THE PRODUCTION OF WHEAT BREADS ON A LABORATORY CONTINUOUS MIX UNIT

by 149

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Introduction

The commercial development of the continuous breadmaking process in 1954 brought about many changes in the technology of breadmaking. Today, upwards to 40% of all bread produced in the United States is by this process. The rapid acceptance of the continuous mix process was due to several factors. Most important was consumer acceptance of the bread which was widespread and immediate in most areas. Another factor which lead to its rapid expansion was that it meant automation for the baker. The baker could now produce a large volume of a quality product using a low labor force. One of the problems of continuous mix is that certain types of speciality products have never been produced by this process, and in some instances if they are being produced, many problems exist due to the lack of established methods of production. There are many types of speciality products that offer potential for adaptation to the continuous mix process; wheat breads, rye breads, raisin bread, and sweet goods to name a few. This research however, was confined to the area of wheat speciality breads. The aims of this work were to establish workable procedures for the production of wheat bread by the continuous breadmaking process.

Literature Review

Continuous Breadmaking Progress: Many important developments have been incorporated into the continuous breadmaking process since its commercial introduction in 1954. With only six units in commercial operation, Baker (1) reported methods for successful production of white bread. He suggested the use of a liquid broth or ferment system that replaced the conventional sponge of the sponge dough process. He found that the fermentation of yeast and sugar replaced the fermentation of the sponge. Dextrose at a level of 4 percent was used in the broth while 4 percent sucrose was added at the premixer. He also stated that due to the higher dough temperature, the shortening used must have a melting point greater than 100° F. Whole wheat and rye breads were reported to have been made on these units with some success.

The traditional use of milk in most bread formulas was somewhat thwarted in the continuous process. Milk produced deleterious effects such as decreased volume and poor grain and texture. Swortfiguer (24) reported that an oxidant ratio of 3 parts $KBrO_3$ to 1 part KIO_3 produced the best results in high milk formulas. He also reported the use of calcium - acid - phosphate for lowering the pH of high milk brews. Meyer (13) suggested replacing dry milk solids with buttermilk solids. With the use of buttermilk solids, he reported improved flavor and volume even when used at a level of up to 6 percent in the formula.

The introduction of continuous mix processing laboratory units in 1959 was an important factor in improving methods of continuous mix production (15). With these scaled-down pilot models, complicated factorial designed experiments could be performed because of reduction of cost of ingredients and less time involved in operation. Redfern, et. al. (16) using the Amflow Continuous Mix unit reported good reproducability and was able to deliver dough from the developer head at a rate that was within 1.0 - 1.5 percent of the rate calculated from the sum of the individual streams. They found, however, that this accuracy could be enhanced by increasing thruput from 200 to 300 pounds of dough per hour. They recommended the use of a factorially designed experiment as a most desirable procedure in working with a laboratory continuous mix unit. They stated that the factorial design was appropriate due to the desirability of studying the effects of several factors simultaneously. With a factorial experiment, each factor could be studied individually or compared to allow testing for interaction. They found to provide the most meaning replicate experiments should be performed on different days.

Titcomb, et. al. (25) studied the reproducability of different laboratory continuous breadmaking units. They found that reproducability could be predicted within a certain laboratory. Precision, however, was found to depend on the techniques involved in a particular laboratory and the type of unit involved.

Much work in the area of preferment or stable ferment baking process was applicable to the continuous breadmaking process. Choi (6) in (1954) did some of the earliest work in the area of preferments. He reported that the bacterial population decreased with time from a high initial count, possibly due to the alcohol produced during fermentation. He also reported on the effect of milk in stabilizing the pH of the preferments. McLaren (11) in 1954 described a stable ferment baking process in which a solution of all ingredients except the flour and shortening was allowed to ferment for about 6 hours. After fermentation this material along with the other ingredients were mixed in a conventional mixer. After this step, the procedure of the sponge dough process was followed. He described the ferment as being stable up to 36 hours if cooled to 50° - 60° F. Meigs (12) in 1956 extended this preferment process to the making of variety type breads. Wheat bread was made at a level of 25 percent whole wheat. The bread was described as having adequate volume and acceptable flavor. Nine percent sugar and four percent nonfat-dry-milk were used in the formula. Carroll, et. al. (5) in 1956 described the use of malted wheat flour and fungal enzyme preparations in the addition of bread made by the preferment process. They found no difference in the quality of the bread whether the enzymes were added in the preferment or in the dough stage. Johnson and Miller (8) in 1957 performed various analysis on preferments. Tests such as pH, CO_2 production, lactic and acetic acid production, ethyl acetate production, and amounts of protease retained in different preferments were performed.

They found that a good baking quality flour by the sponge method also produced good breads by the preferment process. A fair baking quality flour by the sponge process made very poor bread by the preferment process.

The introduction of equipment capable of handling up to 50 percent flour in the brew created some controversy as to the effectiveness of using the liquid sponge method in improving overall quality of continuous mix bread. Trum (28), originally reported that high flour brews resulted in stronger bread crumb and body without loss in softness, an increase in flavor was also noted. Flour in the brew also allowed the exclusion of sugar at this stage. In a later publication (26), he expanded on the list of these advantages reporting; 1. increased loaf volume, 2. stronger crumb body, 3. greater retention of crumb resistance, 4. greater consumer acceptance, 5. reduction of mechanical work input requirements, and 6. reduction in total sugar in the formula. Snell, et. al. (22) reported advantages of firmer sidewalls, less amylose in crumb due to action of the amylases on the damaged starch, and a more open grain. He cited such disadvantages however, as a required absorption decrease of 1 percent for every 20 percent flour in the brew and the high cost of equipment for handling. Mauseth, et. al. (10) reported that an increase in mixing was required with high flour brews but percentage flour in the brew had no effect on cell size. It was also reported that the deleterious effects of milk could be somewhat overcome when the flour in the brew increased.

The level of oxidation is a critical factor in continuous bread production. Tremendous stress on the dough during development, short mixing time, and a short period of time between mixing and oven are all reasons for a required increase in oxidation. Factors affecting oxidation include: flour type and age, and level of milk. Redfern, et. al. (17) in 1956, reported that in using a 20 percent flour brew, when the oxidation level was increased, mixing requirements increased, power requirements increased, and crumb structure was strengthened. Optimum oxidant ratio was 5 parts $KBrO_3$ to 1 part KIO_3. Altering this ratio affected mixing tolerance and optimum developer speed.

