EFFECT OF STORAGE AND OTHER TREATMENTS ON CERTAIN PHYSICAL AND CHEMICAL PROPERTIES OF FLOUR

by

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INTRODUCTION

Flour technologists have long sought satisfactory physical and chemical methods for the evaluation of flour. Theirs is an immediate goal, a test for flour quality; but there are others who are interested in the more fundamental aspects of flour behavior. Organic chemists are interested in the structure of protein and of starch--indeed, one of the enticing problems of biochemistry is protein structural specificity. Such studies frequently involve flour because here is an ideal natural product from the structural point of view and one which is probably unsurpassed in complexity and in the number of specific characteristics of its protein. Flour is a rich source for investigations in both "applied" and "pure" science.

One of the fundamental problems facing both the technologist and the theoretical chemist in the interpretation of his data is the effect of storage upon the flour with which he is working since this is a variable he cannot escape. Possibilities for the study of this subject are far from exhausted.

In the field of cereal chemistry, evaluation of flour quality has nearly always involved the experimental bake. If a shorter, less expensive, less arbitrary adjunct to the experimental bake could be developed, it would be helpful to the flour technologist. One of the objectives of this work was to develop farinograph and extensogram evaluation methods not strictly confined to flour-water and flour-water-salt doughs, without dealing with fermenting doughs--for the action of fermentation upon protein structure is like scrambling a completed jig saw puzzle. With this in mind flour was stored in various atmospheres and at different temperatures, mixed in different gaseous atmospheres, and mixed with various reagents such as NaCl, $KBrO_3$, HCl, CH_3COOH, and NH_4OH, the purpose being to find practical adjuncts to farinograph and extensograph procedure.

LITERATURE AND HISTORICAL REVIEW

This review, by no means exhaustive, cites some of the literature pertinent to the experimental work in this thesis. The chapter is subdivided under the headings Physical Dough Testers and Chemical Tests.

Physical Dough Testers

A number and variety of instruments for physically testing wheat flour doughs have been devised. One of the earliest devices for determining the physical properties of dough was the aleurometer invented by Boland in 1848 to measure the expansibility of gluten. The farinometer invented by Kunis in 1891, and Foster's gluten tester in 1898 are devices based on the principle of the aleurometer. Other early devices are Kedzie's farinometer, the viscometer of Jago, the perfekdo of Briggs, and the device of Henderson et al. (11).

The various instruments may be classified either upon the mechanical principle governing the operation of the instrument, or upon the kind of work it does upon the dough. Some of the instruments, such as the Hogarth mixer with recording dyamometer, the Hankoczy-Brabender farinograph and valorigraph, and the Swanson-Working mixograph, are recording dough mixers. Other instruments, such as the alveograph, the extensograph, the Buehler comparetor, the Rejte Zerrisamaschine, the Naszali alphitograph, the Borasio and de Rege pneumodyamometer, the Schofield and Scott-Blair apparatus, and the Halton and Fischer apparatus, are concerned with the effort to measure resistance to extension.

Various other mechanical testing systems not directly related to the two foregoing types have been applied to dough. These include the scheme used by Schofield and Scott-Blair for measuring rigidity modulus or elasticity, the pachimeter for a somewhat related application, Kosutany's Belastungsprobe, Engledow's distensiometer, and others.

<u>The Alveograph</u>. Bailey and LeVesconte (3) believed that the alveograph readings afford a useful index of the extensibility of a dough and are of value as an indication of the strength or baking value of a flour, giving in one simple and rapid test the result of the several factors that may affect the extensibility.

Bailey and LeVesconte (3) found that prolonged mechanical treatment of a dough decreased the extensibility, probably, they thought, because of an increase in the degree of dispersion of the colloidal particles. Water added to ordinary bread dough tended to make it more extensible, less tenacious and more easily stretched. After reaching an optimum absorption, the dough became less extensible. Starch mixed with a flour decreased the extensibility of the dough appreciably, indicating that the quantity of gluten in a flour is an important factor in determining flour strength.

Hydrogen-ion concentration, they found, was a factor in determining the extensibility of dough. At approximately pH 6, the dough was most extensible, and below a pH 5 or above a pH 7, the extensibility was greatly lowered.

Chlorine treatment of the flours, according to Bailey and LeVesconte (3), tended to decrease slightly the elasticity of the dough, probably because it increased the hydrogen-ion concentration, although it may be of value in increasing the baking value because of accelerated enzyme activity.

Flour improvers, they found, are primarily yeast foods and do not necessarily increase the strength of a flour. Calcium acid phosphate tended to increase the extensibility of a dough, phosphoric acid decreased it only slightly in the proportions used.

Johnson (12) found that the extensibility of ether-extracted flours was slightly lower than that of the corresponding natural flours, but that absorption and wet and dry gluten were not affected. Treatment of the flour with 70 percent alcohol or with 96 percent alcohol markedly lowered its quality for bread making and reduced its extensibility. Treatment of the flour with water did not notably affect its properties for breadmaking but did reduce its extensibility.

St. John and Bailey (28) found that the force required to extend dough surface, as measured with the Chopin extensimeter likewise tended to decrease as the proportion of water was increased. This was observed both with the control or milk-free doughs and with those containing dry skim milk. Extensibility of doughs was not substantially affected by the inclusion of 10 percent or less of dry skim milk in the dough.

<u>The Swanson-Working Mixograph</u>. Swanson and Working (30) devised a recording dough mixer which they used in studies on mixing and absorption. They believed that the greatest possibilities with the device were in connection with the testing of wheat varieties.

Johnson, Swanson, and Bayfield (15) made an extensive study of the mixograph to evaluate wheat varieties with different protein levels. They found that height, width, and weakening angle of the mixograms were positively correlated with protein content and loaf volume. Loaf volumes were more closely associated with the protein content than with any of the mixogram characteristics. The height, independent of protein content, was not significantly correlated with loaf volume. Width, independent of protein content, was not found significantly correlated with loaf volume. The multiple correlation coefficients, including protein content and any one of the three mixogram characteristics when correlated with loaf volume from either formula, were found to be probably not significantly different from the simple correlation coefficients between loaf volume and protein content. Mixogram characteristics tended to reflect baking strength for a flour mainly because of the high correlation between loaf volume and protein content on the one hand, and between protein content and the mixogram characteristic on the other. The angle expressing range of mixing tolerance tended to decrease with increasing protein but not in a linear fashion.

The relationship of mixing time and of development angle with protein content was curvilinear. Development angle and mixing time were moderately and negatively correlated with areas under mixograms from starting point to point of minimum mobility. Area was presented as a measurement of energy input required to mix a dough to optimum development. Area was not significantly correlated with loaf volume.

Johnson et al. (15) found that overmixing the dough resulted in a decrease in loaf volume, the largest being in the high-protein samples. A fair degree of association between decrease in loaf volume and the weakening angle was found. The weakening angle, independent of protein content, was positively correlated with decrease in loaf volume caused by over mixing.

<u>The Ostwald and MacMichael Viscosimeters</u>. Sharp and

Gortner (25), using these devices, employed viscosity as a measure of hydration capacity of wheat flour and investigated its relation to baking strength.

According to Sharp and Gortner (25), they confirmed the earlier conclusion of Gortner and Doherty, that there is an inherent difference in the physico-chemical properties of the gluten from strong and weak flours and that these differences are due to the colloidal state of the gluten proteins. In addition, they showed that the differences in colloidal properties apparently reside in the protein, glutenin.

Different acids, they found, apparently do not produce the same maximum imbibitional effect with wheat proteins, failure of some acids to produce imbibition probably being related to their effect as protein precipitants.

They found that viscosity in the presence of alkalies is not so markedly affected by the soluble materials present in the natural flour as in the presence of acids.

The Farinograph. In the early 1930's, the significance of farinograms was sometimes overstated. With the lapse of time, and the experience that has been gained, increasingly conservative and more acceptable interpretations of the farinograms have made their appearance in the literature. For example, the interpretation that the width of the farinogram, as drawn by a properly calibrated farinograph, indicates the actual elasticity of the dough is largely no longer held.

As Markley and Bailey (18) showed, the width of the line is a function of mobility of the dough, the relation being slightly curvilinear when extended through a large mobility range. Also Markley's (17) wheat starch-water pastes gave wide farinogram lines, yet such pastes possessed little tensile or shearing elasticity. At no time has it been suggested that the farinogram actually disclosed certain other physical properties which probably determine the behaviors of dough in actual baking, such as modulus of elasticity, ductility, and tensile strength. The characteristics of the farinogram may be correlated with certain of these properties, though there are specific instances when such correlations are not apparent.

Skovholt and Bailey (26) were among the first to publish work conducted using the farinograph in the United States. They observed the effect of temperature and of the addition of dry skim milk upon the properties of doughs as measured with the farinograph.

In 1932 Brabender (5) analyzed the farinograph curve and in 1934 he described previous work done with the farinograph (6).

Near and Sullivan (24) found that the farinograph measured absorption accurately and was well correlated with their baking data when absorption values at 580 units were used.

It was the experience of Stamberg and Bailey (27) that doughs are really overmixed when the farinogram curve has reached its peak, and that better bread will result if the mixing is arrested somewhat short of that stage.

Bayfield, Working and Harris (4) found that absorption increased with increase in protein content, but not to the same extent in the different varieties, nor was the rate of change as great with the low protein flours as with the high. This indicated a curvilinear relationship. Some workers found that below 9 percent protein there was little further decrease in absorption. This is accredited to the large proportion of water absorbed by the starch. Above 10 percent it was often found that absorptions vary about 1.5 percent for each percent change in protein.

Johnson, Shellenberger and Swanson (13) found that as protein increased, the absorption, mixing requirements, and farinograph valorimeter reading also increased.

Geddes, Aitken and Fisher (10) made an extensive study of the relation between the farinogram characteristics and baking value of Western Canadian wheat. They concluded that the farinogram characteristics were not as valuable as flour protein as an index of loaf volume, but the instrument provided valuable accessory information on such properties as absorption, optimum mixing time, and mixing tolerance.

Freilich and Frey (9) studied the effect of mixing both straight and sponge doughs in oxygen, air and nitrogen on farinogram height and loaf volume. They studied the effects of oxygen on dough development, the effects of oxygen in doughs made with different bread flours, in doughs containing added protease, and the mechanism involved in the effects of oxygen.

Concerning dough devolopment, they found that oxygen is of fundamental importance as a factor in proper dough development and that such development is evidently unobtainable in the absence of oxygen. Oxygen was found to be most effective when incorporated into the dough during the original mixing. Satisfactory dough development was achieved also by incorporation of oxygen after fermentation. They also concluded that oxygen is essential in the mixing of sponge doughs, as well as in the mixing of straight doughs, if satisfactory dough development and loaf quality are to be obtained.

The oxygen effects during dough mixing were found to be independent of protease activity of the papain type that may be present in the flour. Oxygen produced effects that were immediately apparent, whereas the effects of added papain, both in the dough and in the resulting bread, became evident only after several hours of dough fermentation.

They found evidence which indicated that oxygen is utilized by means of an enzymic mechanism. Cuprous chloride, an enzyme inhibitor, added to a straight dough mixed in oxygen in the farinograph produced a curve similar to that obtained with a straight dough from the same flour, but mixed in nitrogen and containing no added cuprous chloride, indicating the inhibition of the mechanism involved in the oxygen effect. The enzyme activity of the yeast in the dough was also inhibited by the cuprous chloride. Indirect evidence tending to confirm the presence of an oxidizing enzyme system was obtained by adding small amounts of quinua flour to the dough.

The Extensograph. Doughs at rest exhibit distinctly different physical properties from those shown when they are in an "excited" condition, as affected for example by mixing, rounding, or molding. The farinograph is designed to measure dough plasticity as a function of continuous mixing; thus, it cannot reveal the recovery or tendency of the dough to regain certain of its original properties after a physical manipulation, or reveal the direction and magnitude of the effect of chemical treatment, since the effects of these treatments are mainly registered in doughs at rest.

The extensograph was devised to measure the stress and strain relationship of doughs at rest. The instrument determines extensibility after permitting the dough to rest for suitable intervals of time. Of the measurements that might be made of the curve traced during the extension of a dough, among the most important are the linear, horizontal length or base line of the curve, which records extensibility; the maximum height of the curve, which records resistance to extension; and the area between the curve and the base line, which is a function of the work done on the dough during extension.

Doughs exhibit many physical properties, some of which are correlated with their baking characteristics under optimum conditions. Numerous investigations have been made and several instruments designed to obtain quick, reproducible and reliable determinations of those physical properties of a dough which would provide a basis for predicting accurately its utility for baking. The extensograph was designed with this in view.

Much of the preliminary work which Brabender must have done while designing and after having completed the extensograph is, unfortunately, not available for the purpose of review; however, he and Munz have published several important papers on the subject.

Munz and Brabender (21) found that vigorous treatments such as are accorded by mixing, molding, and punching, effect an "excited condition" in a dough--which may be analogous to "work hardening" known in other fields of physics. In this condition it exhibits different physical properties from those shown in a state of relaxation. These induced effects do not remain constant, and the dough tends to return to its original state if allowed to stand undisturbed for a time, and the rate and degree of change depend upon the properties of the flour as well as the treatments to which it, or the dough, has been previously submitted.

The effects of some different variables upon extensogram characteristics have been found to be as follows.

1. Effect of Settings. Aitken, Fisher and Anderson (2) studied the effects of three settings of the extensograph on curve dimensions with duplicate curves for eight doughs from each of three flours. The setting had no effect on curve length, which measures the extensibility of the dough; but the height of the curve which measures resistance to extension was found to

increase as the instrument was made more responsive. They found that most of the latter variation can be removed if resistance is reported in terms of the weight in grams required to produce the given curve height at the setting at which the machine is adjusted, and that the relation between curve height and resistance in grams can be made essentially linear at each setting.

2. Effect of Overmixing. On extended overmixing, Munz and Brabender (21) found that doughs tend to lose extensibility (E) and to increase in resistance to extension (F) on standing. This may be analogous to the reversible thixotropic behavior observed in certain simple gels. In general those flours which evidence the greatest sensitivity to overmixing in the dough stage also exhibit the greatest tendency to recover the properties of a normally mixed dough.

While the ideal procedure in measuring mixing sensitivity with the extensograph is to accord various mixing treatments to a series of doughs prepared from the same flour and then observe the progressive changes in properties, with time, the general class of flour into which most American bread flours fit can be recognized, usually, according to Munz and Brabender, from the farinograms.

They decided that "optimal mixing time" must be regarded as a relative term, depending upon such factors as the type of mixer used, nature of fermentation, and chemicsl treatment accorded the dough. It is not a definite or absolute value, except as thus qualified.

Johnson, Shellenberger, and Swanson (13) found that extensibility, resistance to extension, and extensogram area were each positively correlated with farinogram mixing time.

Merritt and Bailey (19) found that prolonged mixing decreased the extensibility and extensogram areas of fermented doughs at baking time and tended to decrease resistance to extension.

3. Effect of Rounding. Merritt and Bailey (19) found that the optimum number of revolutions of the molder was 20. Below that number, the dough is not uniformly rounded and more than that was unnecessary.

4. Effect of Rest Periods. Munz and Brabender (21) found that successive extensograph tests conducted on one dough aliquot after varying rest periods gave essentially the same relative results for different flour doughs as tests conducted on separate aliquots for each rest period.

Strong American spring wheat flour as well as a weaker European blend were used by Munz and Brabender (21) in their study of the changes in stress/strain relationship of doughs as a function of rest time. Doughs made from the strong wheat increased in extensibility and decreased in resistance to extension when the dough was permitted to stand for a long time after it had been excited by molding. As the dough grew older; i.e., when the molding was done two or four hours after mixing, the relaxing from the excited state as induced by molding proceeded at a slower rate.

The weaker European blend involved in the studies yielded a dough which behaved entirely differently. The F/E ratios of the freshly mixed and the two-hour and four-hour doughs did not materially differ when compared 30 or 60 minutes after molding. In fact such differences appeared to be in the reverse order from the strong-flour doughs, since there was evidence of an increased rigidity in the structure of aging of the latter. It was later found that the change in relaxation on aging is not only dependent upon the kind of flour and variety of wheat but also upon the customary chemical treatments or the age of the flour.

Merritt and Bailey (19) confirmed Brabender's recommendation to repeat tests of the same piece of dough after rest periods of 45 minutes.

5. Effect of Fermentation Time and Tolerance. Fermentation tolerance, according to Munz and Brabender (22), can be estimated from the relative change in extensogram area with the lapse of time. The actual time in minutes through which dough maintains a fairly uniform optimum quality will also be a function of mixing, dough formula, type of bread desired, and other variables. Accordingly, the tolerance must be expressed in relative rather than definite intervals of time. The same is true, in general, of the extimation of optimum fermentation time from the curve area when the latter is plotted as a function of time of rest.

In a further study, Munz and Brabender (23) concluded that fermentation time can be deduced from the time that it takes the extensograms to reach optimum area. They also believed that fermentation tolerance may possibly be deduced from expressions involving change in area on extended rest-time, change in the ratio of F/E as expressed by the angle of the line connecting the different F/E values with the horizontal time axes, and change in the oxy-number on extended rest-time.

Lengthened fermentation decreased resistance and extensogram areas when measured at the end of the proof period (19).

6. Effect of Protein Content. Several studies have been made correlating protein content with extensograph data. Munz and Brabender (22) found that the area under the extensogram is related to gluten content when the gluten is of normal quality and the flour has been accorded proper conditioning or treatment with oxidizing reagents. Tentative relations between these two variables were: area equals 600 for 8 percent crude protein; area equals 1500 for 16 percent crude protein, with equivalent areas for intermediate protein levels.

Aitken, Fisher, and Anderson (1) confirmed the conclusion of Munz and Brabender that the area under the curves increases with increasing protein content. In a study on a variable protein series they found that with increasing protein content the length of the curve, which represents the distance that the dough stretches before it breaks, increases fairly regularly from 16.4 to 25.0 cm; and that the height of the curve, which measures the resistance of the dough to stretching, increases over a narrower range, and less regularly, from 4.6 to 6.6 cm. The curves become much longer and a little higher as protein content increases.

Johnson, Shellenberger, and Swanson (13) also found that extensibility, resistance to extension, and extensogram area were each positively correlated with protein content.

7. Effect of Oxidizing and Reducing Agents. Several extensograph studies dealing with the effect of oxidizing and reducing reagents upon physical dough properties appear in the literature. There are two schools of thought in accounting for the effect of oxidizing agents upon the physical properties of flour doughs, one of which maintains that such agents act indirectly by inhibiting or restraining proteolysis, while the other contends that they function in terms of their direct effect upon colloidal properties of the dough. Farinograms, according to the literature, have not proved useful in elucidating the manner or degree of the changes effected by such reagents, either when the observations are made upon freshly mixed dough, or upon dough previously fermented for varying periods of time. These limitations may be the consequence of the fact that the farinograph so operates as to disclose properties of a dough in a state of continuous agitation, rather than the properties of a resting dough. In resting doughs, prepared either with or without yeast, the action of such reagents becomes evident when tests are made with the extensograph.

Munz and Brabender (22) devised a scale for expressing the sensitivity of flours to oxidizing agents. Extensograms were found to be useful criteria of bromate reaction when subjected to simple mathematical treatment. Properties of untreated doughs which can be determined from the extensogram appeared to be highly indicative of the direction and magnitude of the effect of such oxidizing reagents. Thus the "oxynumber" is computed from the formula:

$$\frac{\text{Area under extensogram}}{F/E \times 10}$$

A low value approaching zero indicates a strongly negative reaction, a high value in excess of 50 means a strongly positive reaction.

In a later paper (23) these authors found further evidence to support their belief that bromate response can be determined from the oxy-number.

Merritt and Bailey (19) studied the effect of oxidizing and reducing agents on extensibility. The oxidizing action of potassium bromate and potassium iodate effected a decrease in extensibility and in area enclosed by the extensogram, as well as an increase in resistance to extension. Two and three successive testings of doughs treated with potassium bromate effected greater reduction in area of extensograms than did the corresponding tests of doughs containing potassium iodate. A positive loaf volume response to potassium bromate was obtained with a strong and medium-strength flour but not with a weak flour.

Reducing agents such as sodium sulfite and sodium thiosulfate were found to effect an increase in extensibility and a decrease in resistance to extension of doughs. Extensogram area was increased slightly by moderate dosages of sodium sulfite and decreased by sodium thiosulfate. Reducing action of sodium sulfite had little effect on the loaf volumes of a strong and a medium-strength flour but increased the loaf volumes of a weak flour.

Simultaneous addition of potassium bromate and sodium sulfite to doughs resulted in a compensatory effect. The compensating action of these reagents was not quantitative but varied with the quantities used and with different flours.

A method of predicting the bromate requirement of doughs was devised by Merritt and Bailey. It involves the use of "age-index" values of doughs which are computed from a formula involving the protein content of the flour and measurements characterizing the extensogram.

Treatment of flour with chlorine effected a substantial change in those physical properties which are registered in the F/E ratio of their doughs according to Munz and Brabender (22). They found that the first increment of chlorine, sufficient to reduce the pH of the dough to 5.4, effected the greatest change in this particular, and additional increments which increased the relative acidity of the dough progressively to pH 4.9 produced little additional change in F/E ratio. Area under the extensogram was greater in the flour treated to pH 5.4

and increased somewhat upon the addition of more chlorine to pH 4.9.

8. Effect of Papain. Papain, according to Munz and Brabender (22) substantially altered those dough properties which can be demonstrated by extensograms, and when bromates were superimposed upon such doughs the action of the papain was restrained or reduced. The same tendencies were observed with cysteine and cysteine-bromate combinations. In regard to the effect of bromate on papain treated flour, they observed that their results afforded support to the conclusion reached by Jorgensen and others that bromates do restrain or control the action of papain and similar proteolytic enzymes, especially when the level of activity of the latter is not too high.

The effect of papain on extensibility was measured by Merritt and Bailey (19) but the dosages of papain used were not large enough to effect any substantial changes in the physical properties of the doughs. Since papain is an enzyme which is thought to act on the wheat protein very much like the natural proteases of wheat flour, it was thought that extensibility would progressively increase, and resistance and area decrease with time. After a certain dosage had been reached this might happen. That it did not might mean, according to Merritt and Bailey, that the action of enzymes like papain can be controlled with either time or mechanical work (punching) and thereby produce a more suitable dough for baking.

9. Effect of Other Additives. The inclusion of malted

wheat flour in doughs in normal proportions, according to Munz and Brabender (22), did not substantially alter the extensograms, which suggested that the gluten properties were not affected greatly by the enzymes thus contributed to the dough. This added support to the earlier conclusion of Munz and Bailey (20) that the modifications in dough plasticity resulting from the addition of wheat malt flour might be traced to the changes in the starch properties effected by the amylases rather than to proteolysis.

Nonfat milk solids decrease extensibility and resistance to extension with flours of low protein content. A dosage of 3 g of nonfat milk solids per 100 g of flour was found to increase extensogram area and stabilized doughs against the effect of repeated tests to a greater extent than a dosage of 6 g per 100 g of flour (19).

Shortenings of several types behaved differently with different flours. In general, it has been found that they increased extensibility but had no uniform effect on resistance or extensogram area (19).

Leavening action of yeast decreased all dimensions of the extensograms but was partially counteracted by the addition of either potassium bromate or sodium sulfite to the formula (19).

10. Effect of Heat Treatment. Heat treatment of flour appeared to effect changes in dough properties analogous to those resulting from the use of bromates (22).

11. Effect of Carbon Dioxide on the Sponge. Sullivan and Richards (29), in investigating the influence of carbon dioxide on fermenting sponges, obtained extensograms and farinograms on the sponges and on the doughs after remixing as the first step in elucidating the effect of cabinet fermentation. The results obtained, in conjunction with the baking data, substantiated the conclusion that shorter sponge times are possible when using the cabinet procedure. Farinograph and extensograph curves were also made on the sponges fermented in oxygen and nitrogen. It was noted that both the farinograms and extensograms on the doughs made from sponges fermented under excess oxygen and nitrogen showed poor handling properties.

12. Evaluating Flours for Specific Purposes. Johnson, Shellenberger, and Swanson (13, 14) used farinograms, mixograms and extensograms as a means of evaluating flours for specific uses. They found that extensogram data representing bread type flours including hearth, bakery, topping, and family groups showed greater extensibility, greater resistance to extension, and larger curve area than did those from the biscuit and cracker or pastry flours. Bread flour doughs also showed greater response to rest periods than did the other types. The biscuit and cracker group tended to have extensogram properties intermediate in magnitude to the bread and pastry flours. The pastry flours produced extensograms of smallest area. Protein content, extensogram height, and area tended to average highest for the hearth group being followed

in order by bakery, topping, and family flours. Cracker dough and cracker sponge flours exhibited doughs with about equal extensibility but the cracker sponge doughs had greater resistance to extension and larger extensogram area. The extensograph data for the biscuit flours were extremely variable. Extensograms for the general pastry and specialty flours were much alike. The extensibility of the dough for these two groups was greater than for the cake flours, while the resistance to extension was less. The fancy cake flour doughs possessed the greatest resistance to extension with 45 minutes of rest, while the medium quality cake flour produced doughs that reached their maximum resistance at 135 minutes of rest.

13. Correlation Between Different Dough Testers. The correlation of data obtained from the various physical dough testers is a subject that has received the attention of several groups of workers.

Aitken, Fisher, and Anderson (1) studied the relations between the various curves obtained from the farinograph, alveograph, and extensograph on a uniform protein series of flours. They found that the instruments did not agree entirely on which samples were similar and which dissimilar. That the farinograph should yield results differing from those of the other instruments was not surprising since it operates on an entirely different principle and measures different properties. The extensograms and alveograms might reasonably have been expected to classify samples in the same way because they measure similar properties, but they did not invariably do so. For example, they found that not only is there no significant correlation between alveogram length and extensogram length but the correlation coefficient is the fourth lowest of those listed. Since both measurements are supposed to reflect the extensibility of the dough it seemed to them that there should have been better correlation. They assumed that the measurements were made under such widely differing conditions that no correlation between the results was possible.

They advanced four interesting points to explain why they found no significant correlation between alveogram length and extensogram length. First, extensograms are made with doughs of uniform consistency whereas alveograms are made at uniform absorption. If the former technique is the better for obtaining a "true" measure of extensibility, then the contradictory results are explainable. Second, the extensograph stretches the dough in only one direction, whereas the alveograph stretches it in several directions. Third, the extensograph stretches the dough at a constant rate, which is essentially independent of the resistance of the dough to stretching; whereas the rate at which the alveograph bubble expands and stretches the dough must be affected by the resistance of the dough to stretching. And fourth, whereas the extensograph dough was made with water and sufficient salt solution to bring the salt content to 2 percent, the alveograph dough was made with 2.5 percent salt solution and was also lubricated with oil.

Johnson, Shellenberger, and Swanson (13, 14) found that extensibility, resistance to extension, and extensogram area were each positively correlated with farinogram mixing time, valorimeter value, mixogram area, and height. Extensogram properties were more highly correlated with protein content than with farinogram or mixogram properties. The correlations between extensogram area and protein content, farinogram, and mixogram characteristics were greater than the correlations between the same mixing factors and the extensibility and the resistance to extension.

14. Effects of Mixing, Salt, and Consistency. Fisher, Aitken, and Anderson (8) studied the effects of initial mixing procedures on extensograms with the Hobart, Brabender farinograph, and Swanson mixers. With the mild mixing action of the Hobart, little change in extensibility or resistance to extension occurred as mixing time was increased, and there was little difference between 45-minute and 135-minute extensograms. With the severe mixing of the Swanson, however, extensibility decreased and resistance increased with increased mixing time, and these changes were greater in 135- than in 45-minute extensograms. The farinograph mixer gave intermediate results. Mild mixing was considered to yield extensograms representing inherent properties of the flour and to provide a control procedure for studies of changes in formula or manipulations. Severe mixing yielded extensograms from which the response of the flour to mixing could be measured by the differences be-

tween 45- and 135-minute curves. Flours with a wide range of wheats differed in both basic properties and in response to mixing.

They found that increasing the consistency of the dough decreased extensibility and increased resistance. By contrast, increasing the salt concentration increased both extensibility and resistance. Salt also changed the shape of the curve by moving the highest point towards the right. Weak and strong flours responded differently to added salt, so that comparisons of extensibility depended upon whether this was measured by the total length of the extensogram or by the length to the highest point (greatest resistance). These two measurements were discussed in terms of their probable relation to elastic and viscous deformation during stretching.

Chemical Tests

Numerous chemical tests on flour have been devised. Zeleny (31, 32) introduced a sedimentation and a photometric protein test which are simple in their procedures and striking in their revelations.

Zeleny Sedimentation. It has long been known that differences among flours from different types of wheat are reflected by the abilities of the gluten proteins to imbibe water. The relationship between the colloidal swelling of gluten and the bread-baking quality of flour was probably first reported by Upson and Calvin. Gortner and Doherty, according to Sharp and Gortner (25), in studying the rate and extent of the swelling of gluten disks in dilute solutions of various acids, found that glutens from "strong" flours have much higher rates of hydration and much higher hydration capacities than do glutens from weak flours. Sharp and Gortner (25) demonstrated the relationship between flour baking strength and hydration capacity as measured by the viscosity of acidulated suspensions of flour in water. Luers and Schneider, according to Sharp and Gortner (25), in comparing various methods for determining the hydration capacity of colloids, found good agreement among Hofmeister's method of weighing before and after the imbibition of water by the colloid, Fischer's method of determining the change in volume, and the viscosity method.

Zeleny's (32) method is based on the rate of sedimentation of the solid phase from an acidulated suspension of flour in water.

The line of demarcation between the solid and liquid phases was found ordinarily to be sharp and distinct so that readings could be made to the nearest milliliter and estimated to the nearest 0.1 ml. Occasionally the line of demarcation was less distinct but rarely was it so indistinct that readings could not be made to the nearest ml. Duplicate determinations usually agreed within less than 1 ml. In a series of 135 samples of flour tested in duplicate, the average difference between duplicates was 0.5 ml and the maximum difference was

2.5 ml.

It was found that the sedimentation value was fully as good an index of the bread loaf volume as was the protein content.

Specific sedimentation (sedimentation value divided by protein percentage) was found to be a useful measure of gluten quality. The relative gluten qualities of flour from nine of the leading commercial varieties of hard red winter wheat were, with one exception, evaluated in essentially the same order by their specific sedimentation values as by their specific loaf volume values.

Flour from Chiefkan and Red Chief wheat (varieties of generally recognized inferior gluten quality) tended to be properly evaluated in respect to potential bread loaf volume by the sedimentation test, while the protein test almost invariably overestimates (often greatly) the bread loaf volume that can be obtained from such flour.

Zeleny Photometric Protein. Zeleny (31) introduced a new simple procedure for determining protein content in wheat and flour. The method is based on the peptization of the wheat proteins by dilute alkali, the preparation of a stable colloidal suspension of the gluten proteins by accurately controlled partial neutralization of the alkaline extract, and the measurement of the light transmission through this suspension by means of a photometer. Zeleny found a close association for flours between light transmission and protein not peptized by 5 percent potassium sulfate solution.

Zeleny, Neustadt, and Dixon (33) also found a close association for wheats between light transmission and a calculated value for endosperm proteins.

Eva and Anderson (7) studied the relations between loaf volume, Zeleny protein, and Kjeldahl protein. They found that the Zeleny method measures some fraction of the total protein that is no more closely related to loaf volume than is total protein determined by the Kjeldahl method. They also found that the Zeleny method can apparently be used for predicting Kjeldahl protein in sound samples of one wheat variety grown in different places, or in samples of different varieties grown at one place.

Effect of Storage on Chemical Tests. Jones and Gersdorff (16) studied the effect of storage under different conditions upon the proteins of wheat kernels, white flour, and whole wheat flour over a period of 2 years. The extent of the changes was found to depend on temperature, type of containers, duration of storage, and the nature of the material stored. Samples stored at 76° F. were affected more than those stored at 30° F., and those in bags more than those in sealed jars. Changes in white flour were, in general, greater than those in whole wheat flour. Significant changes occurred also in the wheat kernels, although not as great as in the flours. The total nitrogen and free ammonia remained unchanged. The rapid rate of some of the changes was notable. White flour stored in a jar at 76° F. showed a decrease in protein solubility in salt solution during the first month of storage of 43 percent, which was three-fourths as much as that observed at the end of 2 years. Wheat kernels stored in jars at 76° F. for 2 years showed a decrease in protein digestibility of 8 percent. White flour stored for 2 years at 76° F. decreased 17 percent in digestibility of the proteins.

SCOPE OF THE PROBLEM

It was believed that the potentialities of the farinograph and extensograph for evaluating dough properties had not been exhausted by previous work, and it was suspected that some previous work in this field may have been misinterpreted due to fundamental defects in farinograph and extensograph technique. One such defect may be the mixing and resting of doughs in a gaseous mixture, air, rather than in an atmosphere consisting more nearly of a single component. For this reason studies were made on the same flour using different mixing and resting atmospheres to determine whether or not this was a critical factor subject to standardization as is for example absorption, in interpreting farinograms and extensograms.

In previous published work little attention was given to the age or storage conditions of the flour used in obtaining farinograph and extensograph data used to formulate general theory. It was believed that this possibility also may have led to conflicting data which might otherwise have been similar.

To study the effect of storage, a technique was developed for storing the flour under controlled conditions and a study involving determination of chemical as well as physical characteristics was undertaken for a period of approximately a year.

It was believed that the full significance of all farinogram and extensogram characteristics had not been completely determined and that those which were known may not have been thoroughly developed. For that reason it was decided to do some fundamental work which might throw more light on the nature of farinograms and extensograms. This involved use of water-flour and water-flour-NaCl dough systems. A further development involved the use of various levels of potassium bromate with accompanying increments of NaCl.

The influence of starch on farinograms and extensograms has been considered to be relatively minor. It was not clear from the literature whether it was always taken into consideration in past work or simple ignored. For this reason a simple study involving the ball-milling of flour was undertaken.

In order to learn more of the fundamental nature of extensograms, modest studies involving several acids and bases were undertaken, as well as the use of flour stored under an atmosphere of hydrogen sulfide.

Since chemical as well as physical tests were desired on the stored flour, it was decided to do a photometric protein study, and a sedimentation study which was quasi chemical in nature.

MATERIALS AND METHODS

The Farinograph

Recording dough mixers such as the farinograph are designed to give a moving picture of the plastic, viscous and elastic properties of the dough as mixing progresses. Each successive instant is a point on the curve which represents physically and mechanically those physical and chemical changes in the dough which can find expression through a physical and mechanical medium.

Among the most essential parts of the farinograph are the following: The mixer is of the Werner-Pfleiderer type and the two helical blades rotate toward each other in a ratio of 3:2. There is a lever system for amplifying the movement of the dynamometer as influenced by the varying resistance of the dough to the mixing blades and registering the variation of this resistance in a curve called the farinogram. To prevent sudden swings of the recording pen which would produce a jagged curve, there is a damper or shock absorber. The cross lines on the chart paper have the same curvature as the arc in which the pen moves. The temperature in the mixing bowl is controlled by circulating water from a thermostat at desired temperature.

The curved lines on the cross section paper on which the farinogram is traced are so spaced that the chart moves from line to line in one-half minute. There are 50 horizontal lines, each line representing two units. These units, read from the bottom line, are used to indicate the consistency of the dough. Since there are 1000 units, the height of the center of the farinogram is indicated by a number commonly referred to as Brabender Units. The horizontal distance from where the farinogram began, to the point where the pen has attained maximum amplitude, indicates the dough development time.

Instrument Settings. The large mixing bowl (250g) was used exclusively, and the following setting was used throughout:

On arm: fifteen hollows of thread showing from end of arm to first counterbalance weight.

On curve width mechanism: one partial revolution of the cogwheel to the measuring point (indicated by indentations) plus five complete revolutions and 20 small, separate movements of the cogwheel which were indicated by a snapping sound.

Farinograph Procedure for Cleanout Doughs and Absorption Determinations. Although farinograph procedure varied depending upon the study at hand, there are general directions which were applicable in all situations.

One of those was the cleanout whose purpose was to remove the thin film of copper oxide which develops on the bronze surface of the mixing bowl after standing. It also gave the moving parts of the instrument time to reach their optimum working condition and become thoroughly lubricated so that friction was constant.

The practice used in these studies was that adopted from Snodgrass according to Aitken, Fisher, and Anderson (2). If the bowl stood for more than 5 minutes without being in use, one cleanout was made; if it stood 4 hours two cleanouts were made. The mixing time was five minutes in all cases. If the bowl stood for 24 hours or more, three cleanouts were made, the first being for 15 minutes and the others for 5 minutes each.

To conduct a cleanout 250 g of stock flour was placed in the bowl. The circulating water bath, started previously, was adjusted at intervals so that by the time an actual determination was ready to be made, the parts of the farinograph and extensograph were at a constant temperature of 30° C. The farinograph was started and enough distilled water from the buret run into the bowl to give a dough of good consistency. After allowing the instrument to mix for the proper time, most of the dough was removed from the bowl before it was taken off. This was facilitated by adding a small handful of dry flour to the dough and continuing the mixing for several seconds more. The use of any artificial dough stiffener such as borax is not recommended since only a trace of this remaining in the bowl will influence the curves of the next mix. The bowl was then taken off, cleaned, making sure that every particle of dough was removed, and dried. Whenever necessary, the above procedure was repeated.

Usually before any investigations on doughs using the farinograph and extensograph can be done, the optimum absorption of the flour must be known. With the water bath functioning at 30° C., 250 g of flour on a 14 percent moisture basis was placed in the clean, dry farinograph bowl. Before the flour was placed into the bowl, the mixing blades were adjusted so that they were in the same relative position that was adopted as standard. The position adopted here was an aligning of the parts of the two blades so that they were parallel with each other. The graph paper and pen were correctly adjusted. The flour was placed in the bowl in such a manner that there were no large air spaces under the blades. The surface of the flour was leveled with a plastic spatula used to help facilitate cleaning the bowl. The buret was moved to the same position over the bowl for all determinations. The buret was filled with distilled water warmed to 35° C. Simultaneously started were the mixing and the rapid running into the bowl of somewhat less of the water than necessary for the anticipated absorption. When the pointer on the scale had settled about a constant consistency value, further small increments of water were added, and the pointer was allowed to rise to a constant mean value between increments, until, finally a consistency of 500 units was reached and maintained before a decrease began.

The trial was repeated by running in the entire volume of water rapidly. If the maximum consistency was not exactly at 500 units, the absorption was changed slightly in the necessary direction and the tiral was repeated until the minimum mobility was exactly 500 units.

Absorption and Mixing Time. Since this work dealt entirely with unfermented doughs, it was decided to use the farinograph exclusively to determine optimum absorption and mixing time. Near and Sullivan (24) found that the farinograph measured absorption accurately and was well correlated with their baking data when 580 units were used. In this study the 500 unit mark was used as it was considered to be standard for flour-water systems.

As this was a study primarily to detect changes in extensogram characteristics, the optimum absorption was determined on the same day the flour was milled and that absorption was used throughout. It was felt that if progressive optimum absorptions were determined and used as the flour aged, changes in physical characteristics would, consequently, be masked.

The same view was held in regard to mixing time, which was determined at the outset and continued as a constant. The mixing time used was the time required to reach maximum consistency or the peak of the curve at optimum absorption. Since it was regarded that slight overmixing was better than slight undermixing, the experience of Stamberg and Bailey (27), that doughs are really overmixed when the farinogram curve has reached its peak, was fortunate as far as this study was concerned.

Farinograph Mixing Under Gases. In this work much of the mixing in the farinograph was done under various gases, oxygen, air, nitrogen, and hydrogen being used. An apparatus for constant gas flow through the farinograph bowl was designed. It consisted of a brass cover machined to fit tightly over the bowl when clamped. Two openings with metal stopcocks were in the cover in a symmetrical position such that the gas flowed evenly through the bowl. One of the openings was for the incoming gas and the other was for the outflow. A small water manometer was introduced into the incoming gas system by means of a glass T-tube, one opening in the T-tube attached to the incoming stopcock on the brass cover, one to the manometer, and the third to the tube from the gas cylinder. The manometer was equipped with a scale in centimeters, and a little coloring matter was added to the water in the manometer tube to facilitate reading. A water manometer was used in preference to a mercury manometer because of the low gas pressure used. In order to have a constant gas flow, small wash bottles with water levels and glass immersion tubes as invariants were connected to the incoming and outgoing gas flow systems. This was in addition to the needle valve attached to the gas cylinder.

Determination of Gas Pressure. In mixing under gases other than air, it was decided, after mixing under various pressure, that a pressure of 25 mm of water above atmospheric pressure was optimum for the apparatus used. Below a pressure of 10 mm, fluctuations occurred, and above 35 mm, flour was blown against the farinograph bowl cover and into the gas outlet system.

Unless otherwise stated, the gas pressure used in farinograph mixing under gases other than air was 25 mm of water above atmospheric pressure.

Farinogram Symbols. The following farinogram symbols are used in this work: H, which is farinogram height, and W, which is farinogram width.

The Extensograph

The extensograph is an instrument designed to subject a cylinder of dough to a measured stress such that the dough is stretched until the elastic limit is reach and exceeded. The force applied to the dough is transmitted by a system of levers and a pen onto graph paper moving at an apparently constant velocity. The resulting curve is a graph which records extension of the dough on the horizontal axis and the force required to extend it on the vertical axis. The area enclosed by the curve and the base line may be taken as an indication of the work done on the dough.

The most essential parts of the extensograph are: the rounding and molding devices, the constant velocity dough-hook which engages and stretches the dough, the dough holders, the constant temperature incubator, and the electrically operated kymograph and an inking stylus for recording, continuously, stresses and strains in the portion of dough under test. The rounder, molder, and incubator are kept at constant temperature by circulating water from the thermostatically controlled water bath. As with the farinograph, the cross lines on the graph paper have the same curvature as the arc through which the pen moves. The dough holders consist of the holder proper and the base on which the holder and the middle of the dough cylinder are cradled during the resting period. The base has a water receptacle to maintain humidity conditions thus preventing the dough surface from crusting during the resting period. The dough holder proper is constructed in such a manner that the dough cylinder is clamped at both ends while the center of the dough cylinder is unsupported, leaving it free to be engaged by the dough-hook when a curve is recorded.

Extensograph paper is practically identical to farinograph paper, all lines having the same spacing. The only difference is in the labeling of the curved vertical lines. On the farinograph paper these lines are so spaced that the chart moves from line to line in one-half minute; these same lines are on the extensograph paper, but they are unlabeled.

Instrument Settings. Since this work was to involve some highly developed doughs, it was decided to use a rather high load setting, in excess of that used in most previous studies. Munz and Brabender (22) who worked with many weak flours had their adjustment so that a 125 g load on the balance corresponded to 100 units of resistance, as recorded on the extensograph paper. Merritt and Bailey (19) had their instrument adjusted to record 60 units of resistance per 100 g load. Aitken, Fisher, and Anderson (2) had the tension on the balance correspond to 200 units on the extensograph paper with a balancing weight of 550 g.

In this work the tension on the balance corresponded to 200 units on the extensograph paper with a balancing weight of 630 g. With 400 g weight, the tension corresponded to 20 units; 500 g to 85 units; 600 g to 175 units; 700 g to 260 units; 800 g to 340 units; 900 g to 420 units; 1000 g to 510 units; 1100 g to 595 units; 1200 g to 675 units; 1300 g to 755 units; 1400 g to 845 units; 1500 g to 920 units; and with a weight of 1600 g the tension corresponded to 990 units. When the tension expressed as grams was plotted against extensograph units, a straight line was obtained.

Munz and Brabender found the velocity of the graph paper of their instrument to be 6.5 mm per second; Merritt and Bailey found theirs to be 6.5 mm per second; and Aitken, Fisher, and Anderson found theirs to be 6.8 mm per second. The extensograph used in this work had a paper velocity of 6.7 mm per second.

The velocity of the dough hook on the instrument used by Munz and Brabender was 13.6 mm per second; Merritt and Bailey found theirs to be 14.1 mm per second; and Aitken, Fisher, and

Anderson found theirs to be 14.6 mm per second. The velocity of the dough hook on the extensograph used in this work had a velocity of 14.3 mm per second.

At the outset, in order to obtain a tension of 200 units with a balancing weight of 630 g, the following setting was used:

On mechanism inside housing: Indicator on both upper and lower scale set at 15 units.

On arm: Thirty hollows of thread showing from end of arm to first counterbalance weight.

This setting was checked at monthly intervals and it did not have to be changed in the course of this work which was of a duration of a year.

The velocity of the graph paper and of the dough hook was also checked at monthly intervals. They remained constant throughout the course of the work.

Extensograph Procedure. Extensograph procedure did not vary as much as did the procedure for the farinograph. Technique for removing the mixed doughs from the farinograph, weighing the dough sample, rounding, molding, resting and stretching the dough remained the same. Before any actual determinations were made, several weeks were spent in getting acquainted with the instrument. Different settings were tried and the optimum one for the work at hand was adopted. Different rounding and molding techniques were used to develop the procedure which gave the best duplicate results when all other factors were constant. This was then accepted as the standard technique and was adhered to rigidly. Likewise, standard technique was developed for all other procedures, down to the most minute detail.

It was felt that this was necessary because flour dough is an extremely complex material in a continuous state of change. Physical measurements of those characteristic changes that take place will, consequently, be masked or distorted unless exactly the same treatment is given to each dough. As in all empirical determinations, the size of the standard error will decrease, the more exactly the conditions are maintained for the measurements, and the smaller the error the more reliable are the results for prediction purposes.

Removing the Dough from the Farinograph. The dough was removed from the farinograph in a single piece, keeping the surface area as small as possible. It was handled as little as possible and the hands were kept free of grease and chemicals. From the farinograph the dough was placed in a dry, clean fermentation bowl and covered with a damp cloth.

Weighing the Dough. Approximately one-half of the dough was removed from the fermentation bowl and weighed on a beam balance with a 150 g counter-weight. The weighing of the 150 g sample was precise to within 0.1 g, the excess dough being cut off with a knife rather than pinched off. After the first sample had been rounded and molded, and placed in a dough holder, the second sample was weighed, then rounded, molded, and placed in the dough holder.

<u>Rounding the Dough</u>. Each dough sample was rounded 20 times. No dusting flour was added except in extreme cases of stickiness when a dough could not otherwise have been rounded.

<u>Molding the Dough</u>. Great care was taken in placing the dough in the molder in order to insure a symmetrical shape and an even seam in the molded sample. No dusting flour was used except in instances of stickiness when the dough could not otherwise have been molded. The molder-plate is fixed and cannot be easily changed to regulate the diameter of the dough cylinder. In instances where the dough is extremely tight, with the conventional setting of the dough molder plate, the resulting dough cylinder is not long enough to be clamped without first stretching the molded dough sample. Provision should be made for molder-plate width adjustments or else dough holders of possibly three sizes should be furnished. Due to correlation complications if different molder widths were used, perhaps the simplest answer would be to have three sizes of dough holders; the present size for normal doughs, larger ones for slack doughs, and smaller ones for tight doughs.

If the molded sample is not symmetrical, uneven tearing of the dough during stretching will result even though the dough hook is properly centered. The critical point in the molding process is when the revolving drum first engages the dough-ball. If the dough-ball is not exactly centered, a nonsymmetrical "sausage" will result which will produce uneven tearing and an erroneous curve.

Extreme care must be taken to see that no dried particles of dough are stuck to the molder. They will pit the sample and in some cases, if they are strategically placed, will change the course of the dough through the molder and give an unsymmetrical sausage. Whenever a sample smears and there is dough in the molder, the revolving drum should be removed and the entire molder thoroughly cleaned and dried.

Dough Holder Technique. The thick cloth support was always lightly greased with shortening. Only enough to keep the dough from sticking was used. With tight doughs, it was necessary to stretch them slightly in order to clamp them; however, if this were not done, during stretching the dough tore at the clamp rather than where the dough-hook engaged it. The result was the introduction of a very small error in the rectification of a very large one. With very slack doughs, the bulb ends of the sausage, instead of being allowed to hang over the sides of the dough holder and thus run and produce a strain on the central part of the sausage during the rest period, were folded slightly on themselves and clamped.

It was important that during the transportation of the sausage from the molder to the holder that it be neither stretched nor compressed.

Resting the Dough. The rest period used throughout was 45 minutes, and two rest periods were taken. After molding, the dough was rested for 45 minutes, stretched, re-molded, rested again for 45 minutes, and stretched a second time.

The dough was rested in the same kind of atmosphere in which it was mixed in the farinograph. Doughs mixed in oxygen were rested in oxygen, those mixed in air rested in air, and those mixed in nitrogen rested in nitrogen. A portable proofing cabinet was designed, large enough to hold one dough-rest plate. Three such boxes were made. They were constructed of light sheet-metal with a removable lid in front and two metal stop-cocks on top. The lids were fitted with sponge rubber gaskets and metal clamps, so that when closed they were air-tight and were even able to hold considerable pressure. After the dough-rest plate with its two holders, each cradling a dough sausage, was placed in the box, and the lid clamped, the resting atmosphere gas was flushed into the box at 30 mm of water pressure for one minute, whereupon both inlet and outlet stopcocks were simultaneously closed. The box was then placed in a constant temperature proofing cabinet for 44 minutes.

In order to assure that humidity conditions within the box were constant, the water-well in the dough-rest plate was kept filled and the boxes were preheated for half an hour in the proofing cabinet.

Stretching the Dough. Proper centering of the dough hook was necessary to obtain even stretching of the dough even though the sausage had been molded properly. The dough hook must be positioned in the center of the exposed portion of the dough when it first makes contact with it. If this is not done, the dough strands will not break evenly and simultaneously and a ragged curve with a smaller F value and a larger E value than is actually the case will result. The same thing results when the dough is not molded properly. The dough hook may be properly centered by means of the screw situated above it.

When the initial setting was made it was kept in mind that the kymograph pen would be at zero units with no slack in the mechanism when the dough holder with a 150 g sample was in position. This was to insure that the curve would begin at zero units and thus facilitate the reading of farinogram heights and render easier the comparison of curves.

During stretching the dough was left exposed to the air for as short a time as possible.

