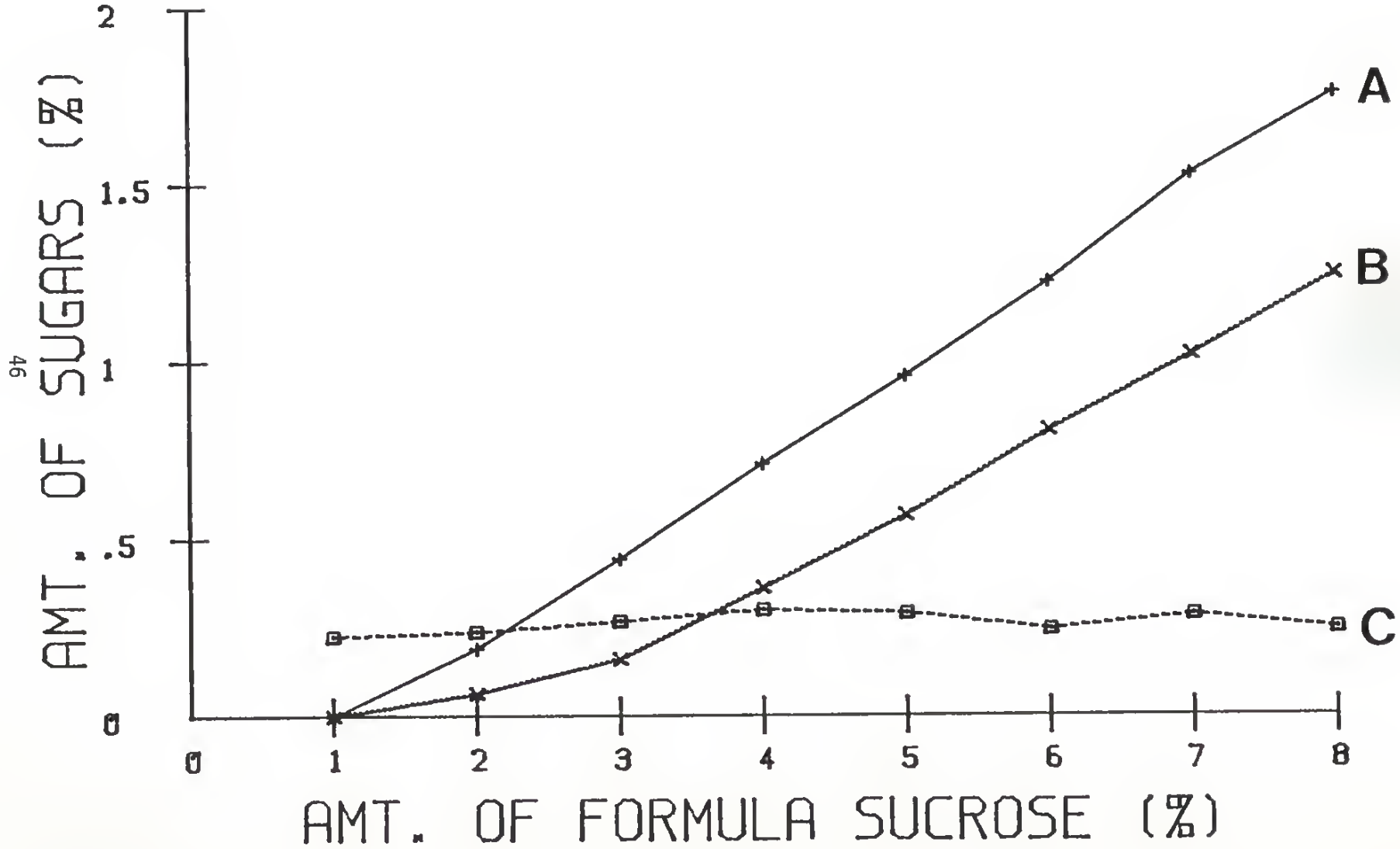

AMT. OF SUGARS (%)
2
1.5
1
.5
0
0
1
2
3
4
5
6
7
8
AMT. OF FORMULA SUCROSE (%)
A
B
C

Figure 14. Amount of Residual Sugars Found in Short-Time Dough Bread (Conventional Mixing), When Amount of Sucrose Was Varied in the Formula.

A : Fructose
B : Glucose
C : Maltose

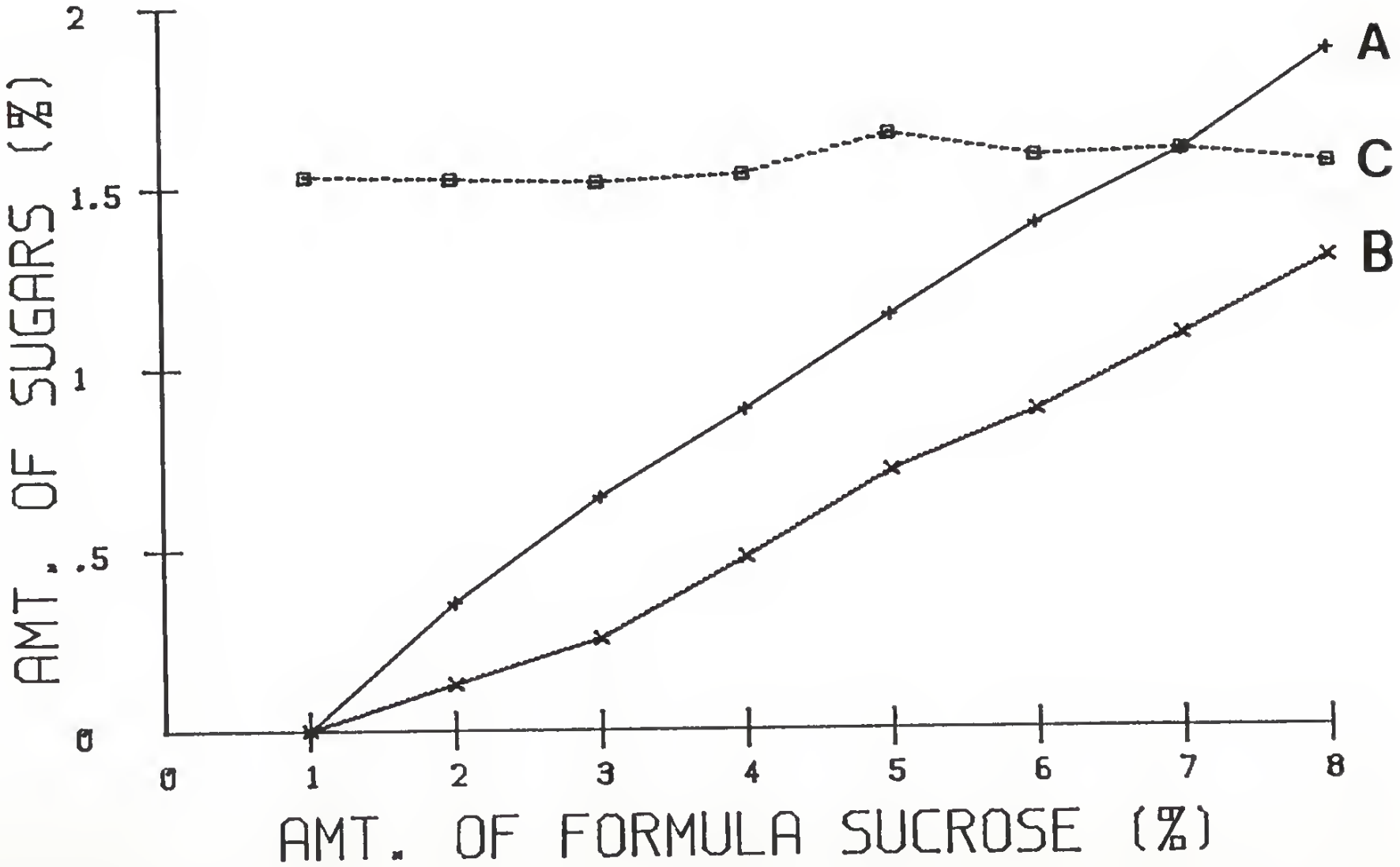

AMT. OF SUGARS (%)
2
1.5
1
.5
0
0
1
2
3
4
5
6
7
8
AMT. OF FORMULA SUCROSE (%)
A
B
C

Figure 15. Amount of Residual Sugars Found in Short-Time Dough Bread (High-Speed Mixing), When Amount of Sucrose Was Varied in the Formula.

A : Fructose
B : Glucose
C : Maltose

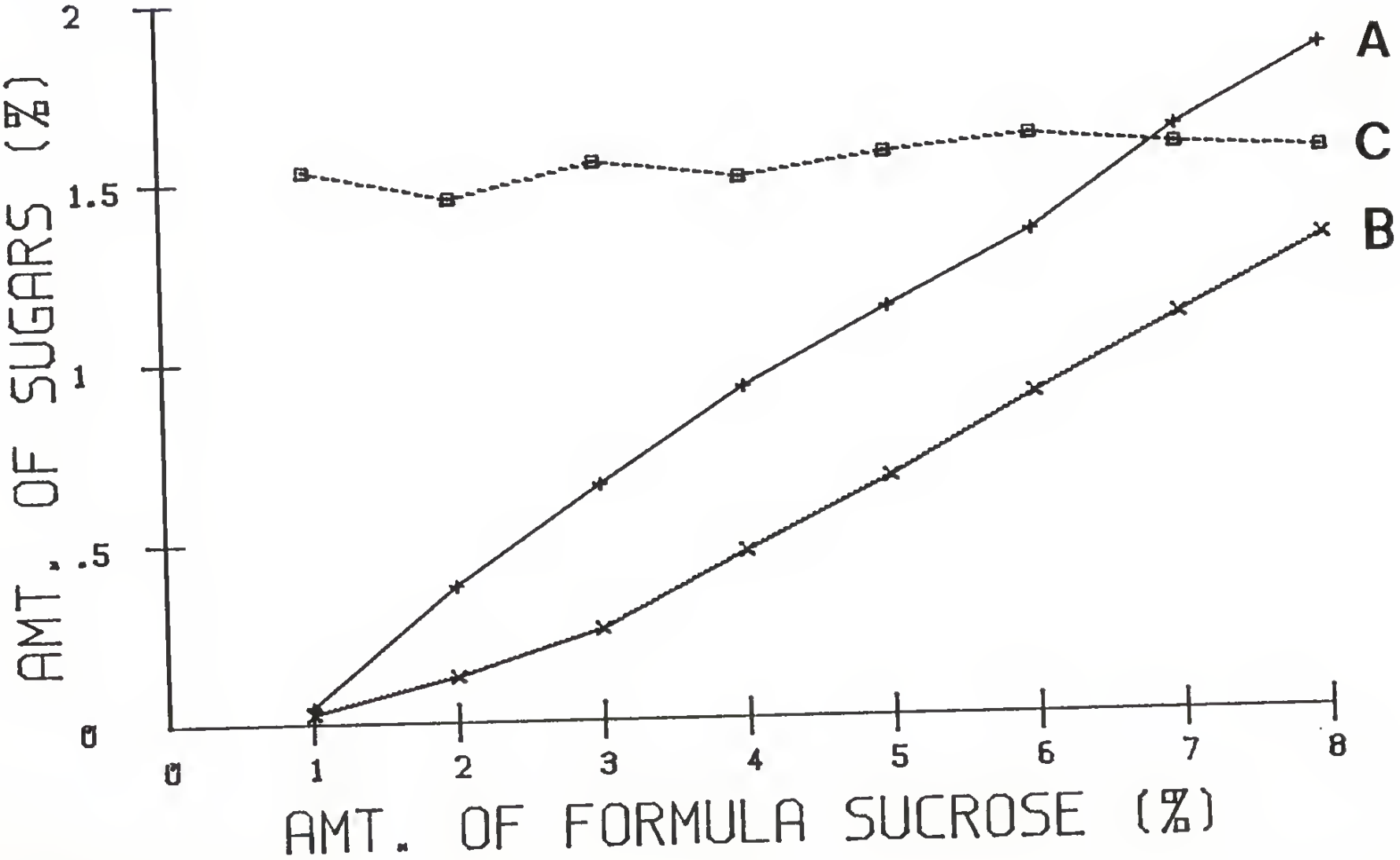

AMT. OF SUGARS (%)
2
1.5
1
.5
0
0
1
2
3
4
5
6
7
8
AMT. OF FORMULA SUCROSE (%)
A
C
B

Table 3. Moisture Content of White Pan Bread Made by the Sponge Dough and Short-Time Dough Processes at Both 1% and 8% Sucrose Level in the Formula.

Process	Sponge Dough	Short-Time Dough	
Mixing Method	Conventional	Conventional	High Speed
Bread Moisture at 1% Sucrose in the Formula	37.8% A	37.7% A	37.9% A
Bread Moisture at 8% Sucrose in the Formula	37.9% A	37.4% A	37.6% A

Means with the same letter are not significantly different at the α=0.05 level.