The type of flour used in continuous mix bread production has been shown to be an important factor. Trum and Rose (27) reported that in calculating absorption an increase of 3 percent should be added to the farinogram value. They also reported on other farinogram measurements which included hydration or arrival time, departure time, and mixing tolerance. They found that flours with rapid arrival time produced best results. Flours with long departure times were found to be undesirable in that throughputs had to be decreased due to the increased mixing and power requirements. When dough properties were measured at 38° C. with a Farinograph, certain dough characteristics such as medium mixing tolerance, with a relatively short departure time were shown to be superior for use in the continuous breadmaking process.

Schiller and Crandall (19) worked with flour that had extreme protein ranges. They found that certain flours by themselves produced bread of inferior quality, but when blended produced high quality bread. This finding agreed with what was known about flour blending in conventional breadmaking processes. Schiller (18) reported on what he called the "time factor" involved in various steps of the continuous breadmaking process as compared with the time for similar steps with the sponge dough process. He concluded that this "time factor" placed limitations on the type of flour that could be used. He concluded that since the time for such things as fermentation, and mixing were shorter in the continuous breadmaking process, greater stresses were placed on the flour. He also concluded that these time effects make it manditory that a flour be of uniform quality.

Fat systems for continuous mix bread production are also important. Baldwin, et. al. (3) found that a hard fat fraction was necessary; however, it was found that its addition in an emulsified or hydrated state, rather than as a melted fat produced much better results. This was one reason for the success of liquid shortenings.

Schiller and Gillis (20) performed a study of optimum developer speed as related to absorption, oxidation level, and starch damage. They found as absorption increased, developer speed had to be increased. Oxidation level was also directly related to optimum developer speed. As starch damage was increased, optimum developer speed increased. Increasing starch damage also decreased tolerance and drastically affected quality of the bread.

Baldwin, et. al. (2) characterized the individual milk proteins as to their effect on continuous mix bread. In his work, calcium-acid-phosphate was used to keep brew pH at an optimum level of 4.8 - 5.0. Casein had no effect other than dilution. The albumin and globulin fraction weakened and slackened the dough. This effect was somewhat overcome by high heat treatment. The heat treatment was thought to result in insolublization and protein - protein interaction, rendering the groups responsible for dough weakening ineffective.

Wheat Bread Production When a basic white bread formula is altered to produce some variety type bread, the effect of these formula changes are usually deleterious with respect to certain attributes of the dough and bread. Bull (4) who investigated the effects of fresh wheat germ on baking quality, found deleterious results. The water soluble portion produced the same deleterious results but these effects were reduced by removing the coaguable portion of the germ. The deleterious effects were attributed to the minerals present, particularly the MgO/CaO ratio and also the nonprotein compound asparagine.

Sullivan, et. al. (23) also found fresh wheat germ to produce harmful results but the deleterious results were not so pronounced when the germ was stored in a sealed container. The effects were shown to be due to the water soluble fraction in both baking and Farinograph tests. They did not attempt to identify the responsible constituents. Grewe and LeClerc (7) found that steeping the wheat germ for 3 hours or more before adding to the sponge greatly reduced the deleterious results.

Granulation of the whole wheat flour used in wheat bread production also has an important effect. This was shown by Shetlar and Lyman (21) who found by grinding raw bran to varying granulations that if adhearing endosperm was not removed before grinding an intermediate granulation produced the best bread. If this endosperm was removed prior to grinding, however, the fine grind produced the best bread. Bran extracts from the different granulations had little effect on bread quality. In an experiment where cellulose was ground to varying granulations, the fine grind also produced the best results. It was thought that the coarse bran brought about cell coalescence reducing loaf volume and interior quality. No postulation was made as to the reason for the deleterious effects of the fine fraction on loaf volume and interior quality in the work with the raw bran.

Parker (14) in 1949 described the development of a high speed grinder in which very fine whole wheat of uniform granularity could be made. He reported successful production of whole wheat bread with this uniform whole wheat flour.

Very little work has been done reporting the application of the continuous breadmaking process to production of wheat breads. There are, however, some current commercial applications, but many problems arise due to the lack of a standard procedure.

Underhill (29) reporting on a Do-Maker commercial unit application of wheat bread production, stated that the dough temperature during development should be somewhat cooler than the dough during white bread production. He also noted a reduction in mixing and less mixing tolerance. Using 20 percent whole wheat in the formula, he found that absorption had to be decreased 3-4 percent from the white bread formulation.

Lorenz and Habighurst (9) using an AMF laboratory continuous mix unit found that mixing was critical and a reduction in mixing was noted as the percent whole wheat in the formula increased, and that dough temperature in the developer became somewhat higher, unless the liquid sponge was cooled prior to incorporation.

The work in this research project gave special attention to the type of grinding of the whole wheat and to the granulation of the bran fraction on the quality of the wheat bread. It was also the objective of this work to determine the maximum amount of whole wheat flour that could be used in the formula and still produce an acceptable loaf of bread.

Materials and Methods

Grinding of Whole Wheat and Bran

A flour milled from a hard red spring wheat blend was obtained from the Pillsbury Company. This was a straight grade flour with a protein content of 15.3 percent and an ash content of 0.52 percent. The flour was chosen because of its widespread commercial use in strengthening flours for continuous mix breadmaking. Another flour from a hard red winter wheat blend that was milled on the Kansas State University Pilot mill was also used. This was a straight grade flour having a protein content of 11.5 percent and an ash content of 0.42 percent. These two flours were blended one to one on the blending system of the Kansas State University Pilot mill. The resultant blend had a protein content of 13.4 percent and an ash content of 0.47 percent. This blend was then used as a control and as the base flour in the wheat bread studies.

Two hundred pounds of a hard red spring wheat blend was subjected to two types of grinding. The blend had a protein content of 13.5 percent and an ash content of 1.7 percent. A grinding method was used where a gradual reduction was performed and to the other extreme a rather harsh method where an immediate reduction took place.

To produce a gradual reduction of the stock, the wheat was milled on a Miag Multomat laboratory mill. The wheat having a moisture content of 12.2 percent was milled without a temper.

The break rolls were set somewhat closer than in conventional milling, and the reduction system was set to obtain maximum reduction of the stock. The bran was kept separate from the rest of the stock and after completion of the milling, was subjected to further reduction on a Ross experimental laboratory roller mill. This mill had corrigated rolls with 24 corrigations per inch, and a differential of 2 1/2 to 1. The rolls were set to almost zero tolerance so as to produce a maximum grinding action. After milling and reduction of the bran, the various streams were placed in a 200 pound capacity ribbon blender and blended for 5 minutes.