<u>Extensogram Symbols</u>. The following extensogram symbols are used in this work:

F = resistance to extension

E_1 = extensibility to the left of the maximum height

E_2 = extensibility to the right of the maximum height

E_3 = extensibility due to uneven tearing of the dough

E = extensibility bounded by the curve

E_t = total extensibility

A_1 = area to the left of the maximum height

A_2 = area to the right of the maximum height

A = area under the curve

The following equations may be formulated:

$$E = E_1 + E_2$$

$$E_t = E_1 + E_2 + E_3 = E + E_3$$

$$A = A_1 + A_2$$

The subscripts a, b, aa, and bb refer to dough duplicate and sequence of stretch, thus:

E_{ta} = total extensibility of the first duplicate first stretch dough

E_{tb} = total extensibility of the second duplicate first stretch dough

E_{taa} = total extensibility of the first duplicate second stretch dough

E_{tbb} = total extensibility of the second duplicate second stretch dough

Storage Study

The effect of storage at different temperatures, 80° F. and 50-60° F., and under different gaseous atmospheres, oxygen and nitrogen, on unbleached standard hard wheat flour was studied at approximately monthly intervals for a period of a year. The effects were observed by making both physical and chemical tests, the physical being made with the farinograph and the extensograph while the chemical ones were on sedimentation and photometric protein values. To find, further, the effect of mixing and resting atmosphere on farinograms and extensograms, mixes and rests under oxygen, air, and nitrogen were made at each interval. A minimum of duplicate mixes for each mixing atmosphere was made, which gave at least four sets of extensogram curves for each mixing atmosphere.

Description of Flour. The wheat used was a standard hard red winter mill mix of moderate protein level and was milled on the Kansas State College Mill. The mean moisture was 12.7 percent, and the mean protein was 10.4 on a 14 percent moisture basis.

Table 1. Characterization of flour.

Sack number	Moisture mean	Protein[1] mean	Flour designation	Storage conditions
1	12.53	10.3	"N_2"	Stored in sealed 1 gallon glass jars, under nitrogen atmosphere, and at 50-60° F.
2	12.74	10.1	"O_2"	Stored in sealed 1 gallon glass jars, under oxygen atmosphere, and at 50-60° F.
3	12.82	10.4	"A" and "B"	"A" flour stored in sealed metal cans at 80° F., and "B" flour stored in sealed metal cans at 50-60° F.
4	12.78	10.6	"A"	Stored in sealed metal cans at 80° F.
5	12.68	10.5	"N_2", "O_2" and "H_2S"	"N_2", "O_2" and "H_2S" flour stored in sealed 1 gallon glass jars under their respective atmospheres, and at 50-60° F.

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[1] 14 percent moisture basis.

Each sack was blended in a tumbler-type mixer for two hours before being put into cans and jars.

The "A" and "B" flours were put in cans holding about 800 g of flour, or enough for three farinogram mixes, as well as duplicate moisture, sedimentation, and photometric determinations. Once a can was opened, the remaining flour was discarded if it was not used within 24 hours. The rims of the lids of the cans were sealed with masking tape and paraffin.

The "O_2", "N_2", and "H_2S" flours were stored in 5 gallon glass jars with screw cap lids having a metal outlet sealed by a short piece of rubber tubing and a screw clamp. Each jar contained 800 g of flour. This left each jar about two-thirds full, the rest of the space being occupied by the storage gas. Preliminary experiments were run to see how much pressure the lids would take without leaking and the glass jars without breaking. Gas pressures were determined by use of a mercury manometer which was designed for the purpose.

<u>Apparatus for Introducing Storage Gas</u>. An apparatus was designed for evacuating the jars of air, flushing them with the storage gas, and, then, introducing the storage gas under pressure. The main feature was a three way stop-cock so that the system could always be opened to the storage jar and the manometer, and either the vacuum pump or the gas cylinder. In this way the storage jar containing the flour was evacuated of air, the storage gas was allowed to enter to flush the jar with its contents and then be evaucated itself, the storage gas

finally stored under pressure after successive flushings, and the storage jar sealed with the screw clamp all without disengaging the apparatus until the operation was completed.

The jars were evacuated and flushed three times, and each time the jar was rotated so that the occluded air had a chance to escape from the flour and be replaced by the storage gas. Each jar was rotated in the same manner, the same number of times, and for two minutes with each flushing. The vacuum used was 20 cm of mercury and the flour was stored under a pressure of 10 cm of mercury. As with the metal cans, the rims of the lids were sealed with masking tape and paraffin. In addition to being clamped, the rubber tubes were stoppered with tight fitting glass plugs.

<u>Preliminary Experiments</u>. Prior to the milling of the storage study flour, several preliminary experiments were made using a standard stock flour.

The effect of mixing and resting in hydrogen was studied. Since the effect was quite similar to mixing and resting in nitrogen, it was decided not to use hydrogen.

Mixing was done under various gas pressures and a pressure of 25 mm of water was regarded as optimum.

Doughs were rested in gaseous atmospheres different from the mixing gas in order to discern whether this variable had any effect on extensogram values. No difference was found.

<u>Determination of Absorption</u>. On the day of milling, the optimum absorption and mixing time was determined using air as

the mixing atmosphere. Air was used as the mixing atmosphere, since in the past it has been regarded, often unconsciously, as the standard procedure. Strictly speaking, absorptions should be determined in an inert or neutral atmosphere which air is not.

Experimental Procedure for Storage Study. Flour stored at 50-60° F. was allowed to reach room temperature before it was used. A schedule was worked out whereby doughs could be mixed, rounded and molded, and stretched while others were being rested. General procedure for farinograph and extensograph as described above was used.

The order of mixing atmosphere was varied, the first set being oxygen, air, and nitrogen, while the second set of duplicates were in the order nitrogen, air, and oxygen; however, as expected, the mixing order had no influence upon farinograms or extensograms.

Dough characteristics as described later were made after completion of the different steps such as mixing, rounding, molding and stretching.

Zeleny Sedimentation Study

The procedure of Zeleny (32) was used. A quantity of flour equivalent to 4.00 g on a 14 percent moisture basis was placed in a 100 ml glass-stoppered graduate cylinder having a distance of from 180 to 185 mm between the zero and 100 ml marks. Fifty milliliters of distilled water were added to the cylinder, the mixture shaken for 30 seconds, and then allowed to stand for 5 minutes; 25 ml of dilute lactic acid were added, then the contents of the cylinder were mixed by inverting the stoppered cylinder and returning it to the upright position 10 times, taking care not to shake the cylinder. Immediately after mixing, the cylinder was placed in an upright position and timing with a stop-watch was started. After an interval of exactly 5 minutes the volume of the solid phase of the material in the graduate was read. This volume in milliliters is the "sedimentation value" of the flour.

The dilute lactic acid is prepared by diluting 250 ml of 85 percent lactic acid to 1000 ml. The diluted acid must be allowed to stand for at least 3 weeks before use, or refluxed at its boiling temperature for 6 hours without loss of volume and cooled to room temperature before use.

A coloring solution to facilitate reading was used occasionally. The formula for preparation (private communication) being one g of acid fuchsin per liter of distilled water, and the testing solution being 15 ml of the stock solution diluted to 18 or 20 liters with distilled water.

In this study determinations were done in duplicate at approximately monthly intervals for each flour.

Zeleny Photometric Protein Study

The procedure of Zeleny (31) was used. To exactly 0.5 g of the sample in a 130 ml centrifuge tube that could be stoppered, 100 ml of 0.05 N KOH solution were added. The stoppered tube was shaken intermittently for about 3 minutes, the stoppers removed, and the tube was centrifuged for 10 minutes at approximately 1800 rpm. Care was taken to see that any flour lumps which formed were completely broken up before centrifuging.

To exactly 5 ml of the centrifugate in a photometer test tube were added exactly 25 ml of a buffer solution made by mixing 6 parts by volume of 0.2 M KH_2PO_4 with 94 parts by volume of 0.2 M Na_2HPO_4. (This buffer should have a pH of 7.8 and should be preserved by the addition of 1 ml of toluene per liter of solution.) The contents of the test tube were mixed by inversion 5 times and allowed to stand for 1 hour.

The transmission of light through the solution in the test tube was determined with a photoelectric photometer, using a light filter having a maximum transmission at a wave length of 530 millimicrons. (Other wave lengths will give different but equally satisfactory results.)

Sodium Chloride Study

This study was undertaken primarily as a preliminary for the potassium bromate-sodium chloride study. It was desired to know what properties would be encountored in doughs with NaCl content as high as 10 and 15 percent. Sinco a more extensive study was to be done lator, it was decided that for this preliminary study only air mixos would be made (since air mixes are intermediate in magnitude for extensogram curve sizes), leaving the study of oxygon and nitrogen mixes until later.

"B" flour, storod 129 days, was used, with the optimum absorption and mixing time using air as tho "standard" mixing atmosphere. The optimum absorption was found to be 64.0 percent. With this absorption, a maximum farinogram height of 500 was obtained after 3 minutes 25 seconds mixing. This was used as tho mixing timo.

Farinograph and extensograph procedures were the same as described previously.

The sodium chloride solutions were made up on the basis of grams of NaCl dissolved into 100 ml of water. Seven concentrations, 0, 1, 2, 3, 5, 10, and 15 percent, of salt were used.

Potassium Bromate Study

One of the objects of this study was to determine if a synergistic effect, as expressed through farinogram and extensogram values, existod between salt and bromate. It was further desired to know tho added effect of different concentrations of of oxygen in the mixing atmosphore.

Five concentrations of salt, 0, 1, 5, 10, and 15 percent; three concentrations of bromate, 0 mg, 3 mg, and 30 mg; and three mixing atmospheres, oxygen, air, and nitrogen were used making a total of 45 mixes. In order to minimize the storage effect, the series was completed as quickly as possible, five days being required. Optimum absorption, and the 0, 5, and 15 percent NaCl mixes of the first day's were repeated at the end of the series and no significant changes were present, indicating that storage was an invariant.

Solutions were made up a day before using; thus the next day's solutions being made up the evening before, after the day's farinograph and extensograph work had been finished. Salt was on the basis of grams per 100 ml of water and bromate on the basis of milligrams per 100 grams of flour, the absorption of the flour entering into the calculation when the amount of potassium bromate to be added to the solution was determined.

The flour used ("B" flour) had been stored 255 days when the study began and, from analysis of the storage data of this flour, with this amount of storage farinograms and extensograms were not subject to significant change within a week.

The optimum absorption was 65.0 and the mixing time was 5:00 minutes.

Farinograph and extensograph procedures were the same as those described previously.

Ball-milled Flour Study

This study was designed to find the effect of ball milling on farinograms, extensograms, and Zeleny sedimentation and photometric protein.

The "A" flour was used and had been stored for 54 days. Three sets of determinations were made: zero time, 24 hours, and 48 hours of ball milling. After ball milling time had been completed, the flour was stored in sealed cans at 80° F. until used. Immediately after ball milling, duplicate moisture determinations were made. Duplicate sedimentation and photometric protein determinations were begun two hours after completion of ball milling and farinograph mixing started six hours after ball milling.

The absorption used was 61.2 with a mixing time of 3:15 minutes. This was the optimum absorption of the "A" flour with zero days storage. Oxygen was used as the mixing atmosphere since it was believed that thereby the differences would be greater. Two percent NaCl was used to further condition the doughs.

Farinograph, extensograph, sedimentation, and photometric protein procedures were the same as those described previously.

Comparison Study Between Farinograph and Hobart-Swanson Mixers

Since there was a possibility that the acid and base studies might affect the lining of the farinograph bowl, it was decided to use the Hobart-Swanson mixer in the studies involving them; consequently, it was desired to know if similar extensograms resulted.

In pursuance of this, it was desired to know if mixing with the Hobart-Swanson mixer could give extensograms which express the development of a dough due to the addition of NaCl as does mixing with the farinograph. For this, flour-water and flour-water-2 percent NaCl dough systems were used.

Another object was to ascertain whether or not the Hobart-Swanson mixer could give extensograms which express different storage treatment of the same flour as does mixing with the farinograph. For this the "A", "B", "O2" and "N_2" flours were used.

The mixing time was 1 minute and 5 seconds and the absorption was 62.9, as in the other studies involving the Swanson-Hobart mixer. The high speed was used.

Extensograph procedure was the same as that used in the storage study.

"A" Flour-Hydrochloric Acid Study

One of the objects of this study was to determine the effect of hydrochloric acid on a flour-water-2 percent NaCl dough system as expressed through extensogram values.

Since it was decided that the acid might affect the farinograph bowl, doughs were mixed in a Hobart-Swanson mixer using the high speed. The mixing time, as in the other acid and base studies, was 1 minute 5 seconds and the absorption was 62.9.

Eleven concentrations of hydrochloric acid, 0.000, 0.050, 0.100, 0.125, 0.150, 0.200, 0.250, 0.300, 0.400, 0.450, and 0.500 normal solutions, were used.

The "A" flour was used for the study and had been stored for 90 days in sealed cans at 80° F.

Extensograph procedure was the same as that used in the storage study.

"A" Flour-Acetic Acid Study

One of the objectives of this study was to determine the effect of acetic acid on a flour-water-2 percent NaCl dough system as expressed through extensogram values.

Since it was decided that the acid might affect the farinograph bowl, doughs were mixed in a Hobart-Swanson mixer using the high speed. The mixing time, as in the other acid and base studies, was 1 minute 5 seconds and the absorption was 62.9.

Six concentrations of acetic acid, 0.000, 0.050, 0.125, 0.200, 0.250 and 0.300 normal solutions, were used.

The "A" flour was used for the study and had been stored for 97 days in sealed cans at 80° F.

Extensograph procedure was the same as that used in the storage study.

Storage-Acid-Base Study

One of the objects of this study was to determine the effects of different storage time and storage conditions on flour mixed with equal amounts of acid and base. The flour stored under the "A", "B", "O_2" and "N_2" conditions was used. Both flour-water and flour-water-2 percent NaCl dough systems were used in conjunction with the added increment of acid or base, and various normalities of acid and base were used.

As with other studies involving the Hobart-Swanson mixer, the mixing time was 1 minute 5 seconds and the absorption was 62.9. The high speed of the mixer was employed.

Extensograph procedure was the same as that described previously.

Hydrogen Sulfide Study

One of the objects of this study was to find the effect of acid and base upon untreated and Agenized flour stored under an atmosphere of hydrogen sulfide.

When the farinograph was employed as the mixer, the absorption used (61.2) was the same as that used in the storage study, and the dough was mixed 3 minutes 15 seconds, the mixing time being determined when the storage of the flour began. It was decided to do the farinograph mixing under oxygen only in order to decrease the slackening effect of the H_2S as much as possible. Even so, the dough of the oxygen mix was so sticky that it could be neither rounded nor molded.

In order to condition the dough enough to be able to make extensogram determinations, it was decided to decrease the absorption, keeping the mixing time as invariant. The absorption had to be lowered to 55.0 (with 2 percent NaCl) before a dough could be handled; even so, the second stretch of this dough was too sticky to be rounded and molded.

When acid or base was employed, the normality used was 0.250. This normality was used because in previous studies it was found that maximum extensogram F values were obtained with 0.250 normal solutions.

When the Hobart-Swanson mixer was used, the absorption was 62.9, the mixing time was 1 minute 5 seconds, and the high speed was used.

Extensograph procedure was the same as that described previously.

Absorption-Storage Study

The objectives of this study were to determine if optimum absorption of a flour changes with age, and to find the effect of storage temperature and sub-optimum absorption on farinograms and extensograms of flour-water systems.

Optimum absorptions were determined on the day of milling, after 129 days of storage and after 255 days of storage. In each case the optimum absorption was considered to be when the maximum consistency or minimum mobility was at 500 Brabender units.

The flour used in the storage temperature-sub-optimum absorption study was untreated flour stored in cans at 50-60° F. The control flour was the same untreated flour stored in cans at 80° F. In both instances the flour had been stored two weeks when farinograms and extensograms were made.

Other conditions and procedure were the same as those that prevailed in the storage study.

Dough Handling Characteristics

As experience in handling the dough increased, certain characteristic properties were noticed. An attempt was made to systematize and evaluate them on qualitative lines in a manner summarized as follows:

Observation	Qualitative evaluation		When observed
	Description	Symbol	
Moisture condition	Very dry	+2	After mixing and after first and second roundings
	Dry	+1	
	Medium	0	
	Wet	-1	
	Very wet	-2	
Extensibility	Very stiff	+2	After mixing and after first and second rests
	Stiff	+1	
	Neutral	0	
	Slightly limp	-1	
	Limp	-2	
	Very limp	-3	
	Running	-4	
Stickiness	Very cohesive	+3	After mixing and after first and second roundings
	Cohesive	+2	
	Slightly cohesive	+1	
	Neutral	0	
	Slightly adhesive	-1	
	Adhesive	-2	
	Very adhesive	-3	
Color	Chalky white	+2	After mixing and after second stretch
	White	+1	
	Creamy	0	
	Creamy yellow	-1	
	Yellow green	-2	
Surface of dough ball	Velvety	+2	After first rounding and after second rounding
	Smooth	+1	
	Rough	-1	
	Pitted	-2	
Length of dough cylinder	Very long	+2	After first molding and after second molding
	Long	+1	
	Medium	0	
	Short	-1	
	Very short	-2	
Shape of dough cylinder	Very concave	+2	After first and second Moldings
	Concave	+1	
	Cylindrical	0	
	Convex	-1	
	Very convex	-2	

EXPERIMENTAL RESULTS

Preliminary Studies

In addition to conducting several preliminary studies on stock flour, some were conducted on the storage flour. In each of these cases the difference in flour had no influence on the farinogram or extensogram value relationship with regard to the experiment being conducted.

Effect of Mixing and Resting in Various Atmospheres. The effect of mixing and resting doughs in atmospheres of oxygen, nitrogen, and hydrogen on farinograph and extensograph characteristics is shown in Table 2. Farinogram and extensogram values of doughs mixed and rested in hydrogen were quite similar to those mixed and rested in nitrogen.

Effect of Mixing Under Various Gas Pressures. It was found that farinograms and extensograms were influenced by the gas pressure. Farinograms and extensograms of doughs mixed in oxygen and nitrogen when the gas pressure was below 10 mm were practically identical with those mixed in air; however, with a pressure of 25 mm, farinogram heights and extensogram force values were higher when mixed in oxygen and lower when mixed in nitrogen than when mixed in air.

When the pressure was above 35 mm, height and force values were slightly higher in oxygen mixes and slightly lower in nitrogen mixes. This meant that at 25 mm the mixing bowl was

Table 2. Effect on farinograms and extensograms of mixing and resting under hydrogen as compared with mixing and resting under air and oxygen.[1]

Curve characteristic	Mixing and resting atmosphere							
	Oxygen		Air		Nitrogen		Hydrogen	
	1	2	1	2	1	2	1	2
	Farinogram value							
H	555	560	520	550	520	515	525	520
	Extensogram value							
Fa	4.90	4.85	-	3.65	2.45	2.20	2.35	2.15
Fb	5.10	5.10	3.60	3.60	2.50	2.20	2.50	2.00
Faa	9.55	9.55	4.50	4.35	2.40	2.10	2.65	2.00
Fbb	9.55	9.75	4.55	4.70	2.25	1.95	2.30	2.05
Ea	16.95	16.95	-	19.55	21.20	20.35	19.65	20.25
Eb	17.00	16.65	18.90	19.55	21.40	20.50	21.30	19.45
Eaa	13.30	13.35	18.50	18.05	21.25	20.45	19.65	21.45
Ebb	10.50	11.55	18.70	19.00	20.65	19.75	20.40	19.25

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[1] Flour used was "A" flour stored 76 days, absorption 61.2 percent with 2 percent NaCl, and mixing time 3:15 minutes.

not cleared of air so rapidly that its influence was not recorded in the farinograms and extensograms. As was stated previously, it was not necessary to have a pure atmosphere in the bowl throughout the mixing time, since a gaseous replacement at 25 mm effected satisfactory differences which illustrated the influence of mixing atmosphere on curve characteristics.

Table 3. Effect on extensograms of resting in an atmosphere different than mixing atmosphere.[1]

Curve characteristic	Resting atmosphere					
	Oxygen		Air		Nitrogen	
			Mixed in oxygen			
Fa	4.95	4.50	4.80	-	4.80	-
Faa	9.10	9.30	9.20	-	9.05	-
Ea	17.35	17.60	17.45	-	17.25	-
Eaa	12.00	12.65	12.75	-	12.70	-
			Mixed in air			
Fa	3.65	-	3.55	3.60	3.50	-
Faa	4.10	-	3.80	4.20	3.80	-
Ea	20.05	-	19.90	20.10	20.15	-
Eaa	18.80	-	19.15	19.85	19.60	-
			Mixed in nitrogen			
Fa	2.60	-	2.55	-	2.50	2.50
Faa	2.60	-	2.35	-	2.30	2.45
Ea	21.30	-	21.40	-	22.20	21.65
Eaa	21.65	-	21.70	-	21.45	21.70

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[1] Flour used was "A" flour stored 54 days, absorption 61.2 percent with 2 percent NaCl, and mixing time 3:15 minutes.

Effect of Resting in Atmosphere Different than Mixing Atmosphere. As recorded in Table 3, it was found that resting atmosphere different than mixing atmosphere had little effect upon extensogram F and E values. With reference to the mixing atmosphere, however, an increase in oxygen in the resting atmosphere caused increases in F values and decreases in E values greater in magnitude than differences between duplicate mixes.

Determination of Optimum Absorption and Mixing Time for Flour Used in Storage Study

The results of a series of air mixes made to determine the optimum absorption and mixing time of the storage flour directly after milling for both flour-water and the flour-water-2 percent NaCl systems are shown in Table 4. For the flour-water system, the optimum absorption was 62.9 percent with a mixing time of 2:30 minutes. For the flour-water-2 percent NaCl system it was 61.2 percent with a mixing time of 3:15 minutes.

Table 4. Optimum absorption and mixing time of storage study flour.

Dough system					
Flour-water			Flour-water-2 percent NaCl		
Absorption	Farinogram height	Mixing time minutes	Absorption	Farinogram height	Mixing time minutes
61.0	540	2:05	59.0	560	2:40
62.8	500*	2:25*	60.5	520	3:05
62.9	500*	2:30*	61.1	505*	3:15*
63.0	500*	2:30*	61.2	500*	3:15*
63.1	495	2:30	61.3	495*	3:15*
63.2	490	2:40	61.5	485	3:25
			62.0	470	3:35

[*] Mean of duplicate determinations.

Storage Study

The purpose of this study was to find the effect of storage on the same flour stored under different conditions of temperature and atmosphere. This effect in the case of farinograms and extensograms also included the effect of mixing in different atmospheres.

The complete data are recorded in Tables A, B, C, D, and E in the Appendix, from which the following results were found:

Changes in Farinogram Values. For the sake of easier comprehension, changes in farinogram values are categorized according to the effect produced by the different variables, first singly and then in combination.

1. Effect of Storage. As a general rule, irrespective of storage atmosphere, storage temperature, and mixing atmosphere, farinogram heights increased, farinogram widths decreased, and the H/W relationship increased with storage. For raw data on this and following effects, see Table A in Appendix.

2. Effect of Mixing Atmosphere. Oxygen generally caused all farinogram values to increase, regardless of time, storage temperature, or storage atmosphere; thus farinogram values of doughs mixed in oxygen were higher than those of their respective doughs mixed in air, and those in air were higher than those mixed in nitrogen. Some H/W values were exceptions to this rule; there being reversals of this trend with "A" flour from 56 days of storage onward and with "B" flour from 202 days

onward.

3. Effect of Storage Temperature. Farinogram heights were usually higher with "A" flour than they were with "B" flour, as were farinogram widths. No overall conclusion concerning H/W values could be made without involving mixing atmospheres.

4. Effect of Storage Atmosphere. Heights of flour stored under nitrogen were higher than those stored under oxygen, and FH values of "O_2 Changed" and "N_2 Changed" flours were higher than those of their respective parent flours. Farinogram widths of flour stored under nitrogen were higher than those stored under oxygen. No significant differences were found between the flours whose atmosphere was periodically changed and those which were not. H/W values of "N_2" flour were higher than those of "O_2" flour and FH values of "O_2 Changed" and "N_2 Changed" flours, as a general rule, were higher than their respective parent flours.

5. Effect of Changing of Storage Atmosphere. Periodic changing of storage atmosphere effected an increase in H values of "O_2 Changed" and "N_2 Changed" flours over their respective parent flours, "O_2" and "N_2" flours. W values were slightly less for the flours whose atmospheres were changed than they were for the respective parent flours. H/W values of "O_2 Changed" and "N_2 Changed" were slightly higher than were their respective parent flours.

6. Effect of Storage and Mixing Atmosphere. The relative relationship of farinogram H, W and H/W values between the three

mixing atmospheres was not significantly affected by storage.

7. Effect of Storage and Storage Temperature. The combined effect of storage and storage temperature could not be ascertained independently of the mixing atmosphere. Storage significantly lowered "B" flour W values more than it did "A" flour. "B" flour H/W values increased more with storage than did those of "A" flour.

8. Effect of Storage and Storage Atmosphere. The relative relationship of farinogram H, W and H/W values between "O_2" and "N_2" flours was not affected by storage.

9. Effect of Storage and Changing of Storage Atmosphere. Farinogram heights of "O_2 Changed" and "N_2 Changed" flours increased with storage. There was no appreciable change in farinogram widths. The H/W relationship increased with storage, as did the means of the H/W values of the different atmosphere mixes. For "O_2 Changed" flour the mean H/W value for 288 days was 347, for 325 days it was 360, and for 358 days it was 349. For "N_2 Changed" flour the mean H/W value for 288 days was 352, for 320 days it was 373, and for 351 days 377.

10. Effect of Mixing Atmosphere and Storage Temperature. The effect of mixing atmosphere on farinogram heights was greater for "A" flour than it was for "B" flour.

No statement concerning farinogram widths could be made without introducing the storage factor. The effect of mixing atmosphere on H/W values was greater for "A" flour than it was for "B" flour.

11. Effect of Mixing Atmosphere and Storage Atmosphere. The effect of mixing atmosphere on farinogram heights was greater for "O_2" flour than it was for "N_2" flour. The storage factor influenced farinogram widths so greatly that no overall statement concerning mixing and storage atmosphere alone could be made. The effect of mixing atmosphere on H/W values was greater for "O_2" flour than it was for "N_2" flour.

12. Effect of Mixing Atmosphere and Changing of Storage Atmosphere. The effect of mixing atmosphere on H values was greater for "O_2 Changed" flour than it was for "N_2 Changed" flour. No overall statements concerning W, and H/W values could be made without introducing the storage factor.

13. Effect of Storage, Mixing Atmosphere, and Storage Temperature. When the effects of the variables time, mixing atmosphere, and storage temperature were combined, farinogram heights increased as the storage, amount of oxygen in the mixing atmosphere, and the storage temperature increased.

However, the influence of the mixing atmosphere at certain periods of storage caused decreases in H values. For "A" flour, nitrogen mix, H values decreased from 525 at 54 days' storage to 515 at 175 days' storage before an increase began again. For "A" flour, air mix, H values were at a plateau of 550 from 54 to 190 days of storage, and "A" flour, oxygen mix, had a plateau of 565 from 54 to 124 days' storage. "B" flour, nitrogen mix, H values did not decrease with storage but a plateau at 550 was reached after 233 days of storage. This plateau lasted until the end of the study at 365 days' storage. Air and oxygen mixes had plateaus of longer duration.

The change in farinogram heights wrought by a year of storage was "A" flour, oxygen mix, 625-535 or 90 units; "A" flour, air mix, 595-500 or 95 units; "A" flour, nitrogen mix, 560-460 or 100 units; "B" flour, oxygen mix, 580-535 or 45 units; "B" flour, air mix, 565-500 or 65 units; and "B" flour, nitrogen mix, 550-460 or 90 units.

The overall effect on farinogram widths was complicated by the fact that opposite forces were at work; storage decreased W values while storage temperature increased, and increase in oxygen in the mixing atmosphere increased W values. However, the overall effect was one of decrease because the W values of the oxygen mixed "A" flour with a year of storage were lower than the nitrogen mixed "B" flour with zero days' storage.

The decrease in farinogram widths brought about by a year of storage was 0.13 cm for oxygen mix "A" flour; 0.04 cm for air mix "A" flour; 0.03 cm for nitrogen mix "A" flour; 0.23 cm for oxygen mix "B" flour; 0.20 cm for air mix "B" flour; and 0.25 cm for nitrogen mix "B" flour. This decrease was a gradual and a progressive one for "B" flour, but for "A" flour nitrogen and air mixes their curves reached their lowest around 140 days of storage, the decrease for "A" flour nitrogen mix being 0.16 cm, and for "A" flour air mix 0.17 cm. The decrease was a gradual and progressive one for "A" flour oxygen mix with the lowest value after a year of storage.

When the effects of the variables time, mixing atmosphere, and storage temperature were combined, the H/W relationship increased as the storage time, amount of oxygen in the mixing atmosphere, and the storage temperature increased. H/W values for "B" flour increased more than "A" flour after 60 days of storage, and up to that time there was no significant difference between storage at 80° F. and at 50-60° F.

14. Effect of Storage, Mixing Atmosphere, and Storage Atmosphere. The combined effect on farinogram heights was such that the duration of the plateau increased with increase of oxygen in the mixing atmosphere, and that the downward dip in the curves after approximately 50 days' storage decreased in like manner until with oxygen mixes there was no decrease for "O_2" flour and very little for "N_2" flour.

The refrigeration unit of the cold room was in erratic working order from 43 to 55 days' storage which may account for the anomolous "O_2" flour values for 49 days' storage.

The change in farinogram heights brought about by a year of storage was "O_2" flour, oxygen mix, 570-535 or 35 units; "O_2" flour, air mix, 540-500 or 40 units; "O_2" flour, nitrogen mix. 515-460 or 55 units; "N_2" flour, oxygen mix, 590-535 or 55 units; "N_2" flour, air mix, 560-500 or 60 units; "N_2" flour, nitrogen mix, 545-460 or 85 units.

The overall effect on farinogram widths was one of decrease. In addition, regardless of storage, with few exceptions, the magnitude of the W values were in this decreasing order: "O_2" flour, oxygen mix; "N_2" flour, oxygen mix; "O_2" flour, air mix; "O_2" flour, nitrogen mix; "N_2" flour, air mix; and "N_2" flour, nitrogen mix. In all cases, the values of oxygen mixes were highest, air mixes intermediate, and nitrogen mixes lowest for the same period of storage.

The overall effect on the H/W relationship was one of increase.

Farinogram H, W and H/W values of "O_2" flour were lower than those of "O_2 Changed" flour, and those of "N_2" flour were lower than those of "N_2 Changed" flour.

Changes in Extensogram Values. For the sake of easier comprehension, changes in extensogram values are categorized according to the effect produced by the different variables, first singly and then in combination.

1. Effect of Storage. Force (F) values increased, extensibility-under-the-curve (E) values decreased, and area (A) values increased with storage. For raw data on this and following effects, see Tables B, C, D, and E in the Appendix.

2. Effect of Mixing Atmosphere. F values of doughs mixed in oxygen were highest, those mixed in air intermediate, and those in nitrogen lowest. E values of doughs mixed in oxygen were lowest, those mixed in air intermediate, and those in nitrogen highest. A values of oxygen mixed doughs were higher than those of doughs mixed in air, and nitrogen mixed A values were lowest, although this difference was not as great as with

F values.

3. Effect of Storage Temperature. "A" flour F values were larger than "B" flour F values. "A" flour E values were smaller than "B" flour E values. "A" flour A values were larger than "B" flour A values.

4. Effect of Storage Atmosphere. "O_2" flour F values tended to be larger and "O_2" flour E values tended to be smaller than "N_2" when not otherwise more greatly influenced by storage time and mixing atmosphere. No overall statement regarding A values could be made without involving the mixing atmosphere.

5. Effect of Changing of Storage Atmosphere. Changing of storage atmosphere effected increases in F values of "O_2 Changed" and "N_2 Changed" flours over their respective parent flours, "O_2" and "N_2" flours. Decreases were effected in E values of "O_2 Changed" and "N_2 Changed" flours over their respective parent flours, "O_2" and "N_2" flours. Area values of the atmosphere changed flours were larger than those of their respective parent flours.

6. Effect of Storage and Mixing Atmosphere. No overall statement concerning extensogram values could be made without involving either storage temperature or storage atmosphere.

7. Effect of Storage and Storage Temperature. Although F values tended to increase, E values tended to decrease, and A values tended to increase, they were greatly influenced by the atmosphere in which the doughs were mixed.

8. Effect of Storage and Storage Atmosphere. Although F

values tended to increase, E values tended to decrease, and A values tended to increase, they were greatly influenced by the mixing atmosphere.

9. Effect of Storage and Changing of Storage Atmosphere. The combined effect of storage and changing of storage atmosphere tended to increase F values, decrease E values, and increase A values.

10. Effect of Mixing Atmosphere and Storage Temperature. Since increased oxygen in the mixing atmosphere and increased storage temperature had the same effect on extensogram values, the combined effect was one of intensification. F values increased, E values decreased, and A values increased as the oxygen content in the mixing atmosphere and the storage atmosphere increased.

11. Effect of Mixing Atmosphere and Storage Atmosphere. Generally, regardless of storage time, there was the following order of magnitude for F and A values: largest, "O_2" flour, oxygen mix; then "N_2" flour, oxygen mix; "O_2" flour, air mix; "N_2" flour, air mix; "O_2" flour, nitrogen mix; and smallest, "N_2" flour, nitrogen mix. For E values this order was reversed. Complete overall statements concerning the combined effect of mixing atmosphere and storage atmosphere on extensograms could not be made without introducing the factor of storage time.

Table 5. Summary of effect of storage, mixing atmosphere, and storage temperature on extensogram force (F) values.[1]

	Mixing atmosphere					
	Oxygen		Air		Nitrogen	
	Flour					
	"A"	"B"	"A"	"B"	"A"	"B"
	First stretch					
Maximum decrease, cm	None	0.05	None	None	None	None
Decrease duration, days	-	40	-	-	-	-
Maximum increase, cm	1.2	0.2	1.7	0.7	1.8	1.7
Increase duration, days	300	105	260	120	150	170
Plateau duration, days	65	195	105	245	215	195
	Second stretch					
Maximum decrease, cm	None	0.2	None	None	None	None
Decrease duration, days	-	110	-	-	-	-
Maximum increase, cm	1.9	0.3	6.1	2.1	4.6	2.5
Increase duration, days	300	190	210	200	180	150
Plateau duration, days	65	65	155	75	185	215

[1] Derived from Table B in the Appendix.

12. Effect of Mixing Atmosphere and Changing of Storage Atmosphere. Since increased oxygen in the mixing atmosphere and increased oxygen in the storage atmosphere had the same effect on extensogram values, the combined effect was one of intensification. F values increased, E values decreased, and A values increased from nitrogen, to air, to oxygen mix and from "N_2" to "O_2" flour.

13. Effect of Storage, Mixing Atmosphere, and Storage Temperature. When the effects of the variables, time, storage temperature, and mixing atmosphere were combined, the two

stretches behaved differently as did the differences between duplicates of the same stretch. The combined effect was, of course, much greater than the differences produced between duplicates, and with the two stretches the effect followed through. Only the relative magnitudes of the values were different, being larger for the second stretch.

The combined effect of storage, mixing atmosphere, and storage temperature on F values is summarized in Table 5, and on E values in Table 6.

Table 6. Summary of effect of storage, mixing atmosphere, and storage temperature on extensogram extensibility-under-the-curve (E) values.[1]

	Mixing atmosphere					
	Oxygen		Air		Nitrogen	
	Flour					
	"A"	"B"	"A"	"B"	"A"	"B"
First stretch						
Initial decrease, cm	5.30	3.85	3.50	2.20	3.00	0.70
Period of initial decrease, days	175	300	175	90	125	100
Maximum decrease, cm	5.30	3.85	3.50	2.20	3.20	0.70
Plateau duration, days	190	65	190	115	240	240
Increase duration, days	None	None	None	60	None	65
Decrease at end of study, cm	5.30	3.85	3.40	1.90	3.20	1.30
Second stretch						
Initial decrease, cm	3.70	2.80	3.45	2.15	3.30	3.20
Period of initial decrease, days	170	145	80	200	365	120
Maximum decrease, cm	3.70	2.80	3.40	2.15	3.30	3.20
Plateau duration, days	65	220	285	165	None	165
Increase duration, days	130	None	None	None	None	80
Decrease at end of study, cm	3.25	2.45	3.45	2.05	3.30	2.50

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[1] Derived from Table C in the Appendix.

The overall effect on extensogram area values was one of increase, although the magnitudes were not as large as for F values.

14. Effect of Storage, Mixing Atmosphere, and Storage Atmosphere. When the effects of the variables, time, mixing atmosphere, and storage atmosphere were combined, the two stretches behaved differently as did the differences between duplicates of the same stretch. The combined effect was, of course, much greater than the differences produced between duplicates, and with the two stretches the effect followed through. Only the relative magnitudes of the values were different, being larger for the second stretch.

The combined effect of storage, mixing atmosphere, and storage atmosphere on F values is summarized in Table 7, and on E values in Table 8.

The overall effect on extensogram area values was one of increase, although the magnitudes were not as large as for F values.

15. Comparison of Atmosphere-Changed-Flours with Atmosphere-Not-Changed-Flours. Periodically changing the storage atmosphere increased the F values in relation to their respective parent flour. This effect on F values of nitrogen stored flour was greater than for flour stored under oxygen. The mixing atmosphere had no influence on this relationship.

Table 7. Summary of effect of storage, mixing atmosphere, and storage atmosphere on extensogram force (F) values.[1]

	Mixing atmosphere					
	Nitrogen		Air		Oxygen	
	Flour					
	"O_2"	"N_2"	"O_2"	"N_2"	"O_2"	"N_2"
	First stretch					
Maximum decrease,cm	None	None	None	None	None	None
Decrease duration,days	-	120	-	-	-	-
Maximum increase,cm	0.4	0.90	1.1	1.2	1.8	1.9
Increase duration,days	180	245	150	290	230	240
Plateau duration,days	185	0	215	75	135	125
	Second stretch					
Maximum decrease,cm	None	0.2	None	None	None	None
Decrease duration,days	-	90	-	-	-	-
Maximum increase,cm	0.4	0.5	2.3	2.5	2.5	2.8
Increase duration,days	260	275	180	320	120	140
Plateau duration,days	105	0	185	45	245	225

[1] Derived from Table B in the Appendix.

E values were influenced differently by the periodic changing of the storage atmosphere, as summarized in Table 8. The changing of nitrogen atmosphere caused a decrease in E values relative to the parent flour, while the changing of oxygen atmosphere caused an increase in E values in relation to the parent flour.

A values of "O_2 Changed" flour were higher than A values of "O_2" flour. Area values of "N_2 Changed" and "N_2" were of the same order of magnitude.

Table 8. Summary of effect of storage, mixing atmosphere, and storage atmosphere on extensograms extensibility-under-the-curve (E) values.[1]

	Mixing atmosphere					
	Nitrogen		Air		Oxygen	
	Flour					
	"O_2"	"N_2"	"O_2"	"N_2"	"O_2"	"N_2"
First stretch						
Initial decrease,cm	3.30	2.70	3.00	1.85	2.10	1.30
Period of initial decrease,days	100	115	50	115	80	115
Maximum decrease,cm	3.30	3.95	3.00	1.85	2.10	1.30
Increase duration,days	135	None	310	85	210	55
Plateau duration,days	None	175	None	165	75	185
Decrease duration,days	130	75	None	None	None	None
Decrease at end of study,cm	2.60	3.95	2.25	1.75	0.90	1.10
Second stretch						
Initial decrease,cm	3.30	3.35	2.85	2.80	3.20	2.35
Period of initial decrease,days	180	120	170	165	125	90
Maximum decrease,cm	3.30	3.35	3.20	2.80	3.20	2.35
Increase duration,days	185	150	65	130	165	None
Plateau duration,days	None	None	None	70	None	275
Decrease duration,days	None	95	130	None	75	None
Decrease at end of study,cm	2.65	3.35	3.20	2.70	2.70	2.50

[1] Derived from Table C in the Appendix.

Sequence and Spread Differences of Extensogram Values of Duplicate Doughs. These traits were studied in the instances of F and E values alone, since A values in a sense are resultants and therefore, strictly speaking, need not be included in an analysis of primary characteristics.

1. Effect of Sequence of Dough Stretch. With force values, when discernible sequence was found, the second of the duplicates

of the first stretch (Fb) had the larger force values, but with the second stretch, the first of the duplicates (Faa) had the larger value. The spread was greater with the first stretch values (Fa and Fb). Of the first stretch values, the spread of those mixed in oxygen were largest, those in air imtermediate, and those mixed in nitrogen smallest. Of those mixed under oxygen, the "A" flour spread was greatest. The "B", "O_2", and "N_2" spreads were of approximately equal magnitude. Second stretch spreads were similar to first stretch spreads but were of lesser magnitude.

With E values, the first duplicate of first stretch values were larger for oxygen and air mixes, while second duplicates of first stretch values were larger for nitrogen mixes. No distinction between second duplicates could be made except for "A" flour oxygen mix where second duplicates were larger than first duplicates.

For E values the spread was greater for first stretch than for second stretch values. Of the first spread values, the spread of those mixed in oxygen were largest, those mixed in air intermediate, and those mixed in nitrogen smallest. There was no appreciable difference in the spread of the E values for the different flours.

2. Effect of Storage. Storage had no discernible effect upon either sequence or spread of F and E values.

3. Effect of Mixing Atmosphere. For F values, sequence was discernible only with doughs mixed in oxygen and air;

nitrogen mixing atmosphere having no influence upon sequence of F values of duplicate doughs. Spread was greatest for doughs mixed in oxygen, being about equal for air and nitrogen, and first stretch was larger than second stretch spread.

Sequence was observed for E values in oxygen, air, and nitrogen mixes. The spread was greatest for doughs mixed in nitrogen, about equal for air and oxygen, and first stretch was larger than second stretch spread.

4. Effect of Storage Temperature. With F values, sequence was discernible for "A" flour first and second stretch air and oxygen mixes; while for "B" flour, first stretch air and oxygen, and second stretch oxygen mixes. "A" flour spreads were larger than were spreads of "B" flour.

For E values, sequence was discernible for "A" flour first stretch oxygen, air and nitrogen mixes, and second stretch oxygen mixes; "B" flour first stretch oxygen, air and nitrogen mixes. "A" flour spreads were larger than those for "B" flour.

5. Effect of Storage Atmosphere. Sequence was discernible for F values only for some first stretch doughs, being "O_2" flour oxygen and air mixes, and "N_2" flour oxygen and air mixes. The oxygen mix sequence effect was more pronounced than the air, while there was no apparent storage atmosphere sequence effect. No significant difference in spread was discernible.

For E values, sequence was discernible for "O_2" flour first stretch oxygen, air and nitrogen mixes and second stretch oxygen mixes. For "N_2" flour sequence was observed for first stretch oxygen, air and nitrogen mixes.

Zeleny Sedimentation Study

Sedimentation values of all the stored flours increased with storage time as indicated by the data in Table 9. Throughout the storage period, the values for "N_2" flour were highest; those of "B" flour slightly lower than "N_2" values; those of "O_2" flour considerably lower than "B" values; and those of "A" flour considerably lower than "O_2" values.

The curves formed by plotting storage time in days against sedimentation values for "N_2" and "B" flours were virtually straight lines for the first two hundred days of storage. After this time, however, they tapered off so that the increase in sedimentation with contined storage was not nearly as great, indeed very little or no increases was found.

"O_2" flour values reached a plateau after approximately 200 days of storage.

"A" flour sedimentation values decreased with storage up to about 60 days after which they increased with acceleration until about 120 days when a tapering off began. After about 200 days of storage, "A" flour values reached a plateau.

No differences between the spread of duplicate determinations were apparent except for "A" flour of which the differ-

Table 9. Sedimentation values of stored flours.

Storage days	Flour designation*			
	A	B	O_2	N_2
27	-	33.4	-	-
	-	33.9	-	-
32	32.8	-	33.3	33.6
	33.2	-	33.5	33.9
51	-	-	33.2	33.7
	-	-	33.6	34.3
58	32.6	33.8	-	-
	33.0	34.1	-	-
79	32.8	-	33.4	-
	33.1	-	33.9	-
89	-	34.3	-	34.2
	-	34.4	-	34.6
103	33.2	-	33.6	-
	33.7	-	34.5	-
117	-	34.5	-	34.7
	-	34.9	-	34.8
126	33.9	-	34.4	-
	34.7	-	34.9	-
141	-	-	-	34.7
	-	-	-	35.2
146	-	35.0	-	-
	-	35.0	-	-
149	-	-	34.5	-
	-	-	35.3	-
152	34.4	-	-	-
	35.0	-	-	-
169	-	35.1	-	35.2
	-	35.5	-	35.5
177	34.4	-	34.8	-
	35.5	-	35.5	-
205	-	35.3	35.3	35.4
	-	35.9	35.4	35.8

Table 9. (concl.)

Storage days	Flour designation*			
	A	B	O_2	N_2
207	34.8 35.3	- -	- -	- -
237	34.4 36.6	35.4 36.0	35.0 35.7	35.5 36.1
264	- -	35.3 36.0	- -	35.6 36.1
267	- -	- -	35.2 35.7	- -
270	34.5 35.5	- -	- -	- -

* "A" flour was stored in sealed cans at 80° F.
"B" flour was stored in sealed cans at 50-60° F.
"O_2" flour was stored under oxygen in sealed glass jars at 50-60° F.
"N_2" flour was stored under nitrogen in sealed glass jars at 50-60° F.

ences between duplicates increased with storage time. These differences were: 32 days 0.4, 58 days 0.4, 79 days 0.3, 103 days 0.5, 126 days 0.8, 152 days 0.6, 177 days 1.1, 207 days 0.5, 237 days 1.2, and 270 days 1.0.

The erratic working order of the refrigeration unit of the cold room from 43 to 55 days' storage was apparently not reflected in the sedimentation results.

Zeleny Photometric Protein Study

Photometric protein values of all the stored flours increased with storage time as indicated by the data recorded in Table 10. After 3 to 4 months' storage, the values for "A" flour were largest, followed by those of "O_2" flour, and then "B" flour, with "N_2" flour photometric protein values being the smallest. Prior to 3 months' storage, "A" and "B" flour values were proportionately larger than "O_2" and "N_2" values than they were after 3 months' storage. In addition, prior to 3 months' study, "B" flour values were larger than "A", and "N_2" values were larger than "O_2" values.

The curves formed by plotting storage time in days against photometric protein values showed that increase in "A" values tapered off sharply after 100 days' storage; increase in "O_2" and "B" values reached plateaus after 140 days; and "N_2" values showed almost no increase after 160 days' storage.

Table 10. Photometric protein values (percent transmission) of stored flours.

Storage days	Flour designation*			
	A	B	O_2	N_2
30	- -	63.0 62.8	- -	- -
32	62.5 62.5	- -	- -	- -
51	- -	- -	62.6 62.4	62.9 62.5
77	64.0 64.0	- -	63.1 63.5	- -
84	- -	64.0 64.5	- -	63.3 63.7
99	64.7 65.0	- -	64.6 64.2	- -
110	- -	64.2 64.6	- -	64.0 64.0
126	65.0 64.8	- -	64.5 64.8	- -
141	- -	64.6 64.6	- -	64.2 64.6
177	65.3 65.0	- -	64.9 64.8	- -
205	- -	65.0 64.5	- -	64.8 64.5
237	65.4 65.0	- -	64.8 65.1	- -
264	- -	65.0 64.9	- -	64.6 65.0
267	- -	- -	65.0 65.1	- -

Table 10. (concl.)

Storage: days :	Flour designation*			
	A :	B :	O_2 :	N_2
270	65.1 65.4	- -	- -	- -

* "A" flour was stored in sealed cans at 80° F.
"B" flour was stored in sealed cans at 50-60° F.
"O_2" flour was stored under oxygen in sealed glass jars at 50-60° F.
"N_2" flour was stored under nitrogen in sealed glass jars at 50-60° F.

No differences between the spread of duplicate determinations were apparent.

The erratic working order of the refrigeration unit of the cold room from 43 to 55 days' storage was apparently not reflected in the photometric protein results.

Sodium Chloride Study

The effect of salt on farinograms and extensograms was studied using the "B" flour, with results as shown in Table 11. When the study was undertaken, the "B" flour had been stored 129 days, and, consequently, its optimum absorption had changed. At 129 days' storage, the optimum absorption was 64.0 percent with a mixing time of 3:15 minutes; this was in contrast to an optimum absorption of 62.9 with a mixing time of 2:30 minutes with zero days of storage.

All of the mixes were done with air as the mixing atmosphere, since air was intermediate in effect on extensogram curve characteristics, and only the limit of the action of salt on extensograms was wanted. It was found that extensogram values decrease with 15 percent salt, and this undoubtedly holds true with many kinds of flour different than the "B" flour both in inherent characteristics and in treatment received.

<u>Effect of NaCl on Farinogram Values</u>. Sodium chloride had a depressing effect upon farinogram heights. Height value decreased from 500 with 0 percent NaCl to 370 with 15 percent

NaCl. Farinogram width decreased with increase in NaCl. The width value decreased from 1.45 cm with 0 percent NaCl to 0.90 cm with 15 percent NaCl. The H/W relationship was lowest (334) with 5 percent NaCl and highest (411) with 15 percent NaCl.

Effect of NaCl on Extensogram Values. All F values increased as percentage of NaCl increased until maximums were reached with 10 percent NaCl, then, with 15 percent NaCl, F values decreased.

All E values increased with increase of NaCl until maximums were reached with 5 percent NaCl, then they decreased. Second stretch E values appeared to have an additional peak with 2 percent NaCl.

First stretch E_t values reached a maximum with 5 percent NaCl, then decreased, while the maximum for second stretch E_t values was a plateau extending from 2 to 5 percent NaCl and then decreasing.

All A values reached a maximum with 1 percent NaCl and then decreased.

For detailed data, see Table 11.

Table 11. Effect of NaCl on "B" flour farinogram and extensogram values.

Curve characteristics	Percent NaCl						
	0	1	2	3	5	10	15
	Farinogram values						
FH	500	480	450	450	435	435	370
FW	1.45	1.35	1.30	1.30	1.30	1.25	0.90
H/W	345	356	346	346	334	340	411
	Extensogram values						
Fa	0.95	1.85	2.35	3.65	5.85	8.15	5.30
Fb	1.10	2.15	2.40	3.70	5.85	8.25	5.85
Faa	1.00	2.10	2.60	4.60	7.75	13.25	12.05
Fbb	1.05	2.05	2.60	4.65	7.40	13.05	12.50
Ea	16.70	18.15	21.75	22.80	25.05	21.30	14.85
Eb	15.60	19.95	23.25	22.30	23.90	21.15	14.20
Eaa	17.20	21.60	23.75	22.15	22.60	17.55	14.35
Ebb	16.60	19.55	21.05	21.90	22.35	17.60	13.05
E_ta	18.25	19.15	23.80	24.65	25.45	23.90	14.85
E_tb	18.60	22.05	23.25	24.60	25.95	23.65	16.15
E_taa	18.30	22.25	23.75	23.65	23.65	17.95	15.45
E_tbb	18.90	22.65	23.10	23.45	23.15	17.60	15.25
Aa	15.94	28.42	40.51	62.72	110.98	132.93	57.60
Ab	16.00	33.92	43.08	62.60	106.11	129.60	65.15
Aaa	16.13	36.42	48.45	79.74	128.51	167.87	123.07
Abb	15.62	32.32	42.44	78.40	122.82	161.54	122.30

<u>Effect of NaCl on Duplicate Doughs</u>. These data are summarized in Table 12. All Fb values were larger than or equal to Fa values, but the second stretch F values lost this characteristic, the values being equal (within plus or minus 0.05) for all NaCl concentrations below 5 percent. For 5 percent NaCl, the Faa value was larger (0.35), then the difference decreased until with 10 percent NaCl Faa was larger than Fbb by

0.20. With 15 percent NaCl, the trend had continued until Fbb was larger than Faa by 0.45. The relative relationship for both first and second stretch F values remained however, for Fa and Faa values in relation to Fb and Fbb values were highest with 5 and lowest with 15 percent NaCl.