Analysis of variance results:

Source	DF	F Value	PR>F	LSD Value
Baking method	2	1.75	0.3636	0.7026
Sucrose level	1	1.56	0.3377	0.5737

CONCLUSIONS

The results are summarized as follows:

1. Residual fructose and glucose content in sponge dough and short-time dough breads were similar at the higher sucrose levels probably because of a balance between fermentation time and yeast level.
2. The increase of residual glucose was slightly slower at lower sucrose levels (<3%) in the formula, probably because the yeast requires that amount of sugar to satisfy metabolism requirements.
3. Residual maltose content was higher in short-time dough bread than in sponge dough bread, because the yeast in short-time doughs have excess glucose substrate and is not required to adapt to maltose fermentation.
4. The amount of residual maltose of sponge dough bread was almost constant with formulas containing varible sucrose.
5. The amount of residual maltose in short-time dough bread increased very slightly as the sucrose level in the formula increased.
6. High-speed mixing had no effect on the sugar fermentation by yeast.

Chapter II. Comparative Firmness Study of White Pan Bread Made by Sponge Dough and Short-Time Dough Processes.

INTRODUCTION

The purpose of this study as mentioned in the general introduction was to determine whether there is a difference in the firming of bread crumb made by the sponge dough process and the short-time dough processes. The sponge dough process is the most popular method in the U.S.A. at present, but the short-time dough process would be expected to become more popular in the future if the keeping properties of this bread were perceived by industry to be satisfactory. If there is a difference in firming between these two processes, a purpose of this study would be to investigate the cause.

In the short-time dough process, both conventinal and high-speed mixing methods were used, since high speed mixing method is widely used in some countries and has attracted some interest in the U.S.

Specific volume of the loaf is considered to affect crumb firmness (Ofelt et al. 1958; Kovats et al. 1960; Axford et al. 1968). Therefore, the specific volume of the bread made by the different baking processes in this study was made similar by adjusting oxidant levels in the dough. Only potassium bromate was used as the oxidant because a possible synergistic action of more than two oxidants might have caused unexpected effects on crumb firmness that would affect a proper comparison of crumb firmness.

For accurate comparison of crumb firmness, bread moisture loss was minimized by wrapping each loaf twice, preceded by sucking internal package air which may absorb moisture from the bread during storage. Caution was observed to not withdraw so much package air that the loaf would deform.

Bread formulas for each method were identical, except for yeast level and bromate level, to minimize any ingredient effect on crumb firmness.

Sucrose (7%) was used int he two different baking processes since the

level is considered to be very common at present for the sponge dough process in U.S.A. (Dubois 1981; Kulp and Dubois 1982), and this level is still applicable for short-time dough processes (Dubois 1981; Kulp and Dubois 1982). With 7% sucrose in the formula, residual fructose and glucose contents would be similar in the two different baking processes according to the results of sugar analysis previously reported. Also, residual maltose would be expected to be higher by about 1.3% in the short-time dough bread than that in the sponge dough bread.

The amylograph was used in this study to obtain some clue to any differences in firming rate related to different baking methods, from the standpoint of starch in the bread crumb (Yasunaga et al. 1968; Ghiasi et al. 1982a; Ghiasi et al 1982c; Kim and D'Appolonia 1977c).

Crumb color and water activity were also measured in the stored bread to find some differences or relationships among these different baking methods in relation to crumb firmness change.

MATERIALS AND METHODS

Flour

The flour used was bleached bread flour from Ross Milling Co. Laboratory analysis showed this flour to contain 12.9% moisture, 11.1% protein, and 0.45% ash (dry basis). The farinograph showed: 60.4% water absorption, and 5.5 min. peak time. The amylograph peak viscosity was 615 B.U. and the falling number was 220, thus indicating this flour to be malted.

Baking Formula

The formula given in Table 4 was used. The formula is based on the reports by Dubois (1981) and Kulp and Dubois (1982).

The reason why modifications were done to the basic formula was already mentioned in the introduction.

Instant dry yeast (Fermipan, Delft, Holland) was used to keep the yeast activity constant at each baking experiment, because fresh compressed yeast changes its activity as each day passes even if it is stored in a refrigerator.

Sponge Oough Procedure

A Oiosna spiral mixer (Osbnabruck, Germany), type SP 800 was used for mixing the sponge and dough. The procedure was as follows:

1. Weigh the sponge and dough ingredients separately.
2 Mix sponge for 3 min at low speed. Sponge temperature was 76±1°F (24-25°C). Yeast was suspended in water before mixing.
3. Place mixed sponge, cut into 1 kg segments, in lightly greased fermentation bowls, then into a fermentation cabinet which was adjusted to 85°F (29°C) and 86% relative humidity (R.H.). Allow to ferment for 4 hours to reach the proper degree of maturity or ripeness which is indicated by perceptible drop in the sponge, usually called the break.
4. After 4 hours, place dough ingredients in mixing bowl and mix for 30 sec at low speed.
5. Place fermented sponge into mixer bowl and mix for 60 sec at low speed (80 rpm), then shift mixer to high-speed (160 rpm) and mix the dough for 7 min to get optimum development. The dough temperature after mixing was 81 1°F (27-28°C).
6. Place the dough in the fermentation cabinet at 85°F (29°C) and 86% R.H. for 30 min rest, then scale dough pieces to 539 grams.
7. Round each dough piece separately by hand.

8. Rest the dough pieces on the bench at 76°F (24°C) and 75% R.H., covering the pieces with a nylon sheet, for an intermediate proof period of 20 min.
9. Mould the dough piece with Oshikiri Moulder, Model MS (Oshikiri Machinery LTD., Tokyo, Japan) adjusted as: top roller, 12; dough feeder, 4; guide rai 25; plate height, 3.5; plate pressure, 2; maximum clearance scale, maximum; return gap scale, 1/16; pressure knob, 1.5.
return gap scale, 1/16; pressure knob, 1.5.
10. Pan the dough piece and proof to height (1.5 cm above pan) at 105°F (41°C) and 92% R.H. (60 2 min).
11. Bake at 425°F (218°C) for 20 min in a Reed Reel Oven (Bakers Engineering & Equipment Co., Kansas City, KS).
12. Cool on the steel rack for one hour at 76°F (24°C) and 75% R.H. for weight and volume measurement.
13. Wrap the loaf twice in a moisture proof plastic bag, and suck internal air without deforming the loaf shape.
14. Store the loaf on a steel rack at 76°F (24°C) and 75% R.H. for firmness and amylograph measurement.

Short-Time Dough Procedure

Two mixing methods, i.e., conventional mixing and high-speed mixing were used. A Diosna spiral mixer type SP 80D (Osnabruck, Germany) was used for conventional mixing method. Mono high-speed mixer, Moder 35F (Mono Bakery Equipment Inc., Melvern, PA) of rotation speed 475 rpm with propeller length 33.0 cm was used for high-speed mixing method. The methods used were as follows:

1. Weigh the ingredients. Yeast was suspended in the water before mixing.
2a. In the conventional mixer, mix the dough for 60 sec at low speed, then

shift mixer to high-speed and mix the dough or 10 min to get optimum development. The dough temperature after mixing was 81 1°F (27-28°C).

2b. In the high-speed mixer, mix the dough for 30 sec and after scraping down any ingredients still attached to the internal face of the mixer, mix the dough for 3 min to get optimum development. The dough temperature after mixing was 81 1°F (27-28°C).

3. Place the mixed dough, cut in 1 kg segments, in lightly greased fermentation bowls and into fermentation cabinet at 85°F (29°C) and 86% R.H. for a dough rest period of 15 min., then scale dough pieces to 539 grams.
4. Round each dough piece separately by hand.
5. Rest the dough pieces on the bench at 76°F (24°C) and 76% R.H., covering the dough pieces with a nylon sheet, for an intermediate proof period of 10 min.
6. Mould the dough piece with Oshikiri Moulder, Model MS adjusted as same as sponge dough procedure except for plate height 3.0.
7. Pan the dough piece and proof to heigth (1.5 cm above pan) at 105°F (41°C) and 92% R.H. (70±2 min for conventional mixing method, 75±2 min for high-speed mixing method).
8. The remaining steps were the same as for sponge dough procedure from step 11 to step 14.

Moisture Determination

Moisture was determined in bread samples according to AACC method 44-15A (American Association of Cereal Chemists 1983).

Firming Measurement

Firmness measurements were taken at day 0 (2 hours), and from day 1 (24 hours)

to day 8 (192 hours), after every 24 hours, using the Voland Stevens LFRA Analyzer (Voland Corporation, Hawthrone, NY) adjusted as follows: penetration speed, 2.0 mm/sec; penetration distance by thumb wheel, 4 mm; mode selection, normal; load choice, 1 g - 1000 g in 1 g increments.

A cut slice of bread was placed on the table of the texture analyzer and adjusted to the height ensuring that the probe was 5 mm from the surface of the slice of bread. Load was displayed digitally in gram units and maximum load was measured as crumb firmness for each slices of bread.

Six 1-inch slices were taken from each loaf (1-inch slices from each end were discarded) for firmness mearurements and average values of the firmness of the six slices were used as a representative crumb firmness value of the loaf. Measurements were made on the center of each slices. The direction of applied force was from the ends towards the center.

Two loaves from two different doughs were used for each measurement and those values were averaged to represent the crumb firmness of the loaf, for each experimental condition.

After measuring the firmness of the loaves, the loaves were discarded and new loaves were used for the next firmness measurement.

Color Measurement

Agtron M-300-A (Magnuson Engineer, INC, San Jose, CA) was used for color measurement of bread crumb. According to AACC Method 14-30 (American Associaiton of Cereal Chemists 1983), the green mode for measuring 546 nm. wavelength was used.

Operation and standardization as described in the instrument manual were followed.

A mask of black paper with a cut-out 1-3/4" x 1-3/4" in its center was placed on the viewer, then the slice of the bread was placed on the mask. Disc M-00 placed on the top of the slice. Then the reading was recorded.

The central portion of the loaf, 2 cm thick, was sliced and both sides of the slice were measured. Four loaves were used for each measurement. After measurement, the loaves were discarded and new loaves were used for the next measurement.

Water Activity Measurement

Water activity was measured with a Beckman Water Activity Meter (Beckman Instruments, Inc., Cedar Grove, NJ) Model VFB, using a 75-100% R.H. module. For the measurements at 24°C, the sensor was covered with a cardboard box to prevent air flow from changing the temperature of the sensor too rapidly.

For each measurement, at least one hour elapsed before the sensor equilibrated and readings were taken.

The central portion of the loaf, 5 mm thick, was sliced and placed into the plastic sample cap.

Two loaves were used for each measurement and discarded after the measurement. A new loaf was used for each measurement.

Hydrogen-Ion Activity (pH) Measurement

The pH was measured in bread crumb samples according to AACC Method 02-52 (American Association of Cereal Chemists 1983). Certified buffer solutions of pH 4.0 and pH 7.0 from Fisher Scientific Co. (Fairlaun, NJ) were used for standardization of the pH meter. Two loaves were used for duplication of the data.

Amylograph Procedure

The amylograph provides a continuous automatic record of the viscosity changes which occur in a flour-water suspension being subjected to a uniform increase in temperature. The viscosity tends to increase as the starch gelatinizes, while the liquefying action of alpha-amylase has an opposing effect. The height of the curve at maximum viscosity is taken as an index of amylase activity (Pyler 1973c).

Yasunaga et al. (1968); Ghiasi et al. 1982a; Ghiasi et al. 1982c; Kim and D'Appolonia 1977c used the amylograph on bread crumb slurries to measure the extent of starch gelatinization. Amylograph peak height decreased with storage, and that change was suggested as an index in estimating bread staling.

In the present study, the method used was basically the same as Yasunaga et al. (1968). The loaf of bread was taken out of the plastic bag, then was cut into 2 cm thick slices. The outer 2 slices from each end were discarded and the central five slices were used for the experiment. After the outer 1 cm crust-containing layer of each slice was cut off, 95 g of the remaining crumb was weighed. This process was done quickly to minimize moisture diffusion from bread into the air.

The 95 g of bread crumb was soaked in 300 ml distilled water at 25°C for one hour and there after dispersed in a Waring Blender (15 sec at low and 60 sec at high-speed) to form a smooth slurry. The slurry was transferred to the amylograph bowl and a further 150 ml of distilled water was added. The amylograph test was then determined with the 700 cm.g cartridge and normal heating cycle.

Photomicrographs

Light photographs of bread curmb were taken at x400 and x160 magnification using the Zeizz light microscope (West Germany) and Kodak ISO 400, 35 mm, black and white film.

Five grams of bread crumb was dispersed in 25 ml of glycerol to pervent starch from swelling by water.