In producing a harsh grinding effect, a high speed Entoleter, pin-mill grinder was used. The pin-mill was set up with an 86 stationary pin liner in position. With the liner in position, the inside diameter was 30 inches. The rotor was 27 inches in diameter with 36 pins. The wheat was passed through at a feed rate of approximately 7 pounds per minute. The speed of the rotor was 3900 r.p.m. The temperature after one pass through the pin-mill was found to be 122° F. The stock was allowed to cool for 30 minutes. This material was then passed through the machine again at the same settings of the first pass. The temperature after this pass was found to be 128° F. The stock was then spread out on a large table and was stirred periodically to assure uniform cooling. After cooling, the stock was placed in the batch ribbon blender and blended for five minutes.

Two hundred pounds of bran was obtained from a commercial flour mill. Three different granulations of bran were investigated on the continuous mix unit. An impact grinder was used to perform the reduction of the stock. Conditions were identical to those used in the grinding of the whole wheat. It was decided to use as the coarse fraction, the bran as it came from the mill and 50 pounds was set aside for this purpose. The medium fraction consisted of stock passed twice through the impact grinder and the fine fraction consisted of stock passed through the impact grinder five times. The temperature of the stock after two passes with a 30 minute break in between was found to be 126° F. The temperature after five passes was found to be 136° F. All materials were stored at 42° F. until used.

Continuous Mix Laboratory Unit

The AMF laboratory continuous pilot doughmaking unit was used in these baking studies. A schematic diagram is shown in figure 1. It was a completely integrated unit that consisted of component parts that make up a complete doughmaking system. The system consisted of two 30 gallon jacketed brew tanks with high and low speed agitators for mixing the ingredients. The water jackets allowed for setting and holding the brew at any desired temperature. After the brew had fermented for the desired length of time, it was pumped by a positive displacement pump into a holding tank. This holding tank and five other ingredients tanks were connected to separate variable speed

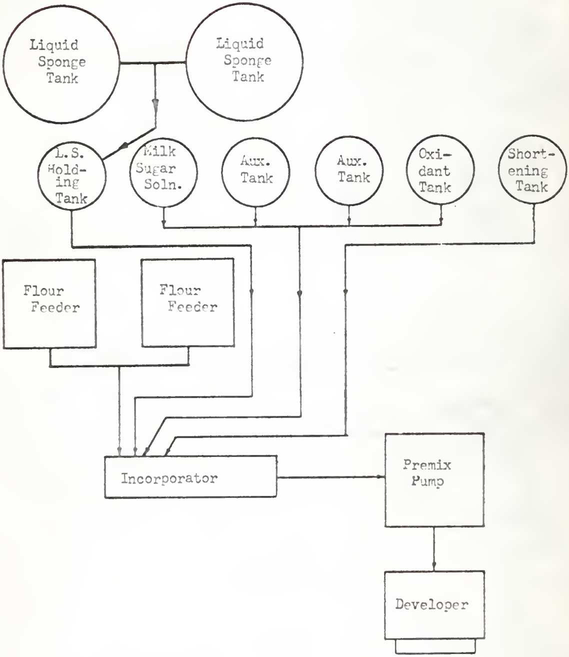

Figure 1. Schematic Diagram of Amflow Continuous Mix Laboratory Unit.

pumps that allowed metering of the ingredients into the premixer. This unit has two volumetric feeders on a track system above the incorporator which allowed for changing flours without recalibration. Besides the brew holding tank, the five other tanks were used for other ingredients not included in the brew. These were either an oxidant solution, milk sugar solution, shortening, or some solution of auxilary ingredient in the formula. From the incorporator, the ingredients entered a positive displacement pump and were pumped to a variable speed developer head. The dough was given final development at this stage. The dough was then extruded and cut off at desired weights by a semi-automatic cutoff device. The panning was performed manually by manipulating the pan in a position so as to allow center positioning of the dough. The unit was designed to operate over a range of from 150-300 pounds of dough per hour. In this work, the unit was operated at approximately 150 pounds of dough per hour. The unit was designed so as to allow from 0 to 50 percent of the total flour in the liquid sponge system.

Experimental Procedure

Two independent experiments were designed factorially. In the first design, the main effects studied were the effect of type of grinding of the whole wheat flour and percent of whole wheat in the formula. The design in total consisted of a 2 x 3 x 3 x 4 factor experiment. Included were two types of grinding, one on the Miag Multomat and the other on the Entoleter pin-mill. Three levels of 15, 25, and 35 percent whole wheat flour were used. The other factors consisted of three levels of oxidation, 45, 75, and 105 p.p.m., and four mixing speeds of 81, 102, 125, and 146 r.p.m.

In a second design, the main effects studied were the granulation of the bran fraction and the percent of bran in the formula. The design in total consisted of a 3 x 3 x 3 x 4 factor experiment. Included were three granulations of bran, a fine, medium and coarse fraction. Another effect was three levels of bran; 3, 6, and 9 percent in the formula. The other factors included oxidation; 45, 75, and 105 p.p.m., and four mixing speeds; 81, 102, 125, and 145 r.p.m.

Preliminary experiments included using a commercial wheat bread premix. This premix consisted of coarse bran flakes, ground whole wheat, ground whole rye, and ground defatted flaxseed. This premix was used in the bread formula at a level of 17 percent. From this work, parameters were established that could be followed in the two designs.

A typical continuous mix white bread formula, utilizing the base flour blend, was used as a control. Oxidation levels used were 45, 75, and 105 p.p.m., the same as in the experimental work. The mixing speeds used were somewhat higher than in wheat bread production. The formula in Table 1 was used as the white bread control.

Table 1. White Bread Control Formula.

Ingredients	% ****	Phase I*	Phase II**	Mixing Phase
Flour	100	35.0		65.0
Water	64.0	50.0	6.0	10.0
Yeast	3.25	3.25		
Malt flour	0.5	0.5		
Yeast food***	0.5	0.5		
Salt	2.0		2.0	
Sugar	6.0	1.0		5.0
Milk	2.0			2.0
Liquid shortening	3.0			3.0
Oxidation	45,75 and 105 p.p.m.			45,75 and 105 p.p.m.

* Initial ingredients of the liquid sponge.

** Included ingredients added to the liquid sponge after 1 hour and 45 minutes fermentation.

*** Arkady.

**** All ingredients compared to flour 100%.

Bread Scoring Procedure

A scoring system was designed that included five loaf characteristics. The maximum score possible with this system was 100. Volume score was allotted in relationship to specific loaf volume. The system used in allowing for volume score is shown in Table 2. A specific volume of six or greater was given a score of 25 points, while a specific volume of 3.4 or less was given a score of 0. Other characteristics scored included 15 points maximum for external loaf appearance, 25 points maximum for crumb texture, 25 points maximum for crumb grain, and 10 points maximum for general crumb appearance.