All Eb values were larger than Ea values except with the extremes of salt concentration, 0 and 15 percent, where Ea was larger than Eb. All Eaa values were larger than Ebb with the exception of 10 percent salt, were Ebb was the larger.

E_ta values were larger than E_tb values for 2 and 3 percent NaCl, while E_tb values were larger for all other salt concentrations. $E_t$aa values were larger than $E_t$bb for all salt concentrations except 0 and 1 percent where they were smaller.

Aa values were higher than Ab values for 3, 5, and 10 percent NaCl and lower for the extremes 0, 1, and 15 percent. All Aaa values were higher than Abb values, but significantly smaller differences were found with the 0 and 15 percent salt concentrations.

Table 12. Extensogram value differences between duplicate doughs influenced by NaCl.*

Curve characteristics	Percent NaCl						
	0	1	2	3	5	10	15
Fa-Fb	-0.15	-0.30	-0.05	-0.05	0.00	-0.10	-0.55
Faa-Fbb	-0.05	0.05	0.00	-0.05	0.35	0.20	-0.45
Ea-Eb	1.10	-1.80	-1.50	-0.50	-1.15	-0.15	0.65
Eaa-Ebb	0.60	2.05	2.70	0.25	0.25	-0.05	1.30
E_ta-E_tb	-0.35	-2.90	0.55	0.05	-0.50	-0.25	-1.30
$E_t$aa-$E_t$bb	-0.60	-0.40	0.65	0.20	0.50	0.35	0.20
Aa-Ab	-0.06	-3.50	-2.57	0.12	4.87	3.33	-7.55
Aaa-Abb	0.51	4.10	6.01	1.44	5.79	6.33	0.77

* Derived from Table 11.

Effect of NaCl on Differences Between Stretches. These data appear in Table 13. The differences between F first stretch and F second stretch values increased in magnitude with increasing NaCl concentration. All Faa values were larger than Fa values. All Fbb were larger than Fb values except for 0 and 1 percent NaCl.

All E second stretch values were higher than E first stretch values with the exception of second stretch having 0 percent NaCl which had a higher value.

E_ta values were higher than $E_t$aa with the exception of the extremes, 0, 1, and 15 percent NaCl, where the $E_t$aa values were higher. With 0, and 1 percent salt, $E_t$bb values were higher than E first stretch values. E_tb values were higher for other salt concentrations, the greatest difference (6.05) being with 10 percent NaCl and then dropping off sharply (0.90) with 15 percent salt.

All second stretch area values were larger than Aa and Ab values with the exception of 0 and 1 percent Ab values which were larger. The differences between area first stretch and area second stretch values increased in magnitude with increasing NaCl concentrations; e.g., Aa-Aaa values: -0.19 having 0 percent salt to -65.5 having 15 percent salt, and Ab-Abb values: 0.38 having 0 percent salt to -57.2 having 15 percent salt.

Table 13. Extensogram value differences between dough stretches influenced by NaCl.[*]

Curve characteristics	Percent NaCl						
	0	1	2	3	5	10	15
Fa-Faa	-0.05	-0.25	-0.25	-0.95	-1.90	-5.10	-6.75
Fb-Fbb	0.05	0.10	-0.20	-0.95	-1.55	-4.80	-6.65
Ea-Eaa	-0.50	-3.45	-2.00	-0.65	-2.45	-3.75	-0.50
Eb-Ebb	1.00	-0.40	-2.20	-0.40	-1.55	-3.55	-1.15
E_ta-$E_t$aa	-0.05	-3.10	0.05	1.00	1.80	5.95	-0.60
E_tb-$E_t$bb	-0.30	-0.60	0.15	1.15	2.80	6.05	0.90
Aa-Aaa	-0.19	-8.00	-8.94	-17.0	-17.5	-34.9	-65.5
Ab-Abb	0.38	1.60	-0.64	-15.8	-16.7	-31.9	-57.2

[*] Derived from Table 11.

Effect of NaCl on pH of Doughs. The pH of the doughs varied within the close limits of 7.05-7.10, with the exception of the doughs with 10 percent NaCl which had pH values of 7.20 both after mixing and after the second stretch. The pH values of all the doughs were taken both after mixing and after the second stretch and no differences outside of what was considered the limits of experimental error (0.05) were detected.

Potassium Bromate Study

The combined effect of salt, bromate, mixing and resting atmosphere was studied using the "B" flour. When the study began the "B" flour had been stored 255 days and its optimum absorption was 65.0 with a mixing time of 5:00 minutes. Thus the absorption of the "B" flour had increased from 62.9 on the day of milling to 64.0 after 129 days of storage, when the Sodium Chloride Study was done, and to 65.0 after 255 days of storage. Likewise the mixing time had increased from 2:30 minutes to 3:15 minutes to 5:00 minutes.

Changes in Farinogram Values. Changes in farinogram values, as shown in Table 14, for the sake of easier comprehension, are categorized according to the effect produced by the different variables, first singly and then in combination.

1. Effect of NaCl. Sodium chloride had a depressing effect upon farinogram heights. Farinogram widths decreased with increasing concentration of salt. The H/W relationship was lowest with 5 percent NaCl and increased with concentrations both greater and lesser than this amount.

2. Effect of $KBrO_3$. Potassium bromate lowered farinogram heights, but this tendency was greatly influenced by mixing atmosphere and by NaCl, the masking effect being greater with NaCl. Farinogram widths were affected in the same manner. No trend concerning the H/W relationship could be made without a qualification involving mixing atmosphere.

Table 14. Influence of potassium bromate and sodium chloride on the farinograms and extensograms of doughs mixed and rested in various gaseous atmospheres.

I Zero mg bromate, oxygen atmosphere

Curve characteristics	Percent sodium chloride				
	0	1	5	10	15
			Farinogram values		
H	540	475	420	350	320
W	1.20	1.15	1.10	0.75	0.50
H/W	450	413	382	467	640
			Extensogram values		
Fa	4.30	7.90	12.00	9.85	3.60
Fb	4.50	8.20	11.15	9.55	4.85
Faa	8.40	13.15	18.35*#	15.60*	9.90
Fbb	8.90	12.85	18.85*#	17.65*	8.55
E_1a	15.05	18.80	15.70	9.60	6.15
E_1b	15.25	17.60	14.85	9.45	6.10
E_1aa	12.45	12.35	10.20*#	7.95*	6.15
E_1bb	13.50	12.15	9.45*#	6.70*	6.10
Ea	17.55	23.45	21.20	13.70	9.75
Eb	18.25	20.45	20.75	13.80	11.05
Eaa	15.05	15.45	16.40#	12.30	10.55
Ebb	16.45	15.60	13.85#	10.00	11.40
E_ta	18.60	23.45	21.20	13.70	9.75
E_tb	18.25	23.60	20.75	13.80	11.05
$E_t$aa	15.05	15.45	16.40#	13.55	11.25
$E_t$bb	16.45	15.60	13.85#	13.65	11.40
A_1a	42.50	93.76	124.80	58.30	15.04
A_1b	45.26	91.01	105.98	56.06	16.88
A_1aa	66.24	98.88	113.73*#	76.93*	37.70
A_1bb	78.20	98.88	123.26*#	78.02*	31.81
Aa	53.44	124.74	182.72	91.14	24.49
Ab	57.46	111.55	163.76	88.38	35.52
Aaa	85.44	132.67	199.17*#	126.66*	62.85
Abb	100.48	163.38	184.58*#	123.33*	61.38

Table 14. (cont.)

II Zero mg bromate, air atmosphere

Curve characteristics	Percent sodium chloride				
	0	1	5	10	15
			Farinogram values		
H	500	435	400	355	290
W	1.15	1.10	1.10	0.75	0.50
H/W	435	395	364	473	580
			Extensogram values		
Fa	3.05	3.65	6.45	6.90	3.15
Fb	3.10	3.90	7.25	7.55	3.20
Faa	3.40	3.95	10.30	12.20	9.65
Fbb	3.25	4.50	10.60	12.55	8.05
E_1a	15.30	20.60	22.35	13.70	7.65
E_1b	15.45	20.50	22.10	13.55	6.65
E_1aa	16.40	17.90	17.55	10.50	9.15
E_1bb	17.00	21.10	18.20	11.10	8.00
Ea	19.50	25.90	29.50*	19.65	12.70
Eb	19.45	23.30	26.95	18.90	12.30
Eaa	20.60	21.20	23.80	15.55	14.10
Ebb	20.05	22.75	23.95	16.45	12.05
E_ta	21.60	26.95	29.50*	21.20	12.70
E_tb	21.70	27.10	29.45*	21.45	12.30
E_taa	20.60	25.80	23.80	17.60	14.10
E_tbb	20.85	26.30	24.25	18.95	15.90
A_1a	34.52	52.86	97.34	64.61	18.50
A_1b	34.62	56.77	108.18	66.04	15.74
A_1aa	38.98	49.73	120.13	87.30	55.17
A_1bb	36.74	67.58	124.57	93.44	41.02
Aa	44.30	69.38	134.02*	100.25	32.19
Ab	45.18	66.24	136.96*	103.10	30.53
Aaa	51.72	61.44	179.00	139.01	92.54
Abb	51.52	71.74	182.61	150.66	66.82

Table 14. (cont.)

III Zero mg bromate, nitrogen atmosphere

Curve char- acter- istics	Percent sodium chloride				
	0	1	5	10	15
			Farinogram values		
H	475	425	390	335	290
W	1.10	1.05	1.10	0.75	0.50
H/W	432	405	355	447	580
			Extensogram values		
Fa	1.35	2.40	5.20*	6.05	2.15
Fb	1.35	2.45	5.25*	6.20	3.25
Faa	1.15	2.40	8.75*	9.50	8.30
Fbb	1.25	2.45	9.25*	10.35	9.40
E_1a	15.65	20.35	21.20*	18.65	8.75
E_1b	15.15	20.15	21.05*	20.55	9.60
E_1aa	14.05	20.25	17.95*	17.70	12.25
E_1bb	14.20	19.00	18.05*	15.70	12.20
Ea	23.70	24.05	27.05	26.60	14.40
Eb	22.60	24.65	27.10	26.70	13.85
Eaa	19.25	24.50	24.55	22.00	18.30
Ebb	20.20	25.50	24.50	21.55	18.50
E_ta	24.75	26.95	27.30	26.60	14.40
E_tb	23.50	25.80	27.10	26.70	16.30
E_taa	21.25	25.40	24.55	25.25	23.00
E_tbb	21.05	25.95	24.50	26.70	20.50
A_1a	17.86	37.50	80.77*	75.58	14.85
A_1b	16.96	37.95	80.45*	88.06	22.91
A_1aa	13.89	38.37	112.19*	112.64	69.50
A_1bb	14.78	34.75	116.67*	112.70	77.44
Aa	29.78	45.50	106.30*	117.25	24.83
Ab	26.75	47.55	107.01*	121.15	35.01
Aaa	18.94	48.32	157.76*	151.23	111.62
Abb	21.31	49.66	165.31*	166.66	125.31

Table 14. (cont.)

IV 3 mg bromate, oxygen atmosphere

Curve characteristics	Percent sodium chloride				
	0	1	5	10	15
			Farinogram values		
H	495	455	405	340	305
W	1.25	1.20	1.15	0.80	0.60
H/W	396	379	352	425	508
			Extensogram values		
Fa	4.15	7.60	11.55	8.70	3.00
Fb	4.70	8.30	13.25	10.25	3.70
Faa	9.50	14.10	19.25*#	18.50*	9.00
Fbb	8.80	14.80	19.10*#	18.25*	7.90
E_1a	15.80	18.30	12.10	8.85	5.45
E_1b	15.65	18.70	13.40	8.85	6.20
E_1aa	10.90	12.75	9.30*#	7.20*	5.90
E_1bb	11.20	11.85	9.65*#	6.75*	5.55
Ea	19.25	22.25	18.70	13.70	12.10
Eb	19.00	21.55	18.85	14.50	10.70
Eaa	13.65	13.45	11.35#	11.60	10.35
Ebb	15.05	13.65	14.20#	11.80	10.45
E_ta	19.25	23.45	18.70	15.90	12.10
E_tb	22.50	23.40	18.85	14.50	10.70
E_taa	13.65	13.45	11.35#	11.60	10.35
E_tbb	15.05	13.65	14.20#	11.80	10.45
A_1a	48.26	86.85	91.14	46.98	11.71
A_1b	53.06	96.90	110.40	57.09	16.00
A_1aa	63.49	99.52	114.50*#	81.73*	32.32
A_1bb	62.72	96.96	119.68*#	74.56*	27.14
Aa	61.50	112.64	150.85	80.06	25.28
Ab	60.86	125.25	174.02	100.16	27.39
Aaa	84.99	120.81	146.79*#	141.18*	58.75
Abb	92.42	124.80	185.92*#	136.58*	50.43

Table 14. (cont.)

V 3 mg bromate, air atmosphere

Curve characteristics	Percent sodium chloride				
	0	1	5	10	15
			Farinogram values		
H	495	430	395	335	305
W	1.20	1.10	1.15	0.85	0.60
H/W	413	391	343	394	508
			Extensogram values		
Fa	3.15	4.80	8.30	7.20	2.05
Fb	3.25	5.05	8.80	7.80	3.25
Faa	4.95	6.75	12.75	15.30	10.40
Fbb	4.20	6.50	12.80	15.40	10.25
E_1a	16.40	18.50	19.65	13.95	8.60
E_1b	14.50	20.50	18.55	12.90	7.00
E_1aa	16.00	18.35	14.45	10.25	8.05
E_1bb	15.70	17.10	13.45	9.80	7.35
Ea	20.65	22.30	26.10	20.50	16.00
Eb	17.75	24.35	23.35	17.75	13.80
Eaa	19.60	23.00	19.35	15.35	13.00
Ebb	19.20	21.05	20.75	15.50	12.80
E_ta	20.65	27.45	26.85	21.45	16.00
E_tb	22.55	27.40	26.55	21.20	13.80
E_taa	19.60	23.00	19.35	15.65	14.05
E_tbb	22.50	22.30	20.75	15.50	13.05
A_1a	38.72	61.50	109.25	70.11	12.22
A_1b	34.75	69.70	109.76	70.34	15.74
A_1aa	55.10	84.22	119.49	95.98	50.56
A_1bb	46.14	74.05	114.18	93.76	48.83
Aa	49.73	78.78	156.99	108.67	23.04
Ab	44.22	87.74	147.84	102.21	29.83
Aaa	70.02	112.45	174.08	160.34	84.16
Abb	60.35	97.15	191.17	162.62	80.83

Table 14. (cont.)

VI 3 mg bromate, nitrogen atmosphere

Curve characteristics	Percent sodium chloride				
	0	1	5	10	15
			Farinogram values		
H	465	420	385	330	305
W	1.05	1.05	0.95	0.75	0.65
H/W	443	400	405	440	469
			Extensogram values		
Fa	2.05	3.30	6.90*	6.10	2.70
Fb	2.05	3.35	6.85*	7.05	3.75
Faa	2.75	3.95	9.80	13.25	9.90
Fbb	2.90	4.35	11.00	12.95	11.15
E_1a	15.25	20.15	23.50*	18.65	10.95
E_1b	14.85	20.80	21.50*	18.70	9.00
E_1aa	15.65	17.60	18.00	13.70	11.95
E_1bb	17.35	17.45	18.45	14.20	11.90
Ea	19.30	26.00	29.30*	24.55	17.30
Eb	19.15	24.55	29.40*	26.75	13.40
Eaa	19.65	21.30	24.45	19.90	16.60
Ebb	21.40	20.70	24.70	20.70	17.90
E_ta	22.35	26.00	29.30*	27.55	17.30
E_tb	20.20	28.35*	29.40*	26.75	14.80
E_taa	20.40	24.80	24.45	19.90	18.65
E_tbb	24.55	26.85	24.70	20.70	17.90
A_1a	23.94	48.06	106.24*	77.44	21.70
A_1b	24.19	48.51	100.35*	88.45	24.13
A_1aa	32.70	51.26	120.32	122.18	73.86
A_1bb	35.20	54.04	139.97	123.71	86.78
Aa	31.04	65.79	140.80*	109.82	34.56
Ab	32.58	60.67	147.65*	136.19	38.02
Aaa	43.33	65.34	177.66	190.78	119.42
Abb	48.13	68.42	204.93	192.26	152.13

Table 14. (cont.)

VII 30 mg bromate, oxygen atmosphere

Curve characteristics	Percent sodium chloride				
	0	1	5	10	15
			Farinogram values		
H	525	455	405	355	315
W	1.25	1.25	1.15	0.85	0.65
H/W	420	364	353	418	485
			Extensogram values		
Fa	6.10	9.70	12.30	11.20	2.50
Fb	7.90	10.60	13.50	11.45	2.75
Faa	13.55	18.05*	20.80*#	17.30*	6.05
Fbb	14.70	18.40*#	20.95*#	18.10*	6.40
E_1a	11.25	12.45	13.25	8.00	5.85
E_1b	10.60	12.15	13.30	7.90	5.95
E_1aa	6.45	9.10*	9.25*#	6.40*	4.85
E_1bb	7.20	9.25*#	9.45*#	6.90*	5.30
Ea	14.05	16.55	18.55	13.45	11.80
Eb	13.00	14.15	18.45	12.85	9.30
Eaa	8.30	12.15	12.55#	11.85	8.70
Ebb	8.25	12.20#	12.40#	10.10	8.55
E_ta	18.00	16.55	18.55	13.45	11.80
E_tb	13.00	17.30	18.45	14.55	12.05
$E_t$aa	8.30	12.15	13.05#	11.85	8.70
$E_t$bb	8.25	12.20#	12.40#	11.75	8.65
A_1a	46.27	78.34	113.86	56.13	10.50
A_1b	54.34	78.27	111.10	56.51	8.26
A_1aa	47.42	108.61*	102.87*#	68.55*	17.47
A_1bb	58.82	114.69*#	103.42*#	77.57*	20.34
Aa	61.76	111.94	160.96	100.35	20.42
Ab	71.04	98.43	162.24	95.42	19.07
Aaa	64.32	154.50*	184.38*#	122.24*	33.09
Abb	72.26	164.80*#	186.50*#	115.81*	35.46

Table 14. (cont.)

VIII 30 mg bromate, air atmosphere

Curve characteristics	Percent sodium chloride				
	0	1	5	10	15
			Farinogram values		
H	480	450	395	345	295
W	1.10	1.15	1.00	0.85	0.60
H/W	436	391	395	406	492
			Extensogram values		
Fa	6.50	8.55	11.75	8.55	1.70
Fb	7.20	9.30	12.10	8.65	2.45
Faa	13.05	17.60*	19.80*#	18.45*	6.70
Fbb	14.55	18.10*	20.05*#	18.95*	7.15
E_1a	12.50	13.65	14.25	10.50	6.80
E_1b	11.15	13.65	13.70	9.80	5.70
E_1aa	6.25	7.10*	8.10*#	7.60*	5.50
E_1bb	6.35	7.15*	8.10*#	7.55*	5.55
Ea	15.60	17.30	19.05	15.65	10.40
Eb	13.80	16.70	18.80	15.15	10.40
Eaa	8.45	10.70	13.45#	12.10	12.95
Ebb	7.70	10.95	13.40#	13.30	10.05
E_ta	17.05	18.95	19.05	17.75	10.40
E_tb	15.85	16.70	19.30	16.65	10.40
E_taa	8.45	10.70	13.95#	12.10	12.95
E_tbb	7.70	10.95	14.15#	13.30	10.05
A_1a	54.21	75.20	114.56	58.05	8.32
A_1b	52.22	81.15	116.93	56.19	10.18
A_1aa	44.54	66.18*	127.49*#	85.89*	22.91
A_1bb	50.88	69.54*	127.87*#	88.19*	25.60
Aa	72.00	102.27	169.86	94.40	13.06
Ab	70.91	106.94	178.88	92.86	18.37
Aaa	64.90	110.72*	195.65*#	142.21*	45.89
Abb	65.98	114.03*	196.16*#	154.56*	48.70

Table 14. (cont.)

IX 30 mg bromate, nitrogen atmosphere

Curve characteristics	Percent sodium chloride				
	0	1	5	10	15
			Farinogram values		
H	455	405	375	335	290
W	1.10	0.95	1.00	0.75	0.60
H/W	414	426	375	447	483
			Extensogram values		
Fa	9.50	10.90	11.35	7.85	4.05
Fb	11.55	11.55	12.25	9.05	5.40
Faa	15.95	17.50#	19.50#	18.50#	13.90
Fbb	14.25	17.70#	19.55#	19.05#	14.40
E_1a	11.10	11.30	12.75	11.25	11.05
E_1b	10.15	10.15	11.20	11.35	11.10
E_1aa	5.30	5.85#	7.10#	6.60#	6.25
E_1bb	5.55	5.65#	7.35#	6.65#	6.35
Ea	13.15	13.75	18.70	17.20	16.95
Eb	12.15	12.20	16.50	16.15	16.90
Eaa	6.40	9.05	12.00	10.90	10.90
Ebb	7.00	7.70	13.25	11.75	11.10
E_ta	14.00	16.20	20.85	17.20	17.00
E_tb	13.05	12.20	17.30	16.15	16.90
E_taa	6.40	9.05	12.00	10.90	10.90
E_tbb	7.00	7.70	13.25	11.75	11.35

Table 14. (concl.)

Curve characteristics	Percent sodium chloride				
	0	1	5	10	15
A_1a	56.70	75.46	87.74	57.41	32.96
A_1b	61.57	70.08	87.42	65.15	41.54
A_1aa	43.14	57.66*	86.14*	77.38*	57.02
A bb	39.04	51.01*	87.62*	83.14*	58.24
Aa	74.18	99.65	146.82	89.34	52.35
Ab	81.22	88.06	144.83	101.31	69.18
Aaa	57.92	96.70*	156.54*	132.93*	95.36
Abb	55.17	82.88*	164.16*	153.02*	101.76

* Extrapolated value or dependent upon extrapolated value.

\# The dough giving this value was so tight (the cylinder of dough was so short in length) that it had to be stretched by hand in order that the dough holder prongs could engage and thus hold it while it was being stretched in the extensograph. This poor technique (but unavoidable because no provision in the dough holder design had been made to permit its adaptation for unusually tight doughs) accounts for the lower results; i.e., the dough was stretched a little, giving it a smaller diameter, thus needing less force to stretch it. Also this stretching by hand was not the same in each case which explains why the duplicates may vary more than with normal procedure.

3. Effect of Mixing Atmosphere. Farinogram heights of doughs mixed in oxygen were higher than those mixed in air, and those mixed in air were higher than those mixed in nitrogen. This relationship held for the different concentrations of NaCl alone, $KBrO_3$ alone, and combinations of sodium chloride and potassium bromate. No overall trend concerning farinogram

widths was found, since increase in NaCl was found to decrease the differences caused by mixing in different atmospheres, until with 15 percent salt there were no differences in farinogram width values of doughs mixed in different atmospheres. Generally, however, farinogram widths were greatest for doughs mixed in oxygen, smallest for those mixed in nitrogen, while those mixed in air were intermediate. The H/W value was found to increase with increasing oxygen in the mixing atmosphere.

4. Effect of Mixing Atmosphere and NaCl. Increasing concentrations of NaCl decreased the differences in farinogram heights caused by mixing in different atmospheres until 15 percent NaCl was used, then an increase began. The farinogram height difference in Brabender units of doughs mixed in O_2, air, and N_2 with increasing percent of salt was as follows: 0 percent: 65, 1 percent: 50, 5 percent: 30, 10 percent: 20, and 15 percent: 25. The differences between O_2 and air mixes were greater than the differences between air and N_2: O_2-air difference, 0 percent: 40, 1 percent: 40, 5 percent: 20, 10 percent: 0, 15 percent: 25; air-N_2 difference, 0 percent: 25, 1 percent: 10, 5 percent: 10, 10 percent: 20, and 15 percent: 0. It is a possibility that the increase in the O_2-air-15 percent NaCl difference was due to a synergestic effect between oxygen and salt. The same may be true of the air-N_2-10 percent NaCl difference, although it is more likely that this figure is anomolous.

Sodium chloride and oxygen were opposing forces where farinogram widths were concerned. Salt decreased the farinogram widths, while oxygen increased them. For the concentrations of salt and the purities of oxygen in the mixing atmospheres used in this study, the influence of NaCl was greater than the effect produced on the dough by the mixing atmosphere as expressed through farinogram widths. With salt concentrations up to 1 percent, the mixing atmosphere was equal to or stronger than salt in effect, but with concentrations above 1 percent, the salt effect completely overshadowed the mixing atmosphere effect.

The H/W relationship was also affected differently by salt and mixing atmosphere. Increase in oxygen alone increased the value, while with salt alone it reached a minimum with 5 percent and then increased again regardless of the mixing atmosphere. The combined effect of salt and mixing atmosphere on the H/W relationship was similar to that on farinogram widths in that the influence of salt was greater than that of mixing atmosphere.

5. Effect of Mixing Atmosphere and $KBrO_3$. Oxygen and $KBrO_3$ had opposing effects on farinogram heights, increased oxygen content of the mixing atmosphere increased farinogram heights while increasing amounts of $KBrO_3$ decreased them. The effect of bromate was completely masked when the dough was mixed under oxygen, but the concentrations of bromate used were not high enough to maks the effect produced by mixing in different atmospheres.

The differences between farinogram widths were not large enough to illustrate the combined effect of mixing atmosphere and potassium bromate.

The H/W relationship with different atmospheres was critical with 3 mg bromate.

6. Effect of NaCl and $KBrO_3$. The combined effect of salt and bromate is intimately connected with the mixing atmosphere when farinogram heights are concerned. In order to consider the combined effect of salt and bromate, the mixing atmosphere must either be eliminated or neutralized. Practically speaking, mixing atmosphere can never be eliminated. In this study, nitrogen atmosphere was the most neutral, and it was with these mixes that conclusions concerning the effect of salt and bromate on FH values were drawn. In a nitrogen atmosphere, there was a synergestic effect between salt and bromate on farinogram heights. Mixing in air and oxygen, obliterated this synergism.

The differences between farinogram widths were not large enough to illustrate any combined effect of salt and bromate.

The combined effect of salt and bromate on the H/W relationship of doughs mixed under nitrogen was to decrease the spread of H/W values in relation to the salt effect on them.

7. Effect of Mixing Atmosphere, NaCl, and $KBrO_3$. The resultants of the combined effect of these three variables are rather complex. Farinogram heights decreased until each successive force came into effect and increased them; thus for O_2 mix the increase came with zero per cent NaCl and 15 mg bromate, with air mix it came with 1 per cent NaCl and 15 mg bromate, and with N_2 mix it came with 10 per cent NaCl and 15 mg

bromate.

The overall picture was one of farinogram width decrease with increases in salt and bromate and approach to a neutral atmosphere.

H/W relationship is best comprehended by comparing 3-dimensional Figs. 1, 2, and 3. One of the salient features was a shift to the right in the direction of flow of the troughs formed by the lowest H/W values of the three atmospheres, O_2, air, and N_2.

Changes in Extensogram Values. Changes in farinogram values, for the sake of easier comprehension, are categorized according to the effect produced by the different variables, first singly and then in combination. For complete data, see Table 14.

1. Effect of NaCl. All extensogram values increased with an increase in NaCl until maximum values were reached after which further increase in NaCl caused reductions in extensogram values.

2. Effect of $KBrO_3$. Force values increased with increase in bromate. No completely overall statement concerning extensibility and area values could be made, but generally there was a decrease in extensibility values and increases in area values with increase in bromate.

3. Effect of Mixing Atmosphere. Force values of doughs mixed in oxygen were higher than those mixed in air, while those mixed in nitrogen were lowest. Extensibility values of doughs mixed in oxygen were smaller than those mixed in air and

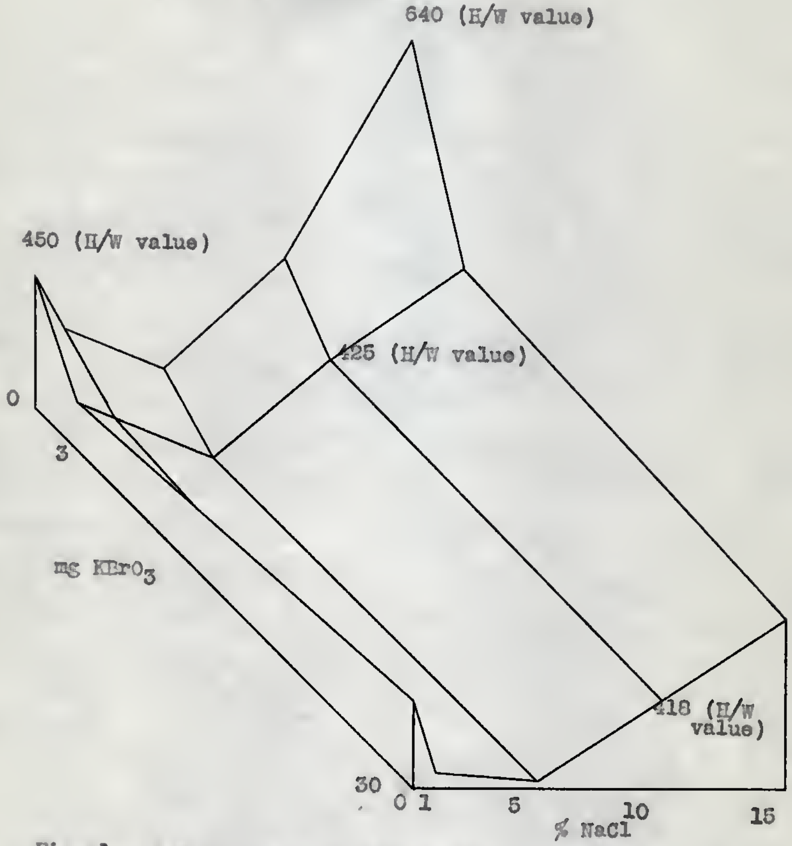

Fig. 1. The influence of sodium chloride and potassium bromate on the H/W relationship of doughs mixed under oxygen.

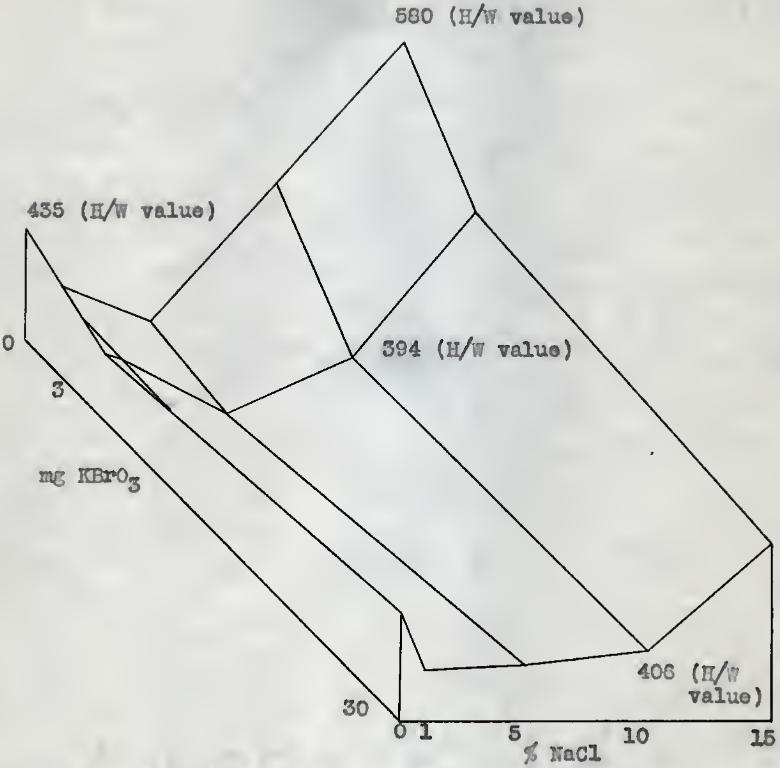

Fig. 2. The influence of sodium chloride and potassium bromate on the H/W relationship of doughs mixed under air.

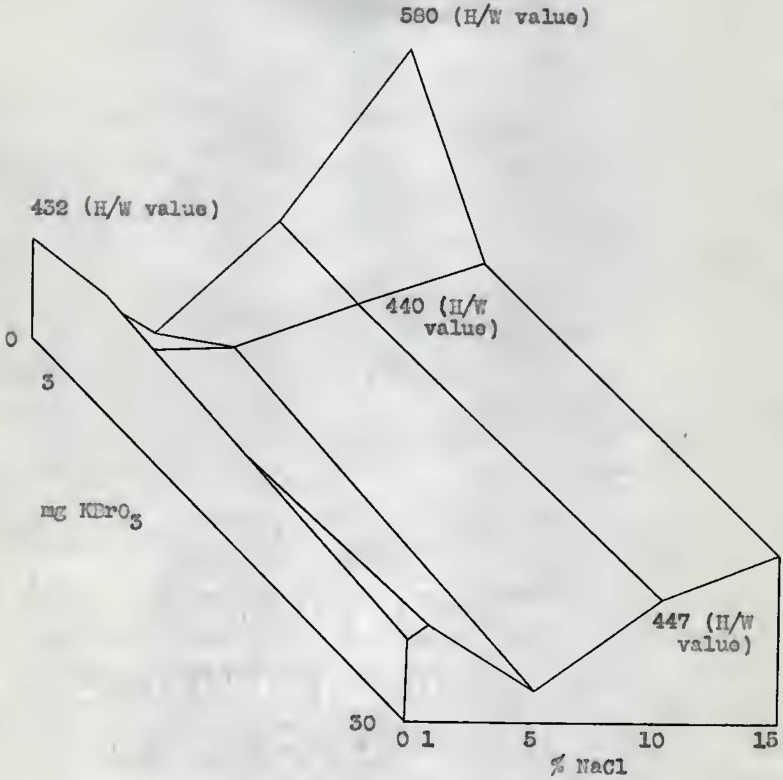

Fig. 3. The influence of sodium chloride and potassium bromate on the H/W relationship of doughs mixed under nitrogen.

nitrogen; generally air mixes were smaller than nitrogen mixes. Area values were largest for doughs mixed under oxygen and smallest when mixed under nitrogen with air mixes being intermediate.

4. Effect of Mixing Atmosphere and NaCl. Oxygen in the mixing atmosphere masked tremendously the effect of salt on F values; e.g., 10 percent NaCl increased F values approximately eight fold when mixed under nitrogen, three fold when mixed under air, while they were only doubled when mixed under oxygen. This effect also held true for area and extensibility values although the magnitude was not as large, being but faintly evident in the case of extensibility. Oxygen in the mixing atmosphere also lowered the percentage of salt needed to give maximum extensogram values; thus with oxygen mixes maximum extensogram F, A_1, and A values were obtained with only 5 percent NaCl, while with nitrogen mixes 10 percent NaCl was necessary, and with E_1, E and E_t maximum values were obtained with one percent NaCl when the mixing was done under oxygen while with nitrogen mixes 5 percent NaCl was necessary.

5. Effect of Mixing Atmosphere and $KBrO_3$. Oxygen in the mixing atmosphere masked to a great extent the effect of bromate on F values; e.g., 30 mg of bromate increased F values approximately 12 fold when mixed under nitrogen, three fold when mixed under air, while they were only doubled when mixed under oxygen. This effect also held true for area values although the magnitudes were not as great. With extensibility values, however,

increase in bromate decreased extensibility values, and doughs mixed under nitrogen showed a greater decrease in extensibility than did those mixed under air, and those mixed in air gave more of a decrease than did those mixed under oxygen. Oxygen in the mixing atmosphere also lowered the percentage of bromate needed to give maximum figures for F, A_1, and A values and it increased the percentage of bromate necessary to give maximums for E_1, E, and E_t values.

6. Effect of NaCl and $KBrO_3$. Force values increased with increased salt and bromate until the influence of excess salt which lowered F values was greater than increased bromate which increased F values, after which F values became smaller but not as small as zero percent salt-zero percent bromate force values, thus showing the continued dough stiffening effect of bromate even though it was masked by excess NaCl. Area values were influenced similarly by increased salt and bromate when mixing atmosphere had no deciding influence. No overall statement concerning extensibility values could be made without introducing the influence of mixing atmosphere.

7. Effect of Mixing Atmosphere, NaCl, and $KBrO_3$. With oxygen mixes, increased bromate resulted in increased F values when the concentrations of NaCl remained the same except with instances of excess NaCl; i.e., when NaCl no longer acted as a dough developer and increased F values as was the case with 15 percent salt, which resulted in lower F values. The same held true with air and nitrogen mixes with the exception that nitrogen

mix F values continued to increase as the bromate increased even with 15 percent NaCl. The magnitude of increase in F values was largest for dough mixed under nitrogen, smallest for those mixed under oxygen and intermediate for those mixed in air.

E_1 values generally decreased with increase in bromate when the concentrations of salt remained the same for oxygen and air mixes. For doughs mixed in nitrogen, E_1 values decreased with increase in bromate when the concentrations of salt remained the same with the exception of the set with 15 percent salt where increase in bromate caused an increase in E_1 values. The magnitude of decrease in E_1 values was greatest for doughs mixed under nitrogen, smallest for those mixed under oxygen and intermediate for those mixed in air.

No overall statement concerning E, E_t, A_1 and A values of oxygen mixes could be made without qualifications concerning sequence of duplicate doughs and stretch.

For air and nitrogen mixes with increase in bromate when the concentrations of salt remained the same, E and E_t values generally decreased, while A_1 and A values increased with 0, 1, and 5 percent salt and generally decreased with 10 and 15 percent NaCl. No overall statement concerning magnitudes of increase or decrease could be made without qualifications concerning sequence of duplicate doughs and stretch.

Extensogram Value Differences Between Dough Duplicates. The extensogram value differences between dough duplicates, as affected by NaCl, $KBrO_3$ and mixing atmosphere, and as shown in Table 15, are categorized according to the effect produced by the different variables, first singly and then in combination.

1. Effect of NaCl. Increased salt caused F value dough duplicates to differ increasingly from each other but characterizing this difference as being positive or negative was not possible without qualifying the mixing atmosphere. No overall statement concerning E_1, E, E_t, A_1 and A values could be made without qualifying the mixing atmosphere.

2. Effect of $KBrO_3$. Increased bromate caused F value dough duplicates to differ increasingly from each other but designating this difference as being positive or negative was not possible without qualifying the mixing atmosphere. No overall statement concerning E_1, E, E_t, A_1 and A values could be made without qualifying the mixing atmosphere.

3. Effect of Mixing Atmosphere. Increased oxygen in the mixing atmosphere caused F, A_1 and A value dough duplicate differences to become slightly more negatively pronounced. No trend concerning E_1, E and E_t values was discernible.

4. Effect of Mixing Atmosphere and NaCl. Increased oxygen and increased salt resulted in increased differences in F duplicates; e.g., N_2 mix-0 percent salt values were 0.00 and -0.10, air mix-5 percent salt values were -0.80 and -0.30 and O_2 mix-15 percent salt values were -1.25 and +1.35. There was a slight tendency for increased oxygen and increased salt to decrease differences in E_1, E and E_t values. For A_1 and A values, the largest duplicate differences for N_2 mixes were

Table 15. Extensogram value differences between duplicate doughs as affected by NaCl, $KBrO_3$ and mixing atmosphere.*

	Percent NaCl				
	0	1	5	10	15
			Zero mg bromate, O_2 atmosphere		
Fa - Fb	-0.20	-0.30	0.85	0.30	-1.25
Faa - Fbb	-0.50	0.30	-0.50	-2.05	1.35
$E_1a - E_1b$	-1.20	1.20	0.85	0.15	0.05
$E_1aa - E_1bb$	-1.05	0.20	0.75	1.25	0.05
Ea - Eb	-1.70	3.00	0.45	-0.10	-1.30
Eaa - Ebb	-1.40	-0.15	2.55	2.30	-0.85
$E_ta - E_tb$	-0.65	-0.15	0.45	-0.10	-1.30
$E_taa - E_tbb$	-1.40	-0.15	2.55	-0.10	-0.15
$A_1a - A_1b$	-5.76	2.75	18.82	2.24	-1.84
$A_1aa - A_1bb$	-11.96	0.00	-9.53	-1.09	5.89
Aa - Ab	-6.02	13.19	18.96	2.76	-11.03
Aaa - Abb	-15.04	-30.71	14.59	3.33	1.47
			3 mg bromate, O_2 atmosphere		
Fa - Fb	-0.55	-0.70	-1.70	-1.55	-0.70
Faa - Fbb	0.70	-0.70	0.15	0.25	1.10
$E_1a - E_1b$	0.15	-0.40	-1.30	0.00	-0.75
$E_1aa - E_1bb$	-0.30	0.90	-0.35	0.45	0.35
Ea - Eb	0.25	0.70	-0.15	-0.80	1.40
Eaa - Ebb	-1.40	-0.20	-2.85	-0.20	-0.10
$E_ta - E_tb$	-3.25	0.05	-0.15	1.40	1.40
$E_taa - E_tbb$	-1.40	-0.20	-2.85	-0.20	-0.10
$A_1a - A_1b$	-4.80	-10.05	-19.26	-10.11	-4.29
$A_1aa - A_1bb$	0.77	2.56	-5.18	7.17	5.18
Aa - Ab	0.64	-12.61	-23.17	-20.10	-2.11
Aaa - Abb	-7.43	-3.99	-39.13	4.60	8.32
			30 mg bromate, O_2 atmosphere		
Fa - Fb	-1.80	-0.90	-0.30	-0.25	-0.25
Faa - Fbb	-1.15	-0.35	-0.15	-0.80	-0.35
$E_1a - E_1b$	0.65	0.30	-0.05	0.10	-0.10
$E_1aa - E_1bb$	-0.75	-0.15	-0.20	-0.50	-0.45
Ea - Eb	1.05	2.40	0.10	0.60	2.50
Eaa - Ebb	0.05	-0.05	0.15	1.75	0.15
$E_ta - E_tb$	5.00	-0.75	0.10	-1.10	-0.25
$E_taa - E_tbb$	0.05	-0.05	0.65	0.10	0.05
$A_1a - A_1b$	-8.07	0.07	2.76	-0.38	2.24
$A_1aa - A_1bb$	-11.40	-6.08	-0.55	-9.02	-2.87
Aa - Ab	-9.28	13.51	-1.28	4.93	1.35
Aaa - Abb	-7.94	-10.30	-2.12	6.43	-2.37

Table 15. (cont.)*

	Percent NaCl				
	0	1	5	10	15
	Zero mg bromate, air atmosphere				
Fa - Fb	-0.05	-0.25	-0.80	-0.65	-0.05
Faa - Fbb	0.15	-0.55	-0.30	-0.35	1.60
E_1a - E_1b	0.85	0.10	0.25	0.15	1.00
E_1aa - E_1bb	-0.60	-3.20	-0.65	-0.60	1.15
Ea - Eb	1.05	2.60	2.55	0.75	0.40
Eaa - Ebb	0.55	-1.55	-0.15	-0.90	2.05
E_ta - E_tb	-0.10	-0.15	0.05	-0.25	0.40
$E_t$aa - $E_t$bb	-0.25	-0.50	-0.45	-1.35	-1.80
A_1a - A_1b	0.90	-3.91	-8.84	-1.43	-2.76
A_1aa - A_1bb	2.24	-17.85	-4.44	-6.14	14.15
Aa - Ab	2.12	3.14	-2.94	-2.85	1.66
Aaa - Abb	0.20	-10.30	-3.61	-11.65	25.72
	3 mg bromate, air atmosphere				
Fa - Fb	-0.10	-0.25	-0.50	-0.60	-1.20
Faa - Fbb	0.75	0.25	-0.05	-0.10	0.15
E_1a - E_1b	1.90	-2.00	1.10	1.05	1.60
E_1aa - E_1bb	0.30	1.25	1.00	0.45	0.70
Ea - Eb	2.90	-2.05	2.75	2.75	2.20
Eaa - Ebb	0.40	1.95	-1.40	-0.15	0.20
E_ta - E_tb	-1.90	0.05	0.30	0.25	2.20
$E_t$aa - $E_t$bb	-2.90	0.70	-1.40	0.15	1.00
A_1a - A_1b	3.97	-8.20	-0.51	-0.23	-3.52
A_1aa - A_1bb	8.96	10.17	5.31	2.22	1.73
Aa - Ab	5.51	-8.96	9.15	6.46	-6.79
Aaa - Abb	9.67	15.30	-17.09	-2.28	3.33
	30 mg bromate, air atmosphere				
Fa - Fb	-0.70	-0.75	-0.35	-0.10	-0.75
Faa - Fbb	-1.50	-0.50	-0.25	-0.50	-0.45
E_1a - E_1b	1.35	0.00	0.55	0.70	1.10
E_1aa - E_1bb	-0.10	-0.05	0.00	0.05	-0.05
Ea - Eb	1.80	0.60	0.25	0.50	0.00
Eaa - Ebb	0.75	-0.25	0.05	-1.20	2.90
E_ta - E_tb	1.20	2.25	-0.25	1.10	0.00
$E_t$aa - $E_t$bb	0.75	-0.25	-0.20	-1.20	2.90
A_1a - A_1b	1.99	-5.95	-2.37	1.86	-1.86
A_1aa - A_1bb	-6.34	-3.36	-0.38	-2.30	-2.69
Aa - Ab	1.09	-4.67	-9.02	1.54	-5.31
Aaa - Abb	-1.08	-3.31	-0.51	-12.35	-2.81

Table 15. (concl.)*

	Percent NaCl				
	0	1	5	10	15
	Zero mg bromate, N_2 atmosphere				
Fa - Fb	0.00	-0.05	-0.05	-0.15	-1.10
Faa - Fbb	-0.10	-0.05	-0.50	-0.85	-1.10
E_1a - E_1b	-3.50	0.20	0.15	-1.90	-0.85
E_1aa - E_1bb	-0.15	1.25	-0.10	2.00	0.05
Ea - Eb	-4.90	-0.60	-0.05	-0.10	0.55
Eaa - Ebb	-0.95	-1.00	0.05	0.45	-0.20
E_ta - E_tb	-2.75	1.15	0.20	-0.10	-1.90
$E_t$aa - $E_t$bb	0.20	-0.55	0.05	-1.45	2.50
A_1a - A_1b	-4.10	-0.45	0.32	-12.48	-8.06
A_1aa - A_1bb	-0.89	3.62	-4.48	-0.06	-7.94
Aa - Ab	-6.97	-2.05	-0.71	-3.90	-10.18
Aaa - Abb	-2.37	-1.34	-7.55	-15.43	-13.69
	3 mg bromate, N_2 atmosphere				
Fa - Fb	0.00	-0.05	0.05	-0.95	-1.05
Faa - Fbb	-0.15	-0.40	-1.20	0.30	-1.25
E_1a - E_1b	0.40	-0.65	2.00	-0.05	1.95
E_1aa - E_1bb	-1.70	0.15	-0.45	-0.50	0.05
Ea - Eb	0.15	1.45	-0.10	-2.20	3.90
Eaa - Ebb	-1.75	0.60	-0.25	-0.80	-1.30
E_ta - E_tb	2.15	-2.35	-0.10	0.80	2.50
$E_t$aa - $E_t$bb	-4.15	-2.05	-0.25	-0.80	0.75
A_1a - A_1b	-0.25	-0.45	5.39	-11.01	-2.43
A_1aa - A_1bb	-2.50	-2.78	-19.65	-1.53	-12.92
Aa - Ab	-1.54	5.12	-6.85	-26.37	-3.46
Aaa - Abb	-4.80	-3.08	-27.27	-1.48	-32.71
	30 mg bromate, N_2 atmosphere				
Fa - Fb	-2.05	-0.65	-0.90	-1.20	-1.35
Faa - Fbb	1.70	-0.20	-0.05	-0.55	-0.50
E_1a - E_1b	0.95	1.15	1.55	-0.10	-0.05
E_1aa - E_1bb	-0.25	0.20	-0.25	-0.05	-0.10
Ea - Eb	1.00	1.55	2.20	1.05	0.05
Eaa - Ebb	-0.60	1.35	-1.25	-0.85	-0.20
E_ta - E_tb	0.95	4.00	3.55	1.05	0.10
$E_t$aa - $E_t$bb	-0.60	1.35	-1.25	-0.85	-0.45
A_1a - A_1b	-4.87	5.38	0.32	-7.74	-8.58
A_1aa - A_1bb	4.10	6.65	-1.48	-5.76	-1.22
Aa - Ab	-7.04	11.59	1.99	-11.97	-16.83
Aaa - Abb	2.75	13.82	-7.62	-20.09	-6.40

* Data derived from Table 14.

the values with 15 percent salt, for air mixes there was no clear cut indication, and for O_2 mixes greatest differences occurred for values with 5 percent salt. As oxygen in the mix increased, there was a distinct tendency for duplicate differences of all values with the exceptions of E and E_t values to be positive rather than negative; i.e., for first duplicate values to be larger than second duplicate values regardless of salt concentration.

5. Effect of Mixing Atmosphere and $KBrO_3$. Although increased oxygen and increased bromate resulted in increased differences between F value duplicates, the combined effect, although larger than the oxygen effect, was not as large as the bromate effect. There was a tendency for first stretch duplicate E_1 values to be positive (E_1a values larger than E_1b values) and second stretch duplicate E_1 values to be negative (E_1bb values larger than E_1aa values); also this tendency became greater with increased bromate regardless of mixing atmosphere. The difference between duplicates of first stretch E_1 values was always larger than the difference between duplicates of second stretch E_1 values regardless of bromate and oxygen concentration. The combined effect of increased bromate and oxygen on E values was to reduce differences between duplicates, tending to make first duplicate values larger than second duplicate values. No tendency regarding E_t values was discernible. There was a tendency for A_1 and A values whose dough had 3 mg bromate to be less negatively or more positively pronounced than those of 0 mg

or 30 mg bromate mixes regardless of oxygen concentration.