Samples from two loaves each from two different doughs were used for each photograph and the most representative was selected.

Photographs were taken at 1 day (24 hours) and 8 days (168 hours) after baking.

Statistical Method

Analysis of variance (Least Significant Difference Test) (Snedecor and Cochran 1980) was used to analyze the data for crumb firmness, amylograph peak viscosity, water activity of bread crumb, and bread crumb color, using the SAS computer program with the kind assistance of Dr. Dallas Johnson, Statistical Laboratory, Kansas State University.

RESULTS AND DISCUSSION

Determination of Oxidant (Potassium Bromate) Level

Potassium bromate ($KRrO_3$) was used as the oxidant in this study to adjust the specific volumes of the white pan breads, made by sponge dough and short-time dough procedures to similar levels such that the effect of specific volume on crumb firmness was minimized.

Figure 16 shows the effect of potassium bromate on the specific volume of white pan bread made by three different baking methods. Four loaves, each from two different doughs were baked at each bromate level to measure the specific volume.

According to this result, bromate levels were selected as follows: 0 ppm for sponge doughs; 80 ppm for short-time with conventional mixing doughs; 50 ppm for short-time with high-speed mixing doughs.

Oxidation requirement is apparently related to fermentation, because sponge dough requires less oxidant than shorter fermentation dough (Magoffin and Hoseney 1974). The present study confirms these previously reported observations. Also, the data suggest that the conventionally-mixed, short-time doughs were more tolerant to bromate than the high-speed mixing doughs.

As the oxidant level increases, loaf volume increases to an optimum. But over-oxidation makes the loaf volume lower, since excessive oxidation ruptures the gluten net work (Pyler 1973a). The present results also agree very well with previous findings.

The results from the sponge dough bread tests indicated that the flour used for this study was already oxidized to the optimum level, for sponge dough bread, or perhaps a little beyond the optimum. It should be recalled

that the formulas used in this study contained 0.5% ppm bromate to all doughs. Also, the commercial flour used in this work was treated by the mill with azodicarbonamide.

Measurement of Crumb Firmness

Figure 17 graphically summarizes the crumb firmness data obtained for the white pan bread made by the sponge dough and short-time dough processes with conventional mixing or high-speed methods. The specific volume of the breads used for the crumb firming study was 6.70±0.05.

According to the statistical analysis (ANDVA) as shown on Table 5, the firmness of white pan bread crumb made by the three different baking methods was significantly different at α=0.05 level.

Short-time dough bread made by the conventional mixing method was slightly softer than that made by the high-speed mixing method. Sponge dough bread was slightly softer than the short-time dough bread made by the conventional mixing method. This result agrees with general observations made by the baking industry, but the obtained difference in the firmness of these three different baking methods was smaller than expected before the experiment. These results suggest that these small differences may be overcome by variation of ingredients. Recent work (Ponte 1984) showed that short-time dough bread containing a commercial dough conditioner was softer than sponge dough bread when stored for more than two days.

The difference in firmness between sponge dough bread and short-time dough bread is presumed to be caused by the difference in fermentation time. As D'Appolonia (1984) explained, the gluten undergoes changes through fermentation, the net overall effect being referred to as maturation or conditioning

--such changes in the gluten structure may affect the degree of softness in the bread crumb as well as the reate of crumb firming. How fermentation produces certain chemical changes is still mostly a mystery (Magoffin and Hoseney 1974). The grain structure of short-time dough bread was slightly coarser than that of sponge dough bread. The difference in grain structure my affect the firmness of firming rate. The possible effect of grain structure on the crumb firmness or firming rate has not yet been studied, but would apparently be an interesting area for further research.

The different mixing methods yielded differences in firming. Since the grain structure of the bread crumb made by conventional and high-speed mixing methods were similar, the effect of mixing must be taken into account as to a causative factor in firming differences.

If the high-speed mixing causes damaged starch during mixing, it may affect the crumb firmness or firming rate, since damaged starch is susceptible to enzyme action. Also, high-speed mixing may deform gluten structure in some manner and may affect the firmness or the firming rate.

The moisture of one-day and eight-day stored breads was determined as shown on Table 6. Two loaves each from two different doughs were used for each moisture determination.

The bread moisture made by each baking method showed a slight decrease after eight days of storage. These decreases in bread moisture might be expected to exert small increases in firming, as shown by Bechtel and Meisner (1954).

Measurement of Water Activity

Table 7 shows the daily change of water activity of the bread crumb made

by different baking methods.

The statistical analysis (ANDVA) showed that water activity or free water, did not change for all three baking methods over a seven-day period at =0.05 level for the bread stored at 24°C. Therefore, water activity, i.e., free water expressed as water activity, seems not to be related to crumb firming. Also, the statistical analysis showed at α=0.05 level that the water activity of sponge dough bread is slightly but significantly lower than short-time dough bread, even though moisture content was almost the same (Table 6). This means that the status of bound, intermediate and free water (Davis 1980) in the sponge dough bread is slightly different from that of short-time dough bread. These data suggest that sponge dough bread should have a longer shelf life (mold free) than the short-time dough bread.

Measurement of Crumb Color

Table 8 shows the daily change of crumb color of the white pan bread made by three different baking methods.

The statistical analysis (ANDVA) showed that crumb color did not change for all three baking methods over an eight day period at α=0.05 level. This result means that there is no relation between crumb color change and crumb firmness change.

Also, statistical analysis shows at α=0.05 level that the crumb color of short-time dough with conventional mixing was slightly, but significantly, whiter than that of sponge dough bread, perhaps because of the higher oxidation level in the short time with conventional mixing. Also, it was shown that the crumb color of sponge dough bread was slightly, but significantly, whiter than that of short-time dough with high-speed mixing, probably because

some fermentation products may have affected the crumb pigment (xanthophyl) of sponge dough bread to make it whiter, but we have no direct evidence for this supposition.

Measurement of Amylograph Peak Viscosity of Bread Crumb

Figure 18 graphically summarizes the analytical data for amylograph peak viscosities of the white pan bread crumb made by three different baking methods. Two loaves from each of three different doughs were analyzed for each experimental condition.

The statistical analysis (ANOVA) of these data showed that the peak viscosity of the bread crumb was significantly different for the three different baking methods at =0.05 level, as shown on Table 9.

Figures 19-21 show the daily change in amylograms of bread crumb made by each baking method.

The peak viscosity of sponge dough bread crumb was higher than that of short-time dough bread, while conventional mixing bread was somewhat higher than that of high-speed mixing bread. This result is apparently related to the result of crumb firming change (Fig. 17), and indicates that the bread crumb that has higher firmness shows lower amylograph peak viscosity. This point will be discussed in a following section.

The amylograph peak viscosity of bread crumb made by each baking method increased as the bread staled (Fig.18). This result is entirely opposite to those results reported by Yasunaga et al. (1968). They showed that amylograph peak viscosity decreased with storage and that change was suggested as an index for estimating staling. An explanation for this phenomenon was that starch crystallization toughens the partially swollen granules and results in

decreased peak viscosity (Kulp and Ponte 1981). Also, Yasunaga et al. (1968) observed a minor additional peak in the amylogram at a tempearture lower than that of the major peak, which is not normally present in flour or starch amylograms, but our amylograms did not show the minor peak. Furtheremore, our major peak appeared c.a. 2.5 min after the temperature reached 95°C, though the major peak of Yasunaga et al. (1968) appeared just when the temperature reached 95°C.

The Canadian workers used the GRL (Grain Research Laboratory) Remix method (Irvine and McMullan 1960). The flour used was a straight grade flour milled from Canadian Hard Red Spring wheat on the experimetal Buhler mill and the analytical data of their flour was: protein, 13.5%; ash, 0.44%.

Possible factors to account for the opposite results noted above may be related to differences in bread formulation or processing, or to the method of sample prepareation (Ghiasi et al. 1982a; Ghiasi et al. 1982c; Kim and D'Appolonia 1977c). A more systematic study would be required to resolve these differing research findings.

Work was done to explain the effects of SSL on bread crumb viscosity inasmuch as crumb softerners are widely used by the baking industry. Short-time dough with conventional mixing was used to produce the white pan bread both with SSL and without SSL, then the amylograph peak viscosity was measured as the bread staled. Two loaves from each of two different doughs were used for each experimental condition.

Figure 22 graphically summarizes the change in crumb peak viscosities as a function of time. Figure 23 shows the actual amylograms obtained by the experimental bread without SSL. Figure 24 graphically summarizes the data obtained by a similar experiment when the crumb amount was increased from 95 g

to 120 g, and Figures 25 and 26 show the amylograms obtained in these experiments.

These results show that the peak viscosity increased as bread staled whether or not SSL is used in the bread formula. Therefore, SSL is not the factor causing a peak viscosity increase as brea stales. When SSL was not used in the bread formula, the amylogram showed the minor peak which was also obtained by Yasunaga et al. (1968), but the viscosity did not decrease, but remained constant after reaching peak viscosity. Also, these data show that SSL drastically increases the peak viscosity of bread crumb. This effect of surfactant on peak viscosity was shown recently by Riisom et al. (1984), using monoglyceride, and they attributed the effect to amylose-monoglyceride complex formation. SSL also is known to form a complex with amylose during baking (Osman et al. 1961; Ghiasi et al 1983a; Ghiasi et al. 1982b). Ghiasi et al. (1982b) demonstrated that an amylose-surfactant complex is formed within the starch granules before gelatinization takes place. Probably this complex formation is the major cause for SSL to drastically increase in the peak viscosity of the bread crumb.

The amylograph peak viscosity of bread crumb reflects the starch gelatinization taking place during baking in such a way that the degree of starch swelling in the amylograph is inversely related to the amount of starch swelling occurring during baking (Krog and Davis 1984). Therefore, our results indicate that the amount of starch swelling during baking is less in sponge dough bread than in short-time dough bread. Possibly fermentation products produced during sponge fermentation, or the relatively longer hydration occurring during this time, influenced starch swelling in some manner during baking. Also, our results indicate that the amount of starch swelling during bread baking is less with conventional mixing than with high-speed

mixing. High-speed mixing may slightly damage starch so that the starch becomes more susceptible to swelling during baking.

The amylograph peak viscosity increased as bread staled. This indicates that the physical structure of bread crumb starch changes as bread stales. The change of structure of crumb starch during storage may or may not be related to the increase in crumb starch crystallinity during storage. This problem was left for further study.

Table 10 shows that pH of bread samples used for the amylograph measurement. The pH of the bread crumb should be constant for each amylograph analysis, because the crumb pH affects the viscosity obtained on the amylograph. Usually the buffer solution of pH 5.35 is used for flour amylograph analysis. But buffer solution was not used in this study since we followed the method of Yasunaga et al. (1968). Accordingly, the crumb pH was measured to determine variability in our samples. As shown in Table 10, the pH of the breads ranged from 5.10 to 5.38. These relatively small differences would not be expected to exert appreciable effects on the bread crumb.

Figure 27 shows photomicrographs of bread crumb starch after one-day and eight-day storage. No apparent differences were observed as a function of different baking methods or storage period. This result means that changes in peak viscosities of bread crumb made by different baking methods or stored for varying periods can not be easily attributed to differences in the size of starch granules. The reasons for crumb viscosity differences may, in part, have to be explained according to other changes in the physical structure of the crumb starch in relation to bread staling and baking conditions.

Table 4. Formula Used for Baking[a]

Ingredients	Sponge Dough Process			Short-Time Dough Process
	Sponge	Dough	Total	
Flour	70	30	100	100
Water	40	23	63	63
Yeast[b]	2.5	---	2.5	3.5
Yeast Food[c]	0.5	---	0.5	0.5
Sucrose	7.0	---	7.0	7.0
Salt	---	2.0	2.0	2.0
Non Fat Dry Milk	---	2.0	2.0	2.0
Shortening[d]	---	2.5	2.5	2.5
SSLe	---	0.5	0.5	0.5
Bromate Soln.[f]	Variable	---	Variable	Variable

[a]Ingredients, % based on flour weight.

[b]Though yeast % is expressed as fresh yeast, Instant Active Dry Yeast (IADY) was used in the actual experiment in the following manner: IADY % = 0.4 X Fresh Yeast %.

[c]Arkady, Archer Daniels Midland Co., Decatur, IL.

[d]Non emulsified shortening, Archer Daniels Midland Co.

[e]Sodium Stearoyl-2-Lactylate, C. J. Patterson Co., Kansas City, MO.

[f]1% of Potassium bromate solution was prepared with water just before baking.

Figure 16. The Effect of Potassium Bromate on the Specific Volume of White Pan Bread Made by Three Different Baking Methods.