Table 2. Specific Volume Loaf Score Conversion

Specific Volume, cc/gm	Loaf Score
6.0 or greater	25
5.8	23
5.6	21
5.4	19
5.2	17
5.0	15
4.8	13
4.6	11
4.4	9
4.2	7
4.0	5
3.8	3
3.6	1
3.4 or less	0

Results and Discussion

Results of Grinding of Whole Wheat and Bran

Whole Wheat Grinding: Grinding of the whole wheat on either the pin mill or Miag Multomat caused wide variation in the particle size distribution, although the average particle size was similar. Granulation curves of the grinding, figure 2, showed that material over a 36 g.g. (500 microns) was similar for both grinding methods. The Miag Multomat produced a higher percentage of particles within the range of 130 to 500 microns. It was found that 70 percent of the material from the Miag was in this range, while only 40 percent from the pin-mill fell within this range. More flour (material less than 130 microns) was produced by the pin-mill, 40 percent of the material ground on the pin-mill passed through a 10 x x seive, while 12 percent from the Miag Multomat passed through a 10 x x seive.

Bran Grinding: The results of the pin-mill reduction of whole bran are shown in figure 3. It can be seen from the data the increasing difficulty in reducing particle size with each pass through the mill. For example, an increase of 25 percent in material that would pass through a 60 wire (310 micron) seive was observed from zero passes to two passes through the mill. From two passes to five passes, there was a 12 percent increase in material passing through a 60 wire.

The object of the grinding was to produce three grinds of decreasing particle size. From physical observation of the

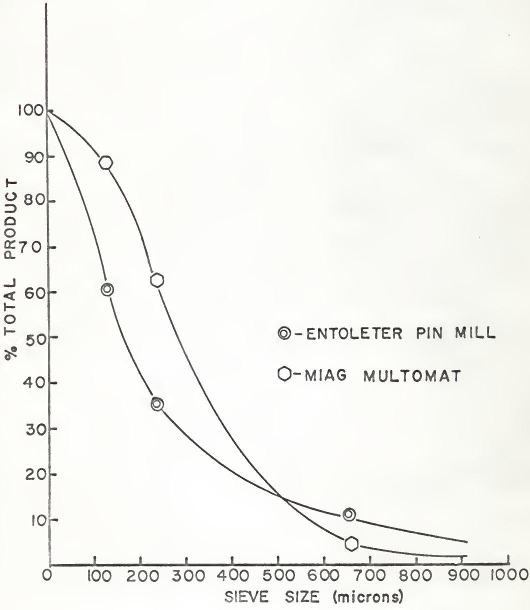

Figure 2. Particle Size Distribution of Ground Whole Wheat Flours.

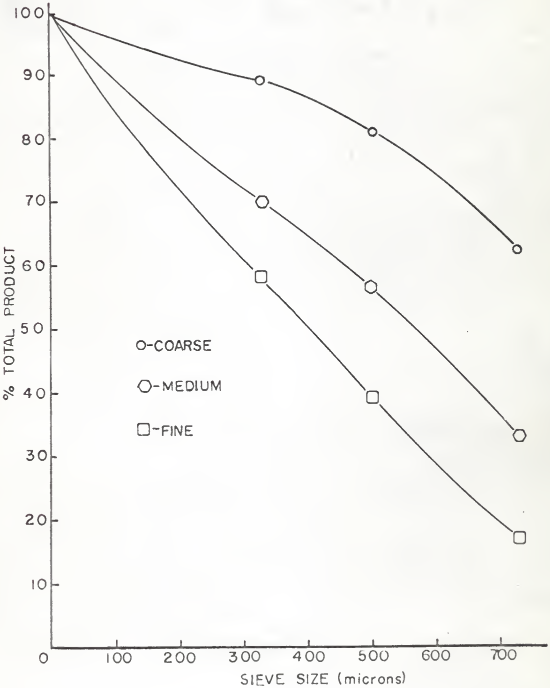

Figure 3. Particle Size Distribution of Ground Brans.

stock and results of the sifting test shown in figure 3, it was assumed that the differences in granularity would be adequate to show the effect of bran particle size on baking characteristics.

Baking of Control Formula

The white bread control was used to determine baking characteristics of the flour blend to be used in the wheat bread studies. Oxidation requirements, absorption level, and optimum developer speed were determined.

Farinograph absorption was found to be 63.4 percent. Absorption used on the continuous mix unit was 66.4 percent.

Oxidation requirements were found to be 75 parts per million. The best oxidant ratio was four parts $KBrO_3$ to one part KIO_3.

This flour was found to have excellent mixing tolerance, figure 4, and very good strength both in proof and in the oven. It was noted that this was not a good continuous mix flour because of its excessive strength and long mixing tolerance; however, it was felt that this extra strength would be advantageous because of dilution with bran in wheat bread production.

Formulation and Production with Whole Wheat Premix

Formulation Procedure: The white bread control formula required some alteration for the production of this speciality bread. The conventional formula for this bread called for a total of 12 percent sugar in the form of honey, molasses, and

Figure 4. Bread Produced Using Control Flour, Showing Results of Oxidation and Developer Speed on Bread Quality.

brown sugar in a 1 - 1 - 2 ratio. Another requirement was that the protein content of the bread be 10 percent on a 38 percent moisture basis. This requirement could be met by the use of a high protein flour, or a gluten supplement.

Work was done using the premix both in the liquid sponge and feeding it in dry at the incorporator. It was found that feeding of the dry material meant delayed hydration by the bran, resulting in an abrasive action on the dough creating a ragged appearance with weak characteristics. Placing the premix in the liquid sponge resulted in complete hydration and softening of the bran particles. This improved the appearance and physical aspects of the dough, and resulted in an improvement in bread quality.

The granularity of the premix created some problems. One problem encountered was that the coarse particles would not stay in suspension in the liquid sponge and also there was a tendency for the gluten to be easily washed out. Another thing noted with this coarse mixture was the tendency for cell coalescence to occur with resulting bread of reduced volume and overall inferior characteristics. Reducing the particle size of the premix by grinding on an Entoleter pin-mill produced much better results. The finer stock resulted in bread with greater volume, finer texture, and better eating characteristics.