6. Effect of NaCl and $KBrO_3$. Although, singly, increased bromate caused F value dough duplicates to increasingly differ from each other, the combined effect resulted in somewhat reduced differences even regardless of mixing atmosphere when compared with values produced by doughs containing high bromate or high salt content. There was also a definite tendency for combined salt and bromate to render second duplicate F values larger than first duplicate values. Combined salt and bromate reduced the differences between first stretch duplicate E_1 values and between second stretch duplicate E_1 values. There was a tendency for combined increased salt and bromate to decrease differences between E values of duplicates, but this was greatly influenced by oxygen content. The combined effect of salt and bromate reduced the differences between E_t values of duplicates. No overall statement concerning A_1 and A values could be made without qualifying the mixing atmosphere.

7. Effect of Mixing Atmosphere, NaCl and $KBrO_3$. Although, singly, increased NaCl, $KBrO_3$ and oxygen caused F value dough duplicate differences to increase, the combined effect was much less pronounced. The combined effect of oxygen, salt and bromate reduced duplicate difference E_1, E and E_t values. There was a tendency for A_1 and A value differences between duplicates to decrease with increased bromate, salt and oxygen; also increased oxygen tended to make this difference a positive rather than a negative value; i.e., for first duplicate values

to be larger than second duplicate values.

Extensogram Value Differences Between Dough Stretches. The extensogram value differences between dough stretches as affected by NaCl, $KBrO_3$, and mixing atmosphere, as shown in Table 16, are categorized according to the effect produced by the different variables, first singly and then in combination.

1. Effect of NaCl. Increased salt caused F value dough stretch differences to become more negatively pronounced; i.e., second stretch F values became progressively larger than first stretch F values. E_1, E, and E_t stretch difference values became more positively pronounced with increased salt until maximums were reached after which increased salt resulted in less positively pronounced or even increased negatively pronounced values. A_1 and A values became tremendously more negatively pronounced.

2. Effect of $KBrO_3$. Increased bromate resulted in F stretch difference values becoming more negatively pronounced, E_1, E, and E_t values becoming more positively pronounced. Although mixing atmosphere greatly influenced A_1 and A stretch difference values, generally increased bromate produced difference values more positively pronounced when mixing atmosphere was disregarded.

3. Effect of Mixing Atmosphere. Increased oxygen in the mixing atmosphere caused F value dough stretch differences to become more negatively pronounced and E_1, E, and E_t values to become more positively pronounced. A_1 and A values dramatically

Table 16. Extensogram value differences between dough stretches as affected by NaCl, $KBrO_3$ and mixing atmosphere.*

Extensogram character-istic	Percent NaCl				
	0	1	5	10	15
			Zero mg bromate, O_2 atmosphere		
Fa - Faa	-4.10	-5.25	-6.35	-5.75	-6.30
Fb - Fbb	-4.40	-4.65	-7.70	-8.10	-3.70
$E_1a - E_1aa$	2.60	6.45	5.50	1.65	0.00
$E_1b - E_1bb$	2.75	5.45	5.40	2.75	0.00
Ea - Eaa	2.50	8.00	4.80	1.40	-0.80
Eb - Ebb	2.80	4.85	6.90	3.80	-0.35
$E_ta - E_taa$	3.55	8.00	4.80	0.15	-1.50
$E_tb - E_tbb$	2.80	8.00	6.90	0.15	-0.35
$A_1a - A_1aa$	-23.74	-5.12	11.07	-18.63	-22.66
$A_1b - A_1bb$	-29.94	-7.87	-17.28	-21.96	-14.93
Aa - Aaa	-32.00	-7.93	-16.45	-35.52	-38.36
Ab - Abb	-41.02	-51.83	-20.82	-34.95	-25.86
			3 mg bromate, O_2 atmosphere		
Fa - Faa	-5.35	-6.50	-7.70	-9.80	-6.00
Fb - Fbb	-4.10	-6.50	-5.85	-8.00	-4.20
$E_1a - E_1aa$	-4.90	5.55	2.80	1.65	-0.45
$E_1b - E_1bb$	4.45	6.85	3.75	2.10	0.65
Ea - Eaa	5.60	8.80	7.35	2.10	1.75
Eb - Ebb	3.95	7.90	4.65	2.70	0.25
$E_ta - E_taa$	5.60	10.00	7.35	4.30	1.75
$E_tb - E_tbb$	7.45	9.75	4.65	2.70	0.25
$A_1a - A_1aa$	-15.23	-12.67	-23.36	-34.75	-20.61
$A_1b - A_1bb$	-9.66	-0.06	-9.28	-17.47	-11.14
Aa - Aaa	-23.49	-8.17	4.06	-61.12	-33.47
Ab - Abb	-31.56	0.45	-11.90	-36.42	-23.04
			30 mg bromate, O_2 atmosphere		
Fa - Faa	-7.45	-8.35	-7.60	-6.10	-3.55
Fb - Fbb	-6.80	-7.80	-7.45	-6.65	-3.65
$E_1a - E_1aa$	4.80	3.35	4.00	1.60	1.00
$E_1b - E_1bb$	3.40	2.90	3.85	1.00	0.65
Ea - Eaa	5.75	4.40	6.00	1.60	3.10
Eb - Ebb	4.75	1.95	6.05	2.75	0.75
$E_ta - E_taa$	9.70	4.40	5.50	1.60	3.10
$E_tb - E_tbb$	4.75	5.10	6.05	2.80	3.40
$A_1a - A_1aa$	-1.15	-30.27	10.99	-12.42	-6.97
$A_1b - A_1bb$	-4.48	-36.42	7.68	-21.06	-12.03
Aa - Aaa	-2.56	-42.56	-23.04	-21.89	-12.67
Ab - Abb	-1.22	-66.37	-24.26	-20.39	-16.39

Table 16. (cont.)*

Extensogram characteristic	Percent NaCl				
	0	1	5	10	15
			Zero mg bromate, air atmosphere		
Fa - Faa	-0.35	-0.30	-3.85	-5.30	-6.50
Fb - Fbb	-0.15	-0.60	-3.35	-5.00	-4.85
$E_1a - E_1aa$	-0.10	2.70	4.80	3.20	-1.50
$E_1b - E_1bb$	-1.55	-0.60	3.90	2.45	-1.35
Ea - Eaa	-0.10	4.70	5.70	4.10	-1.40
Eb - Ebb	-0.60	0.55	3.00	2.45	0.25
$E_ta - E_taa$	1.00	1.15	5.70	3.60	-1.40
$E_tb - E_tbb$	0.85	0.80	5.20	2.50	-3.60
$A_1a - A_1aa$	-3.46	3.13	-22.79	-22.69	-36.67
$A_1b - A_1bb$	-2.12	-10.81	-18.39	-27.40	-25.28
Aa - Aaa	-4.42	7.94	-44.98	-38.76	-60.35
Ab - Abb	-6.34	-5.50	-45.65	-47.56	-36.29
			3 mg bromate, air atmosphere		
Fa - Faa	-1.80	-1.95	-4.45	-8.10	-8.35
Fb - Fbb	-0.95	-1.45	-4.00	-7.60	-7.00
$E_1a - E_1aa$	0.40	0.15	5.20	3.70	0.55
$E_1b - E_1bb$	-1.20	3.40	5.10	3.10	-0.35
Ea - Eaa	1.05	-0.70	6.75	5.15	3.00
Eb - Ebb	-1.45	3.30	2.60	2.25	1.00
$E_ta - E_taa$	1.05	4.45	7.50	5.80	1.95
$E_tb - E_tbb$	0.05	5.10	5.80	5.70	0.75
$A_1a - A_1aa$	-16.38	-22.72	-10.24	-25.87	-38.34
$A_1b - A_1bb$	-11.39	-4.35	-4.42	-23.42	-33.09
Aa - Aaa	-20.29	-33.67	-17.09	-51.67	-61.12
Ab - Abb	-16.13	-9.41	-43.33	-60.41	-51.00
			30 mg bromate, air atmosphere		
Fa - Faa	-6.55	-9.05	-8.05	-9.90	-5.00
Fb - Fbb	-7.35	-8.80	-7.95	-10.30	-4.70
$E_1a - E_1aa$	6.25	6.55	6.15	2.90	1.30
$E_1b - E_1bb$	4.80	6.50	5.60	2.25	0.15
Ea - Eaa	7.15	6.60	5.60	3.55	-2.55
Eb - Ebb	6.10	5.75	5.40	1.85	0.35
$E_ta - E_taa$	8.60	8.25	5.10	5.65	-2.55
$E_tb - E_tbb$	8.15	5.75	5.15	3.35	0.35
$A_1a - A_1aa$	9.67	9.02	-12.93	-27.84	-14.59
$A_1b - A_1bb$	1.34	11.61	-10.94	-32.00	-15.42
Aa - Aaa	7.10	-8.45	-25.79	-47.31	-32.83
Ab - Abb	4.93	-7.09	-17.28	-61.70	-30.33

Table 16. (concl.)*

Extensogram characteristic	Percent NaCl				
	0	1	5	10	15
			Zero mg bromate, N atmosphere		
Fa - Faa	0.20	0.00	-3.55	-3.45	-6.15
Fb - Fbb	0.10	0.00	-4.00	-4.15	-6.15
$E_1a - E_1aa$	-2.40	0.10	3.25	0.95	-3.50
$E_1b - E_1bb$	0.95	1.15	3.00	4.85	-2.60
Ea - Eaa	-1.55	-0.45	2.50	4.60	-3.90
Eb - Ebb	2.40	-0.85	2.60	5.15	-4.65
$E_ta - E_taa$	-0.50	1.55	2.75	1.35	-8.60
$E_tb - E_tbb$	2.45	-0.15	2.60	0.00	-4.20
$A_1a - A_1aa$	-1.03	-0.87	-31.42	-37.06	-54.65
$A_1b - A_1bb$	2.18	3.20	-36.22	-24.64	-54.53
Aa - Aaa	0.84	-2.82	-51.46	-33.98	-36.79
Ab - Abb	5.45	-2.11	-58.30	-45.51	-90.30
			3 mg bromate, N_2 atmosphere		
Fa - Faa	-0.70	-0.65	-2.90	-7.15	-7.20
Fb - Fbb	-0.85	-1.00	-4.15	-5.90	-7.40
$E_1a - E_1aa$	-0.40	2.55	5.50	4.95	-1.00
$E_1b - E_1bb$	-2.50	3.35	3.05	4.50	-2.90
Ea - Eaa	-0.35	4.70	4.85	4.65	0.70
Eb - Ebb	-2.25	3.85	4.70	6.05	-4.50
$E_ta - E_taa$	1.95	1.20	4.85	7.65	-1.35
$E_tb - E_tbb$	-4.35	1.50	4.70	6.05	-3.10
$A_1a - A_1aa$	-8.74	-3.20	-14.08	-44.74	-52.16
$A_1b - A_1bb$	-11.01	-5.53	-39.62	-35.26	-62.65
Aa - Aaa	-12.29	0.45	-36.86	-80.96	-84.86
Ab - Abb	-15.55	-7.75	-57.28	-56.07	-114.11
			30 mg bromate, N_2 atmosphere		
Fa - Faa	-6.45	-6.60	-8.15	-10.65	-9.85
Fb - Fbb	-2.70	-6.15	-7.30	-10.00	-9.00
$E_1a - E_1aa$	5.80	5.45	5.65	4.65	4.80
$E_1b - E_1bb$	4.60	4.50	3.85	4.70	4.75
Ea - Eaa	6.75	4.70	6.70	6.30	6.05
Eb - Ebb	5.15	4.50	3.25	4.40	5.80
$E_ta - E_taa$	7.60	7.15	8.85	8.30	6.10
$E_tb - E_tbb$	6.05	4.50	4.05	4.40	5.55
$A_1a - A_1aa$	13.56	17.80	1.60	-19.97	-24.06
$A_1b - A_1bb$	22.53	19.07	-0.20	-17.99	-16.70
Aa - Aaa	16.26	2.95	-9.72	-43.59	-43.01
Ab - Abb	26.05	5.18	-19.33	-51.71	-32.58

* Data derived from Table 14.

increased negatively, the increase being over thirtyfold.

4. Effect of Mixing Atmosphere and NaCl. Increased oxygen and increased salt resulted in F stretch difference values becoming more negatively pronounced; E_1, E, and E_t stretch difference values became more positively pronounced until maximum values were reached with oxygen mixed-one percent salt dough after which increased salt resulted in less positively pronounced or even increased negatively pronounced values. A_1 and A values from a nitrogen to an oxygen atmosphere without salt became over thirtyfold more negatively pronounced and from zero percent salt to fifteen percent salt with a nitrogen atmosphere became fiftyfold more negatively pronounced; yet a 15 percent salt-oxygen atmosphere mix gave A_1 and A values less than thirtyfold more negatively pronounced than a zero percent salt-nitrogen atmosphere mix.

5. Effect of Mixing Atmosphere and $KBrO_3$. Increased oxygen and increased bromate combined resulted in F stretch difference values becoming more negatively pronounced (-7.23) than when oxygen (-4.25) and $KBrO_3$ (-4.58) were used separately. E_1, E, and E_t stretch difference values became more positively pronounced until maximum values were reached with air mixed-30 mg bromate dough after which increased oxygen resulted in slightly less positively pronounced stretch difference E_1, E, and E_t values. With the exceptions of 3 mg bromate-air and 3 mg bromate-nitrogen mixes, increased oxygen and increased bromate were opposing forces where A_1 and A stretch difference values

were concerned, increased oxygen making the difference more negatively pronounced and increased bromate making the difference more positively pronounced. These opposing forces nullified each other when used in conjunction with each other, as evidenced by the following mean A_1, A results: nitrogen atmosphere-no bromate, 1.86; oxygen atmosphere-no bromate, -41.68; nitrogen atmosphere-30 mg bromate, 19.60; and oxygen atmosphere-30 mg bromate, -2.35. With 3 mg bromate-nitrogen atmosphere there was a striking negative pronouncement which becomes less with 3 mg bromate-air mix, and which disappeared with 3 mg bromate-oxygen mix, A_1, A stretch difference values.

6. Effect of NaCl and $KBrO_3$. Increased salt and increased bromate combined resulted in F stretch difference values becoming more negatively pronounced (-9.43) than when NaCl (-6.15) and $KBrO_3$ (-4.57) were used separately; however, this occurred only with a nitrogen mixing atmosphere; i.e., in the absence of the variable, oxygen. No overall statement concerning the combined effect of salt and bromate on E_1, E, and E_t values could be made without including a qualification brought about by the mixing atmosphere; however, in a nitrogen atmosphere, the effect produced by bromate was stronger than the salt effect as witnessed by the values produced by the combined effect. Although mixing atmosphere greatly influenced A_1 and A stretch difference values, when it was disregarded, combined effect of salt and bromate, which, singularly, had opposing effects, revealed that the salt effect was stronger than the

bromate effect as witnessed by the values produced by the combined effect.

7. Effect of Mixing Atmosphere, NaCl, and $KBrO_3$. All second stretch F values, with the single exception of no salt-no bromate-nitrogen mixed dough, were larger than first stretch F values; i.e., were negatively pronounced. Although singly the actions of increased NaCl, increased $KBrO_3$, and increased oxygen were increasingly negatively pronounced, in combination they were decreasingly negatively pronounced for 15 percent salt-30 mg bromate-mixed in oxygen dough. With nitrogen mix the maximum negative pronouncement was with the 30 mg bromate-10 percent salt combination (-10.33), with air mix it was not as evident (-10.10), and with oxygen mix the maximum negative pronouncements were with the 3 mg bromate-10 percent salt (-8.90) and the 30 mg bromate-1 percent salt (-8.08) combinations while the oxygen mix-30 mg bromate-15 percent salt combination had a mean value of only -3.60.

Although singly the actions of increased salt, increased bromate and increased oxygen produced increasingly positively pronounced E_1, E, and E_t values, the combined effect was positively oriented but not cumulative. The most positively pronounced E_1, E, and E_t stretch difference values were with 1 percent salt-3 mg bromate-O_2 atmosphere mixes, while the most negatively pronounced values were with 15 percent salt-0 mg bromate-N_2 atmosphere mixes, and the smallest values were with 1 percent salt-0 mg bromate-N_2 atmosphere mixes and 15 percent salt-0 mg bromate-O_2 atmosphere mixes.

The combined effect of increased salt, bromate and oxygen resulted in stretch difference A_1 and A values becoming less negatively pronounced until minimum values were reached after which continued increases in salt, bromate and oxygen resulted in A_1 and A values becoming more negatively pronounced. The most negatively pronounced A_1 and A stretch difference values were with 15 percent salt-3 mg bromate-N_2 atmosphere mixes, the most positively pronounced values were with 0 percent salt-30 mg bromate-N_2 atmosphere mixes, and the smallest stretch difference values were with 1 percent salt-0 mg bromate-N_2 atmosphere mixes.

F/E Values and Oxynumbers. The F/E values and oxynumbers of doughs as affected by potassium bromate, sodium chloride and mixing atmosphere, and as shown in Table 17, are categorized according to the effect produced by the different variables, first singly and then in combination.

1. Effect of NaCl. Although increased salt increased F/E values, the extent and the intensity of this increase was dependent upon the mixing atmosphere; in the absence of oxygen (N_2 atmosphere) F/E values continued to increase with continued increase in NaCl while with air and O_2 mixing atmospheres, F/E values increased with increased salt until maximum F/E values were reached after which F/E values decreased with continued increase in NaCl. Oxynumbers increased with increased salt until maximums were obtained after which oxynumbers decreased

with continued increase in salt.

2. Effect of $KBrO_3$. Although increased bromate increased F/E values, the extent and the intensity of this increase was dependent upon the mixing atmosphere. In the absence of oxygen (N_2 atmosphere), F/E values continued to dramatically increase with continued increase in $KBrO_3$; e.g., first duplicate-second stretch (aa)-0 mg bromate mix value: 0.060, first duplicate-second stretch (aa)-3 mg bromate mix value: 0.140, and first duplicate-second stretch-30 mg bromate mix value: 2.492. No overall statement concerning oxynumbers could be made without qualifying the mixing atmosphere although generally increased bromate decreased oxynumbers.

3. Effect of Mixing Atmosphere. Increased oxygen in the mixing atmosphere increased F/E values and decreased oxynumbers. Second stretch F/E values were larger than first stretch values while second stretch oxynumbers were smaller than first stretch oxynumbers. Second stretch F/E values were increased more by increased oxygen than were first stretch values, while second stretch oxynumbers were decreased less than were first stretch oxynumbers.

4. Effect of Mixing Atmosphere and NaCl. When increased singly, salt and oxygen increased F/E values and the combined effect was even greater; e.g., for first duplicate-first stretch values, the 0 percent NaCl-N_2 atmosphere value was 0.057, the 0 percent salt-O_2 atmosphere value was 0.245, the 15 percent salt-N_2 atmosphere value was 0.235 and the 15 percent salt-O_2

Table 17. F/E values and oxynumbers of doughs as affected by potassium bromate, sodium chloride, and mixing atmosphere.*

Per-	F/E values				Oxynumbers			
cent	Duplicates & stretch sequence				Duplicates & stretch sequence			
NaCl	a	b	aa	bb	a	b	aa	bb
Zero mg bromate, O_2 atmosphere								
0	0.245	0.247	0.558	0.541	2.18	2.33	1.53	1.86
1	0.337	0.401	0.851	0.824	3.70	2.78	1.56	1.98
5	0.566	0.537	1.119	1.361	3.23	3.05	1.78	1.36
10	0.719	0.692	1.268	1.765	1.27	1.28	0.99	0.70
15	0.369	0.439	0.938	0.750	0.66	0.81	0.67	0.82
Zero mg bromate, air atmosphere								
0	0.156	0.160	0.165	0.162	2.84	2.82	3.14	3.18
1	0.141	0.167	0.186	0.198	4.92	3.97	3.30	3.62
5	0.219	0.269	0.433	0.443	6.12	5.09	4.13	4.12
10	0.351	0.399	0.785	0.763	2.86	2.58	1.77	1.98
15	0.248	0.260	0.684	0.668	1.30	1.17	1.35	1.00
Zero mg bromate, N_2 atmosphere								
0	0.057	0.060	0.060	0.062	5.23	4.48	3.17	3.44
1	0.100	0.099	0.098	0.096	4.56	4.78	4.94	5.17
5	0.192	0.194	0.356	0.378	5.54	5.52	4.43	4.37
10	0.227	0.232	0.432	0.480	5.17	5.22	3.50	3.47
15	0.235	0.149	0.454	0.508	1.67	1.49	2.46	2.47
3 mg bromate, O_2 atmosphere								
0	0.216	0.247	0.696	0.585	2.85	2.46	1.22	1.58
1	0.342	0.385	1.048	1.084	3.29	3.25	1.15	1.15
5	0.618	0.703	1.696	1.345	2.44	2.48	0.87	1.38
10	0.635	0.707	1.595	1.547	1.26	1.42	0.89	0.88
15	0.248	0.346	0.870	0.756	1.02	0.79	0.68	0.67
3 mg bromate, air atmosphere								
0	0.153	0.183	0.253	0.219	3.25	2.42	2.77	2.76
1	0.215	0.207	0.293	0.309	3.66	4.24	3.84	3.14
5	0.318	0.377	0.659	0.617	4.94	3.92	2.64	3.10
10	0.351	0.439	0.997	0.994	3.10	2.33	1.61	1.64
15	0.128	0.236	0.800	0.801	1.80	1.26	1.05	1.01

Table 17. (concl.)*

Per-	F/E values				Oxynumbers			
cent	Duplicates & stretch sequence				Duplicates & stretch sequence			
NaCl	a	b	aa	bb	a	b	aa	bb
	3 mg bromate, N_2 atmosphere							
0	0.106	0.107	0.140	0.136	2.93	3.05	3.10	3.54
1	0.127	0.136	0.185	0.210	5.18	4.46	3.53	3.26
5	0.235	0.233	0.401	0.445	5.99	6.33	4.43	4.60
10	0.248	0.264	0.666	0.626	4.43	5.16	2.87	3.07
15	0.156	0.280	0.596	0.623	2.22	1.36	2.00	2.44
	30 mg bromate, O_2 atmosphere							
0	0.434	0.608	1.633	1.782	1.07	0.89	0.29	0.33
1	0.586	0.749	1.485	1.508	1.34	1.05	0.73	0.76
5	0.712	0.732	1.657	1.689	1.60	1.52	0.62	0.61
10	0.833	0.891	1.460	1.792	0.67	0.63	0.50	0.43
15	0.212	0.296	0.695	0.749	0.50	0.28	0.25	0.27
	30 mg bromate, air atmosphere							
0	0.417	0.522	1.544	1.890	1.72	1.36	0.42	0.35
1	0.494	0.557	1.645	1.653	2.07	1.92	0.67	0.69
5	0.617	0.644	1.472	1.496	2.75	2.78	1.32	1.31
10	0.546	0.571	1.525	1.425	1.73	1.63	0.93	1.09
15	0.163	0.236	0.517	0.711	0.80	0.78	0.89	0.68
	30 mg bromate, N_2 atmosphere							
0	0.722	0.951	2.492	2.036	1.03	0.85	0.23	0.27
1	0.793	0.947	1.934	2.299	1.26	0.93	0.50	0.36
5	0.607	0.742	1.625	1.475	2.41	1.95	0.96	1.11
10	0.456	0.560	1.697	1.621	1.96	1.80	0.78	0.94
15	0.239	0.320	1.275	1.297	2.19	2.16	0.75	0.78

* Data derived from Table 14.

atmosphere value was 0.369. Maximum values for all duplicates and stretches, however, were obtained from 10 percent salt-O_2 atmosphere mixes, showing that with 15 percent salt-O_2 atmosphere an actual excess for maximum F/E values had been attained. For N_2 mix values, this excess was not actually reached with 15 percent salt but it was rapidly being approached as exemplified by the lessening amount of increase with increase in salt of first duplicate-first stretch mixes: 0-1 percent NaCl, +0.043; 1-5 percent salt, +0.092; 5-10 percent salt, +0.035; 10-15 percent salt, +0.008. Regardless of mixing atmosphere and salt concentration, second stretch F/E values were larger than first stretch values. This difference was greatest (a-aa: -0.549 and b-bb: -1.073) for 10 percent salt-O_2 mixing atmosphere values and practically nil (a-aa: -0.003 and b-bb: -0.002) for 0 percent salt-N_2 mixing atmosphere.

Singly, increased salt increased oxynumbers until maximums were obtained after which oxynumbers decreased with continued increase in salt, and increased oxygen decreased oxynumbers, while with the combined effect the largest first stretch oxynumbers were with 5 percent salt-N_2 atmosphere mixes, the largest second stretch oxynumbers were with 1 percent salt-N_2 atmosphere mixes, and the smallest oxynumbers were obtained with 15 percent salt-O_2 atmosphere mixes, showing that the effect of oxygen was stronger than the salt effect.

5. Effect of Mixing Atmosphere and $KBrO_3$. Smallest F/E values were obtained with 0 mg bromate-N_2 atmosphere mixes

(a, 0.057; b, 0.060; aa, 0.060; bb, 0.062). Increased oxygen increased F/E values as witnessed by 0 mg bromate-O_2 atmosphere mix values: a, 0.245; b, 0.247; aa, 0.558; bb, 0.541. Increased bromate increased F/E values as shown by 30 mg bromate-N_2 atmosphere mixes: a, 0.722; b, 0.951; aa, 2.492; bb, 2.036. The combined effect of increased oxygen and bromate, although greater than the oxygen effect was not as great as the bromate effect as indicated by 30 mg bromate-O_2 atmosphere mix values: a, 0.434; b, 0.608; aa, 1.633; bb, 1.782. Combined increased bromate and oxygen caused a larger increase in second stretch F/E values than in first stretch F/E values. Increase in O_2 did not appreciably increase differences between duplicates, but such differences were greatly increased with increased bromate. In the combined effect, duplicate differences were somewhat less than they were when bromate alone was increased.

Largest oxynumbers were obtained with 0 mg bromate-N_2 atmosphere mixes (a, 5.23; b, 4.48; aa, 3.17; bb, 3.44). Increased oxygen decreased oxynumbers as shown by 0 mg bromate-O_2 atmosphere mix values: a, 2.18; b, 2.33; aa, 1.53; bb, 1.86. Increased bromate decreased oxynumbers even more as shown by 30 mg bromate-N_2 atmosphere mixes: a, 1.03; b, 0.85; aa, 0.23; bb, 0.27. The combined effect of increased oxygen and bromate, although greater than the oxygen effect, was not as great as the bromate effect as witnessed by 30 mg bromate-O_2 atmosphere mix values: a, 1.07; b, 0.89; aa, 0.29; bb, 0.33. Combined increased bromate and oxygen caused a larger decrease in first stretch oxynumbers than in second stretch oxynumbers. Increase in O_2, increase in bromate, and combined increase in O_2 and bromate all slightly decreased differences between oxynumbers of duplicates.

6. Effect of NaCl and $KBrO_3$. Addition of salt increased F/E values and increased oxynumbers. Addition of bromate increased F/E values and decreased oxynumbers. Although the combined effect of added salt and bromate increased F/E values, the increase was not as great as that produced by the addition of either salt or bromate singly. The overall effect of combined increased salt and increased bromate was one of oxynumber decrease.

7. Effect of NaCl, $KBrO_3$ and Mixing Atmosphere. The combined effect of increased salt, increased bromate and increased oxygen gave the following maximum F/E values: a, 0.833 (10 percent salt-30 mg bromate-O_2 atmosphere mix); b, 0.891 (10 percent salt-30 mg bromate-O_2 atmosphere mix); aa, 2.492 (10 percent salt-30 mg bromate-N_2 atmosphere mix); bb, 2.299 (1 percent salt-30 mg bromate-N_2 atmosphere mix). The smallest F/E values were: a, 0.057; b, 0.060; aa, 0.060; bb, 0.062 (all being 0 percent salt-0 mg bromate-N_2 atmosphere mixes). For O_2 mixes the largest F/E values were: a, 0.833 (10 percent salt-0 mg bromate); b, 0.891 (10 percent salt-30 mg bromate); aa, 1.657 (5 percent salt-30 mg bromate); bb, 1.792 (10 percent salt-30 mg bromate). For air mixes the largest F/E values were: a, 0.617 (5 percent salt-30 mg bromate); b, 0.644 (5 percent salt-30 mg bromate); aa, 1.645 (1 percent salt-30 mg bromate); bb, 1.890 (0 percent

salt-30 mg bromate). For N_2 mixes the largest F/E values were: a, 0.793 (1 percent salt-30 mg bromate); b, 0.951 (0 percent salt-30 mg bromate); aa, 2.492 (0 percent salt-30 mg bromate); bb, 2.299 (1 percent salt-30 mg bromate). Thus, regardless of the mixing atmosphere, maximum F/E values were obtained with the same concentration (30 mg) of bromate, while the optimum (to give maximum F/E values) concentration of salt increased with increased O_2 in the mixing atmosphere. Regardless of the mixing atmosphere F/E values were smallest for 0 percent salt-0 mg bromate mixes with the exceptions of first stretch-O_2 atmosphere mix values, where 0 percent salt-0 mg bromate-first stretch-first duplicate (a) F/E value was 0.245, where 0 percent salt-3 mg bromate-first stretch-first duplicate (a) F/E value was 0.216, where 15 percent salt-30 mg bromate-first stretch-first duplicate (a) F/E value was 0.212 and where 0 percent salt-0 mg bromate and 0 percent salt-3 mg bromate-first stretch-second duplicate (b) F/E values were 0.247.

The combined effect of increased salt, increased bromate and increased oxygen gave the following maximum oxynumbers: a, 6.12 (5 percent salt-0 mg bromate-air atmosphere mix); b, 6.33 (5 percent salt-3 mg bromate-air atmosphere mix); aa, 4.94 (1 percent salt-0 mg bromate-N_2 atmosphere mix); bb, 5.17 (1 percent salt-0 mg bromate-N_2 atmosphere mix). Minimum oxynumbers were: a, 0.50 (15 percent salt-30 mg bromate-O_2 atmosphere mix); b, 0.28 (15 percent salt-30 mg bromate-O_2 atmosphere mix); aa, 0.23 (0 percent salt-30 mg bromate-N_2 atmosphere mix); bb, 0.27 (0 percent salt-30 mg bromate-N_2 atmosphere mix). For O_2 mixes maximum oxynumbers were: a, 3.70 (1 percent salt-0 mg bromate; b, 3.25 (1 percent salt-3 mg bromate); aa, 1.78 (5 percent salt-0 mg bromate); bb, 1.98 (1 percent salt-0 mg bromate). For air mixes maximum oxynumbers were: a, 6.12 (5 percent salt-0 mg bromate); b, 5.09 (5 percent salt-0 mg bromate); aa, 4.13 (5 percent salt-0 mg bromate); bb, 4.12 (5 percent salt-0 mg bromate). For N_2 mixes maximum oxynumbers were: a, 5.99 (5 percent salt-3 mg bromate); b, 6.33 (5 percent salt-3 mg bromate); aa, 4.94 (1 percent salt-0 mg bromate); bb, 5.17 (1 percent salt-0 mg bromate). Smallest oxynumbers for O_2 mixes were: a, 0.50 (15 percent salt-30 mg bromate); b, 0.28 (15 percent salt-30 mg bromate); aa, 0.25 (15 percent salt-30 mg bromate); bb, 0.27 (15 percent salt-30 mg bromate). For air mixes minimum oxynumbers were: a, 0.80 (15 percent salt-30 mg bromate); b, 0.78 (15 percent salt-30 mg bromate); aa, 0.89 (15 percent salt-30 mg bromate); bb, 0.68 (15 percent salt-30 mg bromate). For N_2 mixes minimum oxynumbers were: a, 1.03 (0 percent salt-30 mg bromate); b, 0.85 (0 percent salt-30 mg bromate); aa, 0.23 (0 percent salt-30 mg bromate); bb, 0.27 (0 percent salt-30 mg bromate). Thus, regardless of the mixing atmosphere, minimum oxynumbers were obtained with the same concentration (30 mg) of bromate, while in order to maintain minimum oxynumbers with increased oxygen, salt also increased. For 0 percent salt-0 mg bromate mixes the following oxynumbers were obtained: O_2 atmosphere mixes, (a) 2.18, (b) 2.33, (aa) 1.53, (bb) 1.86; air atmosphere mixes, (a) 2.84, (b) 2.82, (aa) 3.14, (bb) 3.18; N_2

atmosphere mixes, (a) 5.23, (b) 4.48, (aa) 3.17, (bb) 3.44. In comparing these control oxynumbers with maximum and minimum values, it will be seen that the combined effect of increased salt, bromate and oxygen is one of oxynumber increase until maximums are reached after which continued increase in salt, bromate and oxygen decrease oxynumbers.

Ball-milled Flour Study

In addition to studying the effects of ball-milling on farinograms and extensograms the results of which are shown in Table 18, the effects on moisture, Zeleny sedimentation, and Zeleny protein were also determined.

Moisture content did not change during ball-milling; duplicate determinations at zero hours being 12.67 and 12.67 percent, with 24 hours ball-milling 12.67 and 12.70, and with 48 hours of ball-milling 12.65 and 12.68 percent.

Zeleny sedimentation of the flour before ball-milling for duplicate determinations was 32.7 and 32.9. With 24 hours of ball-milling there were two distinct demarcations in the falling flour sediment. One of these was heavy, resembling the heavy layer of the initial determination. The other layer was lighter, resembling a starch sedimentation, but was cloudier than the clear layer above it. Duplicates for the heavy layer were at 33, and those for the lighter layer were at 67. Further ball-milling did not change these values for after 48 hours of ball-milling duplicates for the heavy layer were still at 33 and for the lighter layer still at 67.

Ball-milling had no effect upon Zeleny photometric protein. Duplicate determinations with no ball-milling were 61.5 and 63.8, with 24 hours 61.7 and 62.8, and with 48 hours of ball-milling 61.5 and 63.1

Farinogram heights, widths, and H/W values increased with increased ball-milling.

For the sake of easier comprehension, changes in extensogram values are described according to the changes effected in the various characteristics of the curves. The complete data are recorded in Table 18.

Effect on Force (F) Values. All force values increased with ball milling. Second duplicate values were larger than first duplicate values with the exception of the second stretch, non-milled values. Second stretch values were larger than first stretch values. The differences between stretches were much larger than the differences between duplicates.

Effect on Bounded-by-the-curve Extensibility (E) Values. All E values decreased with increased ball milling. Ea and Eaa values were larger than Eb and Ebb values except for 24 hour ball milled mix. Second stretch were larger than first stretch values, and the differences between stretches were much larger than the differences between duplicates.

Effect on Extensibility-to-the-left-of-the -maximum-height (E_1) Values. All E_1 values decreased with increased ball milling. First duplicate first stretch values were larger than second

Table 18. Effect of ball-milling on farinogram and extensogram values of flour* - 2 percent NaCl system mixed in oxygen.

Curve characteristics	Ball milled		
	0 hours	24 hours	48 hours
		Farinogram values	
H	575	665	1000
W	1.75	1.80	3.00
H/W	329	369	333
		Extensogram values	
Fa	4.50	5.60	12.80
Fb	4.90	6.00	15.35
Faa	9.30	10.65	17.60
Fbb	8.80	11.20	17.70
E_1a	13.90	12.80	6.00
E_1b	13.60	12.25	5.05
E_1aa	9.55	8.55	4.95
E_1bb	9.95	8.60	4.55
E_2a	3.70	3.35	2.05
E_2b	3.40	4.35	2.10
E_2aa	3.10	3.40	1.10
E_2bb	2.25	3.55	2.15
Ea	17.65	16.15	8.05
Eb	17.00	16.60	7.15
Eaa	12.65	11.95	6.05
Ebb	12.20	12.15	5.70
E_ta	18.20	16.60	8.05
E_tb	17.85	17.35	7.15
E_taa	12.90	11.95	6.05
E_tbb	12.20	12.15	5.70
Aa	61.12	70.34	75.84
Ab	62.72	77.06	79.36
Aaa	82.88	92.16	68.35
Abb	74.24	100.48	64.45
$E_1a - E_2a$	10.20	9.45	3.95
$E_1b - E_2b$	10.20	8.90	2.95
$E_1aa - E_2aa$	6.45	5.15	3.85
$E_1bb - E_2bb$	7.70	5.05	2.40

* The flour used in this study was "A" flour (flour stored in sealed cans at 80°F.) that had been stored 54 days.

duplicate first stretch values, while second duplicate second stretch values were larger than second duplicate first stretch values with the exception of the 48 hour ball milled mix. The differences between stretches were much larger than the differences between duplicates.

Effect on Extensibility-to-the-right-of-the-maximum-height (E_2) Values. All first stretch E_2 values decreased with increased ball milling, but second stretch E_2 values increased with ball milling up to 24 hours and then decreased with 48 hours ball milling to lower values than with no ball milling. With no ball milling, first duplicates were larger than second duplicate values, but with 24 and 48 hours of ball milling second duplicates were larger than first duplicate values. First stretch values were larger than second stretch values. The differences between stretches were in the same magnitude as the differences between duplicates.

Effect on Total Extensibility (E_t) Values. All E_t values decreased with increased ball milling. All first duplicates were larger than second duplicate values with the exception of the values whose doughs had 24 hours ball milling. All first stretches were larger than second stretch values. The differences between stretches were much larger than the differences between duplicates.

Effect on Area-under-the-curve (A) Values. All first stretch A values increased with increased ball milling. Second stretch A values increased with 24 hours of ball milling, but then decreased with 48 hours, having values significantly lower than with no ball milling. Second duplicate first stretch values were higher than first duplicate first stretch values. Second duplicate second stretch values were lower than second duplicate first stretch values with the exception of the values for 24 hours of ball milling. Second stretches were larger than first stretch values with the exception of the 48 hours ball milled mix. The differences between stretches were much larger than the differences between duplicates.

Effect on Relative Position of Point of Maximum Curve Height. Although the extent and severity of ball milling in this study had not been quite enough to effect extensogram curve height reversals, 48 hours of ball milling effected near reversals.

E_1-E_2 second duplicates were larger than E_1-E_2 first duplicates with no ball milling, but with ball milling E_1-E_2 first duplicates were larger than E_1-E_2 second duplicates and this difference increased with increased ball milling.

E_1-E_2 first stretch values were larger than E_1-E_2 second stretch values, but this difference decreased rapidly with increased ball-milling.

Comparison Study Between Farinograph and Hobart-Swanson Mixers

The purposes of this study were to find whether the Hobart-Swanson mixer gave extensograms which expressed changes due to different flour treatment and whether these differences were similar to those produced by farinograph mixing.

Changes in Extensograms of Doughs Mixed with the Hobart-Swanson Mixer. Doughs with and without 2 percent NaCl were made from flour having different storage, storage temperature and storage atmosphere.

1. Effect of Storage. It was found that doughs both with and without 2 percent NaCl revealed the effect of storage through their extensograms, as recorded in Table 19. With both 0 percent and 2 percent salt mixes, F and A values tended to increase with storage while E and E_ta values tended to decrease with storage. E_t values other than E_ta tended to increase with storage. First stretch F and A values were larger than second stretch F and A values, while for E and E_t values this trend was only very faintly apparent. Second duplicate F, E, E_t and A values tended to be larger than first duplicate values and this trend was slightly more apparent for 2 percent salt dough mixes than for 0 percent NaCl dough mixes. All 2 percent NaCl dough extensograph values were larger than the respective 0 percent salt dough values.

2. Effect of Storage Temperature. Doughs mixed in the Hobart-Swanson mixer revealed the effect of storage temperature through their extensograms as recorded in Table 20. "A" flour (stored at 80°F) F and A values were larger than the respective "B" flour (stored at 55°F) values for both no salt and 2 percent salt doughs, while for E and E_t values "B" flour values were larger than those of "A" flour for both no salt and 2 percent

Table 19. Effect of storage on extensograms of doughs, with and without 2 percent NaCl, mixed in Hobart-Swanson mixer.#

Extensogram characteristic	0 percent NaCl				2 percent NaCl			
	Storage time (days)				Storage time (days)			
	62	97	299	333	69	90	299	333
Fa	0.85	1.05	2.05	2.15	2.30	2.45	3.35	3.50
Fb	0.90	1.20	2.00	2.05	2.45	2.50	3.45	3.70
Faa	0.75	0.80	1.35	1.45	2.20	1.90	2.90	3.00
Fbb	0.80	0.85	1.35	1.40	1.85	2.05	3.00	3.15
Ea	17.80	16.10	16.95	17.90	20.90	21.20	20.70	20.65
Eb	17.30	16.40	16.05	15.75	21.95	21.25	19.40	19.15
Eaa	17.10	15.55	16.00	16.50	20.60	19.15	19.40	19.45
Ebb	17.35	17.20	17.15	17.15	20.95	22.45	20.80	20.15
E_ta	18.25	16.60	18.00	17.90	22.35	23.30	20.75	20.65
E_tb	18.30	17.05	19.85	19.95	23.40	21.45	24.40	25.85
$E_t$aa	18.00	16.65	19.95	20.50	21.10	22.15	22.25	22.20
$E_t$bb	19.05	19.35	21.40	22.05	23.45	23.95	25.05	25.20
Aa	19.93	16.26	30.29	34.24	40.64	41.28	55.46	59.58
Ab	15.67	18.43	28.21	29.76	43.71	41.92	49.37	59.20
Aaa	11.66	11.70	20.76	22.20	37.06	30.08	48.50	49.60
Abb	13.78	14.40	21.48	22.40	32.58	37.19	50.12	52.99

The flour used in this study was "A" flour. The absorption was 62.9 percent and the mixing time was 1 minute and 5 seconds. The high mixing speed was used.

salt doughs with the exceptions of second stretch-no salt-"A" and "B" flour values where the opposite was true. All 2 percent salt extensograph values were larger than the respective no salt values.

Table 20. Effect of storage temperature on extensograms of doughs, with and without 2 percent salt, mixed in Hobart-Swanson mixer.*

Extensogram characteristic	Flour			
	"A"		"B"	
	No salt	2 percent salt	No salt	2 percent salt
Fa	2.15	3.50	1.40	2.75
Fb	2.05	3.70	1.25	2.60
Faa	1.45	3.00	0.80	2.20
Fbb	1.40	3.15	0.60	2.00
Ea	17.90	20.65	17.65	21.50
Eb	15.75	19.15	18.30	22.50
Eaa	16.50	19.45	17.00	21.45
Ebb	17.15	20.15	14.50	20.25
E_ta	17.90	20.65	20.75	25.15
E_tb	19.95	25.85	20.50	25.65
$E_t$aa	20.50	22.20	18.45	26.95
$E_t$bb	22.05	25.20	15.85	25.20
Aa	34.24	59.58	23.65	51.40
Ab	29.76	59.20	21.18	49.08
Aaa	22.20	49.60	13.38	39.42
Abb	22.40	52.99	9.09	33.60

* The flours used in this study were "A" flour, stored 333 days, and "B" flour, stored 330 days. The absorption was 62.9 percent and the mixing time was 1 minute and 5 seconds. The high mixing speed was used.

3. Effect of Storage Atmosphere: Doughs mixed in the Hobart-Swanson mixer revealed the effect of storage atmosphere through their extensograms as recorded in Table 21. With 0 percent salt, "O_2" flour F and A values tended to be larger than "N_2" flour F and A values while "N_2" flour E and E_t values tended to be larger than "O_2" flour E and E_t values. With 2

percent salt, first stretch "O_2" flour F and A values were larger than first stretch "N_2" flour F and A values, while the opposite was true for second stretch values. With 2 percent salt, all "O_2" flour E values were larger than "N_2" flour E values and all "N_2" flour E_t values were larger than "O_2" flour E_t values with the exception of $E_t$aa values where the opposite was true. Salt increased E and A values of "O_2" flour more than it did E and A values of "N_2" flour while no distinction in this regard could be made with F and E_t values. All first stretch F and E values were larger than second stretch F and E values. All N_2 flour first stretch E and E_t values with the exceptions of no salt E values were larger than second stretch E and E_t values. For O_2 flour-2 percent salt mixes, first stretch E values were larger than second stretch E values, while for E_t values the opposite was true. For O_2 flour-0 percent salt no trend was evident. All 2 percent NaCl dough extensograph values were larger than the respective 0 percent salt dough values.

Comparison of Extensograms of Doughs Mixed with the Farinograph and the Hobart-Swanson Mixer. Doughs with 2 percent NaCl were made from flour having different storage time, temperature and atmosphere.

1. Effect of Storage. The effect of storage time on extensogram characteristics of doughs mixed in the farinograph and the Hobart-Swanson mixer is recorded in Table 22. Generally F and A values increased and E and E_t values decreased with flour storage time for both Hobart-Swanson mixer and farinograph mixed

Table 21. Effect of storage atmosphere on extensograms of doughs, with and without 2 percent salt, mixed in Hobart-Swanson mixer.*

Extensogram characteristic	Flour			
	"O_2"		"N_2"	
	No salt	2 percent salt	No salt	2 percent salt
Fa	1.05	2.45	0.95	2.50
Fb	1.05	2.55	1.05	2.50
Faa	0.85	2.15	0.70	2.25
Fbb	0.85	2.15	0.80	2.00
Ea	16.25	23.90	16.75	23.40
Eb	16.25	23.55	15.20	23.45
Eaa	16.20	23.15	17.00	22.05
Ebb	16.40	22.45	17.70	21.80
E_ta	17.75	23.90	19.90	26.15
E_tb	19.60	23.55	21.75	27.10
$E_t$aa	18.00	27.90	18.95	24.75
$E_t$bb	17.80	26.60	17.70	26.80
Aa	20.28	49.21	16.51	50.18
Ab	17.34	50.43	16.00	49.73
Aaa	13.18	42.37	11.58	44.67
Abb	13.76	41.47	14.34	37.50

* The flours used in this study were "O_2" flour, stored 237 days, and "N_2" flour, stored 236 days. The absorption was 62.9 percent and the mixing time was 1 minute and 5 seconds. The high mixing speed was used.

doughs. F and A values increased more with storage for Hobart-Swanson mixed doughs than for farinograph mixed doughs. For F values, first duplicate farinograph mixed doughs decreased more than Hobart-Swanson mixed doughs, while for second duplicate doughs the opposite was true. No distinction between E_t value Hobart-Swanson and farinograph mixed doughs could be made. First stretch Hobart-Swanson mixed dough F and A values were

Table 22. Extensogram characteristics of "A" flour doughs[1] mixed with the farinograph[2] and with the Hobart-Swanson mixer[3] reflecting changes due to storage time.

Extensogram characteristics	Storage time in days and mixer[4] used							
	69 H-S	76 Far.	90 H-S	101 Far.	299 H-S	300 Far.	333 H-S	332 Far.
Fa	2.30	3.65	2.45	3.90	3.35	5.00	3.50	4.18
Fb	2.45	3.60	2.50	3.70	3.45	4.98	3.70	4.08
Faa	2.20	4.43	1.90	4.88	2.90	6.75	3.00	5.50
Fbb	1.85	4.63	2.05	4.88	3.00	6.55	3.15	5.45
Ea	20.90	19.55	21.20	19.40	20.70	18.80	20.65	18.85
Eb	21.95	19.23	21.25	18.88	19.40	19.00	19.15	18.33
Eaa	20.60	18.28	19.15	18.38	19.40	18.68	19.45	18.45
Ebb	20.95	18.85	22.45	19.08	20.80	18.45	20.15	18.60
E_ta	22.35	19.75	23.30	19.80	20.75	19.03	20.60	19.40
E_tb	23.40	19.53	21.45	19.33	24.40	19.58	25.85	18.45
$E_t$aa	21.10	18.55	22.15	19.30	22.25	18.75	22.20	19.08
$E_t$bb	23.45	19.38	23.95	19.10	25.05	18.65	25.20	19.08
Aa	40.65	55.49	41.28	58.72	55.46	71.39	59.58	59.74
Ab	43.81	53.87	41.92	56.54	49.37	66.62	59.20	57.34
Aaa	37.06	63.30	30.08	61.76	48.50	95.52	49.60	78.18
Abb	32.58	70.08	37.19	66.24	50.12	88.45	52.99	78.82

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[1] Doughs mixed in air and with 2 percent NaCl.

[2] Data derived from Tables B, C, and E in Appendix.

[3] Data derived from Table 19.

[4] Hobart-Swanson = H-S; Farinograph = Far.

larger than second stretch values while for farinograph mixes the opposite was true, second stretch F and A values being larger than first stretch values. Generally first stretch E and E_t values of both Hobart-Swanson and farinograph mixed doughs were larger than second stretch values. For Hobart-Swanson mixed doughs, second duplicate F, E, E_t and A values tended to be larger than first duplicate values. No distinction between farinograph mixes could be made.

2. Effect of Storage Temperature. F and A values of "A" and "B" flour, as recorded in Table 23, were larger for farinograph mixes than they were for respective Hobart-Swanson mixes, while E and E_t values of "A" and "B" flour were smaller for farinograph mixes than they were for respective Hobart-Swanson mixes. "A" flour F and A values of both farinograph and Hobart-Swanson mixes were larger than respective "B" flour F and A values. "A" flour E and E_t values of both farinograph and Hobart-Swanson mixes were smaller than respective "B" flour E and E_t values. Second stretch F and A values for farinograph mixes were larger than first stretch F and A values, while for Hobart-Swanson mixes the opposite was true, first stretch F and A values being larger than second stretch values. For "A" flour E and E_t values of both farinograph and Hobart-Swanson mixes no distinction between mixes could be made, while for "B" flour the tendency of both farinograph and Hobart-Swanson mixes was for first stretch E and E_t values to be larger than second stretch E and E_t values.

Table 23. Comparison of extensograms of doughs[1] mixed with the farinograph[2] and with the Hobart-Swanson mixer[3] reflecting changes due to storage temperature and storage atmosphere.

Extensogram characteristics	Flour							
	"A"		"B"		"O_2"		"N_2"	
	Mixer							
	Far.	H-S	Far.	H-S	Far.	H-S	Far.	H-S
	Storage, days							
	332	333	331	330	235	237	234	236
Fa	4.18	3.50	3.20	2.75	3.45	2.45	3.50	2.50
Fb	4.08	3.70	3.40	2.60	3.43	2.55	3.45	2.50
Faa	5.50	3.00	4.78	2.20	4.33	2.15	4.55	2.25
Fbb	5.45	3.15	4.43	2.00	4.15	2.15	4.25	2.00
Ea	18.85	20.65	19.80	21.50	20.83	23.90	20.58	23.40
Eb	18.33	19.15	19.68	22.50	20.38	23.55	20.00	23.45
Eaa	18.45	19.45	19.50	21.45	19.83	23.15	19.68	22.05
Ebb	18.60	20.15	20.05	20.25	19.73	22.45	18.83	21.80
E_ta	19.40	20.65	20.18	25.15	20.98	23.90	20.78	26.15
E_tb	18.45	25.85	20.50	25.65	20.73	23.55	20.28	27.10
E_taa	19.08	22.20	19.78	26.95	20.20	27.90	20.00	24.75
E_tbb	19.08	25.20	20.68	25.20	20.10	26.60	19.55	26.80
Aa	59.74	59.58	52.80	51.40	54.27	49.21	57.18	50.18
Ab	57.34	59.20	52.80	49.08	55.71	50.43	55.81	49.73
Aaa	78.18	49.60	72.99	39.42	64.61	42.37	69.15	44.67
Abb	78.82	52.99	66.88	33.60	67.24	41.47	62.85	37.50

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[1] Doughs mixed in air and with 2 percent NaCl.