A : Sponge Dough Bread
B : Short-Time Dough with High-Speed Mixing Method
C : Short-Time Dough witn Conventional Mixing Method

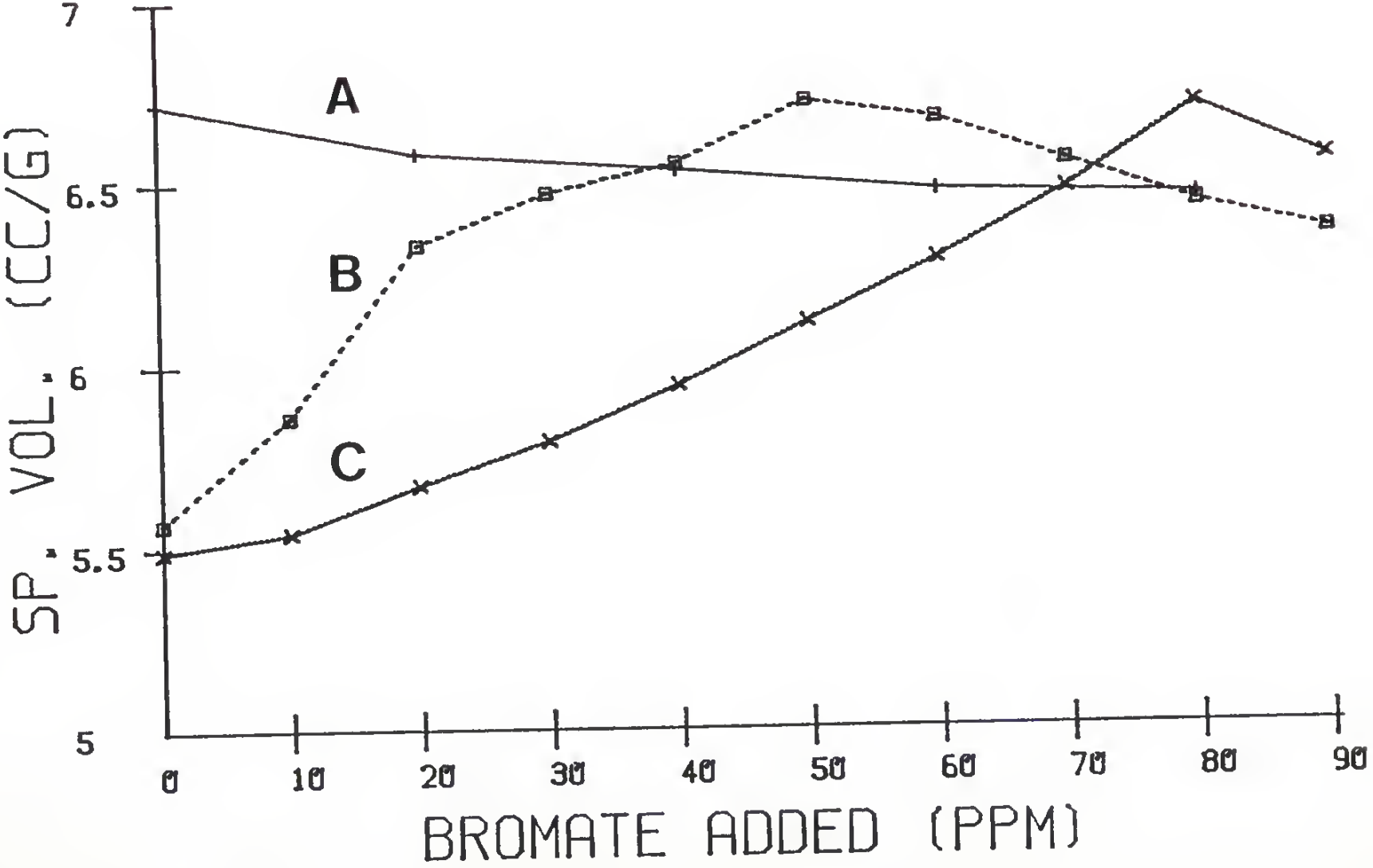

7
6.5
6
5.5
5
SP. VOL. (CC/G)
A
B
C
0
10
20
30
40
50
60
70
80
90
BROMATE ADDED (PPM)

Figure 17. The Change in Crumb Firming (g) for Sponge Dough and Short-Time Dough with Conventional Mixing and High-Speed Mixing Methods over an Eight-Day Period.

A : Short-Time Dough with High-Speed Mixing Method
B : Short-Time Dough with Conventional Mixing Method
C : Sponge Dough Bread

*0-day's sample was measured at 2 hrs after baking

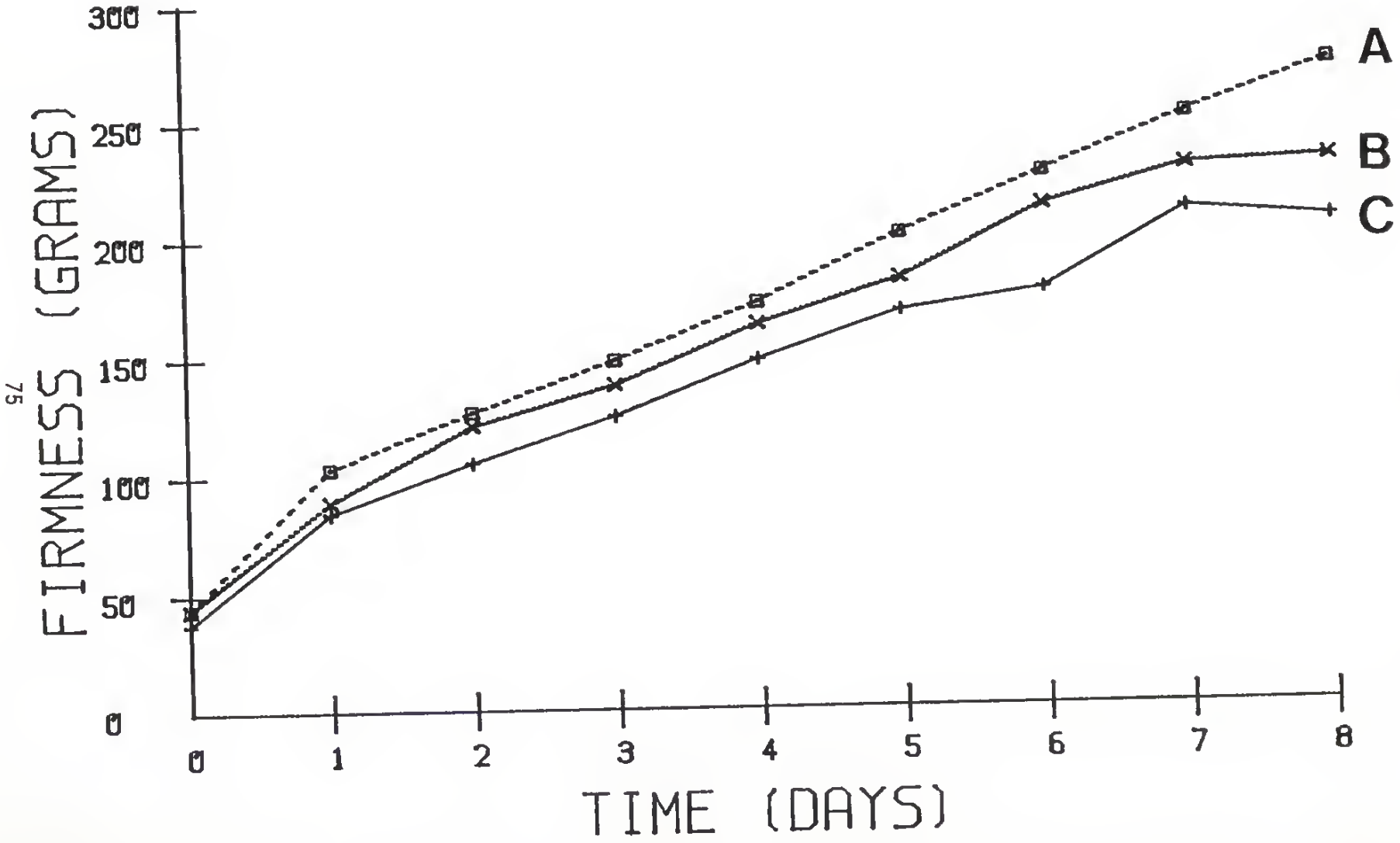

300
250
200
150
100
50
0
FIRMNESS (GRAMS)
0
1
2
3
4
5
6
7
8
TIME (DAYS)
A
B
C

Table 5. Statistical Analysis (ANOVA; LSD Test) of Firmness Change of the White Pan Bread Crumb Made by Three Different Baking Methods.

Baking Procedure	Sponge Dough	Short-Time Dough				
Mixing Method	Conventional	Conventional	High Speed			
Days Stored	Mean	Mean	Mean	F Value	PR>F	LSD Value
0	37.40A	43.98B	44.30B	10.18	0.0460	5.4926
1	83.80A	88.62A	103.17B	43.97	0.0060	6.8460
2	104.97A	120.75A B	126.75B	8.93	0.546	16.8347
3.	124.20A	137.50B	148.12C	67.72	0.0032	6.5560
4.	147.57A	162.60B	171.80B	15.45	0.0263	13.9999
5	167.30A	181.07A B	200.60B	6.68	0.0785	29.1405
6	175.90A	211.57B	225.80B	26.63	0.0123	22.4215
7	209.20A	227.90B	249.70C	118.29	0.0014	8.3878
8	204.80A	230.30B	271.20C	357.33	0.0003	7.9752
Overall Period	139.46A	156.03B	171.25C	341.47	0.0001	6.0511

(1) Means with the same letter compared horizontaly by day are not significantly different.

(2) α= 0.05 level, DF=3

(3) 0-day's sample was measured at 2 hrs. after baking

Table 6. The moisture of White Pan Bread Made by Three Different Baking Methods After 1-Day and 8-Day Storage.

Baking Procedure	Sponge Dough	Short-Time Dough	
Mixing Method	Conventional	Conventional	High Speed
1-day	37.8% A	37.6% A	37.7% A
8-day	37.4% B	37.2% B	37.2% B

Means with the same letter are not significantly different at the α=0.05 level

Analysis of variance results:

Source	DF	F Value	PR>F	LSD Value
Baking Method	2	13.00	0.0714	0.9809
Days Stored	1	169.00	0.0059	0.1434

Table 7. The Change of Water Activity of White Pan Bread Made by Three different Baking Methods over a Seven-Day Period.

Baking Procedure	Sponge Dough	Short-Time Dough	
Mixing Method	Conventional	Conventional	High Speed
Days Stored			
0	0.960	0.964	0.966
1	0.962	0.064	0.969
2	0.960	0.967	0.970
3	0.967	0.967	0.978
4	0.966	0.967	0.969
5	0.959	0.974	0.975
6	0.964	0.968	0.984
7	0.954	0.968	0.084
Average	0.961 A	0.968 B	0.972 B

(1) Means with the same letter are not significantly different at the α=0.05 level.

(2) 0-day's sample was measured at 2 hrs. after baking.

(3) Analysis of variance results:

Source	DF	F Value	PR>F	LSD Value
Baking Method	2	10.41	0.0017	0.4758
Days Stored	7	0.55	0.7845	0.8693

Table 8. The Change of Crumb Color of White Pan Bread Made by Three Different Baking Methods over an Eight-Day Period.

Baking Procedure	Sponge Dough	Short-Time Dough	
Mixing Method	Conventional	Conventional	High-Speed
Days Stored			
0	19.8	19.7	19.0
1	19.8	20.1	19.1
2	19.9	19.9	19.5
3	.19.6	20.1	19.4
4	19.6	20.1	19.2
5	19.8	20.1	19.2
6	19.8	20.4	19.2
7	19.9	20.2	19.4
8	19.6	20.4	19.2
Average	19.8 A	20.1 B	19.3 C

(1) Means with the same letter are not significantly different at the α=0.05 level.

(2) 0-day's sample was measured at 2 hrs.

(3) Analysis of Variance results:

Source	DF	F Value	PR>F	LSD Value
Baking Method	2	53.18	0.001	0.1719
Days Stored	8	1.07	0.4306	0.3023

Figure 18. The Change of Amylograph Peak Viscosity of White Pan Bread Crumb Made by Three Different Baking Methods over a Seven-Day Period.