Best results were obtained with an oxidant ratio of four parts $KBrO_3$ to one part KIO_3 used at 90 parts per million. This represented an increase in oxidation requirements compared to requirements of the white bread control where optimum appeared to be approximately 75 parts per million.

Other requirements of the formula included a reduction in milk to a level of 0.5 percent. Levels over this amount seemed to have a deleterious effect on the bread. Four percent gluten supplement resulted in improved quality of the bread. The added gluten resulted in improved volume and greater mixing tolerance.

A decrease in developer speed was noted in comparison to that of the control formula. Mixing tolerance was also quite low as shown in figure 5.

With this premix it was shown that a wheat type bread of excellent quality could be made on the Amflo laboratory continuous mix unit. This was also shown in a commercial Amflo unit as the procedures of production and formulation developed on the lab unit produced acceptable bread in commercial production.

Wheat Bread Production

Liquid sponge and dough characteristics: From results observed with the whole wheat premix, it was decided to place the whole wheat flour in the liquid sponge. A standard method was developed for setting the liquid sponge. First the water, yeast, yeast food, malt, and 1 percent sugar were mixed under high speed agitation, for approximately two minutes. Secondly, with the high speed agitator in motion, the flour and whole

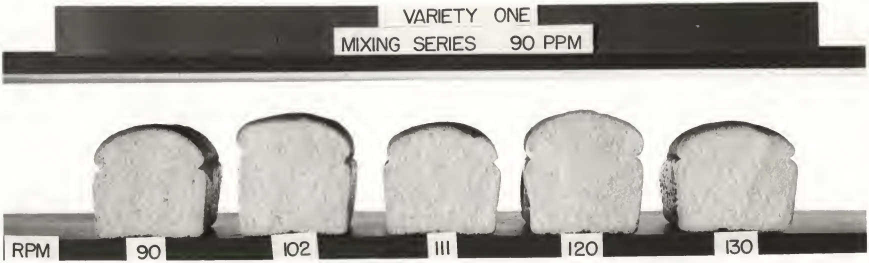

Figure 5. Effect of Developer Speed on Quality of Wheat Bread, Utilizing a Commercial Premix in the Formula.

wheat flour were added. It was found that if no more than one minute was allowed for this second operation, gluten washing could be kept at a minimum. At the 35 percent level of whole wheat in the brew, however, some gluten washout occurred even with this short agitation period. After the brew had been allowed to ferment for 1 hour and 15 minutes with no agitation, the salt solution was added. It was found that the most acceptable method involved addition under slow agitation, with continued slow agitation from this point until production was completed. The pH of the liquid sponge was measured every half hour. It was found that increasing the amounts of whole wheat in the formula had a definite buffering effect, figure 6. This buffering effect did not carry over to the bread crumb, however; as there was no significant differences in pH of the bread crumb from loaves with different whole wheat levels.

Some difficulty was encountered in metering the liquid sponge at the 35 percent level of whole wheat flour. There was a tendency for the flow to be uneven, this was partly due to clumping of the bran particles and partly due to the washed out gluten. The flow was not so uneven however, so as to effect the calibrated weight fed to the incorporator.

An absorption increase of approximately 2.5 percent was noted for each 10 percent increase in whole wheat flour in the formula. The absorption for each level of whole wheat was found by setting an auxiliary tank with water and adjusting the flow after going on stream until proper dough consistency

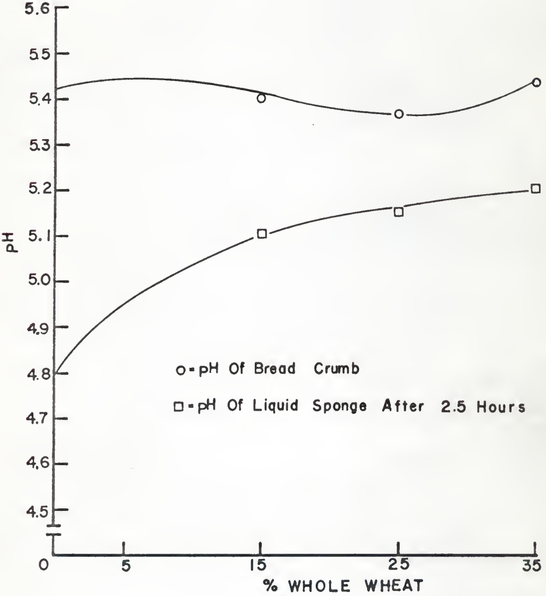

Figure 6. Effect on pH of Liquid Sponge and Bread Crumb by the Addition of Whole Wheat Flour.

was obtained. After each experiment was over, the flow of water would be measured and the absorption calculated.

Dough consistency changed with increasing levels of whole wheat flour in the formula. As whole wheat increased, it became increasingly difficult to pan the dough. Machinability became much poorer with increasing amounts of whole wheat in the formula. It was noted that best results were obtained when the dough at the 25 and 35 percent whole wheat levels had an undermixed appearance in that it was short and would not sheet out easily as in white bread production.

Dough temperature at the developer had a tendency to increase with increasing levels of whole wheat flour in the formula. The temperatures averaged 98° F. at 15 percent whole wheat, 101° F. at 25 percent whole wheat, and 105° F. at 35 percent whole wheat. This increase was thought to be due to increased friction of the bran particles, although little increase in power requirements between levels were noted. Developer speed also had an effect on dough temperature increasing about 2° F. for each increase of 25 r.p.m.

<u>Effects of Different Factors on Baked Product</u>: A statistical analysis of the data representing the effect of grinding method was performed. The analysis of variance are shown in tables 3 through 12. Individual analysis were performed on specific loaf volume in cc/lb., internal loaf score, and total loaf score.

Specific volumes in cc's per pound were determined on four replicate loaves. An average of the internal loaf characteristics of these replicate loaves were determined and expressed as internal and total loaf score.

The method of grinding the whole wheat was shown to be nonsignificant when specific loaf volumes were compared. This indicated that the differences in granularity affected such aspects of the loaf as grain and texture but not specific loaf volume.

The summary in tables 3 through 10 show the effect of grinding on total and internal loaf score. The bread made with the whole wheat flour prepared on the Miag Multomat, produced higher scores than that made from whole wheat flour from the Entoleter pin mill.

The effect of whole wheat level as related to dough oxidation suggested that oxidation had no particular effect on bread volume or total loaf score. This is shown in tables 3 through 6, 11, and 12. In the case of internal loaf characteristics, tables 7 through 10, slightly better characteristics were observed when oxidation was at 45 parts per million at the 15 percent level of whole wheat. At the 25 and 35 percent levels of whole wheat, 105 p.p.m. produced slightly better results. Tables 5 through 8, and 12 suggest that developer speed was more critical at 25 and 35 percent whole wheat. Specific loaf volumes, internal loaf scores, and total loaf scores all decreased as the level of whole wheat in the formula increased.