[2] Data derived from Tables B, C, and E in Appendix.

[3] Data derived from Tables 20 and 21.

3. Effect of Storage Atmosphere. F and A values, as recorded in Table 23, of "O_2" and "N_2" flour were larger for farinograph mixes than they were for respective Hobart-Swanson mixes, while E and E_t values of "O_2" and "N_2" flour were smaller for farinograph mixes than they were for respective Hobart-Swanson mixes. Generally "N_2" flour F and A values of both farinograph and Hobart-Swanson mixes were larger than respective "O_2" flour F and A values. Generally "N_2" flour E and E_t values of both farinograph and Hobart-Swanson mixes were smaller than respective "O_2" flour E and E_t values. Second stretch F and A values for farinograph mixes were larger than first stretch F and A values, while for Hobart-Swanson mixes the opposite was true, first stretch F and A values being larger than second stretch values. First stretch E and E_t values, with the exceptions of Hobart-Swanson mixed E_t values, were larger than second stretch E and E_t values for both farinograph and Hobart-Swanson mixes.

"A" Flour-Hydrochloric Acid Study

For the sake of easier comprehension, changes in extensogram values due to treatment of doughs with hydrochloric acid are described according to the changes effected in the various characteristics of the curves. The complete data are recorded in Table 24.

Effect on Force Values. All force values increased with increasing normality of the HCl in the dough until a maximum F value was reached; increased normality then caused decreased curve heights. With first stretch F values, the maximum height was reached with 0.250 N HCl while with second stretch values, the maximum height was reached with 0.125 N HCl.

Fb values were always larger than Fa values except for 0.150 N HCl mix, while no distinction in this respect between second stretch duplicates could be made.

Faa values were larger than Fa values except for doughs having zero, 0.300, 0.400, 0.450, and 0.500 N HCl. Fbb values were larger than Fb values for 0.125, 0.150, and 0.200 N HCl mixes only.

Effect on Bounded-by-the-curve Extensibility (E) Values. All E values decreased with increased normality of the HCl in the dough until an optimum normality was reached; relative plateaus then ensued with further increase in normality. For all E values these plateaus were reached with 0.200 N acid. Upon closer examination these plateaus trended downward slightly with increased normality of the acid.

No distinction concerning the differences between duplicate doughs could be made.

Eaa values were larger than Ea values except for doughs having zero, 0.050, 0.450, and 0.500 N HCl. Ebb values were larger than Eb values except for 0.125, 0.200, 0.250, and 0.400 N HCl mixes.

Effect on Extensibility-to-the-left-of-the-maximum-height

Table 24. Effect of hydrochloric acid on "A" flour-2 percent sodium chloride-water dough systems mixed in Hobart-Swanson mixer as reflected by extensogram values.[1]

Extensogram :	Normality of HCl										
characteristics:	0.00	0.050	0.100	0.125	0.150	0.200	0.250	0.300	0.400	0.450	0.500
Fa	2.45	4.60	4.85	4.95	5.85	5.15	6.25	6.10	5.55	3.80	5.35
Fb	2.50	4.65	5.05	5.50	5.30	5.25	6.45	6.45	5.75	5.65	5.55
Faa	1.90	4.65	5.90	7.90	7.10	6.30	6.30	5.10	5.35	4.60	4.65
Fbb	2.05	4.55	6.15	7.35	6.95	6.15	6.20	5.15	4.80	4.70	4.60
Ea	21.20	17.00	13.60	10.30	8.90	5.50	5.65	6.20	5.55	5.50	6.00
Eb	21.25	16.00	12.40	11.70	8.65	7.20	7.40	6.35	5.95	5.75	5.60
Eaa	19.15	16.40	13.70	13.95	10.00	6.85	6.65	6.75	6.10	4.90	5.30
Ebb	22.45	16.70	14.15	11.45	9.50	6.55	5.95	7.25	5.50	5.10	4.95
E_1a	16.15	11.70	8.25	6.15	5.25	3.45	3.35	3.50	3.15	2.95	3.05
E_1b	14.80	11.35	8.35	6.75	5.15	3.90	3.25	3.50	3.25	3.25	3.20
E_1aa	14.35	11.80	9.05	7.25	5.75	3.85	3.50	3.10	3.15	3.00	2.85
E_1bb	16.05	11.80	9.15	7.30	5.75	4.05	3.45	3.45	3.05	2.90	2.85
E_2a	5.05	5.30	5.35	4.15	3.65	2.05	2.30	2.70	2.40	2.55	2.95
E_2b	6.45	4.65	4.05	4.95	3.50	3.30	4.15	2.85	2.70	2.50	2.40
E_2aa	4.80	4.60	4.65	6.70	4.25	3.00	3.15	3.65	2.95	1.90	2.45
E_2bb	6.40	4.90	5.00	4.15	3.75	2.50	2.50	3.80	2.45	2.20	2.10
E_ta	23.30	19.00	15.65	11.60	9.60	7.15	6.05	6.20	6.05	5.50	6.00
E_tb	21.45	17.30	13.10	11.70	8.65	7.20	7.85	6.45	6.55	6.20	6.15
E_taa	22.15	18.85	15.35	13.95	10.70	6.85	6.65	6.75	6.10	6.60	5.30
E_tbb	23.95	18.80	14.15	11.45	10.05	7.00	5.95	7.25	5.85	5.85	5.35

Table 24. (concl.)[1]

Extensogram characteristics	Normality of HCl 0.00	0.050	0.100	0.125	0.150	0.200	0.250	0.300	0.400	0.450	0.500
Aa	41.28	61.82	50.56	38.08	35.97	18.88	22.60	24.07	20.54	13.25	19.59
Ab	41.92	58.69	48.00	46.53	30.85	25.40	28.54	37.89	22.14	21.70	20.24
Aaa	30.08	58.11	60.16	68.55	49.79	27.52	27.14	21.88	22.14	15.10	16.45
Abb	37.19	58.43	65.02	60.48	45.57	30.52	23.68	22.92	17.34	15.75	15.01
E_1a-E_2a	11.10	6.40	2.90	2.00	1.60	1.40	1.05	0.80	0.75	0.40	0.10
E_1b-E_2b	8.35	6.70	4.30	1.80	1.65	0.60	-0.90	0.65	0.55	0.75	0.80
E_1aa-E_2aa	9.55	7.20	4.40	0.55	1.50	0.85	0.35	-0.55	0.20	1.10	0.40
E_1bb-E_2bb	9.65	6.90	4.15	3.15	2.00	1.55	0.95	-0.35	0.60	0.70	0.75

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[1] The flour was used after it had been stored 90 days in sealed cans at 80° F.

(E_1) Values. E_1 values decreased with increased acid normality, near plateaus being recorded after 0.200 N HCl.

No distinction between the differences among duplicate doughs could be made.

E_1aa values were larger than E_1a values except for zero, 0.300, 0.400, 0.450, and 0.500 N HCl mixes. E_1bb values were larger than E_1b values except for 0.300, 0.400, 0.450, and 0.500 N HCl mixes.

Effect on Extensibility-to-the-right-of-the-maximum-height (E_2) Values. E_2 values decreased with increased acid normality, near plateaus being reached after 0.200 N HCl.

No distinction concerning differences between duplicate doughs could be made.

E_2aa values were larger than E_2a values except for zero, 0.050, 0.100, 0.450, and 0.500 N acid mixes. E_2bb values were larger than E_2b values for 0.050, 0.100, 0.150, and 0.300 N HCl mixes.

Effect on Total Extensibility (E_t) Values. E_t values decreased with increased acid normality, near plateaus being reached after 0.200 N HCl.

No distinction between the differences among duplicate doughs could be made.

$E_t$aa values were larger than E_ta values except for zero, 0.050, 0.100, 0.450, and 0.500 N acid mixes. $E_t$bb values were larger than E_tb values for zero, 0.050, 0.100, 0.150, and 0.300 N HCl mixes.

Effect on Area-under-the-curve (A) Values. All area values increased with increased normality until an optimum was reached; then increased normality resulted in decreases in area values. With first stretch A values, the maximum areas were reached with 0.050 N acid mixes, while with second stretch values the maximum was with 0.125 N HCl for Aaa and 0.100 N HCl for Abb values. There were secondary peaks with first stretch values (0.300 N HCl for both Aa and Ab values), while second stretch values continued to decrease with increased acid normality in the mixes.

No distinction concerning the differences between duplicate doughs could be made.

Aaa values were larger than Aa values except for zero, 0.050, and 0.500 N HCl mixes. Abb values were larger than Ab values for 0.100, 0.125, 0.150, and 0.200 N acid mixes.

Effect on Relative Position of Point of Maximum Curve Height. Extensogram curve slope reversals were found for the second of the duplicate first stretch doughs with 0.250 N HCl in the mix, and for both duplicate second stretch doughs with 0.300 N HCl in the mixes.

These values were found by subtracting E_2 values from E_1 values (subtracting E_1 values from E_2 values could have been done as validly). When the difference was zero, it meant that the position of the point of maximum curve height was in the exact middle of the curve. When the difference was a negative value, it meant that an extensogram reversal had been effected;

that is the slope of the curve was in the opposite direction from what it had been formerly, or, in other words, the peak of the curve was in the left-half of the curve instead of the right-half where it is "normally".

E_1a-E_2a values continued to decrease with increased normality of HCl in the mixes and its reversal was beyond the highest normality used in this study, but with the other value differences the reversal was affected and the curve reverted to the "normal", this value increasing again as the acid normality continued to increase.

"A" Flour Acetic Acid Study

For the sake of easier comprehension, changes in extensogram values with increments of acetic acid are described according to the changes effected in the various characteristics of the curves. The complete data are recorded in Table 25.

With normality of 0.200 and beyond, the dough began to smear during molding. There was a definite trend in this tendency to smear during molding. Second duplicate-second stretch doughs smeared first; then second duplicate-first stretch doughs; and, finally, with 0.300 N acetic acid, all the doughs smeared upon molding.

Effect on Force Values. Fa values continued to increase with increased normality of acetic acid in the mixes even until the doughs became so sticky they could not be molded and, consequently, no more stretches taken. The other F values were not changed appreciably by addition of acetic acid.

No distinction concerning the differences between duplicate doughs could be made.

All Fa values were larger than Faa values, and all Fb values were larger than Fbb values.

Effect on Bounded-by-the-curve Extensibility (E) Values. All E values decreased with increased acetic acid normality in the mixes.

No distinction concerning the differences between duplicate doughs could be made.

All Ea values were larger than Eaa values, while no distinction concerning the differences between stretches of second duplicate doughs could be made.

Effect on Extensibility-to-the-left-of-the-maximum-height (E_1) Values. E_1 values decreased until a normality of 0.125 was reached after which E_1 values increased.

No distinction concerning the differences between duplicate doughs could be made.

All E_1a values were larger than E_1aa values, while no distinction concerning the differences between stretches of second duplicate doughe could be made.

Effect of Extensibility-to-the-right-of-the-maximum-height (E_2) Values. There was a tendency for E_2 values to decrease with increased acetic acid normality, but this trend was not clear-cut since there were exceptions that may not have been

Table 25. Effect of acetic acid on "A" flour-water dough systems mixed in Hobart-Swanson mixer as reflected by extensogram values.[1]

Extensogram characteristics	Normality of CH3COOH					
	0.00	0.050	0.125	0.200	0.250	0.300
Fa	1.05	1.15	1.30	1.40	1.70	-*
Fb	1.20	1.05	1.25	1.15	-*	
Faa	0.80	0.65	0.80	0.70	0.60	
Fbb	0.85	0.80	0.80	-*	-*	
Ea	16.10	12.75	11.75	11.80	10.70	
Eb	16.40	11.90	11.40	10.40	-*	
Eaa	15.55	10.50	8.75	9.00	6.60	
Ebb	12.70	13.65	11.10	-*	-*	
E_1a	7.70	5.60	4.15	6.35	4.55	
E_1b	7.95	5.80	3.50	5.65	-*	
E_1aa	7.25	4.50	1.55	4.35	3.30	
E_1bb	8.70	5.25	1.80	-*	-*	
E_2a	8.40	7.15	7.60	5.45	6.15	
E_2b	8.45	6.10	7.90	4.75	-*	
E_2aa	8.30	6.00	7.20	4.65	3.30	
E_2bb	8.50	8.40	9.30	-*	-*	
E_ta	16.60	12.75	11.90	12.50	10.70	
E_tb	17.05	12.85	12.15	12.65	-*	
E_taa	16.65	10.50	11.85	9.90	7.60	
E_tbb	19.35	14.80	11.10	-*	-*	
Aa	16.26	13.18	12.67	14.28	14.79	
Ab	18.43	10.95	12.93	10.43	-*	
Aaa	11.70	6.14	6.02	5.76	5.38	
Abb	14.40	11.52	7.30	-*	-*	
E_1a-E_2a	-0.70	-1.55	-3.45	0.90	-1.60	
E_1b-E_2b	-0.50	-0.30	-4.40	0.90	-*	
E_1aa-E_2aa	-1.05	-1.50	-5.65	-0.30	0.00	
E_1bb-E_2bb	0.20	-3.15	-7.50	-*	-*	

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[1] The flour was used after it had been stored 97 days in sealed cans at 80° F.

*These doughs were so sticky that they smeared upon molding and could not be stretched.

due to experimental error.

No distinction concerning the differences between duplicate doughs could be made.

All E_2a values were larger than E_2aa values, but no distinction concerning the differences between stretches of second duplicate doughs could be made.

Effect on Total Extensibility (E_t) Values. There was a reduction in E_t values with increased acetic acid normality. The second duplicate values tended to be larger than first duplicate values.

E_ta values were larger than $E_t$aa values, but no distinction concerning the differences between stretches of second duplicate doughs could be made.

Effect on Area-under-the-curve (A) Values. All of the values decreased progressively with increased acetic acid normality with the exception of Aa values which decreased until 0.125 N acetic acid was in the dough and then increased again with further increase in normality.

No distinction concerning the differences between first stretch duplicates could be made, but second duplicate second stretch values were higher than first duplicate second stretch values, and Ab values were larger than Abb values with the exception of the mix with 0.050 N acetic acid.

Effect on Relative Position of Point of Maximum Curve Height. Extensogram curve slope reversals were found for all the curves with the exceptions of E_1a-E_2a for 0.200 N acetic acid, and E_1b-E_2b for 0.200 N acetic acid.

The extent of the reversal became stronger as the acetic acid normality increased until 0.125 N acetic acid was reached; then with 0.200 N acetic acid the curve slope rapidly approached "normal" again.

Storage-Acid-Base Study

In this study the effect of 0.250 N hydrochloric acid, 0.250 N acetic acid and 0.250 N ammonium hydroxide on extensograms of doughs with and without 2 percent sodium chloride whose flour was stored under different conditions of atmosphere and temperature was observed. The data are recorded in Tables 26 and 27. Mixing was done with the Hobart-Swanson mixer for 1 minute and 5 seconds, and the absorption was 62.9 percent.

With 2 percent sodium chloride the most dramatic extensogram changes were with mixes involving 0.250 N acetic acid. All extensogram values greatly increased with the inclusion of 2 percent salt in conjunction with the acetic acid. For HCl mixes the inclusion of 2 percent salt decreased F and A values and increased E and E_t values. The inclusion of sodium chloride in NH_4OH mixes resulted generally in decreased F and A values. No overall statement concerning NH_4OH mix E and E_t values can be made without qualifying another variable.

Although there were exceptions, generally F and A values

Table 26. Effect of various reagents on extensograms of doughs with and without 2 percent NaCl whose flour was stored under different conditions of atmosphere and temperature.

Extensogram characteristics	"A" flour (stored under air at 80° F.)					
	0.250 N HCl		0.250 N CH_3COOH		0.250 N NH_4OH	
	0% NaCl	2% NaCl	0% NaCl	2% NaCl	0% NaCl	2% NaCl
	Storage, days					
	90		97		89	
Fa	8.65	6.25	1.70	6.25	8.30	7.45
Fb	8.65	6.45	-*	6.85	8.40	8.35
Faa	8.80	6.30	0.60	7.90	14.15	14.50
Fbb	7.55	6.20	-*	8.25	12.85	15.00
Ea	5.10	5.65	10.70	11.95	14.35	11.80
Eb	5.05	7.40	-*	13.15	14.25	11.90
Eaa	5.30	6.65	6.60	13.55	8.25	8.00
Ebb	5.45	5.95	-*	13.75	8.05	7.60
E_ta	5.10	6.05	10.70	12.05	14.35	12.00
E_tb	5.05	7.85	-*	13.15	14.80	11.90
E_taa	5.30	6.65	7.60	15.25	8.25	8.00
E_tbb	5.45	5.95	-*	14.80	8.05	7.60
Aa	28.35	22.60	14.78	54.72	93.18	69.18
Ab	26.69	28.54	-	64.90	86.91	76.03
Aaa	27.26	27.14	5.38	78.27	79.42	72.13
Abb	27.01	23.68	-*	82.88	67.33	70.21
	Storage, days					
	244		244		244	
Fa	9.70	6.60	1.90	7.35	11.55	10.05
Fb	9.30	6.75	1.80	7.50	12.65	10.40
Faa	8.15	5.50	1.45	7.60	14.05	14.20
Fbb	8.10	5.65	-*	7.85	13.95	14.25
Ea	5.25	6.15	12.15	15.45	12.85	12.40
Eb	5.35	6.25	11.90	15.90	12.45	11.45
Eaa	5.45	6.00	12.00	15.95	8.00	8.05
Ebb	5.80	6.45	-*	15.90	7.95	7.80
E_ta	5.35	6.20	12.90	16.05	13.70	13.05
E_tb	5.35	6.30	12.60	15.95	13.95	12.90
E_taa	6.15	6.25	12.95	16.20	8.55	8.25
E_tbb	5.80	6.45	-*	15.90	8.30	7.80
Aa	32.41	27.14	17.81	84.24	139.23	91.04
Ab	32.20	27.32	16.73	86.96	140.61	92.67
Aaa	29.41	22.07	15.69	87.77	70.84	69.26
Abb	31.10	23.18	-*	90.41	70.49	67.98

Table 26. (cont.)

Extensogram characteristics	"B" flour (stored under air at 50-60° F.)					
	0.250 N HCl		0.250 N CH_3COOH		0.250 N NH_4OH	
	0% NaCl	2% NaCl	0% NaCl	2% NaCl	0% NaCl	2% NaCl
	Storage, days					
	88		88		88	
Fa	9.90	6.35	0.75	6.35	6.55	5.20
Fb	8.45	6.70	1.00	5.35	6.50	6.05
Faa	7.20	5.40	-*	6.35	12.90	10.30
Fbb	7.15	5.75	-*	6.15	13.05	11.25
Ea	5.25	6.25	7.10	13.45	13.50	14.70
Eb	6.25	6.25	7.95	14.55	13.35	13.45
Eaa	5.60	5.90	-*	13.10	7.80	7.65
Ebb	5.40	6.30	-*	13.15	8.20	7.70
$E_t a$	5.25	7.25	8.05	14.25	14.65	15.05
$E_t b$	6.25	6.25	9.05	15.30	14.10	14.60
$E_t aa$	5.60	6.50	-*	14.10	7.30	7.65
$E_t bb$	5.40	6.80	-*	15.25	8.20	8.00
Aa	32.51	27.52	4.35	65.72	71.36	61.00
Ab	33.92	27.07	6.59	66.05	68.99	64.90
Aaa	27.26	20.10	-*	66.30	65.79	57.02
Abb	24.32	23.23	-*	59.97	71.36	61.76
	Storage, days					
	245		245		245	
Fa	10.55	7.80	1.95	7.50	10.30	6.20
Fb	10.15	7.30	1.70	7.95	10.75	7.45
Faa	8.35	6.55	1.30	7.90	13.40	12.20
Fbb	8.65	6.25	-*	8.10	13.75	12.55
Ea	5.50	6.35	12.20	15.60	11.65	14.15
Eb	5.25	6.30	12.05	15.55	11.40	13.60
Eaa	6.05	5.90	11.95	15.55	8.35	8.35
Ebb	5.45	6.50	-*	15.75	7.85	8.45
$E_t a$	5.50	6.35	12.65	16.20	11.90	15.80
$E_t b$	5.25	6.60	12.80	16.05	11.30	14.10
$E_t aa$	6.05	6.40	13.50	16.30	8.35	9.05
$E_t bb$	5.45	7.75	-*	17.05	7.35	9.20
Aa	36.67	31.23	19.41	86.53	90.67	70.38
Ab	33.47	29.44	17.52	87.28	92.81	81.32
Aaa	34.56	24.13	13.86	87.04	70.28	66.47
Abb	30.40	24.58	-*	92.47	69.52	73.92

Table 26. (cont.)

Extensogram characteristics	"O_2" flour (stored under oxygen at 50-60°F.)					
	0.250 N HCl		0.250 N CH_3COOH		0.250 N NH_4OH	
	0% NaCl	2% NaCl	0% NaCl	2% NaCl	0% NaCl	2% NaCl
	Storage, days					
	91		91		91	
Fa	9.05	6.95	1.20	5.15	6.10	5.60
Fb	9.20	7.10	1.35	5.85	6.45	6.65
Faa	8.50	5.40	-*	6.20	11.95	10.70
Fbb	7.55	5.05	-*	6.45	12.20	9.60
Ea	5.00	5.40	10.30	13.65	13.30	9.60
Eb	5.50	5.55	10.65	13.15	11.55	10.65
Eaa	5.90	5.70	-*	12.95	7.95	6.65
Ebb	5.20	5.60	-*	13.95	6.05	7.75
E_ta	5.30	5.65	11.20	15.00	13.30	11.05
E_tb	5.75	6.35	11.10	14.60	12.40	11.35
E_taa	5.90	6.00	-*	13.95	8.55	7.50
E_tbb	5.40	6.05	-*	13.95	6.05	8.05
Aa	28.80	27.62	10.01	55.62	65.41	42.75
Ab	32.97	28.28	10.37	58.30	58.75	53.89
Aaa	32.13	20.14	-*	59.90	61.38	45.83
Abb	25.60	19.31	-*	66.75	51.71	50.30

	Storage, days					
	243		240		244	243
Fa	9.85	8.10	1.80	7.10	10.45	6.70
Fb	10.65	8.35	1.65	7.25	10.80	8.20
Faa	7.95	8.25	1.40	7.80	13.50	13.15
Fbb	7.90	6.20	1.25	7.40	14.10	14.30
Ea	5.25	5.90	10.75	14.75	12.20	14.20
Eb	5.70	6.25	11.70	14.85	11.55	13.50
Eaa	5.75	6.55	10.90	14.85	8.50	8.20
Ebb	5.35	6.40	11.20	15.65	8.20	8.50
E_ta	5.25	5.90	10.75	16.55	12.20	16.35
E_tb	5.70	6.85	12.90	15.25	11.55	13.90
E_taa	5.75	6.55	10.90	16.25	8.50	9.50
E_tbb	5.35	7.00	11.20	15.65	8.20	8.50
Aa	31.68	29.89	16.00	78.46	92.80	76.16
Ab	34.63	33.66	19.65	76.66	90.37	87.49
Aaa	28.99	34.18	11.64	84.93	71.87	71.04
Abb	27.20	25.22	9.98	85.25	73.15	78.08

Table 26. (concl.)

Extensogram characteristics	"N_2" flour (stored under nitrogen at 50-60°F.)					
	0.250 N HCl		0.250 N CH_3COOH		0.250 N NH_4OH	
	0% NaCl	2% NaCl	0% NaCl	2% NaCl	0% NaCl	2% NaCl
	Storage, days					
	86		86		86	
Fa	9.00	7.30	1.15	5.95	6.75	5.75
Fb	9.65	7.25	1.30	5.83	7.25	6.05
Faa	7.15	6.30	-*	7.15	13.65	10.70
Fbb	7.20	6.15	-*	6.90	12.55	10.40
Ea	5.10	6.05	9.75	14.05	13.10	15.50
Eb	5.45	6.15	11.00	14.20	13.60	14.10
Eaa	6.05	6.10	-*	12.00	7.85	7.70
Ebb	5.85	6.25	-*	14.60	7.55	7.70
E_ta	6.10	6.05	11.90	16.20	14.80	15.80
E_tb	5.45	6.15	11.00	15.50	14.65	14.45
$E_t$aa	6.60	6.10	-*	14.10	7.85	8.25
$E_t$bb	5.85	6.80	-*	16.30	7.55	8.15
Aa	29.24	27.46	9.73	64.77	70.28	69.25
Ab	35.20	28.03	10.88	83.71	76.35	68.99
Aaa	28.35	27.20	-*	69.90	70.85	56.39
Abb	27.52	24.32	-*	76.54	64.96	55.36
	Storage, days					
	243		240		244	
Fa	10.15	7.45	1.80	7.40	11.25	7.05
Fb	9.55	7.85	1.50	8.20	11.60	7.20
Faa	7.95	8.00	1.20	7.75	13.55	13.70
Fbb	7.80	6.75	-*	7.90	13.60	12.75
Ea	5.45	6.15	11.80	15.30	11.00	15.15
Eb	5.10	6.25	10.85	14.05	11.25	13.20
Eaa	4.70	6.70	12.55	14.60	8.80	8.10
Ebb	5.35	6.60	-*	15.70	7.60	7.75
E_ta	5.45	6.15	12.45	16.75	11.95	15.15
E_tb	5.10	6.45	10.85	15.90	11.25	13.65
$E_t$aa	4.70	6.70	13.20	15.80	8.80	8.30
$E_t$bb	5.35	7.05	-*	17.30	7.60	8.35
Aa	34.24	27.71	16.51	84.48	88.70	85.71
Ab	31.30	30.85	13.31	81.28	94.21	72.94
Aaa	24.32	33.66	12.42	85.18	80.38	75.65
Abb	27.65	27.52	-*	91.07	65.15	63.68

* Smeared upon rounding and molding so no extensograms were taken.

Table 27. Effect of 0.250 N NH_4OH on extensograms of doughs with and without 2 percent NaCl whose flour was stored under different conditions of atmosphere and temperature.

Extensogram characteristics	0 percent NaCl				2 percent NaCl			
	Flour				Flour			
	"A"	"B"	"O_2"	"N_2"	"A"	"B"	"O_2"	"N_2"
	Storage, days							
	89	86	91	86	89	86	91	86
Fa	8.30	6.65	6.10	6.75	7.45	5.20	5.60	5.75
Fb	8.40	6.50	6.45	7.25	8.35	6.05	6.65	6.05
Faa	14.15	12.90	11.95	13.65	14.50	10.60	10.70	10.75
Fbb	12.85	13.05	12.20	12.55	15.00	11.25	9.60	10.40
Ea	14.35	13.50	13.30	13.10	11.80	14.70	9.60	15.50
Eb	14.25	13.35	11.55	13.60	11.90	13.45	10.65	14.10
Eaa	8.25	7.80	7.95	7.85	8.00	7.65	6.65	7.70
Ebb	8.05	8.20	6.05	7.55	7.60	7.70	7.75	7.70
$E_t a$	14.35	14.65	13.30	14.80	12.00	15.05	11.05	15.80
$E_t b$	14.80	14.10	12.40	14.65	11.90	14.60	11.35	14.45
$E_t aa$	8.25	7.80	8.55	7.85	8.00	7.65	7.50	8.25
$E_t bb$	8.05	8.20	6.05	7.55	7.60	8.00	8.05	8.15
Aa	93.18	71.36	64.41	70.28	69.18	61.00	42.75	69.25
Ab	86.91	68.99	58.75	76.35	76.03	64.90	53.89	68.99
Aaa	79.42	65.79	61.38	70.85	72.13	57.02	45.83	56.39
Abb	67.33	71.36	51.71	64.96	70.21	61.76	50.30	55.36
	Storage, days							
	182	161	125	161	182	161	125	161
Fa	10.50	7.70	7.85	8.65	9.85	6.30	6.65	6.60
Fb	11.90	8.15	8.50	8.45	10.70	6.70	6.60	7.40
Faa	14.95	14.35	12.15	13.80	14.70	13.25	12.10	12.55
Fbb	15.00	13.55	13.40	13.10	13.95	11.60	11.75	12.80
Ea	12.55	13.55	13.30	16.20	12.15	14.35	14.10	14.15
Eb	11.20	13.40	12.90	13.00	10.90	14.05	12.95	13.75
Eaa	7.70	8.10	7.90	8.30	7.90	8.40	8.10	7.75
Ebb	7.70	8.60	7.80	7.70	7.70	7.85	8.60	7.90
$E_t a$	12.55	14.40	14.25	16.20	12.90	15.05	15.05	15.50
$E_t b$	11.20	13.55	14.50	13.00	12.70	15.45	13.85	14.20
$E_t aa$	8.50	8.10	7.90	8.65	8.25	8.40	9.35	8.30
$E_t bb$	7.70	8.60	7.80	7.95	7.70	8.30	8.85	8.20
Aa	98.18	82.18	80.19	108.80	88.51	72.32	74.42	74.18
Ab	95.49	83.58	82.82	83.58	82.43	75.27	67.39	81.60
Aaa	76.22	79.68	62.27	72.59	72.19	77.38	63.75	64.45
Abb	70.21	78.21	70.85	65.60	65.92	62.20	70.02	68.02

Table 27. (concl.)

Extensogram characteristics	0 percent NaCl				2 percent NaCl			
	Flour				Flour			
	"A"	"B"	"O_2"	"N_2"	"A"	"B"	"O_2"	"N_2"
	Storage, days							
	200	206	182	206	200	206	182	206
Fa	11.45	8.35	8.60	8.10	10.20	6.80	6.80	6.90
Fb	12.80	9.75	9.10	9.05	10.95	7.30	7.55	7.10
Faa	15.20	13.35	13.60	12.30	14.50	11.70	13.45	13.70
Fbb	15.35	13.55	14.95	13.00	14.05	13.80	11.55	12.75
Ea	12.90	12.50	11.70	13.80	12.30	14.90	12.20	15.15
Eb	12.65	13.90	12.25	12.40	11.25	13.00	12.35	13.20
Eaa	9.20	7.55	9.05	8.50	8.20	8.00	8.10	8.10
Ebb	9.00	8.00	8.45	8.80	7.85	7.90	7.90	7.75
E_ta	13.45	14.75	12.05	14.45	12.70	15.75	13.50	15.15
E_tb	13.20	13.90	13.20	13.65	12.05	15.20	12.95	13.65
$E_t$aa	9.20	8.00	9.05	10.20	8.20	8.00	9.50	8.30
$E_t$bb	9.00	8.00	8.45	8.80	7.85	7.90	9.20	8.35
Aa	138.51	77.57	77.25	85.82	91.62	78.98	64.00	84.41
Ab	141.92	100.93	84.22	84.74	93.48	73.98	73.47	71.94
Aaa	96.24	64.96	78.14	76.29	70.23	63.36	73.09	75.65
Abb	96.78	71.42	79.30	75.58	67.36	72.19	59.65	63.68
	Storage, days							
	244	245	244	244	244	245	243	244
Fa	11.55	10.30	10.45	11.25	10.05	6.20	6.70	7.05
Fb	12.65	10.75	10.80	11.60	10.40	7.45	8.20	7.20
Faa	14.05	13.40	13.50	13.55	14.20	12.20	13.15	13.70
Fbb	13.95	13.75	14.10	13.60	14.25	12.55	14.30	12.75
Ea	12.85	11.65	12.20	11.00	12.40	14.15	14.20	15.15
Eb	12.45	11.40	11.55	11.25	11.45	13.60	13.50	13.20
Eaa	8.00	8.35	8.50	8.80	8.05	8.35	8.20	8.10
Ebb	7.95	7.85	8.20	7.60	7.80	8.45	8.50	7.75
E_ta	13.70	11.90	12.20	11.95	13.05	15.80	16.35	15.15
E_tb	13.95	11.60	11.55	11.25	12.90	14.10	13.90	13.65
$E_t$aa	8.55	8.35	8.50	8.80	8.25	9.05	9.50	8.30
$E_t$bb	8.30	7.85	8.20	7.60	7.80	9.20	8.50	8.35
Aa	139.23	90.67	92.80	88.70	91.04	70.38	76.16	85.71
Ab	140.61	92.81	90.37	94.21	92.67	81.32	87.49	72.94
Aaa	70.84	70.28	71.87	80.38	69.26	66.47	71.04	75.65
Abb	70.49	69.52	73.15	65.15	67.98	73.92	78.08	63.68

increased with storage. No overall statement concerning E and E_t values could be made without qualifying another variable. With storage, 0.250 N NH_4OH caused the most changes in extensogram values. Acetic acid gave intermediate values and mixes containing HCl were changed the least.

Effect of Storage. The effect of flour aging between three and eight months on extensogram values of doughs treated with various reagents with and without 2 percent NaCl whose flour was stored under different conditions of atmosphere and temperature is summarized in Table 28.

Effect of Salt. The effect of 2 percent sodium chloride on extensogram values of doughs treated with various reagents whose flour was stored under different conditions of atmosphere and temperature and for different periods is summarized in Table 29.

Effect of Storage Temperature. The effect of increased storage temperature on extensogram values of doughs treated with various reagents with and without 2 percent sodium chloride whose flour was stored for different periods is summarized in Table 30. Differences shown existed between samples stored at 50-60° F. and those maintained at 80° F.

Effect of Oxygen. The effect of oxygen as the storage atmosphere relative to the condition under nitrogen on extensogram values of doughs treated with various reagents with and without 2 percent sodium chloride whose flour was stored for different periods is summarized in Table 31.

Table 28. Effect of flour age on extensogram values of doughs treated with various reagents with and without 2 percent NaCl whose flour was stored under different conditions of atmosphere and temperature.[1]

Per-cent salt	Reagent 0.250 N	Flour	Extensogram value change due to flour storage from 3 to 8 months															
			F				E				E_t				A			
			a	b	aa	bb	a	b	aa	bb	a	b	aa	bb	a	b	aa	bb
0	HCl	A	i	i	d	i	i	i	i	i	i	i	i	i	i	i	i	i
		B	i	i	i	i	i	d	i	i	i	d	i	i	i	d	i	i
		O_2	i	i	d	i	i	i	d	i	d	d	d	d	i	i	d	i
		N_2	i	d	i	i	i	d	d	d	d	d	d	d	i	d	d	i
	Acetic	A	i	i	i	-	i	i	i	-	i	i	i	-	i	i	i	-
		B	i	i	i	-	i	i	i	-	i	i	i	-	i	i	i	-
		O_2	i	i	i	i	i	i	i	i	d	i	i	i	i	i	i	i
		N_2	i	i	i	-	i	d	i	-	i	d	i	-	i	i	i	-
	NH_4OH	A	i	i	d	i	d	d	d	d	d	d	i	d	i	i	d	i
		B	i	i	i	i	d	d	i	d	d	d	i	d	i	i	i	d
		O_2	i	i	i	i	o	o	i	i	d	d	d	i	i	i	i	i
		N_2	i	i	d	i	d	d	i	i	d	d	i	i	i	i	i	i
2	HCl	A	i	i	d	d	i	d	d	i	i	d	d	i	d	i	d	d
		B	i	i	i	i	i	i	o	d	d	i	d	i	i	i	i	i
		O_2	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i
		N_2	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i
	Acetic	A	i	i	d	d	i	i	i	i	i	i	i	i	i	i	i	i
		B	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i
		O_2	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i
		N_2	i	i	i	i	i	d	i	i	i	i	i	i	i	d	i	i
	NH_4OH	A	i	i	d	d	i	d	i	i	i	i	i	i	i	i	d	d
		B	i	i	i	i	d	i	i	i	i	d	i	i	i	i	i	i
		O_2	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i
		N_2	i	i	i	i	d	d	i	i	d	d	i	i	i	i	i	i

* Data derived from Table 26.
Explanation of symbols:
i = extensogram value increase
d = extensogram value decrease
o = no change

Table 29. Effect of 2 percent sodium chloride on extensogram values of doughs treated with various reagents whose flour was stored under different conditions of atmosphere and temperature and for different periods.[1]

Storage (months)	Reagent 0.250 N	Flour	Extensogram value change due to 2 percent salt															
			F				E				E_1				A			
			a	b	aa	bb	a	b	aa	bb	a	b	aa	bb	a	b	aa	bb
3	HCl	A	d	d	d	d	i	i	i	i	i	i	i	i	d	i	d	d
		B	d	d	d	d	i	o	i	i	i	o	i	i	i	d	d	d
		O_2	d	d	d	d	i	i	d	i	i	i	i	i	d	d	d	d
		N_2	d	d	d	d	i	i	i	i	d	i	d	d	d	d	d	d
	Acetic	A	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i
		B	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i
		O_2	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i
		N_2	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i
	NH_4OH	A	d	d	i	i	d	d	d	d	d	d	d	d	d	d	d	i
		B	d	d	d	d	i	i	d	d	i	i	d	d	d	d	d	d
		O_2	d	i	d	d	d	d	d	i	d	d	d	i	d	d	d	d
		N_2	d	d	d	d	i	i	d	i	i	d	i	i	d	d	d	d
8	HCl	A	d	d	d	d	i	i	i	i	i	i	i	i	d	d	d	d
		B	d	d	d	d	i	i	d	i	i	i	i	i	d	d	d	d
		O_2	d	d	i	d	i	i	i	i	i	i	i	i	d	d	i	d
		N_2	d	d	i	d	i	i	i	i	i	i	i	i	d	d	i	d
	Acetic	A	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i
		B	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i
		O_2	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i
		N_2	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i
	NH_4OH	A	d	d	i	i	d	d	i	i	d	d	d	d	d	d	d	d
		B	d	d	d	d	i	i	o	o	i	i	i	i	d	d	d	i
		O_2	d	d	d	i	i	i	d	d	d	d	i	i	d	d	d	i
		N_2	d	d	i	d	i	i	d	d	i	i	d	i	d	d	d	d

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[1] Data derived from Table 26.
Explanation of symbols: i = extensogram value increase
d = extensogram value decrease
o = no change

Table 30. Effect of increased storage temperature on extensogram values of doughs treated with various reagents with and without 2 percent sodium chloride whose flour was stored for different periods.[1]

Storage (months)	Percent NaCl	Reagent	Extensogram value change due to increased storage temperature															
			F				E				E_t				A			
			a	b	aa	bb	a	b	aa	bb	a	b	aa	bb	a	b	aa	bb
3	0	HCl	d	i	i	i	d	d	d	i	d	d	d	i	d	d	o	i
		Acetic	i	-	-	-	i	-	-	-	i	-	-	-	i	-	-	-
		NH_4OH	i	i	i	d	d	i	i	d	d	i	i	d	i	i	i	d
	2	HCl	d	d	i	i	d	i	i	d	d	i	i	d	d	i	i	i
		Acetic	d	i	i	i	d	d	i	i	d	d	i	d	d	d	i	i
		NH_4OH	i	i	i	i	d	d	i	d	d	d	i	d	i	i	d	i
8	0	HCl	d	d	d	d	d	i	d	i	d	i	i	i	d	d	d	i
		Acetic	d	i	i	-	d	d	i	-	i	d	d	-	d	d	i	-
		NH_4OH	i	i	i	i	i	i	d	d	i	i	i	i	i	i	i	i
	2	HCl	d	d	d	d	d	d	i	d	d	d	d	d	d	d	d	d
		Acetic	d	d	d	i	d	i	i	i	d	d	d	d	d	d	i	d
		NH_4OH	i	i	i	i	d	d	d	d	d	d	d	d	i	i	i	d

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[1] Data derived from Table 26.
Explanation of symbols: i = extensogram value increase
d = extensogram value decrease
o = no change

Table 31. Effect of oxygen in the storage atmosphere on extensogram values of doughs treated with various reagents with and without 2 percent salt whose flour was stored for different periods.[1]

Storage (months)	Percent NaCl	Reagent 0.250 N	Extensogram value change due to oxygen															
			F				E				E_t				A			
			a	b	aa	bb	a	b	aa	bb	a	b	aa	bb	a	b	aa	bb
3	0	HCl	i	d	i	i	d	i	d	d	d	i	d	d	d	d	i	d
		Acetic	d	i	-	-	i	d	-	-	d	i	-	-	i	d	-	-
		NH_4OH	d	i	d	d	i	d	i	d	d	d	i	d	d	d	d	d
	2	HCl	d	d	d	d	d	d	d	d	d	i	d	d	i	i	d	d
		Acetic	d	o	d	d	d	d	i	d	d	d	d	d	d	d	d	d
		NH_4OH	d	i	o	d	d	d	d	i	d	d	d	d	d	d	d	d
8	0	HCl	d	i	o	i	d	i	i	o	d	i	i	o	d	i	i	d
		Acetic	o	i	i	i	d	i	d	i	d	i	d	i	d	i	d	i
		NH_4OH	d	d	d	i	i	i	d	d	i	i	d	i	i	d	d	i
	2	HCl	i	i	i	d	d	o	d	d	d	i	d	d	i	i	i	d
		Acetic	d	d	i	d	d	i	i	d	d	d	i	d	d	d	d	d
		NH OH	d	i	d	i	d	i	i	i	i	i	i	i	d	i	d	i

[1] Data derived From Table 26.
Explanation of symbols: i = extensogram value increase
d = extensogram value decrease
o = no change

Hydrogen Sulfide Study

The effect of mixing atmosphere and various reagents on untreated and Agenized flour stored under an atmosphere of hydrogen sulfide was studied.

Effect of Mixing Atmosphere. The effect of mixing atmos- on farinograms and extensograms of both untreated and treated flour (Agenized to commercial levels) is recorded in Table 32.

1. Effect on Untreated Flour. For the untreated flour the absorption (61.2) with 2 percent salt that was used throughout the Storage Study was employed, and the dough was mixed 3 minutes and 15 seconds, which was the optimum mixing time determined when the storage of the flour began. It was decided to do the farinograph mixing under oxygen in order to decrease the slackening effect of the H_2S as much as possible. Even so the dough of the oxygen mix was so sticky that it could be neither rounded nor molded. The farinogram height for this dough, however, was 510, the farinogram width was 1.05 and the H/W value was 486.

In order to change the handling condition of the dough enough to be able to make extensograph determinations, it was decided to decrease the absorption, keeping the mixing time as invariant. The absorption had to be lowered to 55.0 percent (with 2 percent NaCl) before a dough could be handled; even so the second stretch of this dough was too sticky to be rounded and molded. Second duplicate F and A_1 values were larger than

Table 32. Effect of storage under H_2S atmosphere upon farinograms and extensograms of untreated and Agenized flour doughs mixed in the farinograph using various absorptions and mixing atmospheres.[1]

Curve characteristics	Control flour[2] ("B" flour, stored 88 days, O_2 mix, 61.2 % absorption)	Untreated flour		Agenized flour	
		O_2 mix, 61.2 % absorption	O_2 mix, 55.0 % absorption	O_2 mix, 61.2 % absorption	N_2 mix, 61.2 % absorption
		Farinogram values			
H	570	510	705	580	575
W	1.60	1.05	1.25	1.15	1.10
H/W	356	486	564	504	523
		Extensogram values			
Fa	4.70	*	0.95	1.45	1.05
Fb	4.95		1.05	1.75	0.95
Faa	9.40		*	2.55	1.05
Fbb	9.55		*	2.35	1.20
E_1a	-		1.25	7.20	7.80
E_1b	-		1.25	6.75	9.95
E_1aa	-		*	5.75	9.80
E_1bb	-		*	5.95	10.65
E_2a	-		15.60	11.05	12.05
E_2b	-		15.15	10.40	12.75
E_2aa	-		*	12.70	10.50
E_2bb	-		*	11.30	9.45
Ea	18.10		16.85	18.25	19.95
Eb	18.00		16.40	17.15	22.70
Eaa	13.20		*	18.45	20.30
Ebb	13.40		*	17.25	20.10
E_ta	18.75		16.85	19.05	20.40
E_tb	18.15		16.40	18.85	22.70
$E_t$aa	13.25		*	18.45	22.10
$E_t$bb	13.40		*	21.45	24.30
A_1a	-		0.77	9.54	7.80
A_1b	-		0.96	10.24	9.15
A_1aa	-		*	11.70	10.18
A_1bb	-		*	11.14	12.42
Aa	63.23		7.24	24.65	19.71
Ab	66.30		6.20	26.69	20.86
Aaa	88.64		*	36.29	20.28
Abb	86.91		*	32.26	23.49

Table 32. (concl.)[1]

Curve characteristics	Control flour[2] ("B" flour, stored 88 days, O_2 mix, 61.2 % absorption	Untreated flour		Agenized flour	
		O_2 mix, 61.2 % absorption	O_2 mix, 55.0 % absorption	O_2 mix, 61.2 % absorption	N_2 mix, 61.2 % absorption
E_1a-E_2a	-	#	-14.35	-3.85	-4.15
E_1b-E_2b	-	#	-13.90	-3.65	-2.80
E_1aa-E_2aa	-	#	#	-6.95	-0.70
E_1bb-E_2bb	-	#	#	-5.35	1.20

[1] This flour was used after it had been stored 94 days under an H_2S atmosphere at 50-60° F. The mixing time was 3 minutes, 15 seconds. Two percent NaCl was used.

[2] These data were obtained from the Storage Study whose E_1, E_2 and A_1 values were not determined.

\# These doughs were so sticky that they smeared upon molding and could not be stretched.

first duplicate F and A values, and first duplicate E_1, E_2, E, E_t and A values were larger than second duplicate values. Both duplicates gave extensogram reversals. The farinograph height for this dough was 705, the width 1.25 and the H/W value was 564.

2. Effect on Agenized Flour. Treatment with Agene had conditioned the H_2S stored flour enough so that 61.2 percent absorption (with 2 percent salt) gave doughs which could be rounded and molded, so the effect of mixing atmosphere was studied, using N_2 and O_2 mixing atmospheres. Oxygen increased farinogram height and width, yet decreased the H/W value.

Oxygen increased all F, second stretch E_2, first stretch A_1, first duplicate-second stretch A_1 and all A values. Oxygen decreased all E_1, first stretch E_2, all E, all E_t and second duplicate-second stretch A_1 values. Oxygen decreased the extent of extensogram reversal in first stretch mixes and increased it in second stretch mixes. Both O_2 and N_2 mix second stretch F values were larger than first stretch values. First stretch O_2 mix E_1 values were smaller than second stretch O_2 mix values, while for N_2 mix the opposite was true, second stretch E_1 values being larger than first stretch values. E_2 values were opposite E_1 values. There was a tendency for both O_2 and N_2 mix second stretch E and E_t values to be larger than first stretch values. Both O_2 and N_2 second stretch A_1 and A values were larger than first stretch values. For O_2 mixes second stretch extensogram curve reversals were more extreme, while for N_2 mixes the opposite was true, first stretch extensogram curve reversals being more extreme than second stretch.

Effect of Various Reagents. The effect of various reagents on extensograms of untreated and Agenized flour is recorded in Table 33.

1. Effect of Agenizing. Agenizing a flour previous to storage under H_2S caused F and E_1 values of doughs treated with 0.250 N HCl to double, E_2 values to decrease slightly, E values to remain unchanged, E_t values to increase slightly, and A values to more than double. The reversal of the extensogram peak was less apparent with the Agenized flour.

Table 33. Effect on extensograms of acid and alkali with and without 2 percent NaCl with untreated and Agenized flour stored under H_2S and mixed in air with the Hobart-Swanson mixer.[1]

Extensogram value	Untreated flour: 0.250 N HCl No NaCl	Agenized flour: 0.250 N HCl No NaCl	0.250 N HCl NaCl	0.250 N CH_3COOH NaCl	0.250 N NH_4OH NaCl	0.250 N NH_4OH No NaCl
Fa	1.85	4.25	7.00	6.70	5.15	6.30
Fb	*	4.40	7.25	6.75	5.30	6.30
Faa	1.20	3.95	6.75	8.05	7.60	8.70
Fbb	*	4.40	6.85	8.65	7.10	8.05
E_1a	1.90	2.80	3.75	8.10	7.00	5.80
E_1b		2.55	3.65	8.40	6.25	6.00
E_1aa	1.65	2.95	3.70	6.85	5.90	5.85
E_1bb	*	3.20	3.90	7.35	5.05	5.50
E_2a	4.50	3.75	3.10	3.35	5.40	4.15
E_2b	*	3.65	2.60	4.35	4.50	4.30
E_2aa	4.80	3.35	2.65	3.25	3.00	2.60
E_2bb	*	3.40	2.95	2.65	2.50	2.20
Ea	6.40	6.55	6.85	11.45	12.40	9.95
Eb	*	6.20	6.25	12.75	10.75	10.30
Eaa	6.45	6.30	6.35	10.10	8.90	8.45
Ebb	*	6.60	6.85	10.00	7.55	7.70
E_ta	6.40	6.75	6.85	13.00	13.20	10.20
E_tb	*	6.70	7.15	12.75	12.40	11.00
E_taa	6.45	6.65	6.35	10.10	8.90	9.95
E_tbb	*	7.05	6.86	11.05	7.75	8.05
Aa	7.42	18.74	32.58	58.43	51.52	49.73
Ab	*	18.21	30.40	64.70	45.47	50.69
Aaa	4.86	16.32	28.86	56.32	47.48	53.05
Abb	*	19.56	31.23	61.25	37.76	44.29
E_1a-E_2a	-2.60	-0.95	0.65	4.75	1.60	1.65
E_1b-E_2b	*	-1.10	1.05	4.05	1.75	1.70
E_1aa-E_2aa	-3.15	-0.40	1.05	3.60	2.90	3.25
E_1bb-E_2bb	*	-0.20	0.95	4.70	2.55	3.30

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[1] This flour was used after it had been stored 96 days under an H_2S atmosphere at 50-60o F. With 0 percent NaCl mixes, the absorption was 62.9 percent. With 2 percent NaCl mixes, the absorption was 61.2 percent. The mixing time was 1 minute and 5 seconds.

* These doughs were so sticky that they smeared upon molding and could not be stretched.

2. Effect of NaCl. The addition of 2 percent NaCl in conjunction with 0.250 N HCl to dough of the Agenized flour stored under H_2S caused F and E_1 values to increase, E_2 values to decrease, E and E_t values to increase slightly and A values to approximately double. The addition of the salt caused the extensogram peak reversal to disappear.