A : Sponge Dough Bread
B : Short-Time Dough with Conventional Mixing Bread
C : Short-Time Dough with High-Speed Mixing Bread

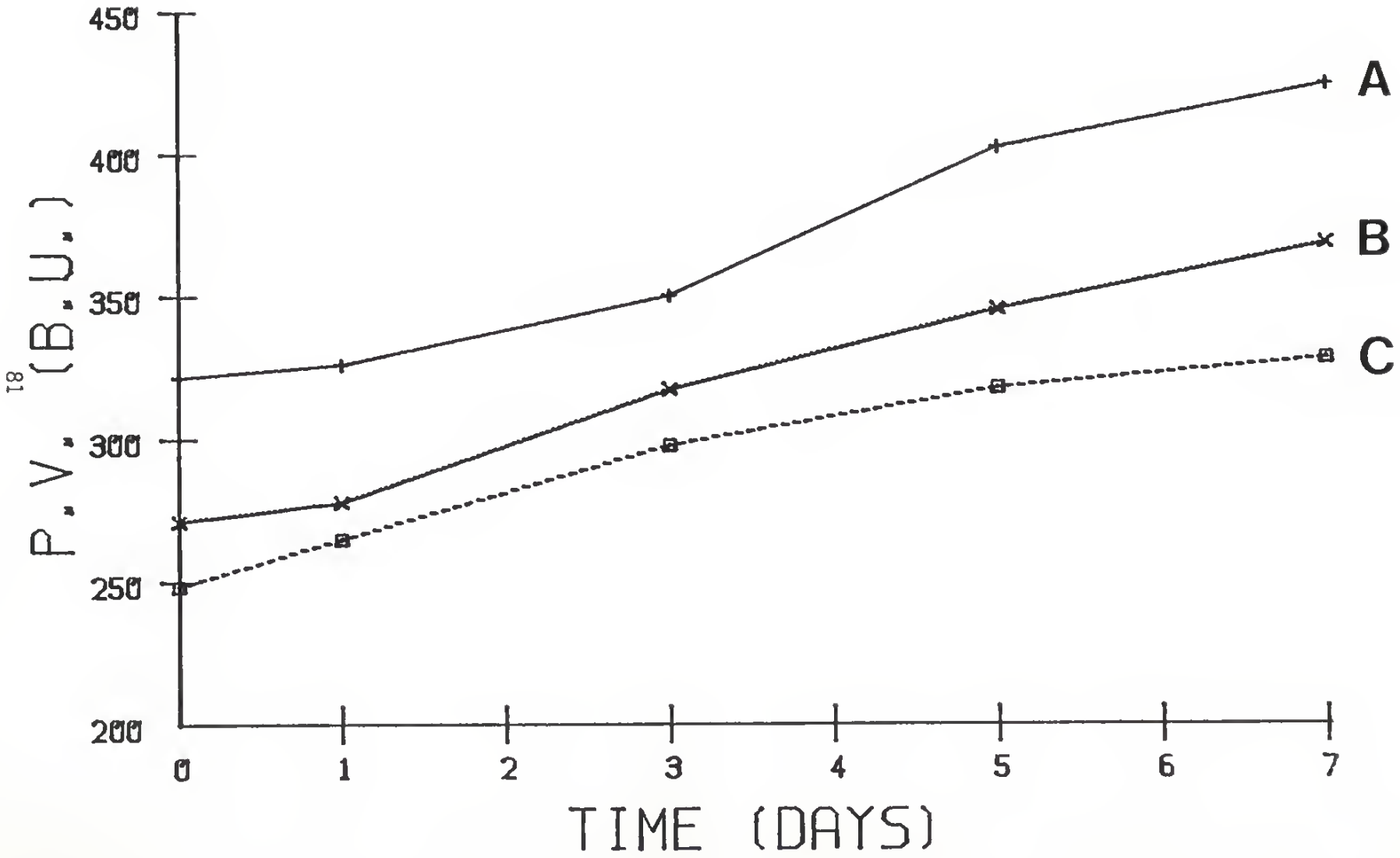

450
400
350
300
250
200
P. V. (B. U.)
81
0
1
2
3
4
5
6
7
TIME (DAYS)
A
B
C

Table 9. Statistical Analysis (ANOVA; LSO Test) of the Amylograph Peak Viscosities of White Pan Bread Made by Three Different Baking Methods.

Baking Procedure	Sponge Dough	Short-Time Dough				
Mixing Method	Conventional	Conventional	High-Speed			
Days Stored	Mean	Mean	Mean	F Value	PR>F	LSD Value
0	321.67 A	271.00 B	248.67 C	37.97	0.0004	21.0069
1	326.17 A	277.83 B	265.00 B	24.79	0.0013	22.4164
3	350.17 A	317.67 A B	298.00 B	6.44	0.0321	35.9236
5	402.00 A	345.67 B	318.00 C	28.87	0.0008	27.5713
7	424.17 A	368.33 B	328.00 C	54.60	0.0001	22.6159
Overall Period	364.83 A	316.10 B	291.53 C	57.10	0.0001	20.1621

(1) Means with the same letter compared horizontally by day are not significantly different.

(2) α=0.05 level, DF=6

(3) 0-day's sample was measured at 2 hrs. after baking.

Figure 19. The Effect of Storage on Amylograms of White Pan Bread Crumb Made by Sponge Dough Procedure.

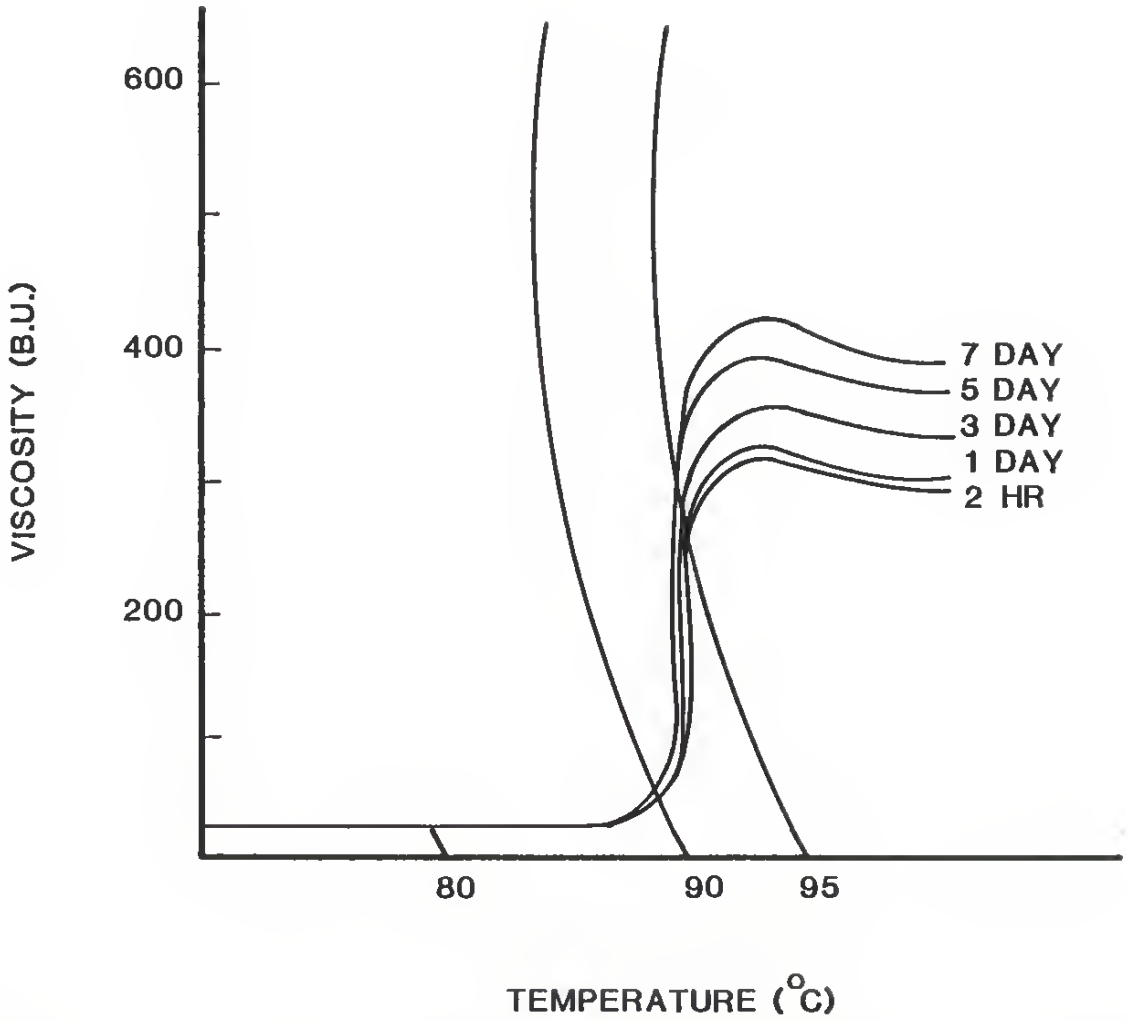

600
400
200
VISCOSITY (B.U.)
7 DAY
5 DAY
3 DAY
1 DAY
2 HR
80
90
95
TEMPERATURE (°C)

Figure 20. The Effect of Storage on Amylograms of White Pan Bread Crumb Made by Short-Time Dough with Conventional Mixing.

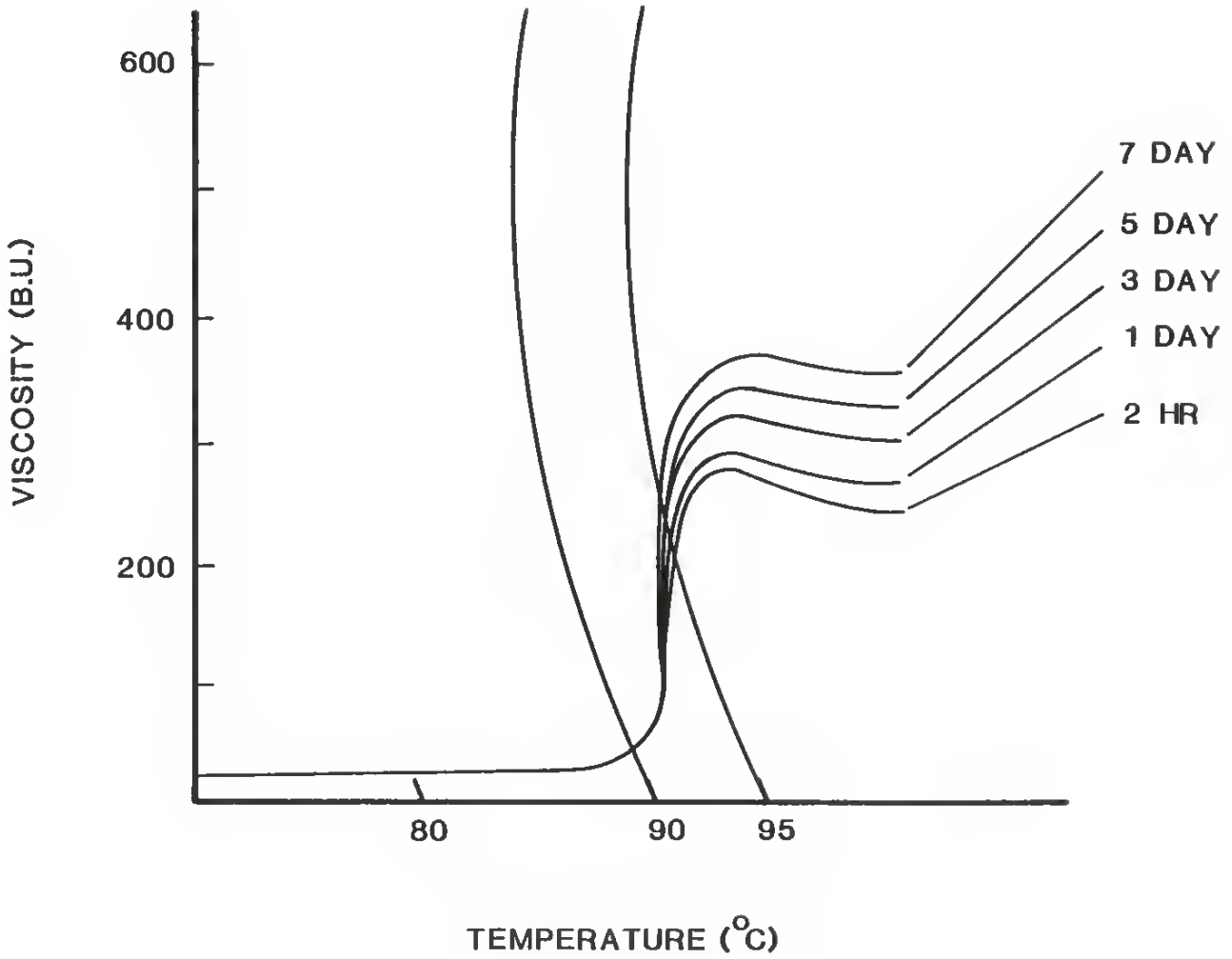

600
400
200
VISCOSITY (B.U.)
7 DAY
5 DAY
3 DAY
1 DAY
2 HR
80
90
95
TEMPERATURE (°C)

Figure 21. The Effect of Storage on Amylograms of White Pan Bread Crumb Made by Short-Time Dough with High-Speed Mixing.