A summary of the second and third order interaction effects in the whole wheat experiments is shown in table 13. Analysis of variance tables for the whole wheat experiments are presented in the appendix. No attempt was made to analyse the third order interactions other than showing significance or non-significance by the use of the F test. This was because no meaningful postulations could be made.

In figures 7-12 the results of the whole wheat experiments are illustrated. It was noted that increasing levels of whole wheat flour in the formula produced bread with a more open grain with thicker cell walls. The grain became more open when increasing developer speed, but became somewhat finer with increasing oxidant especially at the 35 percent level of whole wheat flour in the formula. A decrease in developer speed was required with increasing levels of whole wheat. At the 15 percent level of whole wheat flour acceptable bread was made at each of the developer speeds used. At the 35 percent level of whole wheat flour however, acceptable bread was made only at the lowest developer speed.

The bread crumb became increasingly dark as the amount of whole wheat flour in the formula was increased. Figure 13 shows an almost linear decrease in percent reflectance with increasing levels of whole wheat flour in the formula.

Table 3. Effect of Whole Wheat Level, and Dough Oxidant on Total Loaf Score (100 Max.).

	Grinding Treatment									
	Pin Mill					Miag Multomat				
	Whole Wheat Level (%)									
p.p.m.	15		25		35	15		25		35
45	87.2	*	65.3	*	50.8	82.0	*	75.0	*	52.2
75	78.5	*	52.3		51.5	72.0		67.7	*	58.5
105	60.8		64.5	*	52.7	78.7		80.0	*	61.7

Oxidation non-significant by prior F test

LSD = 4.90, 5% Level of Significance (Whole Wheat Level)

* = significantly different than adjacent value

Table 4. Effect of Grinding Method, and Dough Oxidant on Total Loaf Score (100 Max.).

	Whole Wheat Level (%)							
	15			25			35		
	Grinding Treatment								
p.p.m.	Pin Mill		Miag Multomat	Pin Mill		Miag Multomat	Pin Mill		Miag Multomat
45	87.2	*	82.0	65.3	*	75.0	50.8		52.2
75	78.5	*	72.0	52.3	*	67.7	51.5	*	58.5
105	60.8	*	78.7	64.5	*	80.0	52.7	*	61.7

Oxidation non-significant by prior F test

LSD = 4.0, 5% level of significance (Whole Wheat Grinding)

* = significantly different than adjacent value

Table 5. Effect of Whole Wheat Level, and Developer r.p.m. on Total Loaf Score (100 Max.).

	Grinding Treatment									
	Pin Mill					Miag Multomat				
	Whole Wheat Level (%)									
r.p.m.	15		25		35	15		25		35
81	84.0	*	69.0	*	62.0	67.0	*	73.3		74.0
			*		*	*		*		*
102	81.7	*	62.3	*	52.0	85.7		82.7	*	61.0
	*		*					*		*
125	71.0	*	55.3	*	48.0	82.3	*	75.3	*	52.3
	*				*	*		*		*
146	65.3	*	56.0	*	40.7	75.3	*	65.7	*	42.7

LSD = 5.65, 5% Level of significance (Mixing speed)

LSD = 4.90, 5% Level of significance (Whole Wheat Level)

* = Significantly different than adjacent value

Table 6. Effect of Whole Wheat Grinding, and Developer r.p.m. on Total Loaf Score (100 Max.).

	Whole Wheat Level (%)								
	15			25			35		
r.p.m.	Grinding Treatment								
	Pin Mill		Miag Multomat	Pin Mill		Miag Multomat	Pin Mill		Miag Multomat
81	84.0	*	67.0	69.0		73.3	62.0	*	74.0
			*	*		*	*		*
102	81.7		85.7	62.3	*	82.7	52.0	*	61.0
	*			*		*			*
125	71.0	*	82.3	55.3	*	75.3	48.0		52.3
	*		*			*	*		*
146	65.3	*	75.3	56.0	*	65.7	40.7		42.7

LSD = 5.65, 5% Level of significance (Mixing speed)

LSD = 4.00, 5% Level of significance (Whole Wheat grinding)

* = Significantly different than adjacent value

Table 7. Effect of Whole Wheat Level, and Developer r.p.m. on Internal Loaf Score (65 Max.).

	Grinding Treatment									
	Pin Mill					Miag Multomat				
	Whole Wheat Level (%)									
r.p.m.	15		25		35	15		25		35
81	59.7	*	51.0	*	42.7	49.0		50.7		49.3
			*		*	*		*		*
102	59.7	*	40.7	*	32.7	61.3	*	58.0	*	45.3
	*		*			*		*		*
125	49.0	*	34.7		32.3	56.3	*	52.3	*	38.3
	*		*		*	*		*		*
146	43.3	*	29.3	*	24.3	53.0	*	44.3	*	32.3

LSD = 3.11, 5% Level of significance (Mixing speed)

LSD = 2.70, 5% Level of significance (Whole Wheat Level)

* = Significantly different than adjacent value

Table 8. Effects of Whole Wheat Grinding, and Developer r.p.m. on Internal Loaf Score (65 Max.).

	Whole Wheat Level (%)								
	15			25			35		
r.p.m.	Grinding Treatment								
	Pin Mill		Miag Multomat	Pin Mill		Miag Multomat	Pin Mill		Miag Multomat
81	59.7	*	49.0	51.0		50.7	42.7	*	49.3
			*	*		*	*		*
102	59.7		61.3	50.7	*	58.0	32.7	*	45.3
	*		*	*		*			*
125	49.0	*	56.3	34.7	*	52.3	32.3	*	38.3
	*		*	*		*	*		*
146	43.3	*	53.0	29.3	*	44.3	24.3	*	32.3

LSD = 3.11, 5% level of significance (Mixing Speed)

LSD = 2.20, 5% level of significance (Whole Wheat Grinding)

* = Significantly different than adjacent value

Table 9. Effect of Whole Wheat Level, and Dough Oxidant on Internal Loaf Score (65 Max.).