3. Effect of NaCl and NH_4OH. The addition of 2 percent salt in conjunction with 0.250 N ammonium hydroxide to dough of the Agenized flour stored under hydrogen sulfide caused F values to decrease, and E_1, E_2, E and E_t values to increase with the exceptions of second duplicate-second stretch E_1, E and E_t values and first duplicate-second stretch E_t values where decreases occurred with inclusion of salt. With inclusion of salt, first duplicate-first stretch A values increased while all others decreased, the amount of decrease being 5.22 for second duplicate-first stretch dough, 5.57 for first duplicate-second stretch dough and 6.53 for second duplicate-second stretch dough. Salt caused a decrease in second stretch E_1-E_2 values while first stretch E_1-E_2 values remained unchanged.

4. Comparison of Effects. In comparing the effects of 0.250 N HCl, 0.250 N acetic acid and 0.250 N NH_4OH used in conjunction with 2 percent NaCl on doughs of Agenized flour stored under H_2S, it was found that first stretch F values were largest with HCl, intermediate with acetic acid and lowest with NH_4OH, while for second stretch F values acetic acid gave the largest values, ammonium hydroxide gave intermediate and hydrochloric

acid gave the smallest values. E_1, E, E_t and A values were largest for acetic acid, intermediate for NH_4OH and smallest for HCl for both first and second stretch doughs. For first stretch E_2 values NH_4OH values were largest, acetic acid intermediate and HCl values smallest while no overall statement concerning second stretch values could be made with differentiating dough duplicates. E_1-E_2 values for both dough stretches were largest for acetic acid, intermediate for NH_4OH and smallest for HCl.

5. Comparison of Dough Stretches. First stretch F values were larger than second stretch F values for HCl-0 percent NaCl mixes and HCl-2 percent NaCl mixes, while for acetic acid-2 percent NaCl, NH_4OH-2 percent and NH_4OH-0 percent NaCl mixes the opposite was true, second stretch mixes being larger than first stretch mixes. There was a tendency for first stretch E_1 values to HCl-0 percent salt and HCl-2 percent salt to be smaller than second stretch values, while for acetic acid-2 percent NaCl, NH_4OH-2 percent NaCl and NH_4OH-0 percent NaCl the opposite was true, second stretch mixes being smaller than first stretch mixes. First stretch E_2 values were larger than second stretch E_2 values for all mixes. First stretch E values were larger than second stretch E values for acetic acid-2 percent NaCl, NH_4OH-2 percent NaCl and NH_4OH-0 percent NaCl. No overall statement concerning HCl-0 percent NaCl and HCl-2 percent NaCl mixes could be made without qualifying the dough duplicate. First stretch A values were larger than second stretch A values

for acetic acid-2 percent salt and NH_4OH-2 percent salt mixes. No overall statement concerning HCl-0 percent NaCl, HCl-2 percent NaCl and NH_4OH-0 percent NaCl mixes could be made without qualifying the dough duplicate. For HCl-0 percent NaCl mixes, first stretch mixes gave more intense extensogram reversals than did second stretch mixes. For NH_4OH-2 percent NaCl and NH_4OH-0 percent NaCl mixes, second stretch mixes gave more "normal" extensogram peaks than did first stretch mixes. For HCl-2 percent salt and acetic acid-2 percent salt mixes, no overall statement could be made without qualifying the dough duplicate.

Comparison with Control Flour. The storage of untreated flour under hydrogen sulfide significantly decreased all farinogram and extensogram values, with the single exception with F/W values when a significant increase occurred, when compared with the control flour.

Absorption-Storage Study

In this study the objectives were to find the effect of storage time on the optimum absorption of a flour, and to find the effect of storage temperature and sub-optimum absorption on farinograms and extensograms of flour-water systems. Only first stretch extensograms were taken.

Effect of Storage Time. The data used to determine the effect of storage time on the optimum absorption were obtained from the Storage Study, Sodium Chloride Study and Potassium

Bromate Study, as recorded in Table 34.

Table 34. Effect of storage time on optimum absorption and mixing time of "B" flour-water systems.

Storage (days)	Optimum absorption	Mixing time (minutes)
0	62.9	$2\frac{1}{2}$
129	64.0	$3\frac{1}{4}$
255	65.0	5

From the data in Table 34, it will be seen that optimum absorption and mixing time increase as the age of the flour increases.

Effect of Storage Temperature and Sub-optimum Absorption. The effect of storage temperature and sub-optimum absorption on farinograms and extensograms of doughs of flour-water systems is recorded in Table 35.

1. Effect of Storage Temperature. No significant differences due to the effect of storage temperature were found for farinogram values and for extensogram F, E and A values. "A" flour E_1 and E_t values were larger and "A" flour E_2 values were smaller than the respective "B" flour values. "A" flour extensogram peak values were more "normal" than those of "B" flour.

2. Effect of Sub-optimum Absorption. The effect of sub-optimum absorption on "A" flour was to increase farinogram H, W and H/W values; to increase extensogram F, E_2 and A values; and to decrease extensogram E_1 values. No significant changes in E

Table 35. Effect of storage temperature and sub-optimum absorption on farinograms and extensograms of flour-water systems.[1]

	"A" flour			"B" flour		
	Absorption (percent)			Absorption (percent)		
character-istics	62.9	52.9		62.9	52.9	
		1st replicate	2nd replicate		1st replicate	2nd replicate
			Farinogram values			
H	505	920	925	500	930	920
W	1.60	2.45	2.55	1.60	2.55	2.40
H/W	316	376	362	313	365	383
			Extensogram values			
Fa	1.05	2.70	2.70	0.95	1.35	1.40
Fb	0.95	2.50	2.40	1.00	1.40	1.30
E_1a	11.55	2.95	2.30	10.50	2.50	2.35
E_1b	11.70	2.45	2.65	10.45	2.30	2.30
E_2a	5.05	13.85	12.30	6.25	10.15	11.15
E_2b	5.25	15.40	14.20	6.40	11.40	11.20
Ea	16.60	16.80	15.60	16.70	12.65	13.50
Eb	16.95	17.85	16.85	16.85	13.70	13.50
E_ta	17.50	17.30	16.00	16.70	13.05	13.50
E_tb	17.45	18.35	17.30	16.95	13.70	13.50
Aa	15.62	38.72	35.33	15.94	15.10	16.10
Ab	16.51	40.19	36.67	16.27	16.32	16.01
E_1a-E_2a	6.50	-10.90	-10.00	4.25	-7.60	-8.80
E_1b-E_2b	5.45	-12.95	-11.55	4.05	-9.10	-8.90

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[1] Flour stored 13 days and air mixed for 2½ minutes.

and E_t values were found. Sub-optimum absorption caused distinct extensogram peak reversals. On "B" flour, the effect of sub-optimum absorption was to increase farinogram H, W and H/W values; to increase F and E_2 values; and to decrease E_1, E and E_t values. No significant changes in A values were found. Sub-optimum absorption caused distinct extensogram peak reversals.

3. Comparison of "A" and "B" Flour Values of Doughs Having Sub-optimum Absorption. No differentiation of farinograms could be made. "A" flour F and E_2 values increased more than did "B" flour F and E_2 values. "A" flour E_1 values decreased more than "B" flour E_1 values. "A" flour E and E_t values remained the same while "B" flour values decreased, and "A" flour A values increased while "B" flour values remained the same. Extensogram peak reversals were more extreme for the "A" flour than they were for the "B" flour.

Dough Handling Characteristics

The objective of this study was to determine whether a method of qualitative observation as developed in this study could detect differences in flours and doughs having different treatments, and whether these differences, if present, are correlated in any manner with farinograms and extensograms. Examples of typical changes are recorded below.

Effect of Storage Atmosphere. The effect of storage atmosphere on dough handling characteristics in the case of the untreated flour used in the Storage Study is recorded in Table 37. The mixing atmosphere either masked or augmented the trends due to storage atmosphere and storage temperature. With oxygen in the storage atmosphere, the dough became less stiff for oxygen mixes and more adhesive with nitrogen mixes. The dough cylinder became slightly shorter with nitrogen mixes, and the shape of the dough after molding became cylindrical instead of remaining concave with oxygen mixes.

Effect of Storage Temperature. With flour stored under a higher temperature (80° F. instead of 50-60° F.) the dough became slightly more wet in all three mixing atmospheres, slightly more limp for oxygen and nitrogen mixes, and slightly more cohesive for oxygen mixes as recorded in Table 37. The length of the dough cylinder increased for all three mixing atmospheres with the higher temperature, and the dough changed in shape after molding from concave to cylindrical with oxygen and air as mixing atmospheres.

Effect of Salt. The effect of salt on dough handling characteristics in the case of the untreated flour used in the Potassium Bromate Study is recorded in Table 38. Increased salt made the dough appear wetter, although increase in oxygen in the mixing atmosphere retarded this appearance. Increased salt resulted in stiffer doughs. Cohesiveness increased throughout the range of salt increase for nitrogen mixed doughs, but with air and oxygen-mixed doughs cohesiveness increased with salt

Table 37. Quantitative evaluation of the effect of storage atmosphere and storage temperature on dough handling characteristics.

Observation	Flour											
	"N_2" stored 291 days			"O_2" stored 292 days			"B" stored 295 days			"A" stored 300 days		
	Mixing atmosphere			Mixing atmosphere			Mixing atmosphere			Mixing atmosphere		
	O_2	Air	N_2	O_2	Air	N_2	O_2	Air	N_2	O_2	Air	N_2
Moisture condition												
After mixing	+1	0	0	+1	0	0	0	0	0	-1	-1	-1
After 1st rounding	+1	+1	0	+1	+1	0	0	0	0	0	0	0
After 2nd rounding	+1	0	0	+1	0	0	0	0	0	0	0	0
Extensibility												
After mixing	-1	-1	-1	-1	-1	-1	-1	0	0	+1	0	0
After 1st rest	0	-1	-2	-1	-1	-2	0	-1	-2	0	-1	-1
After 2nd rest	+1	0	-1	+1	0	-1	0	0	-1	+1	0	-1
Stickiness												
After mixing	-1	0	0	-1	0	-1	0	-1	-1	+1	-1	-1
After 1st rounding	-1	0	0	-1	0	-1	-1	-1	-1	0	-1	-1
After 2nd rounding	0	+1	0	0	+1	-1	+1	0	0	+1	0	0
Color												
After mixing	+1	+1	+1	+1	+1	+1	0	0	0	0	0	0
After 2nd stretch	+1	+1	+1	+1	+1	+1	0	0	0	0	0	0
Surface of dough ball												
After 1st rounding	+2	+2	+1	+2	+2	+1	+1	+1	+1	+1	+1	+1
After 2nd rounding	+2	+1	+1	+2	+1	+1	+1	+1	+1	+1	+1	+1

Table 37. (concl.)

Observation	Flour											
	"N_2" stored 291 days			"O_2" stored 292 days			"B" stored 295 days			"A" stored 300 days		
	Mixing atmosphere			Mixing atmosphere			Mixing atmosphere			Mixing atmosphere		
	O_2	Air	N_2	O_2	Air	N_2	O_2	Air	N_2	O_2	Air	N_2
Length of dough cylinder												
After 1st molding	+2	+1	+1	+2	+1	0	0	0	0	+1	+1	+1
After 2nd molding	0	0	+1	0	0	0	0	0	0	0	0	0
Shape of dough cylinder												
After 1st molding	+1	+1	0	+1	+1	0	+1	+1	0	0	0	0
After 2nd molding	+1	0	0	0	0	0	+1	0	0	0	0	0

until a reversal in the trend of physical properties was reached after which further increase in salt concentration caused the doughs to become adhesive again. Salt had no effect upon the color of the dough. The surface of the dough ball became smoother and the length of the dough cylinder became less with increased salt until a reversal in the trend of the physical properties was reached after which further increase in salt concentration caused the surface of the dough ball to become rougher and the length of the dough cylinder to increase again. With increased salt, the molded dough became convex in shape until a reversal in the trend of the physical properties was reached after which further increase in salt caused the molded dough to again assume a concave shape.

Effect of Bromate. The effect of salt on dough handling characteristics in the case of the non-agenized flour used in the Potassium Bromate Study is recorded in Table 38. With increased bromate doughs became wetter, less limp, more cohesive, smoother, shorter in length, and more concave. Increased bromate changed the color of the dough from creamy to white. (The addition of NH_4OH on the other hand changed the color of the dough from the same flour from a creamy to a yellow-green color.)

Effect of Mixing Atmosphere. The effect of increased oxygen on dough handling characteristics in the case of non-agenized flour used in the Potassium Bromate Study is recorded in Table 36. With increased oxygen in the mixing atmosphere doughs became longer and slightly more concave. No other change was

Table 38. Evaluation of qualitative changes in dough handling characteristics in the potassium bromate study.

I. Mixed in Oxygen

Observation	NaCl, percent														
	0			1			5			10			15		
	$KBrO_3$, mg			$KBrO_3$, mg			$KBrO_3$, mg			$KBrO_3$, mg			$KBrO_3$, mg		
	0	3	30	0	3	30	0	3	30	0	3	30	0	3	30
Moisture condition															
After mixing	+1	+1	-1	+1	0	0	0	0	-1	0	-1	-1	0	-1	-1
After 1st rounding	+1	0	0	0	0	0	0	0	0	0	0	-1	0	0	-1
After 2nd rounding	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Extensibility															
After mixing	-2	-1	-1	-1	-1	0	0	0	0	+1	+1	+1	+1	+1	+1
After 1st rest	-1	-1	-1	0	0	0	0	0	0	0	0	0	+1	+1	+1
After 2nd rest	-1	-1	-1	0	0	0	0	0	0	0	0	0	0	0	0
Stickiness															
After mixing	-1	-1	-1	+1	+1	+1	+2	+2	+2	0	0	0	-1	-1	-1
After 1st rounding	-1	-1	-1	+1	+1	+1	+2	+2	+2	+1	+1	+1	-1	-1	-1
After 2nd rounding	-1	-1	-1	+1	+1	+1	+2	+2	+2	+1	+1	+1	0	0	0
Color															
After mixing	0	0	0	0	0	+1	0	0	+1	0	0	+1	0	0	+1
After 2nd stretch	0	0	0	0	0	+1	0	0	+1	0	0	+1	0	0	+1
Surface of dough ball															
After 1st rounding	-1	-1	+1	+1	+2	+2	+1	+2	+2	+1	+1	+1	-1	-1	-1
After 2nd rounding	+1	+1	+1	+1	+2	+2	+2	+2	+2	+2	+1	+1	+1	+1	+1
Length of dough cylinder															
After 1st molding	+2	+1	+1	+1	0	0	0	-1	-1	-1	-1	0	0	+1	+1
After 2nd molding	+2	+1	+1	+1	0	0	0	-1	-1	-2	-1	-1	0	+1	+1
Shape of dough cylinder															
After 1st molding	+1	+1	+1	0	+1	+1	0	0	0	+1	+1	-1	+1	+1	0
After 2nd molding	0	+1	+1	0	+1	+1	0	0	0	+1	+1	0	+1	0	0

Table 38. (cont.)

II. Mixed in Air

Observation	NaCl, percent														
	0			1			5			10			15		
	$KBrO_3$, mg			$KBrO_3$, mg			$KBrO_3$, mg			$KBrO_3$, mg			$KBrO_3$, mg		
	0	3	30	0	3	30	0	3	30	0	3	30	0	3	30
Moisture condition															
After mixing	+1	+1	0	0	0	-1	-1	-1	0	-1	-2	0	-1	-1	-2
After 1st rounding	0	0	0	0	0	0	0	0	0	0	-1	-1	-1	-2	-1
After 2nd rounding	0	0	0	0	0	0	0	0	0	0	0	0	-1	-1	-1
Extensibility															
After mixing	-2	-1	-1	-1	0	0	-1	0	0	0	0	+1	+1	+1	+1
After 1st rest	-1	-2	-1	0	0	0	0	0	0	0	+1	0	+1	+1	0
After 2nd rounding	-1	-1	-1	-1	0	0	0	0	0	0	0	0	0	0	0
Stickiness															
After mixing	-2	-2	-1	-1	-1	-1	0	0	0	0	-1	-1	-1	-2	-2
After 1st founding	-2	-2	-1	-1	0	0	0	0	0	0	-1	-1	-1	-2	-2
After 2nd rounding	-2	-2	-1	-1	0	0	0	0	0	0	0	0	-1	-1	-1
Color															
After mixing	0	0	0	0	0	0	0	0	+1	0	0	+1	0	0	+1
After 2nd stretch	0	0	0	0	0	0	0	0	+1	0	0	+1	0	0	+1
Surface of dough ball															
After 1st rounding	-1	-1	+1	+1	+1	-1	+1	+1	+1	-1	-1	-2	-1	-2	-2
After 2nd rounding	+1	+1	+1	+2	+1	+1	+2	+1	+1	+1	+1	+1	+1	-1	-1
Length of dough cylinder															
After 1st molding	+1	+1	+1	0	-1	0	-1	-2	-1	0	+1	0	+1	+1	+1
After 2nd molding	+2	+1	+1	0	-1	-1	-1	-2	-1	-1	0	0	+1	+1	+1
Shape of dough cylinder															
After 1st molding	0	0	+2	-1	-1	+1	-1	-1	0	0	0	-1	0	0	0
After 2nd molding	0	+1	-1	-1	-1	0	-1	-1	0	0	0	-1	0	0	0

Table 38. (concl.)

III. Mixed in Nitrogen

Observation	NaCl, percent 0			1			5			10			15		
	$KBrO_3$, mg 0	3	30	$KBrO_3$, mg 0	3	30	$KBrO_3$, mg 0	3	30	$KBrO_3$, mg 0	3	30	$KBrO_3$, mg 0	3	30
Moisture condition															
After mixing	+2	+1	0	0	-1	0	0	-1	-1	-1	-2	-2	-2	-2	-2
After 1st rounding	+1	0	0	0	0	0	0	0	-1	0	-1	-1	-2	-2	-1
After 2nd rounding	0	0	0	0	0	0	0	0	0	0	0	0	-1	-1	0
Extensibility															
After mixing	-2	-1	-1	-1	0	-1	0	0	0	0	+1	+1	+1	+1	+2
After 1st rest	-1	-1	0	-1	-1	0	0	0	0	0	0	0	+1	+1	0
After 2nd rest	-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Stickiness															
After mixing	-1	-1	-1	-1	0	-1	0	0	0	+1	+1	+1	+1	+1	+2
After 1st rounding	-1	-1	0	-1	-1	0	0	0	0	+1	+1	0	+1	+1	+1
After 2nd rounding	-1	-1	0	0	0	0	0	0	0	+1	+1	0	0	0	0
Color															
After mixing	0	0	0	0	0	0	0	0	0	0	0	0	0	0	+1
After 2nd stretch	0	0	0	0	0	0	0	0	0	0	0	0	0	0	+1
Surface of dough ball															
After 1st rounding	-1	-1	-1	-1	+1	+1	-2	+1	+1	-2	-2	-1	-2	-2	-1
After 2nd rounding	+1	+1	+1	+1	+2	+1	+1	+2	+1	+1	+1	+1	+1	+1	+1
Length of dough cylinder															
After 1st molding	+1	+1	+1	0	-1	0	-2	-2	-1	0	+1	0	+1	+1	+1
After 2nd molding	+1	0	0	0	-1	-1	-2	-2	-1	0	0	0	+1	+1	+1
Shape of dough cylinder															
After 1st molding	0	0	+2	-1	-1	+1	-1	-1	0	0	0	-1	0	0	0
After 2nd molding	0	+1	+1	-1	-1	+1	-1	-1	0	0	0	-1	0	0	0

noticeable.

Effect of Hydrogen Sulfide. Change effected in dough handling characteristics by storage of non-agonized flour under an atmosphere of hydrogen sulfide is shown in Table 39. Hydrogen sulfide made the dough very wet, runny, and adhesive. It changed the color of the dough from a creamy to a white color, pitted the surface of the dough ball, and made the molded dough very long and concave.

Table 39. Evaluation of qualitative changes in dough handling characteristics due to storage under hydrogen sulfide on untreated flour mixed in air.

Observation	"Normal" dough	Dough from flour stored under hydrogen sulfide
Moisture condition		
After mixing	0	-1
After 1st rounding	0	-1
After 2nd rounding	0	-2
Extensibility		
After mixing	0	-2
After 1st rest	0	-3
After 2nd rounding	0	-4
Stickiness		
After mixing	0	-2
After 1st rounding	0	-3
After 2nd rounding	+1	-3
Color		
After mixing	0	+1
After 2nd stretch	0	+1
Surface of dough ball		
After 1st rounding	+1	-2
After 2nd rounding	+1	-2
Length of dough cylinder		
After 1st molding	0	+2
After 2nd molding	0	+2
Shape of dough cylinder		
After 1st molding	0	+2
After 2nd molding	0	+2

DISCUSSION AND CONCLUSIONS

The fundamental physical properties responsible for the behavior of a dough in the extensograph are elastic deformation and plastic flow. Since both properties are involved simultaneously throughout most of the stretching, the extensograph curve is a reflection of both properties rather than of each singly. In the extensogram, measurements of elastic deformation are force values, and until the elastic limit of the dough has been exceeded, there is a dynamic tension present which, if permitted, would tend to return the dough to its original form. Extensibility, on the other hand, is plastic flow, and, although energy is required to perform plastic flow, there is no internal force present which would tend to return the dough to its original form. Thus elastic deformation is reversible while plastic flow is irreversible. A steel spring classically exhibits properties of elastic deformation. A straight line with slope proportional to the stiffness of the spring would be drawn until the elastic limits were reached after which there would be a sharp, almost perpendicular drop in the curve. A classical example of plastic flow, to be facetious, is a strand of molasses in January. With this there is the abrupt initial rise in the extensogram, due partially to the inertia of the extensograph, but, primarily, due to the cohesive forces between the molecules of the molasses, this being their reaction to the physical passage of the dough hook through them. Once the reaction of the cohesive forces has been overcome, the initial rise in the curve is followed by a gradual decline in the curve picturing plastic flow as the strand becomes thinner with elongation. If the strand exhibited perfect plastic flow, there would be no elastic deformation (the force value would be zero) shortly before the strand parted. An example exhibiting predominant elastic deformation is a rubber band, while flour shows slightly predominant plastic flow properties, with a well developed dough having higher elastic deformation properties than a slack dough.

The component primarily responsible for elastic deformation and plastic flow in flour is the protein, with starch playing a minor, but not insignificant role. All protein change may, in a sense, be considered denaturation, if denaturation be defined as a change in the structure of a native protein which involves the spatial arrangement of the peptide chain without breaking the chain itself. Various degrees of such changes are feasible, from the disarrangement of a few amino acids to a complete unfolding of the chain. This (denaturation in the proper sense) is apparently preceded by the breaking of hydrogen bonds or salt linkages (and possibly of disulfide bridges) between the side chains of the peptide backbone. These primary alterations cause, or at least facilitate, the disarrangement of the peptide chain. There is no longer any doubt that denaturation as defined above can be reversed, though it has not been proved that a completely unfolded peptide chain can be rearranged to form the native protein.

Two types of linkage are present in a native protein in addition to the peptide linkage, those which may be ruptured by pH change alone such as salt linkages, and those linkages which require reduction for their rupture. The rupture of the latter linkage may be facilitated by changes in pH which in themselves are unable to bring it about. In this work ruptures due to changes in pH were effected by the use of hydrochloric acid, acetic acid and ammonium hydroxide. Reduction was done by storing the flour under an atmosphere of hydrogen sulfide.

The addition of water to a flour acts on the protein and the starch in different manners. It prepares the protein so that elastic deformation may take place by forming weak cross linkages between protein molecules and thus facilitate their ability to unfold. It also uncoils the starch molecules of the ruptured cells and reduces the cohesive forces binding them thus facilitating plastic flow.

The chemical bonds between protein and starch are quite weak and in an unfermented dough the cohesive forces between protein and starch are primarily physical. So with sub-optimum absorption, elastic deformation forces are at work, while with above optimum absorption exaggerated plastic flow properties are present. This work shows that when absorption is sub-optimum, the force value is abnormally large, the extensibility value abnormally short with E_2 larger than E_1 (forming extensogram peak reversals), and the area value larger than the area value of a dough having optimum absorption. With optimum absorption, although E values are larger than F values, the difference is not as great and depends upon the protein content and quality of the flour, E_1 is larger than E_2, and area values are maximum. When absorption is above optimum, force values are abnormally small, extensibility values abnormally large, with E_1 much larger than E_2, and area values smaller than area values of a dough having optimum absorption.

After the inertia of the extensograph has been overcome, there is an initial immediate rise in the extensogram curve which is the reflection of the force needed to overcome cohesive forces within the resting dough before appreciable stretching can begin. The extent of this initial rise is dependent upon the extensograph used, the flour employed, and the treatment the flour and the dough have received. The variables inherent in the extensograph are the inertia of the mechanism, the setting of the instrument, and the velocities of the graph paper and of the dough hook. Stretching results in unfolding and extension of the three dimensional network of the fibrillar molecules of the protein complex. The elastic limit is probably exceeded at various parts distributed at random throughout the dough, and the cohesive forces between certain molecules are broken as pictured by the extensogram as a continued rise in the curve. Accompanying this process of elastic deformation there is also simultaneous plastic flow which also affects the shape of the curve. After the elastic limit of the dough has been reached, plastic flow alone continues and the curve tends to fall. If the speed of the dough hook exceeds the plastic flow of the dough, as it does with all doughs except those having undergone severe reduction such as the action of hydrogen sulfide, the tensile strength of the dough strands is exceeded and the curve begins to drop rapidly.

It was found that farinograms and extensograms are influenced by the pressure of the gas used in the mixing atmosphere. Farinograms and extensograms of doughs mixed in oxygen and nitrogen when the gas pressure was below 10 mm were practically identical with those mixed in air; however, with a pressure of 25 mm, H and F values were larger when mixed in oxygen and smaller when mixed in nitrogen than when mixed in air. It is believed that the low pressure was not sufficient to wash out the occluded air and replace it with either oxygen or nitrogen before the contaminant was incorporated into the dough.

Resting atmosphere different than mixing atmosphere had little effect upon F and E values. With reference to the mixing atmosphere, however, an increase in oxygen in the resting atmosphere caused increases in F values and decreases in E values greater in magnitude than differences between duplicate mixes. Oxygen is absorbed at the dough surface and then enters into the protein molecular structure.

Farinogram and extensogram values of doughs mixed under hydrogen were quite similar to those mixed under nitrogen. Thus molecular hydrogen is not active as a reducing agent in doughs.

All extensogram force values increased, extensibility values decreased, and area values increased with storage, oxygen in the storage atmosphere, storage temperature at 80° F. instead of 50-60° F., and oxygen in the mixing atmosphere when these variables were analyzed both singly and in progressive combination as summarized in Table 40. This means they are dough "stiffeners", since they increased extensogram area, but they are not dough "developers" since they did not increase extensibility values. As used in this work dough "developers" increase all three primary extensogram characteristics--force, extensibility, and area--while dough "stiffeners" merely increase force values, and although they usually increase area values this need not necessarily occur. Sodium chloride was found to be a true dough "developer", since in the sodium chloride and the potassium bromate studies salt increased extensogram force, extensibility, and area values. Potassium bromate for the levels used in unfermented doughs was found to be merely a dough "stiffener" since with its addition only force and area values increased.

Periodically changing the storage atmosphere increased the force values in relation to the behavior of the respective parent flour. This effect on force values of nitrogen stored flour was greater than for flour stored under oxygen. The mixing atmosphere had no influence on this relationship. Extensibility values were influenced differently by the periodic changing of the storage atmosphere. The changing of the nitrogen atmosphere caused a decrease in extensibility values relative to

Table 40. Summary of the effect of controlled variables in the storage study upon farinogram and extensogram characteristics.[1]

Variables	Characteristics					
	Farinogram			Extensogram		
	H	W	H/W	F	E	A
Increased storage time	i	d	i	i	d	i
Oxygen in the mixing atmosphere	i	i	i	i	d	i
Oxygen in the storage atmosphere	d	d	d	i	d	i
Storage at 80° F. instead of 50-60° F.	i	i	o	i	d	i
Increased storage time and oxygen in the mixing atmosphor	i	o	i	i	d	i
Increased storage time and storage at 80° F. instead of 50-60° F.	i	i	i	i	d	i
Increased storage time and oxygen in the storage atmosphere	o	o	o	i	d	i
Oxygen in the mixing atmosphere and storage at 80° F. instead of 50-60° F.	i	i	i	i	d	i
Oxygen in the mixing atmosphere and oxygen in the storage atmosphere	i	o	i	i	d	i
Increased storage time, oxygen in the mixing atmosphere and storage at 80° F. instead of 50-60° F.	i	d	i	i	d	i
Increased storage time, oxygen in the mixing atmosphere and oxygen in the storage atmosphere	i	d	i	i	d	i

---

[1] Data derived from Tables A, B, C, D, and E in the Appendix, and Tables 5, 6, 7, and 8 in the section on Experimental Results.

the parent flour, while the changing of oxygen atmosphere caused an increase in extensibility values in relation to the parent flour. Area values of "O_2 changed" flour were higher than area values of "O_2" flour, while area values of "N_2 changed" and "N_2" flour were of the same order of magnitude.

When the effects of the variables, time, storage, temperature, storage atmosphere, and mixing atmosphere were compared singly and then in progressive combination, the two stretches occasionally behaved differently as did duplicates of the same stretch.

This difference in behavior of stretches and duplicates of the same stretch is defined in this work as sequence. Spread is defined as the difference between replicates. From analysis of the data, when trends in sequence and spread occur; it can be seen that these trends are due to changes in the dough caused by controlled treatment rather than by experimental error.

The mixing atmosphere greatly influenced the sequence of the stretches and duplicates of the stretches. To a lesser extent sequence was also more apparent with the flour stored at 80° F. than with the flours stored at 50-60° F. There was no apparent sequence caused by storage or storage atmosphere.

Greatest spread between replicates was caused by oxygen in the mixing atmosphere, and the higher storage temperature, 80° F. over the flour stored at 50-60° F.

All the variables of the storage study had similar effects upon extensograms; however, such was not the case with farinograms as is seen by the summary given in Table 40. One of the more striking differences is the different effects on farinograms of oxygen in the mixing atmosphere and in the storage atmosphere.

Oxygen in the storage atmosphere decreased all farinograms, while oxygen in the mixing atmosphere increased all farinograms. All the remaining variables both singly and in combination either increased or instigated no change in farinogram values, with the exception of storage time whose farinogram width value decreased. This latter was a dominant variable for its influence was carried over in instances where it was in combination with other variables.

Sedimentation values of all the stored flours increased with storage time. Specific sedimentation (sedimentation value divided by protein percentage) has been found to be a useful measure of gluten quality (32); specific sedimentation values increasing with increased specific loaf volume values. In light of the results obtained in this study it appears that gluten quality improves with age. Throughout the storage period the values for "N_2" flour were highest, and then "B", "O_2", and "A" flour in decreasing order.

In the sedimentation study, the rates of increase after 6-7 months' storage were less for "B" and "O_2" flour and nil for "A" flour. "N_2" flour increase did not begin to taper off until after 200 days' storage. "O_2" flour values revealed a plateau after approximately 200 days of storage. This means that after these storage times for the particular flour used further storage no longer improved gluten quality.

With the flour stored in cans at 80° F. ("A" flour), sedimentation values decreased with storage up to about 60 days after which they increased with acceleration until about 120 days when a tapering off began which ended in a plateau after 200 days' storage.

Photometric protein values of all the stored flours increased with storage time. After 3 to 4 months' storage, the values for "A" flour were largest, followed by those of "O_2" flour, and then "B" flour, with "N_2" flour photometric protein values being the smallest. Prior to 3 months' storage, "A" and "B" flour values were proportionally larger than "O_2" and "N_2" values than they were after 3 months' storage. In addition, prior to 3 months' study, "B" flour values were larger than "A", and "N_2" values were larger than "O_2" values. Zeleny (31) found photometric protein values to be a useful measure of gluten quality. In light of the results obtained in this study, it appears that gluten quality improves with age.

With the photometric protein study, increase in "A" values tapered off sharply after 100 days' storage, "O_2" and "B" flour values reached plateaus after 140 days, and "N_2" values showed almost no increase after 160 days' storage. Thus after these storage times further storage no longer improved gluten quality.

No differences between the spread of duplicate determinations were apparent for both sedimentation and photometric protein values with the exception of "A" flour sedimentation values of which the differences between duplicates increased with storage time.

Storage time increased sedimentation values, photometric protein values, extensogram force and area values, and farinogram heights and the H/W relationship which means that they all may be used as an index of the development in protein quality due to storage.

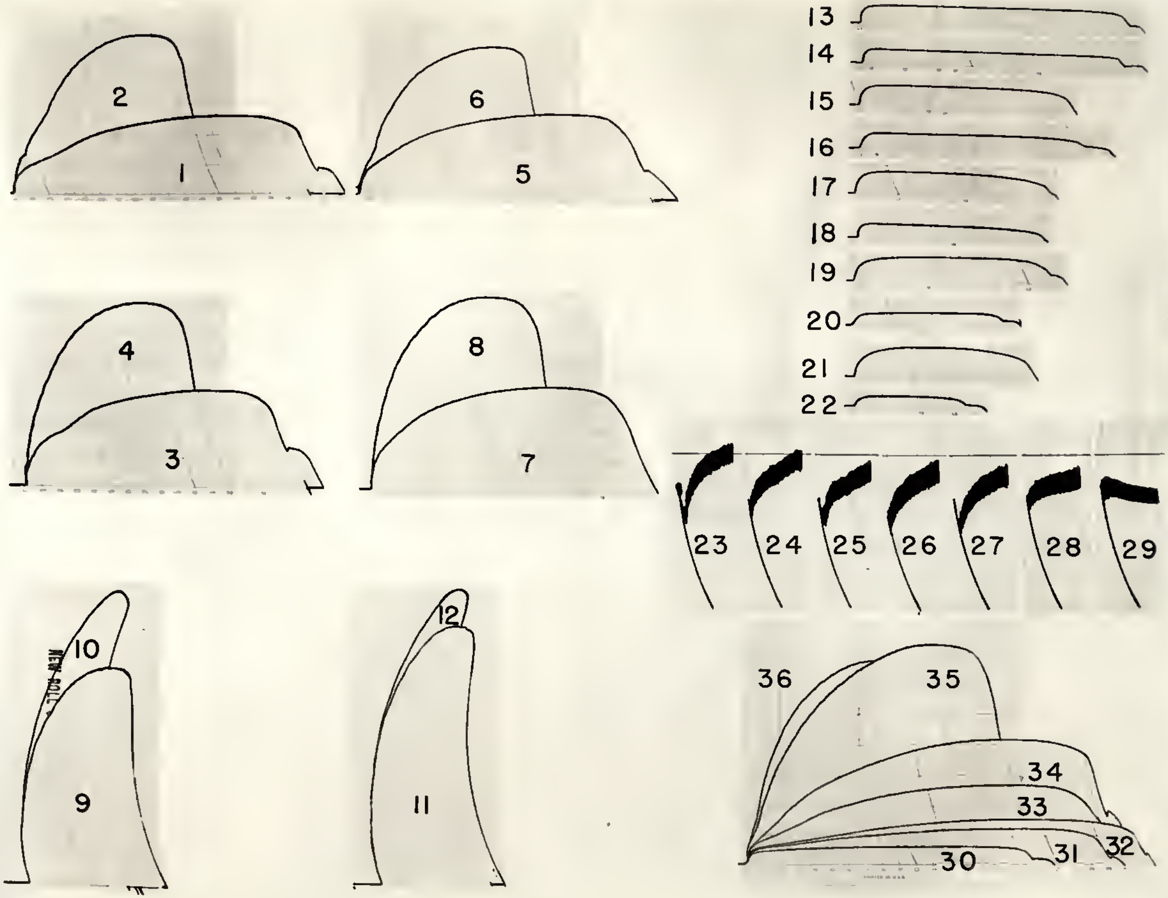
Sodium chloride depressed farinogram heights and widths as witnessed by Figs. 23-29 of Plate I and the summary data in Table 42. The H/W relationship was lowest with 5 percent NaCl and highest with 15 percent NaCl. All extensogram force values increased as percentage of NaCl increased until maximums were reached with 10 percent salt, then with 15 percent NaCl force values decreased as seen from Figs. 30-36 of Plate I. All E values increased with increase of NaCl until maximums were reached with 5 percent NaCl, then they decreased. All area values reached a maximum with 10 percent salt and then decreased. Thus extensogram F, E and A values reveal a salt effect which farinograph H and W values do not reveal, but which the shape of the farinogram curve does, as witnessed by Figs. 28 and 35 of Plate I. In other words, the doughs with horizontal farinograms give extensograms with approach maximum elastic and plastic deformation and optimum dough development. In the study maximum plastic deformation was obtained with 10 percent salt and maximum plastic deformation was obtained with

EXPLANATION OF PLATE I

Treatment

1	0	hours ball milling,	1st duplicate	1st stretch
2	0	,	2nd	1st
3	24	,	1st	1st
4	24	,	2nd	1st
5	0	,	1st	2nd
6	0	,	2nd	2nd
7	24	,	1st	2nd
8	24	,	2nd	2nd
9	48	,	1st	1st
10	48	,	2nd	1st
11	48	,	1st	2nd
12	48	,	2nd	2nd
13	0.000	N acetic acid ,	1st duplicate	
14	0.000	,	2nd	
15	0.050	,	1st	
16	0.050	,	2nd	
17	0.125	,	1st	
18	0.125	,	2nd	
19	0.200	,	1st	
20	0.200	,	2nd	
21	0.250	,	1st	
22	0.250	,	2nd	
23	0	percent NaCl		
24	1			
25	2			
26	3			
27	5			
28	10			
29	15			
30	0			
31	1			
32	2			
33	3			
34	5			
35	10			
36	15			

PLATE I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NEW ROLL
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5 percent salt. If extensogram area is taken as a criterion of dough development, then optimum dough development was obtained with 10 percent salt. It may be that initially after milling each flour has its optimum NaCl concentration giving horizontal farinograms and that this concentration may change with storage, thus serving as an index of flour maturity.

All farinogram values in the sodium chloride study had instances when increase in salt concentration did not alter farinogram values; thus height values remained the same for 2 and 3 percent salt, width values stayed constant for 2, 3, and 5 percent salt, and the H/W relationship remained constant for 2 and 3 percent salt. It may be that this plateau, where increased salt effects no change in farinogram characteristics, may be related to flour strength. The duration of the plateau, as measured by the different concentrations in NaCl when no change in the farinogram curve was evident, would thus be an index of flour strength.

In the salt study the sequence of force values of duplicate doughs was that all Fb values were larger than or equal to Fa values, and with second stretch force values having salt concentration between 5-10 percent the opposite was true, Faa values being larger than Fbb. This sequence was the same as that in the storage study. Above and below the optimum salt range, Fbb values were larger than Faa values. All Eb values were larger than Ea values except for the extremes of salt concentration, 0 and 15 percent, when Ea was larger than Eb. All

Eaa values were larger than Ebb values with the exception of 10 percent salt, where Ebb was the larger. In comparing with the storage study, it is seen that for first stretch E values sequence was the same for nitrogen mixes and optimum percent salt, while doughs with extremes in salt concentration had the same sequence as oxygen and air mixed doughs.

The sequence of area values of duplicate doughs in the salt study was that Aa values were higher than Ab values for 3, 5, and 10 percent salt and lower for the extremes, 0, 1, and 15 percent. All Aaa values were larger than Abb values, but significantly smaller differences were found with the 0 and 15 percent salt concentrations.

In the salt study the differences between F first stretch and F second stretch values increased in magnitude with increasing NaCl concentration. All Faa values were larger than Fa values. All Fbb values were larger than Fb values except for 0 and 1 percent NaCl. All E second stretch values were larger than E first stretch values with the exception of the second stretch having 0 percent NaCl which had a higher value. All second stretch area values were larger than Aa and Ab values with the exception of 0 and 1 percent Ab values which were larger. The differences between area first stretch and area second stretch values increased in magnitude with increasing salt concentration.

The addition of salt effected no change in the pH of the doughs.

The effects of salt, potassium bromate and oxygen in the mixing atmosphere on farinograms are summarized in Table 42 and illustrated with typical farinograms obtained in the study by Plate II. With farinogram H values, salt and oxygen in the mixing atmosphere are opposing forces with the oxygen effect being the more powerful of the two. With farinogram W values, salt and oxygen are again opposing forces, but in this instance the salt effect is predominant; the same holds true for the H/W relationship.

Oxygen and $KBrO_3$ have opposing effects on farinogram heights; increased oxygen content of the mixing atmosphere increases farinogram heights while increasing amounts of $KBrO_3$ decrease them. The effect of bromate was completely masked when the dough was mixed under oxygen, but the concentrations of bromate used were not high enough to mask the effect produced by mixing in different atmospheres. The opposing forces cancelled differences in W and H/W values.

The combined effect of salt and bromate is intimately connected with the mixing atmosphere when farinogram heights are concerned. In order to consider the combined effect of salt and bromate, the mixing atmosphere must be either eliminated or neutralized. The former being impossible, nitrogen atmosphere was considered the most "neutral", and it was with these mixes that conclusions concerning the effect of salt and bromate were drawn. In a nitrogen atmosphere, there was a synergestic effect between salt and bromate on farinogram

EXPLANATION OF PLATE II

Treatment

1	O_2 mixing atmosphere,	0 mg bromate,	0 percent salt
2	,	,	1
3	,	,	5
4	,	,	10
5	,	,	15
6	,	3 ,	0
7	,	,	1
8	,	,	5
9	,	,	10
10	,	,	15
11	,	30 ,	0
12	,	,	1
13	,	,	5
14	,	,	10
15	,	,	15
16	air ,	0 ,	0
17	,	,	1
18	,	,	5
19	,	,	10
20	,	,	15
21	,	3 ,	0
22	,	,	1
23	,	,	5
24	,	,	10
25	,	,	15
26	,	30 ,	0
27	,	,	1
28	,	,	5
29	,	,	10
30	,	,	15
31	N_2 ,	0 ,	0
32	,	,	1
33	,	,	5
34	,	,	10
35	,	,	15
36	,	3 ,	0
37	,	,	1
38	,	,	5
39	,	,	10
40	,	,	15
41	,	30 ,	0
42	,	,	1
43	,	,	5
44	,	,	10
45	,	,	15

PLATE II


1
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26
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36
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2
7
12
17
22
27
32
37
42
3
8
13
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28
33
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43
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heights. Mixing in air and oxygen masked this synergism because of their overpowering effect. Thus it is seen that the selection of the mixing atmosphere can be of prime importance, and if this is not taken into consideration, effects may be masked and, consequently, be considered absent, or erroneous conclusions may be drawn from the data obtained. Some previous data in the literature may also be profitably reinterrupted in light of the above.

The differences between W and H/W values were not large enough to illustrate any combined effect of salt and bromate.

With increased NaCl, increased $KBrO_3$ and change in the mixing atmosphere from "neutral" to one with oxygen, farinogram H values decreased then increased, W values increased then decreased, and H/W values decreased then increased. Since oxygen was an opposing force to the action of salt and bromate, from the results of the combined effect, the conclusions are drawn that with H and H/W values oxygen in the mixing atmosphere is the stronger force, while with W values salt and bromate were the dominant factors.

The effects of salt, potassium bromate and oxygen in the mixing atmosphere on extensograms are summarized in Table 42 and the effects of potassium bromate and oxygen in the mixing atmosphere are illustrated with typical extensograms obtained in the study by Plate III. The effect of salt on extensogram in the Potassium Bromate Study was the same as that found previously in the Sodium Chloride Study. All extensogram values increased until optimum concentrations of salt had been reached after which further increase in salt concentration decreased extensogram values. Oxygen in the mixing atmosphere in the Potassium Bromate Study affected extensograms the same as it had the Storage Study. Force values increased, extensibility values decreased, and area values increased with increase in oxygen in the mixing atmosphere.

Oxygen in the mixing atmosphere masked tremendously the effect of salt on force values; e.g., 10 percent NaCl increased force values approximately eight fold when mixed under nitrogen, three fold when mixed under air, while they were only doubled when mixed under oxygen. This effect also held true for area and extensibility values although the magnitude was not as large, being but faintly evident in the case of extensibility. From this, the importance of mixing atmosphere is evident. It is seen that certain effects can be either masked or brought out by differences in oxygen content in the mixing atmosphere. If this fact is not taken into consideration, the results of data obtained may be misinterrupted or erroneous.

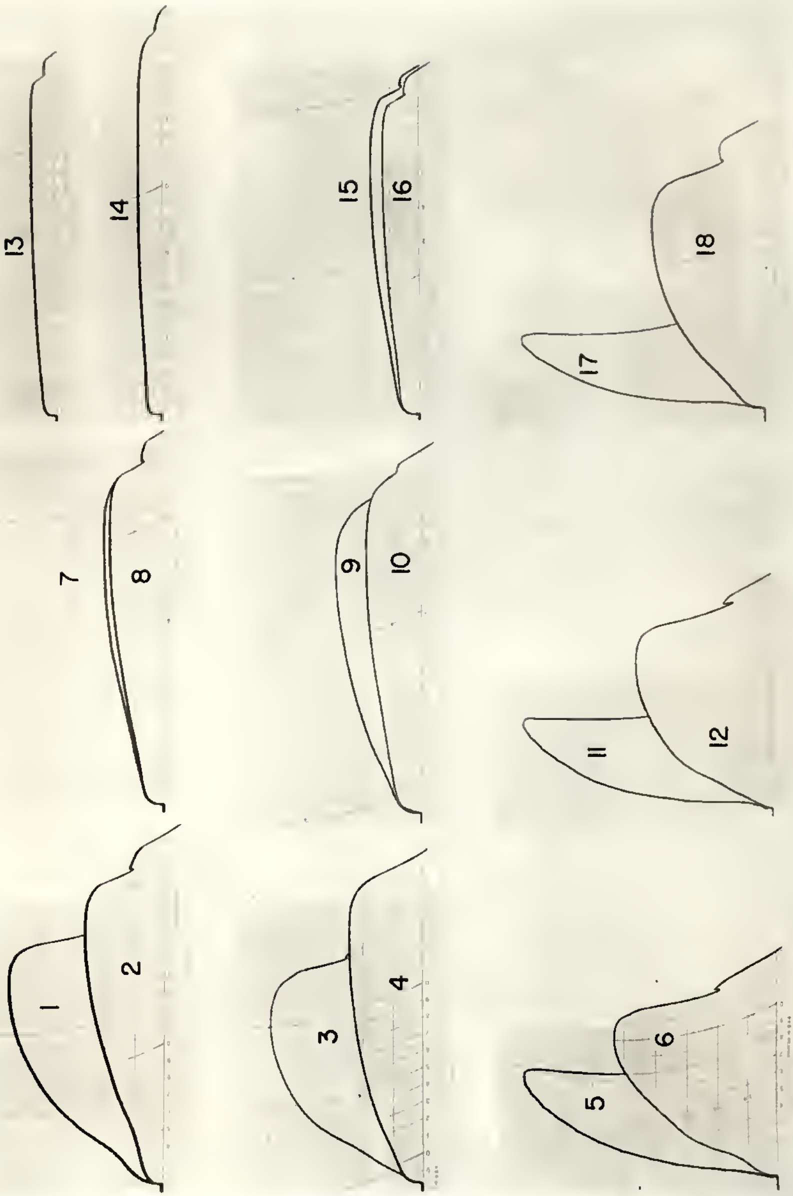
Oxygen in the mixing atmosphere masked to a great extent the effect of bromate on force values; e.g., 30 mg of bromate increased F values approximately 12 fold when mixed under nitrogen, three fold when mixed under air, while they were only doubled when mixed under oxygen. This effect also held true for area values although the magnitudes were not as great. With extensibility values increase in bromate decreased exten-

EXPLANATION OF PLATE III

Treatment

1	O_2 mixed,	0 mg $KBrO_3$,	0 percent NaCl,	2nd stretch
2	,	0	,	, 1st
3	,	3	,	, 2nd
4	,	3	,	, 1st
5	,	30	,	, 2nd
6	,	30	,	, 1st
7	air ,	0	,	, 2nd
8	,	0	,	, 1st
9	,	3	,	, 2nd
10	,	3	,	, 1st
11	,	30	,	, 2nd
12	,	30	,	, 1st
13	N_2 ,	0	,	, 2nd
14	,	0	,	, 1st
15	,	3	,	, 2nd
16	,	3	,	, 1st
17	,	30	,	, 2nd
18	,	30	,	, 1st

PLATE III



sibility values, and doughs mixed under nitrogen showed a greater decrease in extensibility than did those mixed under air, and those mixed in air gave more of a decrease than did those mixed under oxygen.

Oxygen in the mixing atmosphere lowered the percentage of salt needed to give maximum extensogram values. It also lowered the percentage of bromate needed to give maximum values of F, A_1 and A values; however, it increased the percentage of bromate necessary to give maximums for E_1, E and E_t values. This latter is in decided contrast with the salt effect.

Force values increased with increased salt and bromate until the influence of excess salt which lowered force values was greater than increased bromate which increased force values, after which force values became smaller but not as small as zero percent salt - zero percent bromate force values, thus showing the continued dough stiffening effect of bromate even though it was masked by excess NaCl. Area values were influenced similarly by increased salt and bromate when mixing atmosphere had no deciding influence.

With oxygen mixes, increased bromate resulted in increased F values when the concentrations of NaCl remained the same except with instances of excess NaCl; i.e., when NaCl no longer acted as a dough developer and increased F values as was the case with 15 percent salt, which resulted in lower F values. The same held true with air and nitrogen mixes with the exception that nitrogen mix F values continued to increase as the bromate increased even with 15 percent NaCl. The magnitude of increase in F values continued to increase as the bromate increased even with 15 percent NaCl. The magnitude of increase in F values was largest for doughs mixed under nitrogen, smallest for those mixed under oxygen, and intermediate for those mixed in air.

E_1 values generally decreased with increase in bromate when the concentrations of salt remained the same for oxygen and air mixes. For doughs mixed in nitrogen, E_1 values decreased with increase in bromate when the concentrations of salt remained the same with the exception of the set with 15 percent salt where increase in bromate caused an increase in E_1 values. The magnitude of decrease in E_1 values was greatest for doughs mixed under nitrogen, smallest for those mixed under oxygen, and intermediate for those mixed in air.

For air and nitrogen mixes with increase in bromate when the concentrations of salt remained the same, E and E_t values generally decreased, while A_1 and A values increased with 0, 1, and 5 percent salt and generally decreased with 10 and 15 percent NaCl.

Increased salt in the Bromate Study caused F value dough stretch differences to become more negatively pronounced; i.e., second stretch F values become progressively larger than first stretch F values. E_1, E and E_t stretch difference values became more positively pronounced with increased salt until maximums were reached after which increased salt resulted in less positively pronounced or even increased negatively pronounced values. A_1 and A values became tremendously more negatively pronounced.

Increased bromate resulted in F stretch difference values becomeing more negatively pronounced, and with E_1, E and E_t values becoming more positively pronounced. Although mixing atmosphere greatly influenced A_1 and A stretch difference values, generally increased bromate produced difference values more positively pronounced when mixing atmosphere was disregarded.