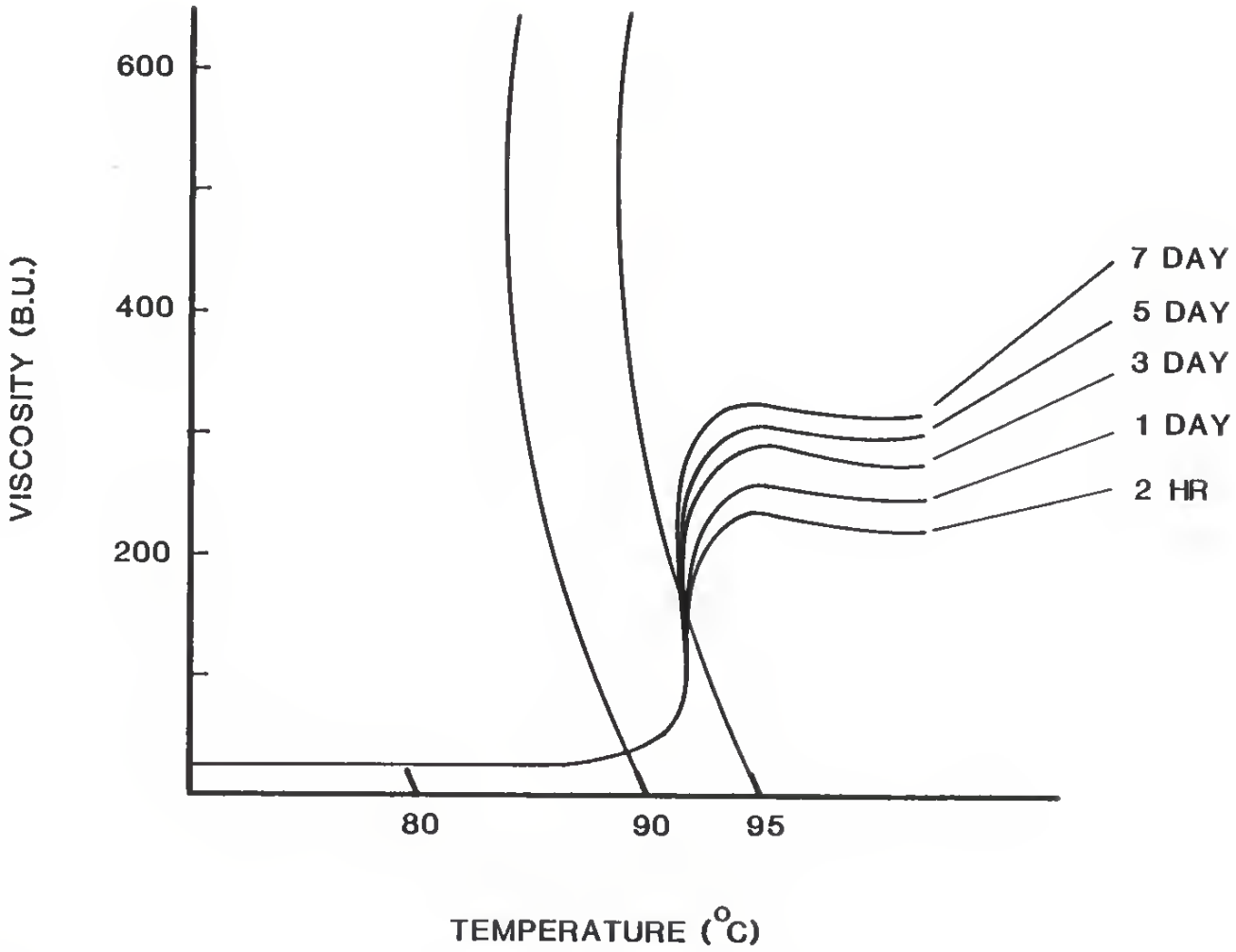

600
400
200
VISCOSITY (B.U.)
7 DAY
5 DAY
3 DAY
1 DAY
2 HR
80
90
95
TEMPERATURE (°C)

Figure 22. The Change of Amylograph Peak Viscosity of White Pan Bread Crumb Made by Short-Time Dough Procedure over a Seven-Day Period.

A : Bread Crumb with SSL
B : Bread Crumb without SSL

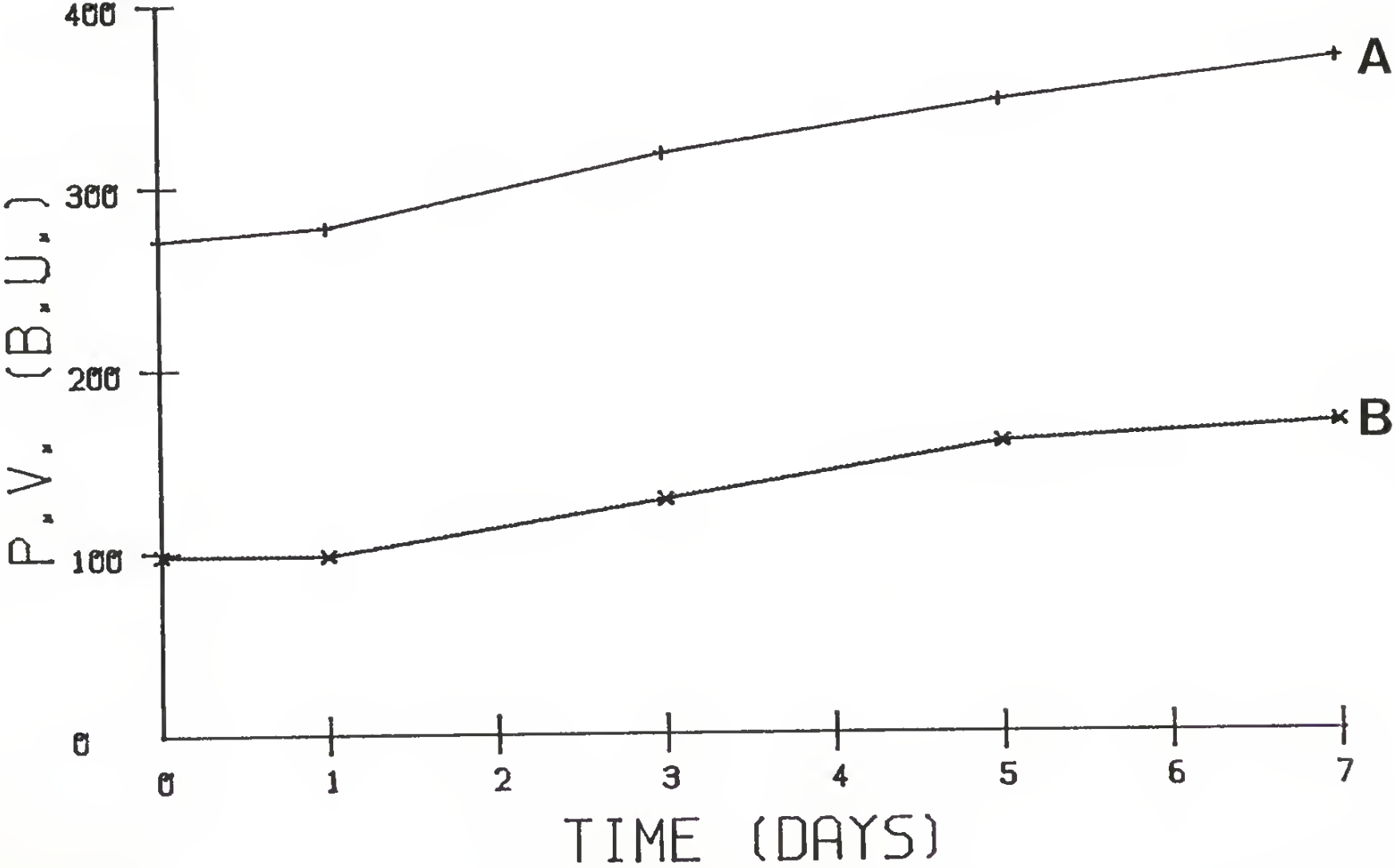

400
300
200
100
0
P. V. (B. U.)
A
B
0
1
2
3
4
5
6
7
TIME (DAYS)

Figure 23. The Effect of Storage on Amylograms of White Pan Bread Crumb Made by Short-Time Dough Procedure Without SSL.

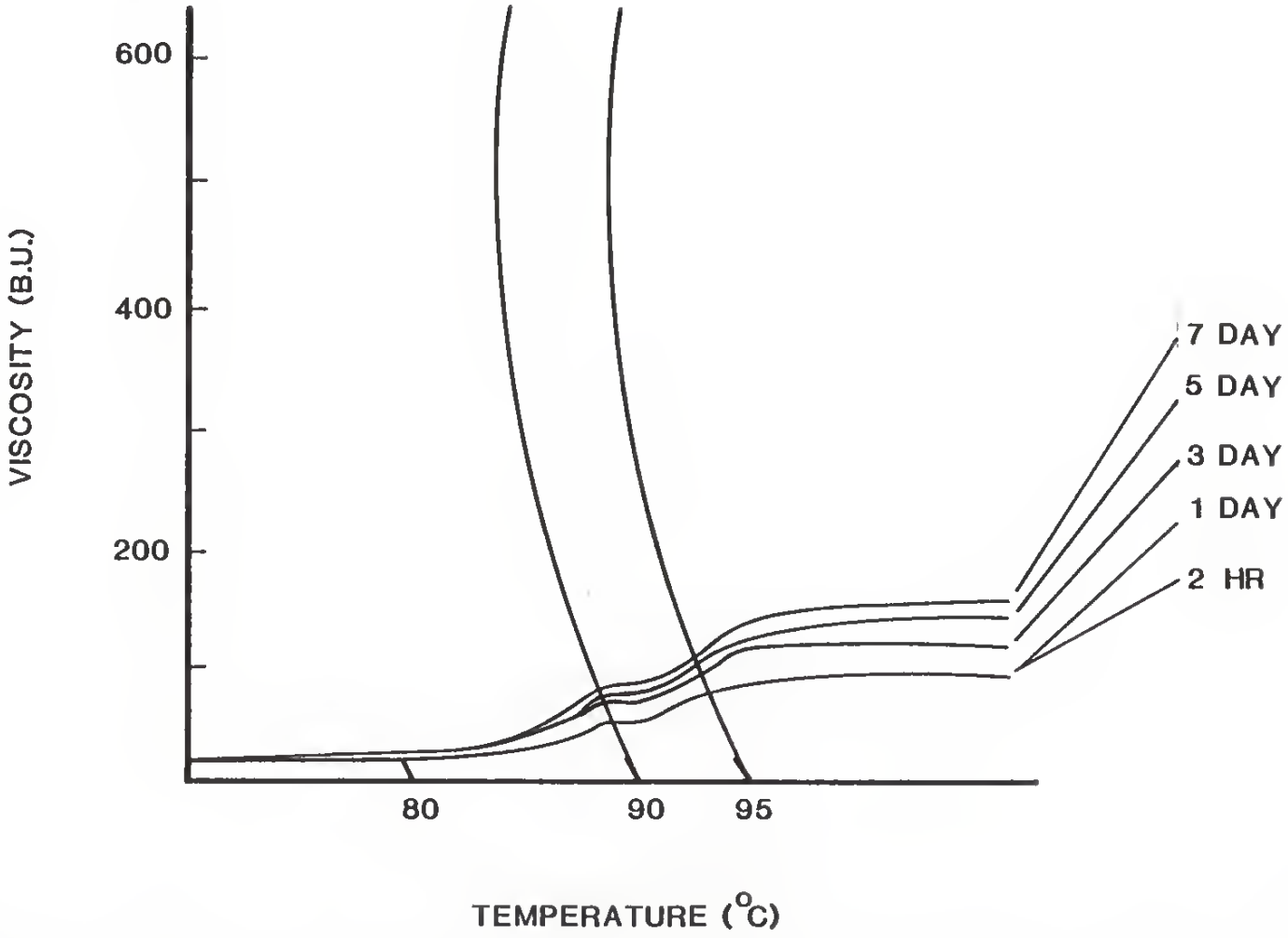

600
400
200
VISCOSITY (B.U.)
7 DAY
5 DAY
3 DAY
1 DAY
2 HR
80
90
95
TEMPERATURE (°C)

Figure 24. The Change of Amylograph Peak Viscosity of White Pan Bread Crumb Made by Short-Time Dough Procedure, when Increased Amount of Bread Crumb (120 g) was Used for the Analysis.