	Grinding Treatment									
	Pin Mill					Miag Multomat				
	Whole Wheat Level (%)									
r.p.m.	15		25		35	15		25		35
45	63.0	*	42.0	*	32.0	56.0	*	51.5	*	40.7
	*		*			*		*		
75	54.0	*	32.0		31.0	49.5		47.0	*	42.0
	*		*		*	*		*		
105	41.7		42.7	*	35.2	58.5	*	55.5	*	41.2

LSD = 2.70, 5% Level of significance (Oxidation level)

LSD = 2.70, 5% Level of significance (Whole Wheat Level)

* = Significantly different than adjacent value

Table 10. Effect of Whole Wheat Grinding, and Dough Oxidant on Internal Loaf Score (65 Max.).

	Whole Wheat Level (%)								
	15			25			35		
	Grinding Treatment								
p.p.m.	Pin Mill		Miag Multomat	Pin Mill		Miag Multomat	Pin Mill		Miag Multomat
45	63.0	*	56.0	42.5	*	51.5	32.0	*	40.7
	*		*	*		*			
75	54.0	*	49.5	32.0	*	47.0	31.0	*	42.0
	*		*	*		*	*		
105	41.7	*	58.5	42.7	*	55.5	35.2	*	41.2

LSD = 2.70, 5% Level of significance (Oxidation level)

LSD = 2.20, 5% Level of significance (Whole Wheat Grinding)

* = Significantly different than adjacent value

Table 11. Effect of Whole Wheat Grinding, Level, and Dough Oxidant on Bread Loaf Volume (c.c./lb.).

	Grinding Treatment									
	Pin Mill					Miag Multomat				
	Whole Wheat Level (%)									
p.p.m.	15		25		35	15		25		35
45	2848	*	2594	*	2420	2687		2678	*	2159
75	2789	*	2446	*	2494	2616	*	2590	*	2329
105	2468	*	2582	*	2343	2688	*	2812	*	2403

Whole Wheat Grinding non-significant by prior F test

Oxidation non-significant by prior F test

LSD = 25.4, 5% Level of significance (Whole Wheat Level)

* = Significantly different than adjacent value

Table 12. Effect of Whole Wheat Grinding, Level, and Developer r.p.m. on Loaf Volume.

	Grinding Treatment									
	Pin Mill					Miag Multomat				
	Whole Wheat Level (%)									
r.p.m.	15		25		35	15		25		35
81	2709	*	2655	*	2614	2436	*	2712	*	2588
					*	*		*		*
102	2712	*	2653	*	2387	2769		2796	*	2307
			*		*			*		*
125	2712	*	2337		2357	2761	*	2693	*	2213
	*		*		*	*		*		*
146	2674	*	2417	*	2285	2599		2572	*	2081

Whole Wheat Grinding non-significant by prior F test

LSD = 29.3, 5% Level of Significance (Mixing Speed)

LSD = 25.4, 5% Level of Significance (Whole Wheat Level)

* = Significantly different than adjacent value

Table 13. Summary of Interaction Effects Whole Wheat Series

	Specific Loaf Volume	Internal Loaf Score	Total Loaf Score
AXB	S	S	N
AXC	S	S	S
AXD	S	S	N
BXC	S	S	S
BXD	S	S	N
CXD	S	S	N
AXBXC	S	S	N
AXBXD	S	N	N
AXCXD	S	N	N
BXCXD	S	N	N

A = Method of grinding

B = Level of whole wheat

C = Level of oxidant

D = Developer speed

S = Significant interaction by prior F test

N = Nonsignificant interaction by prior F test

Figure 7. Wheat Bread Series
(Impact Grinder)

Figure 8. Wheat Bread Series
(Impact Grinder)

Figure 9. Wheat Bread Series
(Impact Grinder)

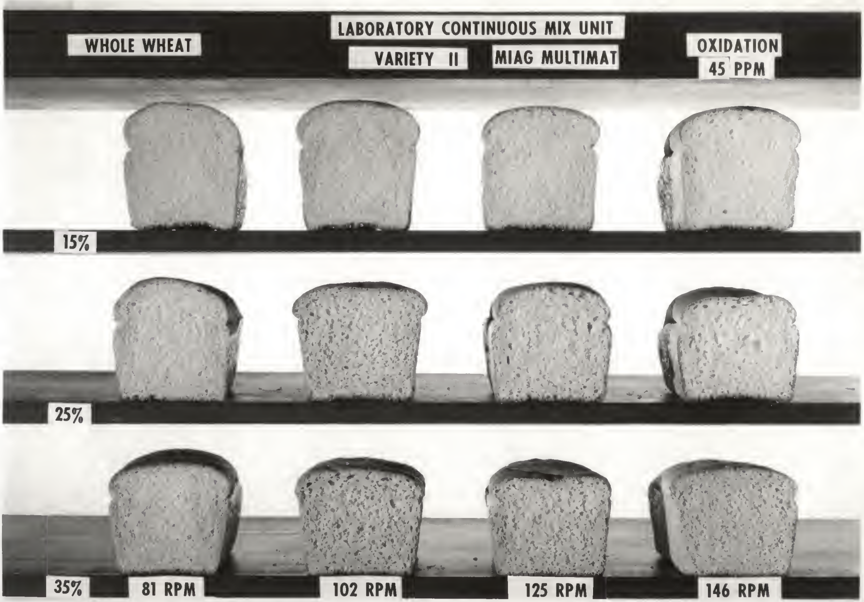

Figure 10. Wheat Bread Series
(Miag Multimat)

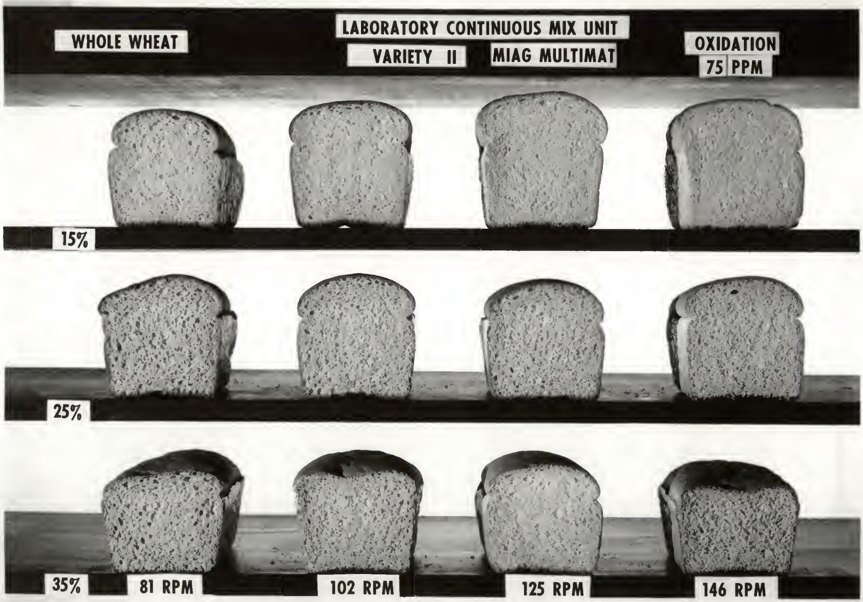

Figure 11. Wheat Bread Series
(Miag Multimat)