In the bromate study increased oxygen in the mixing atmosphere caused F value dough stretch differences to become more negatively pronounced and E_1, E and E_t values to become more positively pronounced. A_1, and A values dramatically increased negatively, the increase being over thirty fold.

Although, singly, increased salt, bromate, and oxygen caused F value dough duplicate differences to increase, the combined effect was much less pronounced. The combined effect of oxygen, salt, and bromate reduced duplicate difference E_1, E and E_t values. There was a tendency for A_1 and A value differences between duplicates to decrease with increased bromate, salt, and oxygen; also, increased oxygen tended to make this difference a positive rather than a negative value; i.e., for first duplicate values to be larger than second duplicate values.

Table 41. Summary of the effect of the controlled variables in the potassium bromate study upon farinogram and extensogram characteristics.

Variables	F/E values	Oxynumbers
Increase in sodium chloride	i then d	i then d
Increase in potassium bromate	i	d
Oxygen in the mixing atmosphere	i	d
Increase in sodium chloride and oxygen in the mixing atmosphere	i then d	i then d
Increase in potassium bromate and oxygen in the mixing atmosphere	i	d
Increase in sodium chloride and potassium bromate	i	d
Increase in sodium chloride and potassium bromate and oxygen in the mixing atmosphere	i then d	i then d

The effects of salt, potassium bromate and oxygen in the mixing atmosphere on F/E values and oxynumbers are summarized in Table 41. From Table 41 it will be seen that the different variables both singly and in combination affect F/E values and oxynumbers similarly with the exception of increase in bromate, oxygen in the mixing atmosphere, increase in bromate and oxygen in the mixing atmosphere, and increase in salt and bromate where the bromate effect was stronger.

Farinogram heights, widths, and H/W values increased with ball milling as recorded in summary Table 42. Oxygen in the mixing atmosphere in both the storage study and the potassium bromate study also caused all farinogram values to increase. No other variables in the storage or the potassium bromate studies caused all farinogram values to increase. In the case of ball milling the changes noticed are probably associated with fracturing of starch granules causing them to bind water more strongly. The oxygen effect on the other hand probably involves formation of additional cross linkages in the protein structure thus conferring added rigidity to the system.

In this study ball milling greatly affected the minimum mobility, showing that fundamentally optimum absorption is at least equally dependent upon starch as it is upon protein, if not more so. It is only due to the fact that the differences between milling severities are not great enough to dramatically illustrate this as does ball milling.

All extensogram force and area values increased, and all extensibility values decreased with ball milling, as recorded in summary Table 42 and illustrated by Figs. 1-12 in Plate I.

All second stretch force values and all second stretch area values were larger than first stretch values with the exception of 48 hour ball milled area values where the opposite was true, first stretch values being larger than second stretch values. All first stretch E_1, E_2, E, and E_t values were larger than their respective second stretch values.

Although the extent and severity of ball milling in this study was not enough to cause extensogram peak reversals, 48 hours of ball milling effected near reversals.

Ball milling did not change either sedimentation or photometric protein values. This is further evidence that ball milling acts primarily upon starch, rupturing the granules and breaking the starch chains.

Mixing with the Hobart-Swanson mixer revealed the effects of storage time, storage temperature, and storage atmosphere on extensograms in the same manner as did mixing in the farinograph. Mixing in the Hobart-Swanson mixer also revealed the effects of agenization and storage under hydrogen sulfide in the same manner as these effects were revealed by mixing in the farinograph. Thus farinograph and Hobart-Swanson mixing are similar when one compares the extensograph properties of doughs when mixed with both.

Extensogram force and area values increased with increased concentrations of hydrochloric acid until optimum concentrations of acid were reached after which further increase in acid concentration caused force and area value decreases, as recorded in Table 42 and illustrated by the figures of Plate IV. On the other hand extensogram extensibility values decreased with increased concentrations of acid until the critical concentration was reached; relative plateaus in extensibility values then ensued with further increase in acid normality.

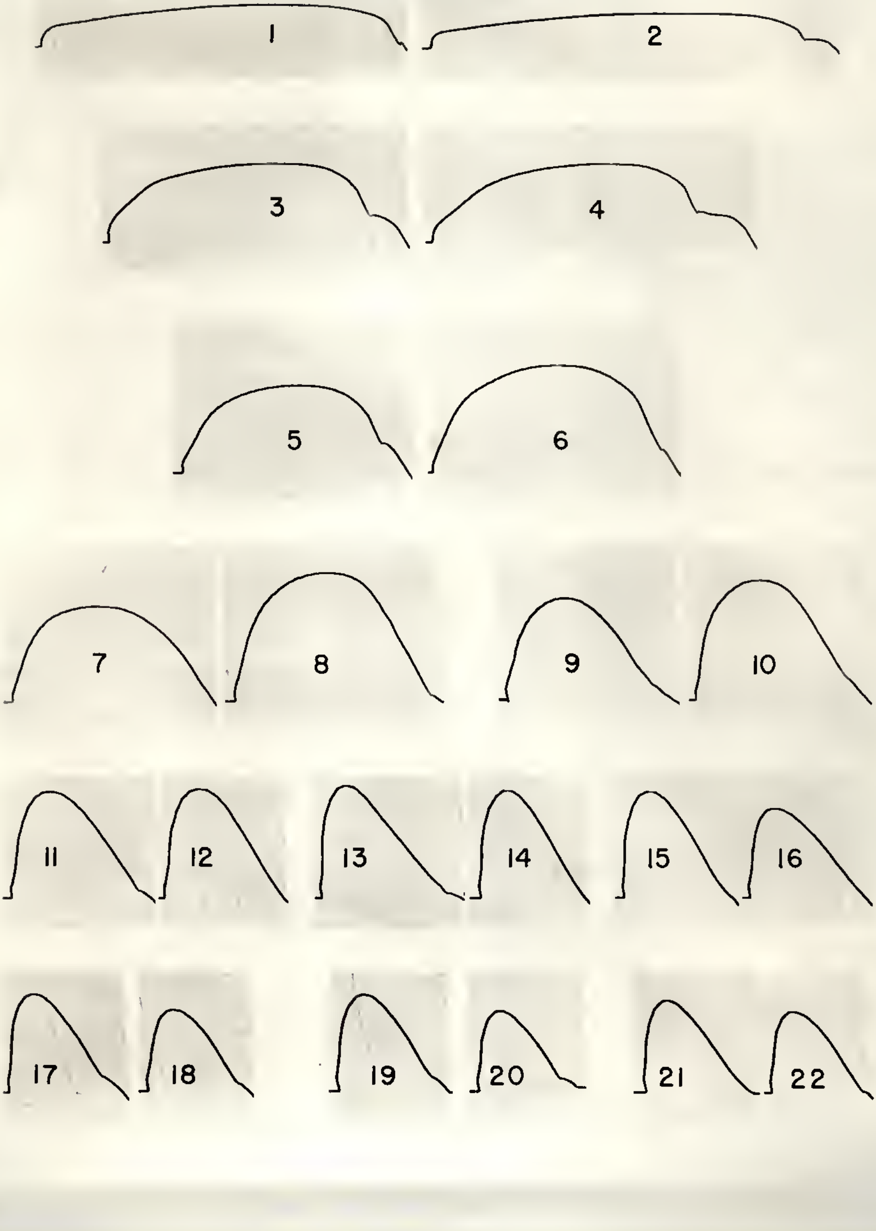
Extensogram peak reversals (curve slope reversals) were effected by hydrochloric acid. It is believed that each flour has its specific concentration of acid where peak reversals will occur.

EXPLANATION OF PLATE IV

Treatment

1	0.000	N HCl,	1st duplicate
2	0.000	,	2nd
3	0.050	,	1st
4	0.050	,	2nd
5	0.100	,	1st
6	0.100	,	2nd
7	0.125	,	1st
8	0.125	,	2nd
9	0.150	,	1st
10	0.150	,	2nd
11	0.200	,	1st
12	0.200	,	2nd
13	0.250	,	1st
14	0.250	,	2nd
15	0.300	,	1st
16	0.300	,	2nd
17	0.400	,	1st
18	0.400	,	2nd
19	0.450	,	1st
20	0.450	,	2nd
21	0.500	,	1st
22	0.500	,	2nd

PLATE IV



First duplicate-first stretch extensogram force values increased with increased concentration of acetic acid in the mixes, as illustrated by Figs. 13-22 of Plate I, even until the doughs became so sticky they could not be molded, and, consequently, no more stretches could be taken. This means that although plastic flow had greatly increased there was also an increase in elastic deformation which resulted in extensibility values being smaller. The other force values were not appreciably changed by the addition of acetic acid. It is believed that acetic acid denatures the gluten protein more severely than does hydrochloric acid, and it may possibly affect the starch as well.

Extensogram extensibility and area values decreased with increased acetic acid concentration.

Extensogram slope reversals became more evident as the acetic acid concentration increased until maximums were reached after which the curve slope rapidly approached "normal" again with further increase in acetic acid.

All extensogram values greatly increased with the inclusion of 2 percent salt along with acetic acid, which was in decided contrast to the action of salt in conjunction with hydrochloric acid and ammonium hydroxide. For HCl mixes, the inclusion of 2 percent salt decreased force and area values and increased extensibility values. The inclusion of 2 percent NaCl in NH_4OH mixes resulted generally in decreased force, extensibility, and area values. Thus, the actions of the same concentration of hydrochloric acid, acetic acid, and ammonium hydroxide upon extensogram characteristics are each different when used in conjunction with salt. This leads to the belief that specific chemical reactions occur with the various reagents rather than purely physical or colloidal effects, or differences due to enzymatic causes.

All extensograms increased with storage when ammonium hydroxide was used in the flours of the storage study either with or without 2 percent salt, as recorded in Table 27. This means that ammonium hydroxide is a dough developer.

The increase in extensograms with storage was larger when only the ammonium hydroxide was used. In other words, ammonium hydroxide and increased salt caused all extensogram values to decrease, as recorded in summary Table 42. Although both salt and ammonium hydroxide are dough developers, their combined action is not cumulative, but, rather, in combination, their individual effect is retarded.

All farinogram and extensogram values of doughs of untreated flour stored under an atmosphere of hydrogen sulfide drastically decreased, as recorded in Table 42. This means that H_2S acted as a reducing agent causing a rupture of certain linkages in the macro molecules of the protein. This was also demonstrated by the dough handling characteristics, the doughs being excessively wet, limp, and sticky.

Agenization prior to storage inhibited the action of hydrogen sulfide since all farinogram and extensogram values of dough of the agonized flour increased markedly over those of the untreated flour. It is believed that nitrogen trichloride entered into chemical combination with the linkages in the protein susceptible to reduction and, thus, prevented reduction by the hydrogen sulfide.

Oxygen in the mixing atmosphere increased farinogram heights and widths, but, even so, the H/W relationship decreased slightly. With oxygen in the mixing atmosphere, extensogram force values increased, extensibility values decreased, and area values increased as illustrated by Figs. 1-4 and 9-12 of Plate V. These results were the same as found in the storage study and in the potassium bromate study; thus showing that oxygen in the mixing atmosphere is a dominant variable and its effect is felt in numerous instances having varied conditions in treatment of flour and dough. It cannot be over emphasized that the mixing atmosphere in studies involving the farinograph and extensograph must be taken into consideration before data can be correctly and properly interpreted.

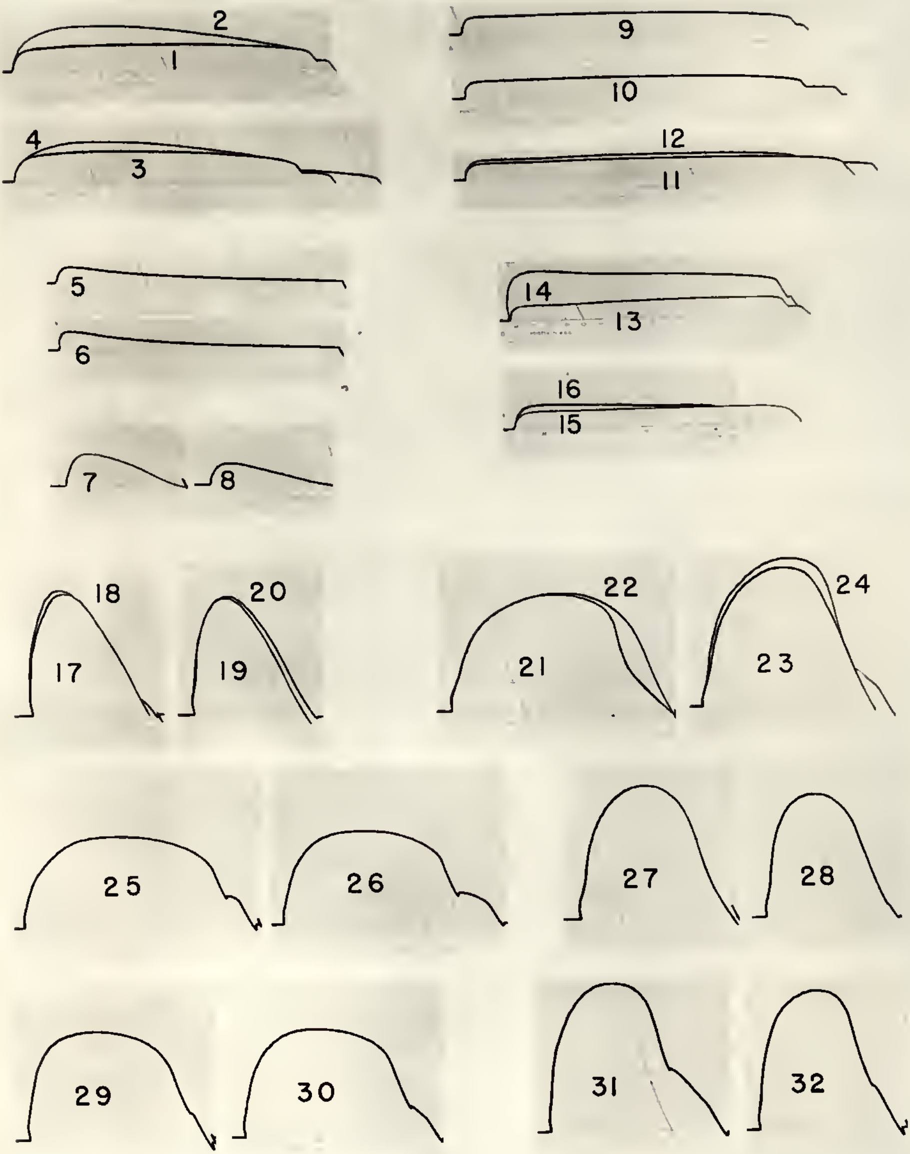
Extensogram slope reversals were found in curves of doughs treated with hydrogen sulfide regardless of agonization prior to storage under hydrogen sulfide or oxygen in the mixing atmosphere, but agonization did decrease drastically the degree of slope reversal. Oxygen in the mixing atmosphere of first duplicate-first stretch doughs slightly reduced extensogram peak reversals, but this action was progressively and increasingly lost with the remaining duplicate-stretch combinations.

EXPLANATION OF PLATE V

Treatment (flour stored under hydrogen sulfide)

1	Agenized flour	, 61.2 % abs.,	O_2 mix	,1st dupl.	, 1st stretch
2		,	O_2	,2nd	, 1st
3		,	O_2	,1st	, 1st
4		,	O_2	,2nd	, 1st
5	Untreated	,	,0.250 N CH_3COOH	,1st	, 1st
6		,	,	,1st	, 2nd
7		,	,0.250 N HCl	,1st	, 1st
8		,	,	,1st	, 2nd
9	Agenized	,	, N_2 mix	,1st	, 1st
10		,	,	,2nd	, 1st
11		,	,	,1st	, 2nd
12		,	,	,2nd	, 2nd
13	Untreated	, 55.0	,2% NaCl, O_2 mix	,1st	, 1st
14		,	, , O_2	,2nd	, 1st
15		,	, , N_2	,1st	, 2nd
16		,	, , N_2	,2nd	, 2nd
17	Agenized flour	, 2 % NaCl	,0.250 N HCl	,1st	, 1st
18		,	,	,2nd	, 1st
19		,	,	,1st	, 2nd
20		,	,	,2nd	, 2nd
21		,	, CH_2COOH	,1st	, 1st
22		,	,	,2nd	, 1st
23		,	,	,1st	, 2nd
24		,	,	,2nd	, 2nd
25		,	, NH_4OH	,1st	, 1st
26		,	,	,2nd	, 1st
27		,	,	,1st	, 2nd
28		,	,	,2nd	, 2nd
29		, 0	,	,1st	, 1st
30		,	,	,2nd	, 1st
31		,	,	,1st	, 2nd
32		,	,	,2nd	, 2nd

PLATE V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The effect of agenization, when considering both the untreated and agenized flours stored under hydrogen sulfide and receiving subsequent treatment with 2 percent salt and equal concentrations of HCl and mixed in the Hobart-Swanson mixer, was to increase all extensogram characteristics. Results were similar when the mixing was done with the farinograph. Thus nitrogen trichloride is a dough developer.

The inclusion of salt in HCl treated doughs made up from agenized flour increased all extensogram values; yet, those same doughs where NH_4OH was substituted for HCl, resulted in decreases in extensogram force and area values, and only extensibility values increased. Ammonium hydroxide thus acted as an inhibitor on the action of salt as a dough developer to counteract the changes due to the reduction by hydrogen sulfide. By the same token, hydrochloric acid supplemented the dough developing properties of salt in this instance.

In comparing the relative effects of equal concentrations of hydrochloric acid, acetic acid, and ammonium hydroxide on extensograms of doughs of agenized flour treated with 2 percent sodium chloride, it was found that the order of magnitude for force, extensibility, and area values in increasing order is acetic acid, ammonium hydroxide, and hydrochloric acid, as illustrated by Figs. 17-28 of Plate V.

Extensogram slope reversals were found in both untreated and agenized flours having no salt and equal concentrations of hydrochloric acid. As in the study when the mixing was done with the fainograph, agenization also decreased the degree of slope reversal in this study when mixing was done with the Hobart-Swanson mixer.

Optimum absorption and mixing time were found to increase with the age of the flour. This means that if the protein is responsible for this increased water imbibition then the number of accessible hydrogen bonds in the protein molecules must increase with age. It is believed that starch imbibition also increases as flour ages.

Sub-optimum absorption increased all farinogram values, increased extensogram force and area values, and decreased extensogram extensibility-under-the-curve (E) values, as recorded in summary Table 42. Since sub-optimum absorption greatly decreased E_1 values and tremendously increased E_2 values, there were consequent and extensive slope reversals with sub-optimum absorption.

With sub-optimum absorption, extensogram F, E, and A values increased with increase in storage temperature (flour stored at 80° F. compared with flour stored at $50-60^{\circ}$ F.). Although E_1 values increased slightly, a greater increase in E_2 values resulted in extensogram slope reversals becoming more pronounced with doughs whose flour had been stored at the higher temperature. It is believed from analyses of the above data that a method can be devised to reveal the temperature treatments which have been applied to an unknown flour through extensograms of doughs having sub-optimum absorption.

Table 42. Summary of the effect of controlled variables upon extensogram characteristics in various studies.

Variables	Characteristics					
	Farinogram			Extensogram		
	H	W	H/W	F	E	A
Sodium Chloride Study[1]						
Increase in sodium chloride	d	d	i	i then d	i then d	i then d
Potassium Bromate Study[2]						
Increase in sodium chloride	d	d	d then i	i then d	i then d	i then d
Increase in potassium bromate	d	d	o	i	d	i
Oxygen in the mixing atmosphere	i	i	i	i	d	i
Increase in sodium chloride and oxygen in the mixing atmosphere	i	d	d then i	i	d	i
Increase in potassium bromate and oxygen in the mixing atmosphere	d	o	o	i	d	i
Increase in sodium chloride and potassium bromate	d	o	o	i then d	d	i then d
Increase in sodium chloride and potassium bromate and oxygen in the mixing atmosphere	d then i	i then d	d then i	i then d	i then d	i then d
Ball Milled Flour Study[3]						
Increased ball milling	i	i	i	i	d	i then d
"A" Flour-Hydrochloric Acid Study[4]						
Increased hydrochloric acid	-	-	-	i then d	d then o	i then d
"A" Flour-Acetic Acid Study[5]						
Increased acetic acid	-	-	-	i or o	d	d

Table 42. (cont.)

Variables	Characteristics					
	Farinogram			Extensogram		
	H	W	H/W	F	E	A
Storage-Acid-Base Study[6]						
HCl and increase in storage time	-	-	-	i	d	i
Acetic acid and increase in storage time	-	-	-	i	i	i
NH_4OH and increase in storage time	-	-	-	i	i	i
HCl and increase in salt	-	-	-	d	i	d
Acetic acid and increase in salt	-	-	-	i	i	i
NH_4OH and increase in salt	-	-	-	d	d	d
HCl and increase in storage temperature	-	-	-	o	o	o
Acetic acid and increase in storage temperature	-	-	-	o	o	o
NH_4OH and increase in storage temperature	-	-	-	o	o	o
HCl and oxygen in storage atmosphere	-	-	-	i	d	o
Acetic acid and oxygen in storage atmosphere	-	-	-	i	d	o
NH_4OH and oxygen in storage atmosphere	-	-	-	d	o	d

Table 42. (concl.)

Variables	Characteristics					
	Farinogram			Extensogram		
	H	W	H/W	F	E	A
Hydrogen Sulfide Study[7]						
Storage of untreated flour under H_2S	d	d	i	d	d	d
Agenization prior to H_2S storage	i	i	i	i	i	i
Oxygen in mixing atmosphere of agenized flour stored under H_2S atmosphere	i	i	d	i	d	i
Agenization (with both untreated and agenized flours treated with salt and HCl)	-	-	-	i	i	i
Salt on agenized flour with HCl	-	-	-	i	i	i
Salt on agenized flour with NH_4OH	-	-	-	d	i	d
Absorption-Storage Study						
Sub-optimum absorption	i	i	i	i	d	i

[1] Data derived from Table 11
[2] Data derived from Table 14
[3] Data derived from Table 18
[4] Data derived from Table 24
[5] Data derived from Table 25
[6] Data derived from Tables 26, 27, 28, 29, 30, and 31
[7] Data derived from Tables 32 and 33

With oxygen in the storage atmosphere, the dough became less stiff for oxygen mixes and more adhesive with nitrogen mixes. The dough cylinder became slightly shorter with nitrogen mixes, and the shape of the dough after molding became cylindrical instead of remaining concave with oxygen mixes.

With flour stored at a higher temperature (80° F. instead of 50-60° F.) the dough became slightly wetter in all three mixing atmospheres, slightly more limp for oxygen and nitrogen mixes, and slightly more cohesive for oxygen mixes. The length of the dough cylinder increased for all three mixing atmospheres with the higher temperature, and the dough changed in shape after molding from concave to cylindrical with oxygen and air as mixing atmospheres.

Increased salt made the dough appear wetter and stiffer. Cohesiveness increased throughout the range of salt increase for nitrogen mixed doughs, but with air and oxygen-mixed doughs cohesiveness increased with salt until a reversal in the trend of physical properties was reached after which further increase in salt concentration caused the doughs to become adhesive again. Salt had no effect on dough color. The surface of the dough ball became smoother, the length of the dough cylinder became less, the molded dough became convex with increased salt until a reversal in the trends of the physical properties were reached after which further increase in salt concentration caused the surface of the dough ball to become rougher, the length of the dough cylinder to become longer, and the molded dough to again resume a concave shape.

With increased bromate doughs became wetter, less limp, more cohesive, smoother, shorter in length, more concave, and whiter in color.

Increased oxygen in the mixing atmosphere caused doughs to become longer and slightly more concave.

Storage of an untreated flour under hydrogen sulfide made the dough very wet, runny, and adhesive. It changed the color of the dough from a creamy to a white color, pitted the surface of the dough ball, and made the molded dough very long and concave. Agenization of the flour prior to storage under hydrogen sulfide improved the dough handling characteristics.

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APPENDIX

Table A. Farinogram height (H, in Brabender units), width (W, in centimeters), and H/W values of stored flour.

	Mixing atmosphere									
Storage	Oxygen			Air			Nitrogen			Mean
(days)	H	W	H/W	H	W	H/W	H	W	H/W	H/W
Stock flour on day of milling from which stored flours were made										
0	535	1.80	297	500	1.70	294	460	1.70	271	
	530	1.85	286	500*	1.75	286	490*	1.60	306	
	550*	1.70	324	505	1.75	289	455	1.70	268	308
"A" flour										
7	540	1.75	309	500	1.80	278	480	1.65	291	
	545	1.80	303	505	1.60	316	475	1.70	279	
	535	1.85	289							295
14	550	1.70	324	500	1.70	294	490	1.60	306	
	545	1.90	287	505	1.70	297	500	1.65	303	
				495	1.60	309				303
28	560	1.75	320	515	1.65	312	505	1.65	306	
	565	1.85	305	520	1.75	297	515*	1.60	322	312
54	575	1.75	329	550	1.60	344	525	1.55	339	
	570	1.85	308	550	1.65	333	530	1.60	331	
				580	1.75	331				331
76	555	1.75	317	520	1.60	325	520	1.60	325	
	560	1.80	311	550	1.65	333	515	1.55	332	324
101	565	1.75	323	550	1.55	355	520	1.55	335	
	595*	1.90	313	575*	1.70	338	560*	1.70	329	
	560	1.75	320	550	1.65	333	530	1.55	342	332
124	565	1.65	342	555	1.60	370	515	1.50	343	
	565	1.75	323	560	1.60	350	510	1.55	329	343
151	570	1.70	335	550	1.55	355	515	1.60	322	
	570*	1.65	345	545*	1.55	352	510*	1.50	340	342
175	580	1.70	341	545	1.50	363	510	1.55	329	
	575	1.75	329	540	1.60	338	515	1.55	329	338
206	585	1.75	334	555	1.60	347	525	1.55	339	
	580	1.65	352	550	1.65	333	525	1.60	350	343

Table A. (cont.)

	Mixing atmosphere									
Storage	Oxygen			Air			Nitrogen			Mean
(days)	H	W	H/W	H	W	H/W	H	W	H/W	H/W
236	595	1.70	350	560	1.60	350	540	1.55	348	
	590	1.70	347	560	1.65	339	535	1.60	334	345
268	600	1.75	343	565	1.60	353	545	1.50	363	
	580*	1.60	363	565	1.70	332	555	1.60	347	350
300	610	1.75	349	575	1.65	348	550	1.70	324	
	610	1.65	370	575	1.70	338	550	1.60	344	346
332	630	1.70	371	590	1.65	358	555	1.65	336	
	620	1.65	376	600	1.70	353	560	1.65	339	356
364	625	1.70	368	595	1.65	361	560	1.65	339	356
					"B" flour					
8	535	1.80	297	500	1.65	303	470	1.65	285	
	520*	1.90	274	505	1.75	289	475	1.80	264	285
15	540	1.75	309	500	1.75	286	480	1.65	291	
	540	1.80	300	500	1.65	303	485	1.70	285	
				505	1.70	297				294
26	545	1.65	330	525	1.75	300	510	1.60	319	
	545	1.70	321	525	1.65	318	505	1.70	297	316
57	560	1.60	350	540	1.60	338	525	1.60	328	
	555	1.70	326	530	1.65	321	520	1.65	315	330
88	570	1.60	356	550	1.55	355	535	1.55	345	
	570	1.65	345	555	1.65	336	535	1.65	324	344
				540	1.55	348				
116	570	1.65	345	550	1.60	344	535	1.60	334	
	545	1.55	352	525	1.50	350	515	1.50	343	345
145	570	1.50	380	545	1.55	352	540	1.50	360	
	570*	1.65	345							359
168	570	1.70	335	545	1.60	340	540	1.50	360	
	550	1.50	367	540	1.50	360	510	1.45	352	
				550	1.55	355	535	1.50	357	366
202	575	1.55	371	550	1.50	367	545	1.50	363	
	575	1.60	359	550	1.55	355	545	1.45	376	365

Table A. (cont.)

Storage (days)	Mixing atmosphere									Mean H/W
	Oxygen			Air			Nitrogen			
	H	W	H/W	H	W	H/W	H	W	H/W	
233	575	1.55	371	555	1.55	358	550	1.50	367	
	580	1.65	352							
	545	1.50	363							362
263	580	1.55	374	560	1.55	361	550	1.45	379	
	575	1.65	348							366
295	580	1.65	352	565	1.55	365	550	1.40	393	
	575	1.55	371	570	1.50	380	555	1.50	370	372
331	580	1.55	374	565	1.60	353	540	1.45	372	
	585	1.60	366	575	1.50	383	550	1.45	379	371
365	580	1.60	363	565	1.50	377	550	1.40	393	
	585	1.50	390	570	1.55	368	550	1.50	367	376
"O_2" flour, storage atmosphere not changed										
31	565	1.80	308	535	1.70	315	510	1.65	309	
	560	1.80	311	530	1.75	303	505	1.70	297	307
49	575*	1.80	319	555	1.75	317	525	1.70	309	
	630	1.75	360	540*	1.70	318	530	1.70	312	
	635	1.70	374	560	1.75	320				329
78	570	1.75	326	545	1.75	311	525	1.60	328	
	570	1.80	317	540	1.70	318	530	1.75	303	317
102	570	1.75	326	545	1.65	330	520	1.65	315	
	575	1.70	338	540	1.75	309	520	1.70	306	321
125	570	1.70	335	545	1.70	321	515	1.60	322	
	565	1.80	314	550	1.70	324	520	1.60	325	324
148	565	1.80	314	535	1.60	334	510	1.55	329	
	570	1.70	335	540	1.75	309	520	1.65	315	323
176	560	1.80	311	525	1.55	339	500	1.50	333	
	565	1.70	332	530	1.75	303	505	1.70	297	319
204	565	1.65	342	535	1.60	334	505	1.65	306	
	570	1.80	317	540	1.70	318	510	1.55	329	
	565	1.75	323							324
235	570	1.60	356	540	1.70	318	510	1.50	340	
	570	1.80	317	535	1.55	345	500	1.75	286	327

Table A. (cont.)

Storage (days)	Mixing atmosphere									Mean H/W
	Oxygen			Air			Nitrogen			
	H	W	H/W	H	W	H/W	H	W	H/W	
266	570	1.70	335	540	1.60	338	510	1.55	329	334
292	570	1.75	326	450	1.60	338	510	1.65	309	
	585	1.60	366	540	1.65	327	530	1.50	353	337
325	565	1.65	342	540	1.60	338	515	1.50	343	
	570	1.65	345	545	1.65	330	510	1.60	319	336
358	580	1.60	363	540	1.60	338	520	1.55	335	
	570	1.60	356	545	1.50	363	515	1.45	355	
							520	1.40	371	354
"N_2" flour, storage atmosphere not changed										
30	570	1.65	345	530	1.50	353	515	1.60	322	
	565	1.75	323	545	1.70	321	505	1.50	337	333
50	590	1.65	358	580	1.45	400	555	1.40	396	
	575*	1.60	359	575	1.55	371	550	1.55	355	
				560	1.55	361				371
87	595	1.65	361	565	1.60	353	545	1.55	352	
	590	1.65	358	575	1.60	359	545	1.55	352	356
115	580	1.55	374	560	1.50	373	555	1.50	370	
	590	1.70	347	570	1.70	335	540	1.55	348	358
140	590	1.60	369	560	1.55	361	540	1.55	348	
	590	1.70	347	555	1.60	347	535	1.50	357	355
166	585	1.65	355	555	1.50	370	530	1.50	353	
	590	1.65	358	560	1.65	339	535	1.50	357	355
203	590	1.65	358	560	1.55	361	530	1.45	366	
	585	1.60	366	560	1.55	361	540	1.50	360	362
234	585	1.60	366	560	1.50	373	545	1.65	330	
	590	1.80	328	565	1.60	353	545	1.40	389	357
262	590	1.75	337	560	1.55	361	545	1.50	363	
	595	1.55	384	555*	1.70	326	545*	1.55	352	354
291	590	1.60	369	550	1.65	333	540	1.50	360	
	600	1.70	353	560	1.55	361	545	1.70	321	350
320	600	1.55	387	555	1.55	358	545	1.60	341	
	590	1.70	347	560	1.60	350	545	1.45	376	360

Table A. (concl.)

Storage	Mixing atmosphere									
	Oxygen			Air			Nitrogen			Mean
(days)	H	W	H/W	H	W	H/W	H	W	H/W	H/W
351	595	1.60	372	565	1.50	377	550	1.50	367	
	590	1.45	407	560	1.60	350	545	1.50	363	373
				"O_2" flour, storage atmosphere changed						
288	580	1.60	363	550	1.55	355	525	1.55	339	
	575	1.65	348	560	1.60	350	520	1.60	325	
	595	1.70	350	540*	1.45	372	535	1.65	324	347
325	585	1.60	366	550	1.55	355	530	1.50	353	
	585	1.60	366	555	1.50	370	540	1.55	348	
							525	1.45	362	360
358	590	1.60	369	550	1.65	333	530	1.55	342	
	610	1.70	359	545	1.60	341	530	1.55	342	349
	585	1.65	355							
				"N_2" flour, storage atmosphere changed						
288	600	1.65	364	565	1.60	353	550	1.50	367	
	595	1.75	340	560	1.65	339	560	1.60	350	352
320	595	1.55	384	565	1.55	365	555	1.50	370	
	600	1.60	375	570	1.50	380	555	1.50	370	374
351	605	1.60	378	575	1.65	348	560	1.45	386	
	600	1.55	387	575	1.45	397	555	1.50	370	378

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* Extensograms not taken

Table B. Force (F) values in centimeters of extensograms of stored flour.

Storage (days)	Mixing atmosphere											
	Oxygen				Air				Nitrogen			
	a	b	aa	bb	a	b	aa	bb	a	b	aa	bb
	Stock flour on day of milling from which stored flours were made											
0	3.60 3.65	3.85 3.85	7.60 7.50	7.45 7.30	2.50 2.50	2.60 2.55	2.60 2.65	2.45 2.55	2.10 2.05	2.05 2.00	2.05 1.95	1.95 1.95
	"A" flour											
7	3.90 3.85 3.80	4.10 4.10 4.00	7.75 7.85 7.60	7.65 7.60 -	2.85 -	2.95 3.00	2.75 2.95	2.70 -	2.10 2.10	2.05 2.05	1.95 2.00	2.00 2.00
14	4.15 4.10	4.30 4.25	7.95 7.90	7.90 7.95	3.10 3.10 2.90	3.05 3.05 2.90	2.95 2.95 2.90	2.85 2.90 3.00	2.10 2.05	2.05 2.05	2.00 2.05	2.05 2.00
28	4.45 4.60	4.60 -	8.40 8.40	8.35 8.30	3.30 3.45	3.35 3.40	3.25 3.50	3.25 3.40	2.30	2.30	2.05	2.05
54	4.95 4.50	4.75 4.90	9.10 9.30	8.95 8.80	3.55 3.55 3.60	3.55 3.65 3.60	4.00 3.80 4.20	3.90 3.90 4.35	2.50 2.50	2.45 2.75	2.30 2.45	2.20 2.40
76	4.90 4.85	5.10 5.10	9.55 9.55	9.55 9.75	- 3.65	3.60 3.60	4.50 4.35	4.55 4.70	2.45 2.20	2.50 2.20	2.40 2.10	2.25 1.95
101	5.80 5.15	5.40 5.80	10.15 9.75	10.20 10.35	3.90 3.90	3.70 3.70	5.25 4.50	5.25 4.50	2.65 2.70	2.65 2.65	2.50 2.50	2.55 2.55
124	6.95 7.20	7.55 7.55	10.70 10.80	10.60 10.60	4.35 4.60	4.20 4.40	5.90 6.15	5.75 5.55	2.65 2.45	2.75 2.65	2.75 2.30	2.65 2.40

Table B. (cont.)

	Mixing atmosphere											
Storage:	Oxygen				Air				Nitrogen			
(days)	a	b	aa	bb	a	b	aa	bb	a	b	aa	bb
151	6.40	6.65	11.00	10.95	4.20 4.25	4.10 4.05	6.35 6.35	6.25 6.15	2.80	2.85	2.90	2.90
175	6.15 5.75	6.25 6.25	11.15 11.15	11.00 11.00	4.10 3.95	4.00 4.35	6.45 6.40	6.45 6.50	2.95 3.10	2.95 3.15	3.10 3.15	3.05 3.05
206	6.20 6.15	6.40 6.40	11.10 11.05	11.00 11.05	4.25 4.15	4.05 4.00	6.70 6.55	6.50 6.45	2.95 3.00	3.00 2.95	3.30 3.25	3.25 3.30
236	6.30 6.30	6.50 6.60	11.20 11.15	11.05 10.95	4.40 4.45	4.30 4.40	6.70 6.75	6.55 6.50	3.00 2.95	3.05 3.05	3.45 3.40	3.50 3.55
268	6.40	6.60	11.15	11.05	4.60 4.55	4.50 4.55	6.65 6.70	6.60 6.55	3.10 3.10	3.15 3.10	3.70 3.75	3.70 3.65
300	6.25 6.40	6.45 6.55	11.20 10.20	11.05 9.80	4.80 5.20	4.75 5.20	6.75 6.75	6.55 6.55	3.20 3.60	3.20 3.55	3.95 3.95	3.85 3.85
332	5.80 5.60	6.10 6.10	11.30 11.30	11.10 11.10	4.55 3.80	4.40 3.75	6.55 4.45	6.40 4.50	3.10 3.05	3.10 3.10	3.85 3.05	3.80 2.80
364	6.00	6.25	11.30	11.15	4.60	4.55	6.65	6.50	3.10	3.10	3.90	3.80
						"B" flour						
8	3.65	3.85	7.70	7.60	2.55 2.60	2.60 2.60	2.80 2.70	2.60 2.65	2.10 -	2.05 2.10	2.00 1.90	1.95 -
15	3.65 3.70	3.90 3.85	7.85 7.80	7.80 7.70	2.50 2.50 2.60	2.55 2.55 2.50	2.75 2.85 2.80	2.85 2.75 -	2.05 2.05	2.10 2.05	1.85 1.90	1.90 1.95

Table B. (cont.)

Storage (days)	Mixing atmosphere											
	Oxygen				Air				Nitrogen			
	a	b	aa	bb	a	b	aa	bb	a	b	aa	bb
26	3.70	3.90	-	7.95	2.60	2.70	2.95	3.05	2.00	2.05	1.85	1.95
	3.80	4.05	8.05	8.00	2.60	2.70	3.10	3.20	2.05	2.00	1.95	1.90
57	4.10	4.30	8.65	8.80	3.05	3.10	3.35	3.50	2.05	2.00	1.85	-
	4.20	4.35	8.75	8.95	-	3.15	3.45	3.55	2.05	2.10	1.90	1.85
88	4.70	4.95	9.40	9.55	3.30	3.30	3.55	3.70	2.05	2.10	1.75	1.85
	4.80	5.55	9.40	10.00	3.35	3.20	3.75	3.60	1.55	1.75	1.80	1.80
					-	-	3.70	3.75				
116	4.95	5.20	9.75	9.85	3.25	3.35	3.70	3.80	2.15	2.25	1.95	2.05
	4.80	5.35	9.65	9.85	3.10	3.35	3.75	-	2.25	2.35	2.20	2.35
145	5.10	5.35	9.95	10.05	3.25	3.35	3.75	3.85	2.25	2.25	2.00	2.05
168	5.15	5.40	9.95	9.90	3.15	3.30	3.80	3.90	2.25	2.30	2.05	2.05
	5.05	5.55	10.15	10.10	3.10	3.35	3.75	3.95	2.10	2.15	1.90	1.95
					3.20	3.40	3.85	-	2.20	2.30	-	2.00
202	5.10	5.40	9.95	10.00	3.10	3.10	3.90	3.80	2.25	2.30	2.10	2.20
	4.65	4.90	9.85	10.00	3.10	3.00	3.80	3.70	2.30	2.55	1.85	2.25
233	5.35	5.50	9.75	9.90	3.10	3.25	4.15	4.15	2.25	2.25	2.20	2.25
	5.30	5.45	9.80	9.95								
	5.50	5.60	9.85	9.90								
263	5.15	5.40	9.75	9.85	3.25	3.35	4.50	4.55	2.25	2.30	2.30	2.35
	4.90	5.25	9.45	9.50								
295	5.00	5.15	9.70	9.90	3.25	3.45	4.65	4.60	2.25	2.35	2.40	2.35
	5.25	5.90	9.40	9.90	3.25	3.45	4.80	4.55	2.25	2.40	2.45	2.30

Table B. (cont.)

Storage (days)	Mixing atmosphere											
	Oxygen				Air				Nitrogen			
	a	b	aa	bb	a	b	aa	bb	a	b	aa	bb
331	5.10	5.25	9.80	9.90	3.20	3.40	4.65	4.55	2.15	2.15	2.25	2.15
	5.00	5.35	11.20	11.20	3.20	3.40	4.90	4.30	2.05	2.05	1.95	1.70
365	5.10	5.30	9.75	9.85	3.25	3.40	4.65	4.65	2.10	2.20	2.10	2.15
	5.15	5.40	-	-	3.20	3.45	4.70	4.55	2.20	2.25	2.20	2.10
"O_2" flour, storage atmosphere not changed												
31	4.60	4.80	8.85	8.65	3.45	3.65	3.65	3.60	2.35	2.35	2.10	2.00
	4.35	4.60	8.60	8.60	3.10	3.25	3.45	3.50	2.10	2.25	1.95	2.00
49	4.95	5.15	9.70	9.95	4.30	4.55	5.30	5.45	2.60	2.45	2.20	2.05
	5.00	5.25	9.70	10.40	4.50	4.95	8.30	8.45	3.25	3.10	3.45	-
									2.15	2.20	2.10	2.00
78	4.50	4.75	9.00	9.20	3.15	3.30	3.75	3.70	2.10	2.05	1.90	1.80
	4.30	4.55	7.40	8.50	2.55	3.05	3.75	3.70	1.95	2.05	1.90	1.80
102	5.00	5.10	9.70	9.60	3.35	3.40	3.90	3.80	2.15	2.15	1.90	1.80
	5.15	5.30	10.70	10.35	2.90	2.95	4.15	3.70	2.10	2.05	1.90	1.70
125	5.20	5.25	10.15	10.00	3.60	3.65	4.00	4.00	2.25	2.15	2.00	1.95
	5.20	5.15	-	10.15	3.65	3.75	4.05	4.05	2.30	2.10	2.00	-
148	5.20	5.30	10.10	9.95	3.60	3.70	4.45	4.40	2.25	2.25	2.00	2.10
	5.25	5.40	10.10	10.05	3.70	3.80	-	-	2.35	2.30	2.05	2.00
176	5.30	5.50	9.90	9.95	3.70	3.75	4.75	4.70	2.40	2.45	2.20	2.05
	5.05	5.60	9.65	9.95	3.70	3.75	4.85	4.80	2.35	2.50	2.15	2.15
204	5.30	5.35	9.70	9.90	3.55	3.60	4.45	4.65	2.30	2.30	2.20	2.15
	5.35	5.55	9.90	10.05	3.60	3.70	4.60	4.60	2.35	2.40	2.25	2.30
	5.40	-	-	-								

Table B. (cont.)

Storage (days)	Mixing atmosphere											
	Oxygen				Air				Nitrogen			
	a	b	aa	bb	a	b	aa	bb	a	b	aa	bb
235	5.45 5.30	5.65 5.80	9.75 9.65	9.90 10.00	3.50 3.40	3.50 3.35	4.45 4.20	4.35 3.95	2.30 2.30	2.20 2.15	2.35 2.35	2.30 1.95
266	5.35	5.55	9.80	9.70	3.40	3.50	4.65	4.65	2.25	2.20	2.45	2.35
292	5.15 4.95	5.30 4.80	9.95 9.75	9.80 9.45	3.45 3.30	3.55 3.65	4.75 5.50	4.70 4.65	2.30 2.50	2.25 2.25	2.40 -	2.45 -
325	5.30 5.70	5.55 5.15	10.05 10.60	9.90 -	3.45 3.50	3.60 3.65	4.80 -	4.85 4.80	2.35 2.30	2.30 2.30	2.35 2.40	2.40 2.40
358	5.35 5.25	5.50 5.60	10.05 10.00	9.90 9.95	3.50 3.55	3.60 3.70	4.80 4.75	4.95 4.95	2.20 2.05	2.35 2.35	2.35 2.05	2.25 2.15
"O_2" flour, storage atmosphere changed												
288	5.10 - 5.15	5.10 4.95 5.20	10.10 9.30 10.05	10.15 9.45 10.00	3.45 3.45	3.70 3.65	5.00 4.70	5.10 4.95	2.45 2.50 2.55	2.50 2.55 -	2.70 2.75 2.60	2.80 2.70 2.55
325	5.20 5.20	5.50 5.60	10.30 10.20	10.25 10.30	3.65 4.25	3.65 4.25	5.05 5.40	5.10 5.35	2.50 2.70 2.45	2.55 2.90 2.50	2.75 3.05 2.60	2.70 2.95 2.65
358	5.20 4.85 5.10	5.40 5.20 5.35	10.55 10.90 -	10.50 10.80 10.30	3.45 3.10	3.60 3.60	5.00 5.20	5.15 5.05	2.30 2.30	2.45 2.45	2.40 2.25	2.50 2.40

Table B. (cont.)

Storage (days)	Mixing atmosphere											
	Oxygen				Air				Nitrogen			
	a	b	aa	bb	a	b	aa	bb	a	b	aa	bb
	"N_2" flour, storage atmosphere not changed											
30	3.70	4.05	8.15	-	2.65	2.70	2.90	2.90	2.10	2.05	1.90	1.90
	3.80	3.90	8.10	7.95	2.55	2.70	3.00	2.85	2.15	2.00	1.95	1.85
50	3.90	4.15	8.60	8.40	-	2.85	3.10	3.20	2.15	2.05	1.90	1.90
					2.70	2.75	3.10	3.20	2.05	1.80	2.20	2.05
					2.70	-	3.40	-				
87	4.50	4.75	9.50	9.25	3.05	3.15	3.65	3.65	2.15	2.05	1.90	1.90
	4.45	4.80	10.65	9.25	3.05	3.25	3.75	3.75	2.05	1.80	2.20	2.05
115	4.80	5.10	10.10	9.95	3.10	3.20	3.80	3.75	1.90	2.00	1.90	1.85
	4.75	5.00	10.70	9.95	3.20	3.15	3.90	3.65	1.95	1.95	1.90	1.85
140	4.75	5.30	-	10.00	3.10	3.20	3.80	3.80	2.05	2.00	1.95	1.90
	4.90	5.15	10.05	9.95	3.15	-	3.70	-	2.05	2.05	2.00	1.90
166	5.05	5.25	10.00	10.05	3.05	3.20	3.80	3.75	2.05	2.05	2.00	2.00
	4.90	5.30	9.85	10.50	2.90	3.20	3.90	3.65	2.10	2.10	2.00	2.00
203	5.25	5.50	9.90	9.85	3.30	3.40	4.05	4.20	-	2.15	1.95	2.05
	5.20	5.55	9.60	9.55	3.20	3.40	3.90	4.35	2.10	2.15	1.65	2.20
234	-	5.50	10.00	9.85	3.55	3.45	4.55	4.45	2.20	2.20	-	2.05
	5.45	5.60	10.50	9.45	3.45	3.45	4.55	4.05	2.25	2.15	2.00	2.00
262	5.30	5.55	9.95	9.90	3.60	3.70	4.75	4.65	2.25	2.30	2.20	2.15
	5.40	5.55	9.90	-								

Table B. (concl.)

Storage	Mixing atmosphere											
	Oxygen				Air				Nitrogen			
(days)	a	b	aa	bb	a	b	aa	bb	a	b	aa	bb
291	5.00	5.20	9.90	10.00	3.65	3.80	4.80	4.80	2.35	2.40	2.35	2.25
	4.85	5.25	9.45	10.05	3.75	3.80	4.80	4.40	2.20	2.45	2.50	2.30
320	5.30	5.55	10.15	10.20	3.70	3.85	4.95	5.05	2.40	2.40	2.30	2.40
	5.15	5.45	9.25	10.50	3.55	4.00	4.95	5.20	2.35	2.45	2.25	2.45
351	5.55	5.70	10.40	10.35	3.70	3.80	5.05	5.00	2.45	2.50	2.60	2.55
	5.45	5.85	10.35	10.65	3.60	3.75	5.10	-	2.70	2.80	-	-
	"N_2" flour, storage atmosphere changed											
288	5.40	5.45	10.40	10.35	3.60	3.60	5.00	4.90	2.50	2.55	2.60	2.50
	6.05	6.00	10.35	10.15	3.55	3.55	5.10	5.05	2.50	2.65	2.75	2.70
320	5.30	5.45	10.50	10.45	3.70	3.90	5.20	5.10	2.45	2.55	2.70	2.50
	5.20	5.30	10.30	10.35	3.70	3.95	5.00	5.45	2.50	2.50	2.55	2.65
351	5.50	5.80	10.50	10.40	3.75	3.90	5.25	5.15	2.50	2.60	2.50	2.55
	5.40	5.80	10.35	10.60	3.80	4.00	5.20	5.35	2.70	2.50	2.35	2.45

Table C. Bounded-by-the-curve extensibility (E) values in centimeters of extensograms of stored flour.

Storage	Mixing atmosphere											
	Oxygen				Air				Nitrogen			
(days)	a	b	aa	bb	a	b	aa	bb	a	b	aa	bb
	Stock flour on day of milling from which stored flours were made											
0	20.40 20.50	20.30 20.05	15.40 15.15	15.95 15.80	22.00 21.40	21.60 21.00	21.95 22.15	22.15 22.30	22.90 22.60	22.65 22.30	23.10 23.25	23.30 23.35
	"A" flour											
7	20.00 19.65 19.35	19.60 19.85 19.25	14.45 14.55 14.15	15.00 15.10 -	21.60 -	21.35 21.30	21.40 21.05	21.75 -	22.65 22.45	22.50 22.60	22.75 22.95	22.95 22.95
14	19.05 18.70	18.75 19.45	12.95 12.60	13.30, 13.40	21.20 21.05 20.60	20.85 20.55 20.25	20.60 20.90 20.75	20.75 20.85 21.10	22.60 22.45	22.65 22.45	22.75 22.40	22.30 22.45
28	17.80 17.10	17.45 -	12.60 12.75	13.35 13.10	19.95 20.60	20.20 19.90	19.55 20.30	19.80 20.20	21.45	21.70	22.15	22.05
54	17.35 17.65	17.15 17.00	12.00 12.65	11.80 12.20	19.90 20.30 20.10	18.75 19.95 20.00	19.15 18.00 19.85	19.70 18.65 19.80	22.00 21.65	20.45 21.15	21.45 21.70	21.40 21.50
76	16.95 16.95	17.00 16.65	13.30 13.35	10.50 11.55	- 19.55	18.90 19.55	18.50 18.05	18.70 19.00	21.20 20.35	21.40 20.50	21.25 20.45	20.65 19.75
101	16.45 16.25	16.50 16.05	11.85 11.40	10.95 11.85	19.10 19.70	19.00 18.75	19.00 17.75	19.35 18.80	20.35 20.60	20.65 21.05	21.20 20.30	21.00 20.50

Table C. (cont.)