A : Bread Crumb with SSL
B : Bread Crumb Without SSL

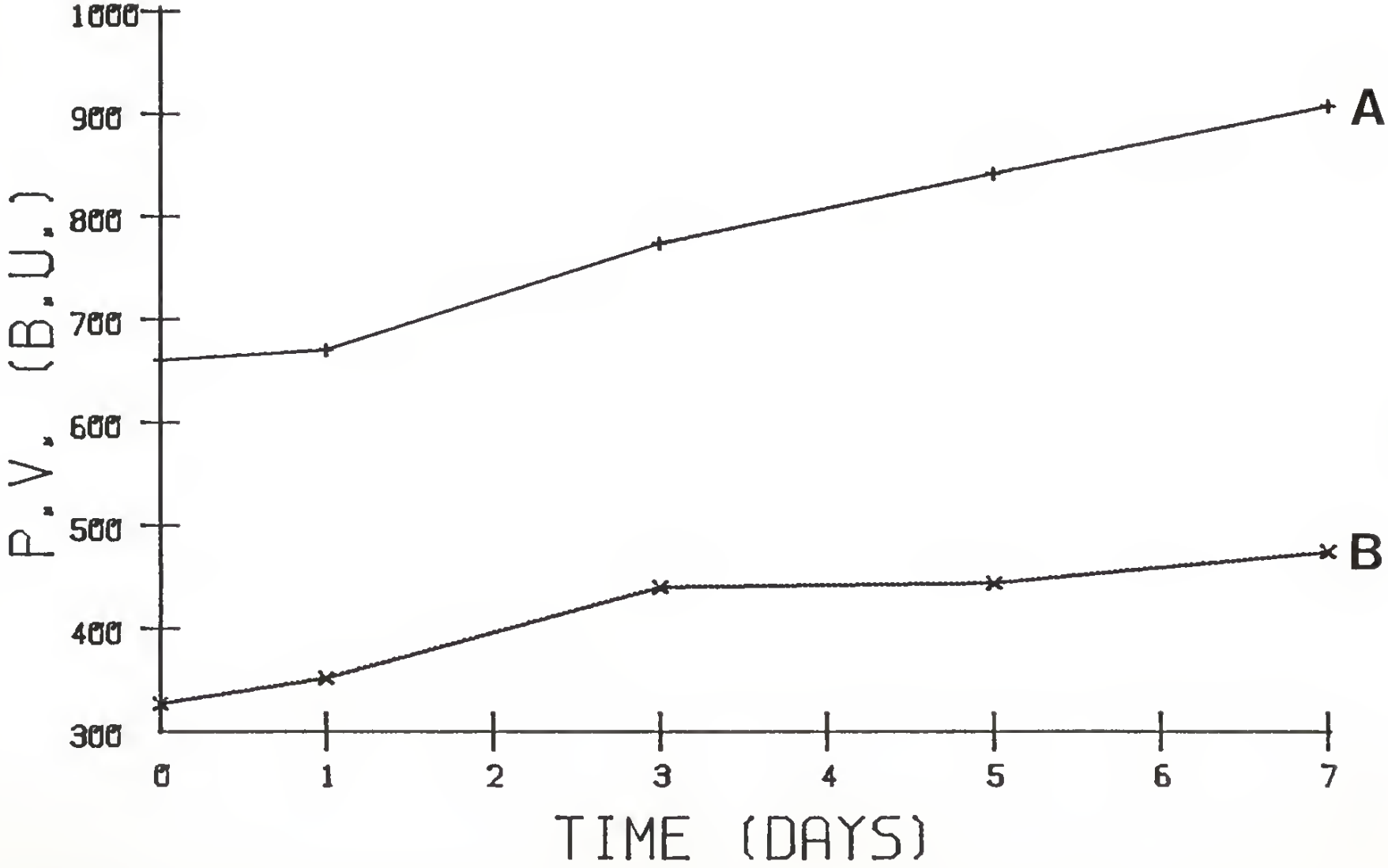

1000
900
800
700
600
500
400
300
P. V. (B. U.)
A
B
0
1
2
3
4
5
6
7
TIME (DAYS)

Figure 25. The Effect of Storage on Amylograms of White Pan Bread Crumb with SSL Made by Short-Time Dough Procedure, when Increased Amount of Bread Crumb (120 g) was Used.

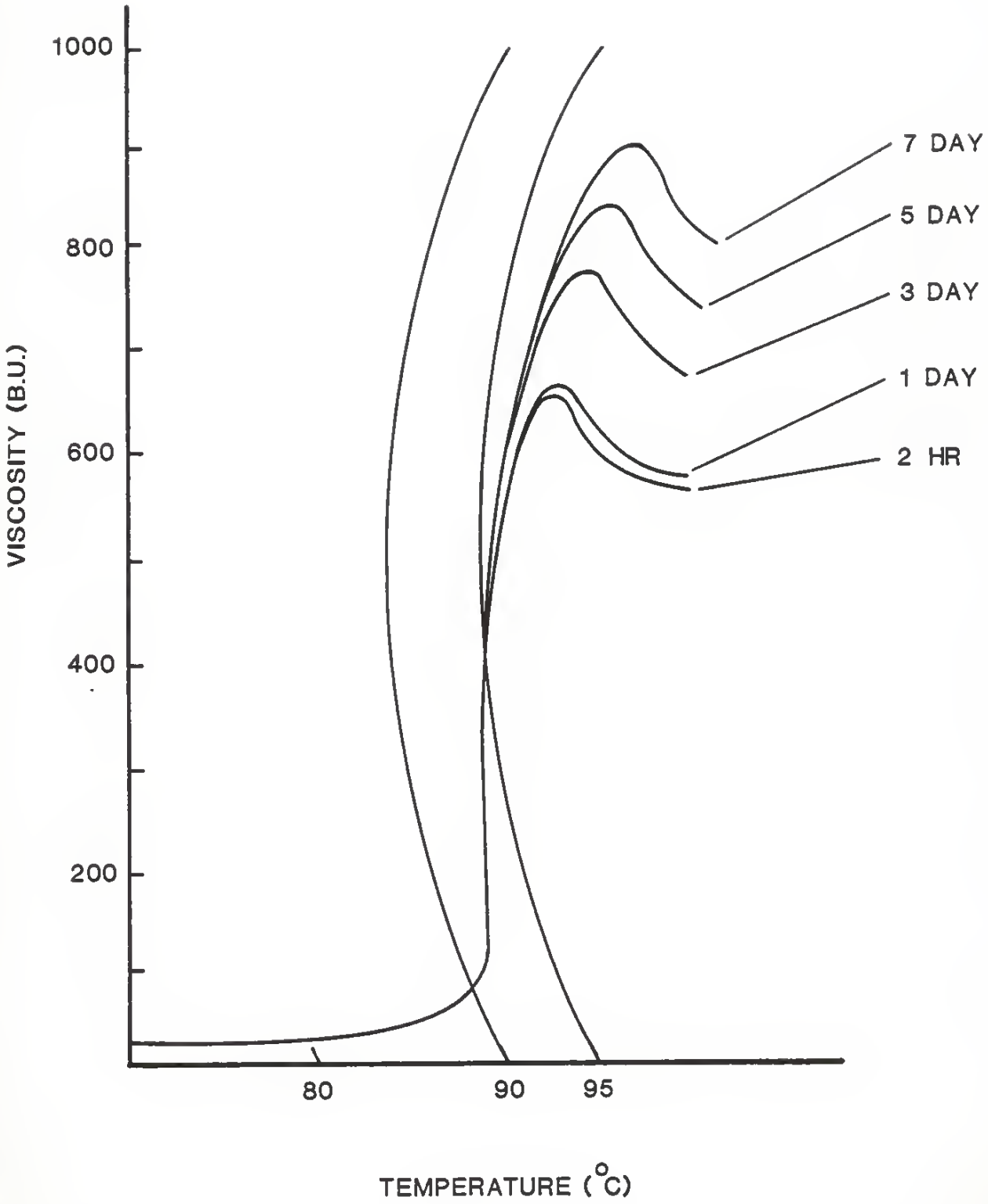

1000
800
600
400
200
VISCOSITY (B.U.)
7 DAY
5 DAY
3 DAY
1 DAY
2 HR
80
90
95
TEMPERATURE (°C)

Figure 26. The Effect of Storage on Amylograms of White Pan Bread Crumb Without SSL Made by Short-Time Dough Procedure, When Increased Amount of Bread Crumb (120 g) was Used.

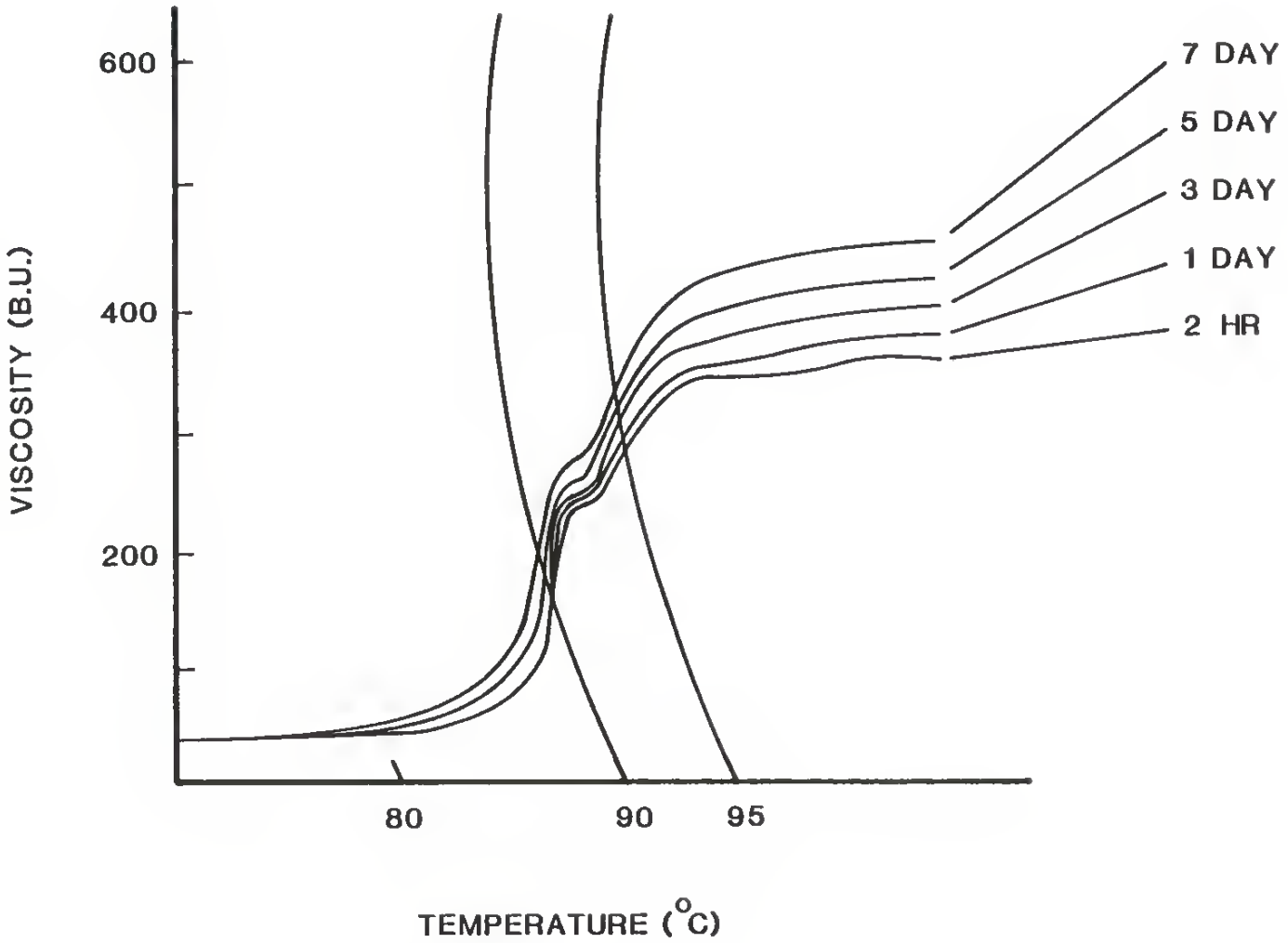

600
400
200
VISCOSITY (B.U.)
7 DAY
5 DAY
3 DAY
1 DAY
2 HR
80
90
95
TEMPERATURE (°C)

Table 10. The pH of Bread Crumb Used for Amylograph Analysis.

Baking Procedure	Sponge Dough	Short-Time Dough		
Mixing Method	Conventional	Conventional		High Speed
SSL, %	0.5	0.5	0	0.5
Days Stored				
0	5.20	5.38	5.31	5.35
1	5.28	5.25	5.38	5.29
3	5.17	5.26	5.33	5.30
5	5.17	5.26	5.33	5.30
7	5.10	5.20	5.35	5.30

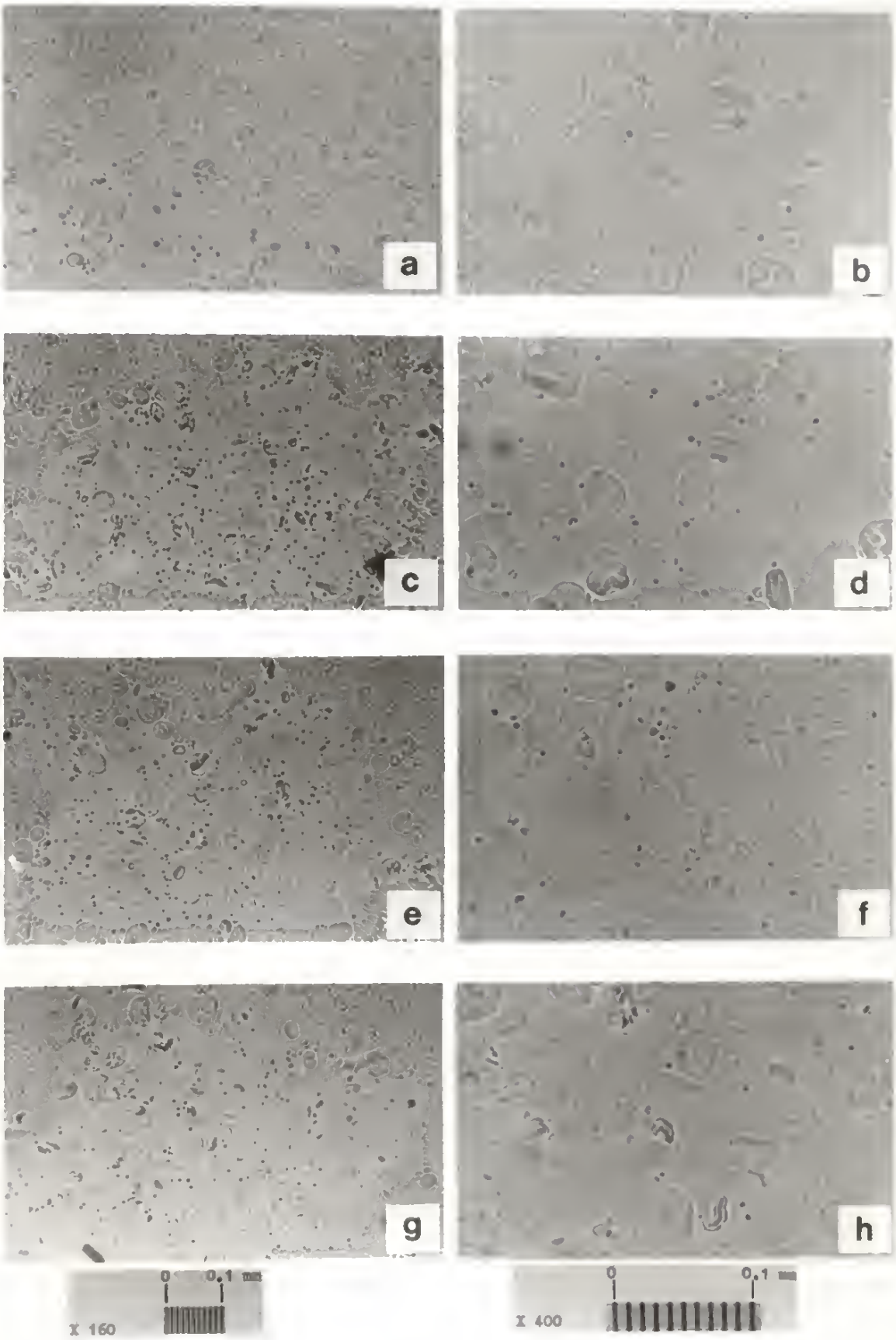
*0-day's sample was measured at 2 hrs. after baking.

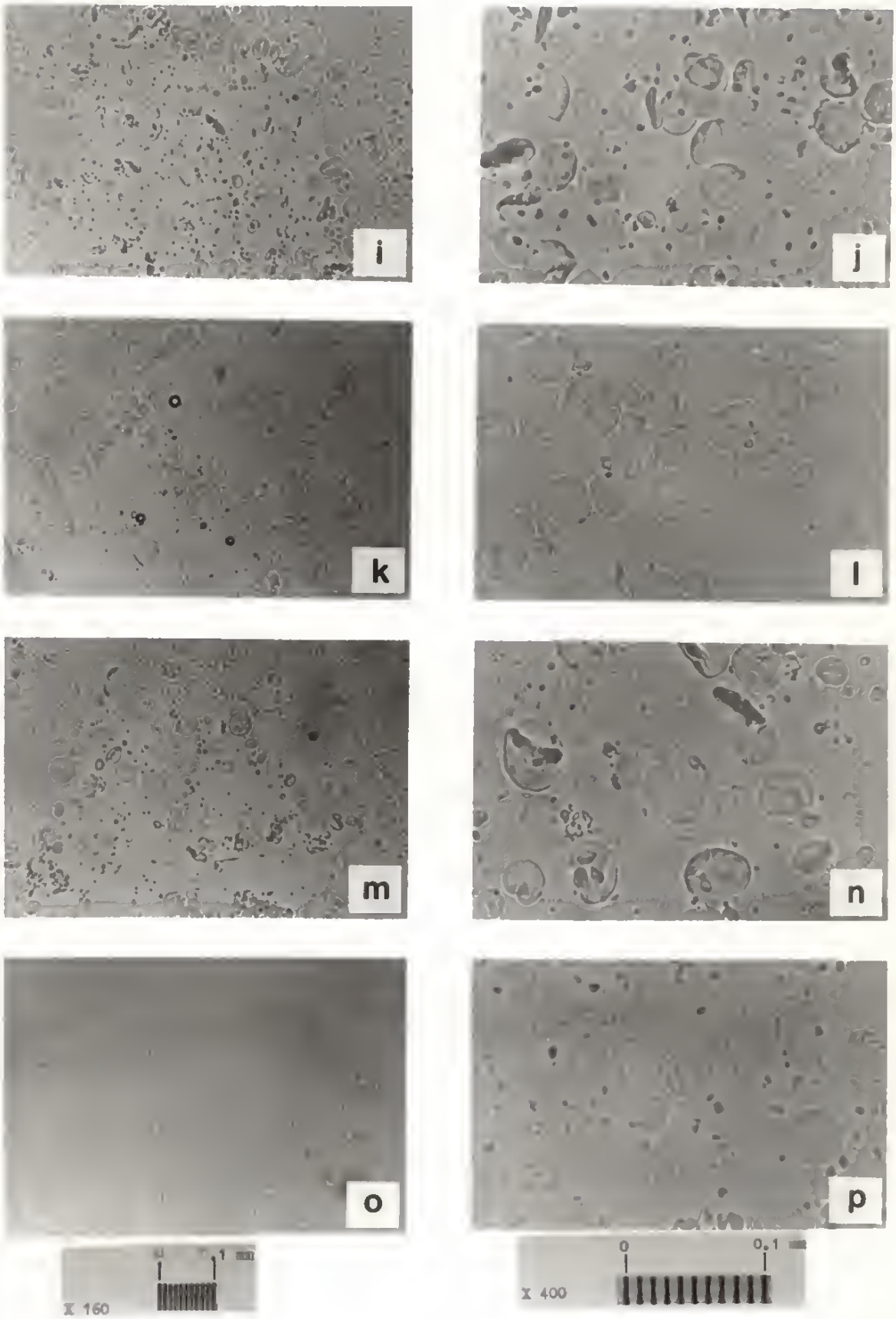
Figure 27. Photomicrographs of Bread Crumb Starch.

Contents:

No.	Days Stored	Baking Procedure	Mixing Method	Contains SSL or Not	Magnification Used
a	1	SP	CV	Yes	X 160
b	1	SP	CV	Yes	X 400
c	1	ST	CV	Yes	X 160
d	1	ST	CV	Yes	X 400
e	1	AT	HS	Yes	X 160
f	1	ST	CV	Yes	X 400
g	1	ST	CV	No	X 160
h	1	St	CV	No	X 400
i	8	SP	CV	Yes	X 160
j	8	SP	CV	Yes	X 400
k	8	ST	CV	Yes	X 160
l	8	ST	CV	Yes	X 400
m	8	ST	HS	Yes	X 160
n	8	ST	HS	Yes	X 400
o	8	ST	CV	No	X 160
P	8	ST	CV	No	X 400

SP : Sponge Dough Process
ST : Short-Time Dough Process
CV : Conventional Mixing
HS : High Speed Mixing


a
b
c
d
e
f
g
h
0
0,1 mm
X 160
0
0,1 mm
X 400


i
j
k
l
m
n
o
p
X 160
X 400

CONCLUSION

The change of bread crumb firmness was measured under conditions that minimized the effect of ingredients used in the formula, specific volume of the loaf, and moisture loss of bread. Sponge dough bread was found to have a lower crumb firming than short-time dough bread, while a high-speed mixing method resulted in a higher crumb firming than a conventional mixing method. Hence, the effect of fermentation and mixing method on crumb firming was confirmed.

Water activity and color of bread crumb were constant during storage over a seven day period, which means that there is no relation between rate of crumb firming and water activity or crumb color. However, the water activity of sponge dough bread was significantly lower than that of short-time dough bread.

The degree of amylograph peak viscosity of bread crumb was inversely related to the degree of crumb firmness by baking method, i.e., the bread crumb which had higher firmness showed lower amylograph peak viscosity. Also, as bread staled, the amylograph peak viscosity became higher, which is entirely opposite to the result of previous work reported by Yasunaga et al. (1968). SSL caused an increase in bread crumb viscosity compared to bread without SSL.

Photomicrographic study of bread crumb starch showed that there was no apparent difference in starch size and shape of bread crumb by different baking methods and by storage period. This means that the change of crumb firmness which is related to the change of amylograph peak viscosity has to be studied from the viewpoint of the change of crumb starch structure during storage.

These results are summarized as follows:

1. The crumb firming rate was faster, in increasing order: Short-time with high-speed mixing dough bread, short-time with conventional mixing dough bread, sponge dough bread.
2. Water activity and color of bread crumb were constant during a seven-day storage period.
3. The amylograph peak viscosity was inversely related to the crumb firmness of bread made by three different baking methods.
4. The amylograph peak viscosity of bread crumb increased as bread staled.
5. SSL in the bread formula made the amylograph peak viscosity of bread crumb increase drastically.
6. The shape and the size of crumb starch showed no significant difference by three different baking methods used and by storage period of eight days.

The following subjects are suggested for further research:

1. The search for the reason why the amylograph peak viscosity of bread crumb increased as bread staled, in relation to the structural change of crumb starch and the increase of crumb starch crystallinity during storage.
2. The search for the reason why the opposite result from the former work was obtained in the determination of crumb peak viscosity by amylograph over a period of storage.
3. The effect of crumb grain on crumb firmness and firming rate under conditions that the effect of the loaf specific volume on the firming properties is minimized.
4. The effect of high-speed mixing on starch damage.

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COMPARISON OF RESIOUAL SUGAR ANO FIRMING CHARACTERISTICS OF WHITE PAN BREAOS MADE BY SPONGE OOUGH AND SHORT-TIME OOUGH PROCESSES.

by

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B.S. in Food Chemcial Engineering,

National Kyushu University, Fukuoka, Japan, 1980

AN ABSTRACT OF A MASTER'S THESIS

Submitted in partial fulfillment of

the requirements for the degree

MASTER OF SCIENCE

Department of Grain Science

KANSAS STATE UNIVERSITY

Manhattan, Kansas

1985

ABSTRACT

The firming characteristics and residual sugar distribution of white pan breads made by the sponge dough and short-time dough processes were studied. Short-time dough bread was made with two mixing procedures: conventional and high-speed. Formulation of the doughs were identical, except for yeast and oxidant, to permit a more accurate comparison of the processes.

High performance liquid chromatography was used to estimate fructose, glucose, sucrose and maltose contained in the bread crumb when the formula sucrose was varied from 1% to 8%. Residual fructose and glucose in sponge dough and short-time dough breads were fairly similar at the higher formula sucrose levels (7-8%), probably because of a balance between fermentation time and yeast level. Residual maltose was higher in short-time dough bread than in sponge dough bread probably because yeast had sufficient glucose substrate in short-time doughs and was not required to adapt to maltose fermentation.

Bread crumb firmness was measured over an eight-day period under experimental conditions such that the influence of dough formula, specific volume and moisture diffusion from bread to the air were minimized. Firming was higher in short-time dough bread than in sponge dough bread while high-speed mixing bread showed higher firming than conventional mixing bread. Amylograph peak viscosity of bread crumb showed a strong inverse relation to firming rate in such a manner that bread which had higher crumb firmness had lower peak viscosity. Also, as crumb firmness increased, peak viscosity increased. Thus, firming characteristics of bread crumb was highly related to the swelling properties of the crumb.

Light microphotographic study of the crumb starch showed that size and shape of the crumb starch of sponge dough and short-time dough breads were

similar. Thus, it was suggested that the relation between crumb firming characteristics and crumb swelling properties has to be explained by a molecular level study of crumb starch composition and structure.