Storage (days)	Mixing atmosphere											
	Oxygen				Air				Nitrogen			
	a	b	aa	bb	a	b	aa	bb	a	b	aa	bb
124	16.10	15.90	11.55	11.80	18.70	18.70	18.75	19.00	19.80	20.30	20.20	21.15
	16.45	15.55	11.80	11.65	19.05	19.00	19.00	18.85	19.45	20.55	21.25	21.05
151	15.80	15.50	11.55	11.90	18.95	18.75	18.70	19.10	19.60	20.05	21.15	21.00
					19.20	18.90	18.60	19.25				
175	15.30	15.20	11.40	11.85	18.90	18.60	18.50	19.20	19.60	20.35	21.25	20.80
	14.95	15.30	11.40	11.85	18.65	18.30	18.55	19.15	18.30	20.55	21.10	20.90
206	15.40	15.15	11.65	11.95	18.75	18.50	18.55	18.95	19.70	19.95	20.80	20.70
	15.65	15.35	11.70	12.30	19.25	18.85	18.30	19.05	19.55	20.10	21.05	20.80
236	15.45	15.25	11.80	12.15	19.20	18.95	18.60	18.90	19.45	20.60	20.45	20.75
	15.70	15.25	11.85	12.30	18.90	18.50	18.60	18.75	19.60	20.05	20.80	20.60
268	15.55	15.25	12.10	12.40	18.70	18.75	18.55	18.70	20.05	19.50	20.45	20.40
					19.25	18.55	18.60	18.80	20.30	19.50	20.50	20.30
300	15.50	15.30	12.20	12.65	19.05	18.90	18.65	18.50	19.55	20.05	20.05	20.30
	16.85	16.80	12.45	12.80	18.55	19.10	18.70	18.40	19.60	19.75	20.15	20.30
332	15.65	15.30	12.20	12.65	18.80	18.60	18.95	18.80	19.45	20.25	19.75	20.30
	14.95	15.60	12.10	12.75	18.90	18.05	17.95	18.40	19.40	20.05	18.80	19.75
364	15.45	15.25	12.10	12.70	18.90	18.50	18.70	18.70	19.30	20.05	19.80	20.20
						"B" flour						
8	19.50	19.70	14.90	15.30	20.60	21.20	21.70	21.95	22.05	22.20	22.90	23.15
					21.15	20.95	21.90	21.65	-	22.05	23.00	-

Table C. (cont.)

Storage	Mixing atmosphere											
	Oxygen				Air				Nitrogen			
(days)	a	b	aa	bb	a	b	aa	bb	a	b	aa	bb
15	19.40	19.65	14.30	14.75	21.00	20.90	21.30	21.70	21.85	22.65	22.60	22.85
	19.55	19.70	14.45	14.60	21.15	21.05	21.45	21.55	21.50	22.05	22.70	22.65
					21.20	21.65	21.35	-				
26	19.95	18.65	-	14.05	20.20	21.05	20.60	21.00	21.20	22.25	22.20	22.45
	19.90	20.00	13.85	13.95	20.05	21.30	20.90	21.25	20.90	22.10	22.40	22.65
57	18.35	18.85	13.05	13.45	21.15	20.20	20.50	20.70	20.85	21.30	22.05	-
	18.05	18.50	13.25	13.60	-	19.60	20.65	20.60	20.70	21.60	21.90	22.25
88	18.10	18.00	13.20	13.00	19.40	19.30	20.10	20.15	20.45	21.10	22.75	21.70
	18.05	17.70	13.40	12.60	19.05	19.00	20.00	20.10	18.90	19.80	21.25	20.10
					-	-	19.80	19.50				
116	17.95	17.60	12.60	13.05	19.40	19.65	20.30	20.50	20.55	20.85	22.15	22.00
	17.45	17.45	11.90	12.45	18.55	20.45	19.50	-	20.05	21.55	22.15	19.95
145	17.80	17.25	12.85	12.85	19.25	19.90	20.10	20.30	20.90	20.25	20.85	22.10
168	17.65	16.45	12.80	12.40	19.25	19.90	19.80	20.40	21.20	21.30	21.70	22.30
	17.15	17.40	13.05	12.80	19.50	20.10	19.90	20.15	21.90	20.95	21.05	20.90
					19.70	20.20	19.90	-	21.45	21.60	-	22.25
202	17.45	17.30	13.25	12.80	19.50	20.05	20.05	19.95	21.65	21.45	21.55	20.95
	15.80	16.20	12.95	13.10	19.05	19.80	20.20	19.75	21.30	21.75	20.30	21.30
233	17.40	17.45	13.15	12.90	19.55	19.95	20.20	20.30	21.35	21.30	21.60	21.45
	17.55	17.70	13.25	12.80								
	16.95	17.00	13.30	12.95								
263	17.35	17.00	13.10	12.90	19.80	19.75	20.40	20.30	21.35	21.55	21.30	21.60
	16.40	16.25	12.65	12.55								

Table C. (cont.)

Storage	Mixing atmosphere											
	Oxygen				Air				Nitrogen			
(days)	a	b	aa	bb	a	b	aa	bb	a	b	aa	bb
295	17.20 17.25	15.90 17.10	13.00 11.85	12.90 12.75	20.00 19.95	20.05 19.90	20.40 20.15	20.55 20.20	21.40 20.55	21.50 21.25	21.35 21.40	21.50 20.15
331	17.05 16.80	16.85 16.55	13.25 12.75	13.00 12.00	19.85 19.75	19.70 19.65	18.90 20.10	19.90 20.20	21.65 20.90	22.10 21.25	20.95 19.85	20.70 20.40
365	17.00 16.95	16.75 16.60	13.35 -	13.00 -	19.65 19.70	19.80 20.25	19.90 20.10	20.20 19.95	21.50 21.15	22.30 22.15	19.90 19.90	19.15 19.05
"O_2" flour, storage atmosphere not changed												
31	20.00 18.35	18.50 18.90	13.85 13.50	13.45 13.50	20.45 19.20	20.00 18.85	20.30 20.75	20.65 20.85	21.55 21.65	21.80 21.55	21.50 21.85	21.75 21.70
49	18.00 18.55	18.80 18.25	13.50 13.55	12.85 13.30	19.60 19.45	18.40 19.00	19.95 14.90	20.05 15.25	20.10 21.35 19.45	19.95 20.90 19.35	20.60 19.10 20.50	20.45 - 20.60
78	18.20 17.45	17.65 16.55	13.85 13.30	13.00 12.45	19.70 18.55	19.90 19.55	19.75 20.90	19.30 18.60	20.45 19.45	20.70 20.55	20.30 20.25	20.45 20.30
102	17.00 14.25	16.35 17.10	12.40 12.65	12.80 12.90	20.05 18.80	19.65 19.20	20.20 19.35	19.45 19.20	20.70 20.25	20.65 20.40	20.00 20.20	20.55 20.50
125	17.65 17.40	17.50 17.05	12.30 -	12.35 12.50	20.10 20.55	20.35 20.30	19.35 18.85	19.50 19.20	20.25 20.20	20.50 20.45	20.15 20.00	19.45 -
148	17.95 18.30	18.00 17.80	12.10 12.45	12.30 12.35	19.75 19.50	19.80 19.70	19.40 -	19.40 -	20.80 20.75	21.60 21.55	20.20 20.65	20.35 20.00

Table C. (cont.)

Storage (days)	Mixing atmosphere											
	Oxygen				Air				Nitrogen			
	a	b	aa	bb	a	b	aa	bb	a	b	aa	bb
176	18.40 16.80	18.10 18.25	12.45 12.10	12.25 12.20	19.75 19.60	20.00 19.85	19.30 19.25	18.70 19.20	20.90 20.80	21.35 21.50	20.10 20.05	20.20 20.35
204	18.70 18.95 18.55	18.35 18.65 -	12.40 12.45 -	12.35 12.45 -	19.90 19.85	20.05 20.00	19.55 19.20	19.45 19.40	20.25 20.40	21.95 21.60	20.75 20.50	20.45 20.80
235	19.35 19.10	18.85 19.20	13.35 12.40	12.50 13.40	21.05 20.60	20.60 20.15	20.05 19.60	19.90 19.55	20.95 21.05	21.65 21.30	20.60 20.60	20.45 19.50
266	18.90	19.05	12.60	12.75	20.40	20.35	19.70	19.55	21.05	19.95	20.75	20.70
292	18.85 18.50	18.70 17.85	12.30 12.15	12.60 12.25	19.90 18.65	20.00 19.45	19.45 19.00	19.40 19.25	21.40 21.70	22.45 22.00	21.20 -	20.90 -
325	17.80 18.55	18.40 17.45	12.75 11.90	12.90 -	20.40 20.55	20.35 20.10	19.25 -	19.05 18.70	21.65 22.00	22.20 22.50	20.95 20.45	20.95 20.95
358	18.05 17.70	16.30 17.75	13.05 13.40	12.15 12.90	20.90 20.95	20.70 20.90	19.10 18.75	18.45 18.85	22.05 21.00	22.20 22.45	20.60 19.25	20.65 20.40
"N_2" flour, storage atmosphere not changed												
30	18.60 19.10	18.50 18.10	13.30 13.15	- 13.70	20.65 19.45	20.50 21.05	20.65 21.00	21.10 20.90	22.30 21.35	22.85 22.10	22.00 22.10	22.45 22.20
50	18.35	17.90	13.00	13.05	- 20.60 21.15	20.75 21.50 -	20.35 20.30 20.05	20.40 20.50 -	23.10 22.65	22.40 22.50	21.50 21.80	20.85 21.30

Table C. (cont.)

Storage (days)	Mixing atmosphere											
	Oxygen				Air				Nitrogen			
	a	b	aa	bb	a	b	aa	bb	a	b	aa	bb
87	18.05	18.50	12.20	12.00	20.85	20.60	19.80	20.30	21.05	21.55	20.90	20.85
	17.75	18.65	12.45	12.25	20.30	20.75	19.90	20.05	21.00	21.85	21.35	21.10
115	17.75	17.95	12.30	11.50	17.75	18.05	19.45	20.15	20.15	21.85	21.45	20.45
	17.70	17.45	12.35	12.20	17.30	17.80	19.80	20.05	20.50	22.20	21.25	20.90
140	17.35	18.05	-	12.20	19.75	20.20	19.50	19.45	20.20	21.50	21.20	21.25
	17.55	17.35	12.50	12.35	19.90	-	19.35	-	19.90	22.35	21.30	20.70
166	18.05	17.45	12.80	12.55	19.45	19.85	19.75	18.80	20.00	21.35	19.95	21.15
	17.90	17.40	12.50	12.80	19.30	20.10	19.60	19.45	20.60	21.65	21.00	22.90
203	16.90	16.80	13.15	12.85	20.40	19.70	19.70	19.00	-	21.05	21.45	21.00
	17.55	16.55	12.60	12.80	20.65	20.15	19.65	19.30	20.35	21.65	20.80	20.65
234	-	16.75	12.80	13.10	20.20	19.95	19.60	19.15	20.70	21.85	-	21.05
	16.35	17.20	13.30	12.10	20.95	20.05	19.75	18.50	21.10	21.90	21.00	19.95
262	16.40	16.80	12.90	13.25	20.55	19.40	19.65	19.30	21.05	22.20	21.05	20.90
	17.10	17.15	13.15	-								
291	16.75	17.15	12.80	13.10	20.95	19.80	19.80	19.55	20.55	22.40	20.75	20.35
	15.40	16.60	11.85	13.35	20.30	20.25	19.65	19.30	20.75	21.85	21.05	20.80
320	16.75	16.50	12.10	12.20	21.10	19.45	19.50	19.45	20.70	22.10	21.25	21.60
	16.80	17.15	12.80	12.65	19.55	20.45	19.70	19.55	20.85	21.75	20.90	21.80
351	16.50	16.25	12.30	11.90	20.80	19.15	19.20	19.60	20.55	21.55	20.85	20.50
	17.05	16.20	12.00	12.20	20.45	20.40	19.05	-	21.55	22.60	-	-

Table C. (concl.)

Storage (days)	Mixing atmosphere											
	Oxygen				Air				Nitrogen			
	a	b	aa	bb	a	b	aa	bb	a	b	aa	bb
"O_2" flour, storage atmosphere changed												
288	18.60	18.35	13.40	13.65	19.70	20.05	18.85	20.60	21.65	21.80	21.75	21.40
	-	18.05	13.75	13.55	19.85	19.40	19.95	20.45	21.80	22.05	21.50	21.30
	18.80	18.60	13.30	13.40					21.55	-	22.05	22.20
325	18.25	18.70	13.10	13.80	20.05	20.75	20.60	19.65	21.35	21.25	21.45	21.35
	18.60	18.55	13.45	14.60	20.90	20.15	20.05	20.15	21.30	21.05	21.85	22.60
									21.20	21.00	21.20	21.05
358	17.45	17.40	13.02	13.50	19.85	20.05	19.95	20.10	20.65	21.60	20.20	20.50
	17.20	17.15	12.70	11.45	20.05	20.20	18.50	19.20	20.80	21.55	20.45	20.25
	17.40	17.65	-	13.15								
"N_2" flour, storage atmosphere changed												
288	17.45	17.30	12.05	12.20	19.65	19.70	19.95	18.80	20.75	20.65	21.40	21.35
	17.60	17.55	11.20	12.50	19.70	20.45	18.80	18.85	20.40	20.45	20.75	20.60
320	16.65	16.45	11.80	11.95	19.25	19.50	18.35	18.60	20.00	20.70	20.35	22.00
	16.85	16.70	12.05	12.25	19.60	19.75	18.25	18.95	20.15	20.05	20.40	20.35
351	15.90	16.00	11.05	11.45	19.80	19.90	18.75	18.80	20.55	19.35	20.15	19.60
	16.05	15.70	11.80	12.00	19.50	19.35	18.55	18.85	19.20	19.45	20.00	19.95

Table D. Additional extensibility (E_3) values in centimeters due to tearing of doughs of stored flour during stretching.

Storage (days)	Mixing atmosphere											
	Oxygen				Air				Nitrogen			
	a	b	aa	bb	a	b	aa	bb	a	b	aa	bb
	Stock flour on day of milling from which stored flours were made											
0	0.55	0.40	0.10	0.25	0.45	0.50	0.75	0.50	0.30	0.40	0.70	0.00
	0.35	0.45	0.40	0.30	0.95	1.05	0.20	0.00	0.75	0.95	0.25	0.20
	"A" flour											
7	0.20	0.30	0.40	0.25	0.40	0.45	0.20	0.00	0.25	0.30	0.50	0.05
	0.65	0.35	0.40	0.20	-	0.25	0.75	-	0.20	0.25	0.55	0.30
14	0.50	0.45	0.25	0.30	0.35	0.55	0.75	0.85	0.40	0.20	0.00	0.85
	0.75	0.50	0.60	0.35	0.45	0.60	0.00	0.80	0.25	0.35	0.70	0.60
					1.10	1.45	0.80	0.15				
28	0.30	0.35	0.65	0.00	0.80	0.40	0.85	0.60	0.85	0.50	0.25	0.00
	0.95	-	0.30	0.45	0.35	0.55	0.20	0.15				
54	0.25	0.60	1.50	0.85	0.40	1.35	0.70	0.50	0.30	1.65	0.60	0.65
	0.55	0.85	0.25	0.00	0.30	0.20	1.65	1.20	0.45	0.40	0.05	0.10
					0.15	0.25	0.10	0.15				
76	0.00	0.65	0.30	0.95	-	0.35	0.10	0.30	0.30	0.35	0.15	0.25
	0.40	0.20	0.40	0.30	0.20	0.25	0.45	0.75	1.20	1.05	1.00	0.75
101	0.25	0.60	0.50	0.90	0.50	0.25	0.25	0.10	0.20	0.35	0.10	0.35
	1.60	0.00	1.35	0.25	0.30	0.65	1.60	0.95	0.20	0.10	1.30	1.00
124	0.70	0.20	0.65	0.25	0.95	0.45	0.55	0.15	0.15	0.65	1.35	0.20
	0.15	0.30	0.20	0.40	0.20	0.15	0.20	0.65	0.50	0.25	0.05	0.65

Table D. (cont.)

Storage	Mixing atmosphere											
	Oxygen				Air				Nitrogen			
(days)	a	b	aa	bb	a	b	aa	bb	a	b	aa	bb
151	0.25	0.20	0.40	0.00	0.35 0.00	0.10 0.75	0.10 0.25	0.15 0.00	0.65	0.40	0.20	0.10
175	0.20 0.90	0.35 0.85	0.25 0.00	0.00 0.00	0.20 0.75	0.55 1.50	0.55 0.45	0.20 0.45	0.35 2.20	0.30 0.15	0.10 0.25	0.35 0.20
206	0.60 0.10	0.75 0.30	0.65 0.55	0.65 0.00	1.05 0.20	0.35 0.15	0.00 0.95	0.30 0.20	0.20 0.25	0.60 0.40	0.80 0.50	0.25 0.20
236	0.00 0.35	0.15 0.10	0.15 0.00	0.10 0.10	0.40 0.25	0.10 0.45	0.20 0.00	0.00 0.45	0.10 0.15	0.20 0.55	0.50 0.00	0.00 0.25
268	0.00	0.40	0.00	0.35	0.30 0.50	0.35 0.20	0.20 0.00	0.25 0.10	0.25 0.15	0.05 0.40	0.15 0.10	0.00 0.05
300	0.00 0.20	0.10 0.55	0.00 0.60	0.00 0.85	0.10 0.35	0.50 0.65	0.15 0.00	0.00 0.40	0.90 0.15	0.20 1.35	0.20 0.00	0.00 0.15
332	0.10 0.50	0.35 1.05	0.10 0.05	0.35 0.30	0.25 0.85	0.15 2.10	0.40 1.85	0.35 0.60	0.05 0.50	0.10 0.65	0.00 1.40	0.05 2.50
364	0.15	0.10	0.10	0.05	0.05	0.40	0.00	0.25	0.20	0.45	0.30	0.15
							"E" flour					
8	0.90	0.85	0.30	0.45	1.25 0.70	0.65 0.75	0.65 0.30	0.40 0.75	0.60 -	0.70 0.80	0.50 0.45	0.90 -
15	0.45 0.50	0.75 0.85	0.40 0.25	0.00 0.55	0.55 0.50 0.70	0.60 0.50 0.90	0.90 0.00 0.75	0.25 0.60 -	0.75 0.65	0.30 0.55	0.30 0.65	0.25 0.75

Table D. (cont.)

Storage	Mixing atmosphere											
	Oxygen				Air				Nitrogen			
(days)	a	b	aa	bb	a	b	aa	bb	a	b	aa	bb
26	0.65	1.00	-	0.20	0.30	0.40	0.85	0.95	0.95	0.20	0.60	0.75
	0.50	0.40	0.00	0.50	0.75	0.45	0.15	0.40	0.80	0.30	0.20	0.35
88	0.65	0.15	0.05	0.10	0.75	0.70	0.00	0.10	0.70	0.60	0.00	0.20
	0.20	0.70	0.00	0.25	1.60	0.95	0.15	0.20	1.35	1.80	1.90	2.05
					-	-	0.80	0.50				
116	0.15	0.40	0.00	0.55	0.70	0.65	0.05	0.10	0.45	0.65	0.35	0.30
	2.00	1.40	0.40	1.00	1.85	0.80	0.60	-	0.65	0.40	0.10	0.05
145	0.10	0.50	0.20	0.00	0.85	0.40	0.00	0.00	0.70	0.70	0.30	0.25
168	0.00	1.25	0.55	0.50	0.90	0.65	0.35	0.00	0.50	0.45	0.00	0.00
	0.45	0.30	0.00	0.00	1.15	0.65	0.20	0.40	1.15	1.40	0.80	1.05
					0.50	0.45	0.00	-	0.55	0.50	-	0.15
202	0.10	0.15	0.00	0.90	0.95	0.45	0.20	0.00	0.35	0.55	0.00	0.50
	2.30	1.60	0.65	0.25	1.35	0.80	0.00	0.70	0.50	0.45	1.45	0.00
233	0.25	0.20	0.30	0.00	0.90	0.65	0.25	0.20	0.40	0.75	0.50	0.30
	0.00	0.10	0.00	0.45								
	0.60	0.75	0.00	0.10								
263	0.05	0.30	0.15	0.00	0.55	0.70	0.05	0.10	0.45	0.50	0.25	0.00
	0.95	0.80	0.70	0.85								
295	0.65	1.75	0.00	0.00	0.50	0.30	0.00	0.15	0.60	0.85	0.20	0.00
	0.00	0.05	1.90	0.60	0.35	0.70	0.30	0.50	0.65	0.80	0.35	0.60
331	0.00	0.05	0.00	0.10	0.45	0.75	1.50	1.05	0.45	0.50	0.00	0.30
	0.25	0.30	0.95	1.55	0.20	0.90	0.05	0.20	0.30	0.75	1.80	0.35

Table D. (cont.)

Storage (days)	Mixing atmosphere											
	Oxygen				Air				Nitrogen			
	a	b	aa	bb	a	b	aa	bb	a	b	aa	bb
365	0.00	0.15	0.00	0.25	0.45	0.55	0.45	0.00	0.60	0.15	0.40	0.25
	0.10	0.20	-	-	0.70	0.30	0.25	0.30	0.55	0.00	0.00	0.15
	"O_2" flour, storage atmosphere not changed											
31	0.60	0.70	0.25	0.30	0.65	0.50	0.55	0.40	0.55	0.40	0.40	0.10
	1.25	1.00	1.05	0.35	1.40	1.45	0.00	0.25	0.80	0.60	0.10	0.30
49	0.25	0.20	0.25	0.85	0.50	1.25	0.30	0.30	1.10	0.95	0.30	0.35
	0.30	0.40	0.30	0.00	0.15	0.25	3.85	3.10	0.25	0.30	1.55	-
									2.20	2.05	0.15	0.00
78	0.30	0.25	0.00	0.45	0.20	0.35	0.00	0.25	0.15	0.35	0.20	0.20
	1.00	1.35	0.75	1.05	1.30	0.55	0.00	1.45	0.75	0.70	0.15	0.65
102	0.70	1.05	0.75	0.40	0.15	0.20	0.00	0.20	0.35	1.75	0.95	0.00
	0.20	0.15	0.00	0.00	1.05	1.10	0.90	0.45	0.45	2.20	0.85	0.40
125	0.30	0.40	0.35	0.80	0.75	0.20	0.40	0.35	0.95	0.15	0.00	0.50
	1.00	0.40	-	0.25	0.40	0.10	0.95	0.75	1.20	0.10	1.05	-
148	0.25	0.10	0.65	0.45	0.85	0.60	0.00	0.00	0.45	0.15	0.40	0.00
	0.00	0.05	0.00	0.55	1.05	0.55	-	-	0.70	0.20	0.30	0.45
176	0.20	0.00	0.00	0.35	0.45	0.15	0.55	1.15	0.05	0.30	0.00	0.40
	2.10	0.20	0.95	0.60	0.50	0.45	1.00	0.00	0.50	0.35	0.35	0.25
204	0.55	0.60	0.50	0.20	0.60	0.30	0.60	0.05	0.90	0.05	0.00	0.65
	0.00	0.10	0.55	0.00	0.60	0.55	1.15	0.15	0.85	0.20	0.15	0.00
	0.30	-	-	-								
235	0.10	0.60	0.00	0.85	0.00	0.20	0.10	0.30	0.20	0.55	0.55	0.20
	0.25	0.00	1.05	0.00	0.30	0.50	0.65	0.45	0.10	0.50	0.00	2.05

Table D. (cont.)

Storage (days)	Mixing atmosphere											
	Oxygen				Air				Nitrogen			
	a	b	aa	bb	a	b	aa	bb	a	b	aa	bb
266	0.25	0.05	0.20	0.30	0.25	0.10	0.30	0.05	0.30	0.55	0.40	0.35
292	0.15 0.55	0.10 1.20	0.65 0.90	0.40 1.10	0.45 1.30	0.10 0.75	0.30 0.25	0.25 0.35	1.05 0.20	0.10 0.95	0.15 -	0.30 -
325	1.05 0.10	0.00 1.20	0.30 1.10	0.00 -	0.25 0.15	0.20 0.30	0.40 -	0.00 0.65	0.30 0.05	0.15 0.10	0.00 0.25	0.40 0.00
358	0.30 1.00	2.05 0.35	0.00 0.00	1.50 0.35	0.25 0.10	0.10 0.05	0.20 0.75	0.90 0.10	0.00 1.90	0.15 0.05	0.00 2.30	0.20 0.50
"N_2" flour, storage atmosphere not changed												
30	0.80 0.65	0.55 0.95	0.45 0.70	- 0.30	0.75 1.25	0.60 0.50	0.35 0.00	0.10 0.45	0.70 0.85	0.60 0.45	0.45 0.60	0.00 0.15
50	0.90	1.05	0.40	0.00	- 0.80 0.90	0.75 1.10 -	0.30 0.05 0.70	0.60 0.00 -	0.45 0.60	0.55 0.60	0.65 0.20	1.05 0.15
87	0.30 0.50	0.15 0.05	1.25 0.40	0.35 0.20	0.25 0.20	0.40 0.00	0.40 0.15	0.55 0.10	0.45 0.20	0.65 0.80	0.55 0.10	0.70 0.05
115	0.55 0.85	0.25 0.50	0.35 0.00	1.00 0.25	0.65 0.50	0.05 0.20	0.75 0.20	0.00 0.30	0.60 0.80	0.40 0.35	0.30 0.40	0.80 0.25
140	1.20 0.35	0.00 0.40	- 0.40	0.45 0.30	0.70 0.80	0.25 -	0.10 0.45	0.30 -	0.65 0.50	0.50 0.45	0.40 0.35	0:00 0.20

Table D. (cont.)

Storage (days)	Mixing atmosphere											
	Oxygen				Air				Nitrogen			
	a	b	aa	bb	a	b	aa	bb	a	b	aa	bb
166	0.10	0.30	0.30	0.25	0.95	0.30	0.20	0.65	1.05	0.85	2.05	0.35
	0.40	0.60	0.40	0.50	1.55	0.35	0.00	0.00	0.95	0.90	0.30	0.00
203	0.90	1.10	0.00	0.65	0.30	0.45	0.45	0.60	-	0.75	0.45	0.00
	0.80	0.95	0.45	1.45	0.15	0.35	0.80	0.05	1.00	0.60	0.75	0.20
234	-	0.65	0.30	0.00	0.20	0.25	0.35	0.20	0.60	0.45	-	0.00
	1.15	0.75	0.75	0.85	0.25	0.30	0.30	1.25	0.55	0.55	0.30	1.90
262	1.35	0.70	0.55	0.25	0.45	0.50	0.20	0.15	0.45	0.50	0.00	0.05
	1.00	0.55	0.00	-								
291	1.45	0.95	0.25	0.10	0.30	0.50	0.30	0.20	0.55	0.25	0.60	0.90
	2.35	0.90	1.90	0.00	0.50	0.45	0.25	0.75	0.90	0.35	0.15	0.00
320	0.50	0.30	1.40	0.95	0.40	0.85	0.45	0.00	0.60	0.45	0.00	0.65
	0.90	0.65	0.00	0.00	1.15	0.20	0.10	0.20	0.85	0.50	0.15	0.20
351	0.20	0.65	0.00	0.30	0.60	0.85	0.35	0.10	0.75	0.60	0.35	0.25
	0.40	0.10	0.35	0.15	0.55	0.80	1.05	-	0.00	0.00	-	-
"O_2" flour, storage atmosphere changed												
288	0.70	0.60	0.15	0.35	0.65	0.50	1.70	0.00	1.20	0.45	0.40	0.30
	-	0.95	0.40	1.25	0.60	1.10	0.00	0.80	0.70	0.30	0.35	0.55
	0.20	0.25	0.45	1.10					0.45	-	0.00	0.10

Table D. (concl.)

Storage	Mixing atmosphere											
	Oxygen				Air				Nitrogen			
(days)	a	b	aa	bb	a	b	aa	bb	a	b	aa	bb
325	0.80	0.25	1.30	0.00	1.20	2.00	0.00	0.90	0.95	1.85	0.40	0.45
	0.65	0.20	0.25	0.30	0.45	0.50	0.00	0.20	0.60	1.00	0.30	0.00
									0.90	1.95	0.45	1.30
358	0.40	0.75	0.00	0.00	0.75	1.20	0.00	0.15	1.90	1.80	0.65	0.70
	2.05	1.35	0.00	1.85	1.10	1.45	1.80	0.95	2.40	1.45	1.55	1.40
	0.55	0.70	-	0.70								
"N_2" flour, storage atmosphere changed												
288	0.55	0.70	0.20	0.70	0.70	0.35	0.20	0.25	0.00	0.30	0.00	0.30
	0.30	0.15	1.55	0.00	0.25	0.00	0.65	0.80	0.30	0.65	0.50	0.35
320	0.30	0.55	0.55	0.40	1.05	0.30	0.20	0.95	0.50	0.00	0.50	0.00
	0.00	0.25	0.30	0.35	0.50	0.00	0.95	0.00	0.45	0.60	0.20	0.30
351	0.30	0.00	1.45	0.65	0.50	0.05	0.00	0.55	0.00	0.40	0.00	0.80
	0.25	0.35	0.25	0.10	0.65	0.60	0.75	0.00	0.45	0.30	0.55	0.15

Table E. Under-the-curve area (A) values in square centimeters of extensograms of stored flour.

Storage (days)	Mixing atmosphere											
	Oxygen				Air				Nitrogen			
	a	b	aa	bb	a	b	aa	bb	a	b	aa	bb
	Stock flour on day of milling from which stored flours were made											
0	57.1	62.1	84.3	86.1	46.5	47.0	45.3	44.2	41.5	40.8	40.6	37.8
	58.2	61.3	80.4	80.3	45.3	44.3	46.7	46.0	40.6	40.0	37.7	37.8
	"A" flour											
7	60.2	60.0	78.7	81.7	49.9	51.9	46.1	46.4	41.0	40.5	36.9	40.0
	59.0	60.5	82.2	82.4	-	52.4	50.2	-	40.6	40.6	40.0	40.0
	58.0	58.9	76.2	-					48.0	40.6		
14	60.7	61.6	73.9	75.5	52.6	51.8	49.5	49.0	40.9	40.8	39.7	39.2
	57.5	61.8	71.7	76.4	52.4	50.3	50.0	50.0	40.3	40.3	39.4	39.2
					48.0	47.4	49.5	51.2				
28	58.6	62.7	77.9	72.8	52.7	53.3	50.9	51.7	42.9	43.3	38.9	38.7
	58.2	-	78.8	71.2	55.9	53.8	60.0	57.0				
54	66.0	61.1	75.0	74.7	58.8	51.8	57.7	59.1	46.7	38.1	39.7	37.6
	61.1	62.7	82.9	74.2	58.0	61.2	51.8	56.1	45.1	42.2	43.1	42.6
					60.8	60.2	64.6	69.8				
76	65.6	69.1	95.4	68.3	-	53.3	68.4	69.8	41.5	42.9	42.1	38.4
	66.1	67.4	95.7	73.9	55.5	54.4	58.2	70.4	38.8	35.9	36.2	31.8
101	71.9	66.2	80.1	72.3	57.6	57.0	60.8	63.0	41.9	44.2	43.5	43.5
	65.7	70.7	73.0	81.3	59.8	56.1	62.7	69.4	46.3	46.0	42.2	42.6

Table E. (cont.)

Storage (days)	Mixing atmosphere											
	Oxygen				Air				Nitrogen			
	a	b	aa	bb	a	b	aa	bb	a	b	aa	bb
124	82.2 90.6	91.3 87.4	82.6 84.2	84.2 82.8	67.3 61.8	58.5 62.3	82.2 89.6	82.6 79.7	39.7 37.0	45.4 43.8	44.0 39.2	44.2 41.6
151	77.4	75.4	85.8	76.5	63.2 64.8	62.3 62.8	89.8 89.3	91.1 91.2	46.7	48.3	50.1	49.9
175	72.1 65.0	71.4 72.0	84.6 84.6	76.5 76.5	61.1 57.9	59.3 62.7	94.3 89.4	92.8 92.4	48.9 46.2	50.7 53.5	53.4 53.1	52.2 52.8
206	72.5 73.9	69.6 70.5	86.2 87.2	77.4 95.3	63.2 64.5	59.4 60.3	94.1 87.5	91.1 92.0	49.0 48.8	49.5 49.9	54.7 55.4	54.3 54.7
236	73.9 74.8	73.2 74.6	87.7 88.1	95.0 95.4	66.2 65.2	65.0 63.9	94.4 95.0	91.1 89.8	48.6 48.9	52.7 51.3	57.6 57.9	60.8 60.5
268	76.2	74.6	90.4	97.2	65.8 68.2	65.6 66.9	93.4 94.4	90.6 90.4	52.0 52.5	50.1 49.6	60.6 59.8	60.5 60.5
300	73.6 84.0	75.3 85.2	91.1 86.4	95.4 86.7	70.5 72.3	69.2 74.0	95.0 96.0	88.8 88.1	50.0 55.7	51.1 55.9	60.5 60.8	60.4 60.4
332	67.8 62.8	70.7 72.4	96.0 95.4	95.7 96.3	63.9 55.6	61.6 53.1	91.4 65.0	90.7 68.0	48.2 47.6	49.9 47.6	58.9 48.0	59.7 46.7
364	69.8	72.5	95.4	95.0	65.4	63.6	94.1	89.5	47.6	49.5	59.3	59.1
"B" flour												
8	54.0	57.2	81.9	83.7	39.8 43.2	43.3 42.6	51.8 47.0	45.3 45.4	38.9 -	36.1 38.9	39.9 37.8	38.2 -

Table E. (cont.)

Storage	Mixing atmosphere											
	Oxygen				Air				Nitrogen			
(days)	a	b	aa	bb	a	b	aa	bb	a	b	aa	bb
15	53.8 54.7	58.4 56.3	80.0 79.7	81.6 81.3	41.8 42.0 43.3	40.6 41.1 42.6	45.8 51.7 50.6	48.8 46.7 -	36.4 35.5	40.3 35.6	35.2 37.3	37.5 37.4
26	55.7 57.5	55.6 58.7	- 77.1	78.9 77.1	43.3 40.8	45.6 46.5	49.5 53.0	53.4 55.0	35.2 35.6	36.2 34.9	34.5 37.1	37.1 37.1
57	64.3 59.8	64.1 60.0	76.2 78.4	80.3 84.4	47.0 40.6	44.5 47.7	54.4 57.9	60.7 60.5	35.5 33.3	35.5 37.2	34.2 35.7	- 34.6
88	63.2 67.9	66.3 74.7	88.6 89.9	86.9 89.6	49.9 50.3	49.7 49.9	58.9 58.2 58.7	59.8 59.5 55.7	34.3 29.3	36.5 30.3	32.3 33.6	33.6 32.6
116	66.2 69.0	67.6 71.9	84.8 78.7	88.3 85.6	47.7 42.7	52.7 53.8	60.2 55.7	60.7	36.5 38.3	39.7 39.0	36.7 39.0	38.9 38.1
145	67.6	71.4	90.9	90.6	47.3	53.1	58.8	60.4	39.7	38.8	37.5	39.1
168	66.0 67.5	65.5 74.0	90.6 92.5	85.6 90.8	46.8 43.5 52.5	51.2 52.8 54.3	57.9 57.7 59.3	60.9 60.8 -	40.0 38.1 39.1	37.8 37.4 38.6	38.3 34.3 -	39.2 34.4 38.9
202	66.8 53.5	70.1 59.0	94.1 87.7	90.0 92.5	43.5 43.1	44.2 40.3	60.0 59.1	58.6 58.6	40.9 40.5	40.7 44.4	38.3 31.0	36.7 40.3
233	71.8 69.2 70.1	74.0 76.2 70.3	89.0 90.2 89.3	90.6 90.6 91.1	43.6	49.4	64.0	64.6	40.4	40.3	38.3	41.3
263	65.2 59.6	69.3 63.1	88.6 82.6	87.4 82.2	48.9	52.8	69.6	69.5	40.4	39.0	39.8	41.0

Table E. (cont.)

Storage (days)	Mixing atmosphere											
	Oxygen				Air				Nitrogen			
	a	b	aa	bb	a	b	aa	bb	a	b	aa	bb
295	64.4	59.4	87.6	90.6	49.6	53.4	72.8	70.4	40.6	38.9	42.2	40.6
	68.9	75.8	71.4	89.3	49.4	53.0	72.3	69.2	39.5	40.6	42.4	38.3
331	64.4	67.7	90.2	91.5	52.9	52.9	70.5	68.2	39.6	40.8	39.4	36.2
	63.2	69.8	99.2	93.4	52.7	52.7	75.5	65.6	35.6	34.8	32.6	29.1
365	65.5	69.8	90.6	88.1	48.4	53.2	71.7	72.5	37.0	40.3	35.1	32.6
	64.1	65.9	-	-	52.5	53.9	72.3	68.4	38.3	41.2	34.2	33.5
"O_2" flour, storage atmosphere not changed												
31	69.8	68.2	87.7	82.4	57.2	56.8	58.6	60.2	40.8	41.3	39.0	35.0
	60.7	65.5	82.7	82.7	46.1	48.0	58.7	59.5	40.1	41.2	35.2	34.9
49	67.7	72.3	93.8	91.4	66.4	63.2	82.9	83.8	41.3	41.3	42.7	37.6
	80.6	74.1	94.1	101.4	66.5	71.7	94.2	96.4	55.7	55.2	54.0	-
									37.1	32.3	37.3	34.5
78	62.8	64.2	88.0	82.9	50.1	52.3	60.2	55.1	36.5	36.6	34.5	31.8
	57.7	55.0	73.0	76.6	38.7	46.1	64.3	56.7	33.5	36.4	34.4	32.0
102	70.0	61.4	83.5	85.4	55.9	49.7	63.7	60.0	40.4	40.3	34.0	32.6
	51.1	70.4	93.6	90.2	43.7	45.5	61.1	54.6	36.2	36.2	33.9	29.5
125	72.1	70.4	81.9	85.4	54.9	57.8	61.4	62.1	39.7	40.1	33.9	30.9
	73.1	65.4	-	83.1	58.3	59.5	57.9	61.4	37.8	36.5	33.6	-
148	73.3	76.2	85.3	82.6	54.1	57.4	65.0	64.6	40.4	41.3	33.9	37.6
	74.3	73.7	88.1	86.6	56.3	59.3	-	-	39.4	40.1	37.9	33.6
176	78.7	74.3	84.7	82.1	57.2	57.9	70.7	69.1	40.4	45.6	42.1	37.3
	64.9	77.8	77.7	86.6	56.8	57.0	70.5	70.8	39.5	45.4	35.2	35.8

Table E. (cont.)

	Mixing atmosphere											
Storage	Oxygen				Air				Nitrogen			
(days)	a	b	aa	bb	a	b	aa	bb	a	b	aa	bb
204	80.6	73.3	83.5	84.4	54.1	54.7	65.5	70.4	37.8	40.7	42.9	36.0
	75.8	76.8	84.7	87.4	54.6	58.2	68.0	68.7	38.8	42.6	42.7	42.2
	77.3	-	-	-								
235	80.4	80.9	93.4	85.1	55.8	55.1	67.1	69.6	39.0	37.6	42.2	39.8
	83.2	87.0	81.2	95.0	52.7	56.3	62.1	64.8	39.2	40.4	42.1	31.0
266	75.5	81.5	83.5	87.0	52.1	54.5	71.4	70.7	40.6	33.5	43.1	42.5
292	73.0	80.6	82.6	83.5	55.2	54.4	71.4	70.7	39.9	42.2	43.7	44.1
	69.8	67.6	82.4	81.2	47.2	55.2	78.4	68.8	46.1	41.6	-	-
325	75.0	73.9	89.9	88.8	57.0	55.9	71.0	69.8	41.0	41.1	43.2	43.3
	81.6	68.5	92.4	-	55.0	58.0	-	68.5	40.8	41.6	42.3	43.3
358	71.7	65.7	92.4	82.6	55.4	57.3	70.3	70.7	38.1	42.0	42.2	44.6
	71.4	77.1	95.0	91.9	57.3	61.6	69.1	72.5	37.1	42.5	36.1	35.9
"N_2" flour, storage atmosphere not changed												
30	41.0	55.7	78.1	-	45.1	46.3	49.3	50.9	41.9	40.6	36.9	37.6
	57.7	51.3	76.2	78.7	38.4	47.6	51.0	49.4	39.9	35.4	35.7	34.1
50	51.9	53.4	79.8	77.6	-	47.0	52.8	53.8	41.5	40.2	34.8	35.0
					46.6	49.0	52.5	54.2	40.4	34.9	44.2	38.8
					47.6	-	56.9	-				
87	62.4	69.6	83.2	79.4	54.1	49.9	57.1	58.6	39.4	38.3	35.1	35.0
	61.7	68.5	95.7	82.2	52.6	53.7	60.6	61.1	37.1	33.9	43.7	38.5

Table E. (cont.)

Storage (days)	Mixing atmosphere											
	Oxygen				Air				Nitrogen			
	a	b	aa	bb	a	b	aa	bb	a	b	aa	bb
115	67.5 64.5	68.7 66.4	86.9 93.1	78.4 86.6	41.5 41.6	44.0 41.7	60.0 60.4	61.4 57.9	28.7 32.0	34.8 35.2	34.8 34.4	32.3 33.9
140	62.3 65.9	76.5 67.9	- 87.9	84.1 88.1	48.0 48.3	51.5 -	60.3 55.4	60.6 -	36.0 35.5	34.1 50.1	34.1 34.2	34.4 34.8
166	68.8 67.0	70.1 71.9	89.5 84.8	88.3 96.0	45.7 44.5	49.7 51.0	61.7 60.7	58.3 55.9	35.7 36.5	38.0 40.1	36.1 33.6	33.9 39.0
203	67.6 67.8	68.2 66.6	90.6 86.1	88.3 85.8	54.5 51.8	49.9 51.5	63.4 60.9	59.8 67.3	- 36.5	39.4 40.2	34.6 29.8	34.3 42.6
234	- 66.0	67.9 71.6	89.5 100.2	90.1 80.2	55.0 59.3	55.4 56.2	68.9 69.4	65.2 60.5	38.4 40.6	40.1 40.9	- 33.6	38.4 36.1
262	71.8 70.9	68.5 71.2	91.9 90.6	91.5 -	56.6	42.9	72.3	70.0	40.6	41.1	43.3	36.8
291	71.1 56.4	65.9 66.0	87.9 79.0	92.3 94.8	59.4 59.5	59.5 60.7	73.2 72.9	72.5 64.1	39.0 38.4	42.6 46.5	42.6 44.5	43.8 42.2
320	67.5 63.7	66.2 69.8	80.5 88.3	81.9 94.7	47.1 52.9	56.4 60.7	75.5 76.4	78.1 77.9	39.4 39.6	41.9 46.3	45.1 42.7	44.4 47.3
351	66.2 69.4	67.5 72.3	88.8 86.2	85.1 92.3	46.4 56.3	57.9 60.0	75.5 76.0	81.2 -	42.4 48.8	45.5 51.2	45.2 -	41.3 -

Table E. (concl.)

Storage (days)	Mixing atmosphere											
	Oxygen				Air				Nitrogen			
	a	b	aa	bb	a	b	aa	bb	a	b	aa	bb
	"O_2" flour, storage atmosphere changed											
288	71.6	71.1	95.1	91.9	54.4	46.7	76.0	77.1	46.1	46.5	48.8	48.6
	77.4	67.8	88.0	91.5	55.0	55.1	72.9	79.6	46.5	45.4	49.0	49.2
	66.2	72.9	94.6	95.0					44.3	44.0	47.6	47.4
325	71.2	77.1	96.0	96.3	57.9	58.9	89.9	77.9	44.7	43.6	47.6	46.5
	72.9	77.8	91.5	105.6	64.3	62.2	83.5	84.5	48.2	50.8	54.3	48.3
									45.3	43.4	47.2	47.0
358	67.3	71.4	97.3	101.5	55.0	54.7	83.7	65.9	38.6	46.0	41.7	46.7
	64.5	65.9	95.0	86.4	50.6	55.3	74.2	75.5	38.8	46.0	44.2	41.8
	66.4	71.6	-	96.3								
	"N_2" flour, storage atmosphere changed											
288	71.7	70.4	87.2	87.4	53.6	53.8	83.6	72.3	42.1	41.9	48.5	45.6
	82.1	80.1	78.2	83.1	53.4	55.7	74.4	76.5	41.6	44.2	46.7	46.3
320	68.2	68.4	87.3	87.4	54.9	60.3	73.6	73.3	40.5	42.6	46.5	46.1
	68.0	68.5	86.7	87.4	56.5	65.0	85.8	83.2	41.2	41.0	41.0	42.9
351	69.4	71.6	78.9	80.0	60.4	60.7	76.8	74.9	41.2	39.4	41.3	40.3
	70.0	69.7	84.5	92.7	60.3	62.1	74.6	78.1	39.6	39.2	40.7	41.7

EFFECT OF STORAGE AND OTHER TREATMENTS ON CERTAIN PHYSICAL AND CHEMICAL PROPERTIES OF FLOUR

by

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Studies on changes in the physical properties of doughs were carried out with the farinograph and extensograph to determine the effects of storage time, storage atmosphere, storage temperature, different mixing atmospheres, sodium chloride, potassium bromate, ball milling, different dough mixers, hydrochloric acid, acetic acid, ammonium hydroxide, storage under hydrogen sulfide, treatment with nitrogen trichloride, and sub-optimum absorption on flour were made. In addition sedimentation and photometric protein studies were made on ball milled flour and four stored at different temperatures and under different atmospheres.

The following results were obtained:

1. Farinograms and extensograms were influenced by the pressure of the gas used in the mixing atmosphere.

2. Increase in oxygen in the dough resting atmosphere effected extensogram changes, indicating that oxygen is absorbed through the dough surface and affects the protein molecular structure.

3. Farinograms and extensograms of doughs mixed under hydrogen were similar to those mixed under nitrogen. Molecular hydrogen is not active as a reducing agent in doughs.

4. All extensogram force values increased, extensibility values decreased, and area values increased with storage, oxygen in the storage atmosphere, higher storage temperature, and oxygen in the mixing atmosphere when these variables were analyzed both singly and in progressive combination. They are dough "stiffeners" since they increased extensogram area, but they are not dough

"developers" since they did not increase extensibility values.

5. Maintenance of oxygen and nitrogen at high levels in flour storage atmospheres by periodic replacement of the gases caused greater extensogram changes than in similar atmospheres which were not replaced.

6. When the effects of the variables, time, storage, temperature, storage atmosphere and mixing atmosphere were compared singly and in progressive combination, the two stretches occasionally behaved differently as did duplicates of the same stretch. This difference in behavior of stretches and duplicates of stretches is defined as sequence. Spread is defined as the difference between replicates.

7. Oxygen in the storage atmosphere decreased all farinogram values while oxygen in the mixing atmosphere increased all farinogram values.

8. Sedimentation and photometric protein values increased with storage time indicating that gluten hydration increases with age.

9. Doughs having certain concentrations of salt yield horizontal farinograms and it was found that extensograms of these doughs have maximum elastic and plastic deformation, and optimum dough development. It may be that initially after milling each flour has a specific salt concentration giving horizontal farinograms and that this concentration may change with storage, thus serving as an index of flour maturity.

10. Instances existed where increasing salt concentration

yielded plateaus in farinogram values. The length of the plateau in terms of range of sodium chloride concentration may be an index of flour strength.

11. Sodium chloride was found to be a dough "developer" while potassium bromate was found to be a dough "stiffener".

12. The combined effect of salt and bromate on farinograms and extensograms was found to be intimately connected with the mixing atmosphere. Selection of the mixing atmosphere is of prime importance and if not taken into consideration effects of certain treatments may be masked and, consequently, could be considered absent; erroneous conclusions might then be drawn from the data obtained.

13. Ball milling of flour caused all farinogram values to increase as well as extensogram force and area values, but extensibility values decreased. Oxygen in the mixing atmosphere increased all farinogram values. In the case of ball milling, the changes are probably associated with fracturing of starch granules causing them to bind water more strongly. The oxygen effect on the other hand probably involves formation of additional cross linkages in the protein structure thus conferring added rigidity to the system.

14. Ball milling did not change either sedimentation or photometric protein values. This is further evidence that ball milling acts primarily upon starch, rupturing the granules and breaking the starch chains.

15. The nature of the mixing by the farinograph and the Hobart-Swanson mixer are similar, as revealed through extensograms of doughs mixed in both machines.

16. Extensogram peak reversals (curve slope reversals) were effected by hydrochloric acid. It is believed that each flour shows a specific concentration of acid where peak reversals will occur.

17. From comparative studies of effects of hydrochloric acid and acetic acid on extensograms, it is concluded that acetic acid denatures the gluten protein more severely than does hydrochloric acid and it may possibly affect the starch to some extent as well.

18. The actions of the same concentration of hydrochloric acid, acetic acid, and ammonium hydroxide upon extensogram characteristics are each different when used in conjunction with salt. This leads to the belief that specific chemical reactions occur with the various reagents rather than purely physical or colloidal effects or differences due to enzymatic causes.

19. Ammonium hydroxide and nitrogen trichloride were found to be dough developers, since they increased all extensogram values.

20. All farinogram and extensogram values of doughs stored under hydrogen sulfide drastically decreased. Hydrogen sulfide acts as a reducing agent and probably causes rupture of certain linkages in the protein macro molecules. This was also demonstrated by the dough handling characteristics, the doughs being

excessively wet, limp, and sticky.

21. Agenization prior to storage inhibited the action of hydrogen sulfide since all farinogram and extensogram values of doughs of agenized flour increased markedly over those of the untreated flour. It is believed that nitrogen trichloride, an oxidizing agent, enters into chemical combination with linkages in the protein susceptible to reduction and, thus, prevents their reduction by hydrogen sulfide.

22. Optimum absorption and mixing time were found to increase with flour age, indicating the probability that points for hydrogen bonding in the protein molecules increase with age. It is believed that starch imbitition also increases as flour ages.

23. With sub-optimum absorption extensogram slope reversals became more pronounced with doughs whose flour had been stored at the higher temperature. It is believed that a method can be devised to reveal the temperature treatments which have been applied to an unknown flour by the use of extensograms of doughs having sub-optimum absorption.

24. A technique for accurately correlating the subjective appearance and properties of doughs with the characteristics as determined by means of the farinograph and extensograph was developed.