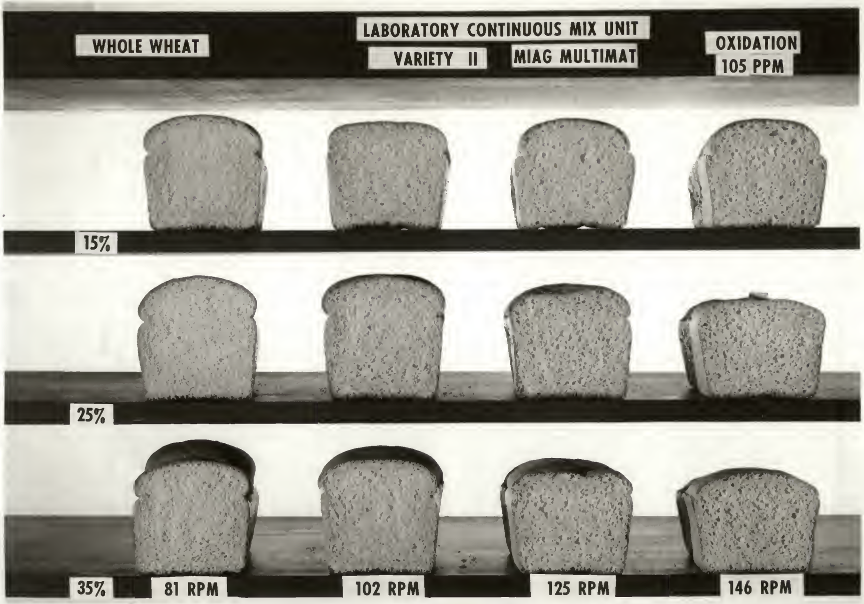

Figure 12. Wheat Bread Series
(Miag Multimat)

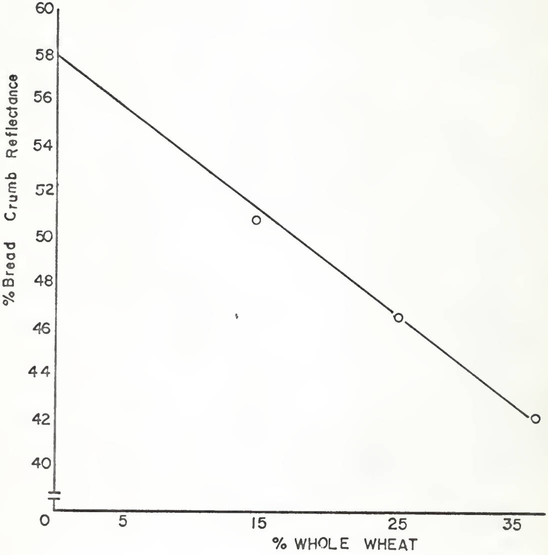

Figure 13. Effect of Percent Whole Wheat on Wheat Bread Crumb Color.

Effect of Bran Granulation

Effect on Liquid Sponge and Dough: The effects of addition of bran on the liquid sponge were similar to those observed using ground whole wheat. It was found with increasing levels of bran, the liquid sponge was much harder to handle. At the 9 percent level of bran, the gluten had a tendency to be washed out. By using the same method developed in the whole wheat experiments, washing-out of the gluten could be minimized. Granulation of the bran effected the consistency and ease of handling in the liquid sponge. The coarse grind was harder to pump and had a greater tendency to wash-out the gluten than the fine grind. It was also noted that the coarse grind had a tendency to float to the top during the initial setting of the liquid sponge.

The amount of bran in the liquid sponge had an effect on the pH of the ferment. As shown in figure 14, there was a definite buffering effect as the percentage of bran increased. This effect was not shown in the bread crumb. Along with pH, titratable acidities were taken every half hour. Table 14 shows that, although there was a buffering effect with increasing amounts of bran of the liquid sponge, there was no apparent effect on titratable acidity. This suggested that there was some substance present in bran that combines with the organic acids produced during fermentation. From the titratable acidity data there was no apparent effect on the fermentation rate due to the presence of bran.

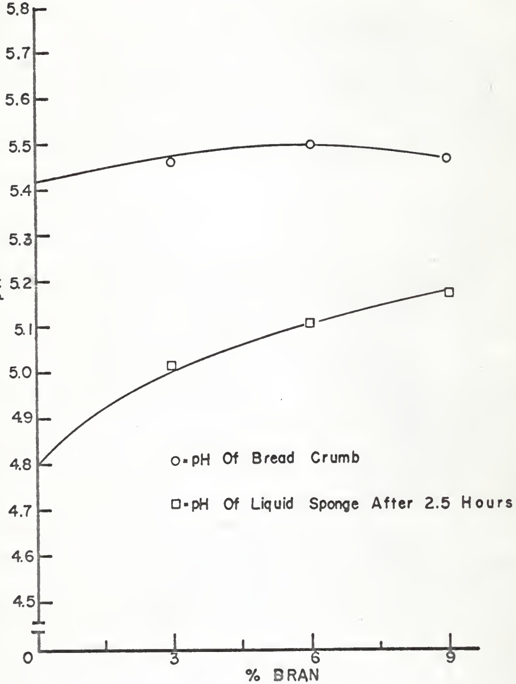

Figure 14. Effect on pH by Bran in Liquid Sponge and Bread Crumb.

TABLE 14. EFFECT OF PER-CENT BRAN IN LIQUID SPONGE* ON TITRATABLE ACIDITY AND pH.

%Bran	0		3		6		9	
Time (Hrs.)	pH	T.A.***	pH	T.A.***	pH	T.A.***	pH	T.A.***
0.0	5.39	32	5.54	27	5.61	30	5.62	33
0.5	4.98	52	5.13	54	5.21	55	5.31	56
1.0	4.91	50	5.05	52	5.21	58	5.29	58
1.5	4.90	51	5.12	57	5.18	55	5.28	57
2.0**	4.89	46	5.10	50	5.16	47	5.24	47
2.5	4.90	48	5.10	50	5.15	47	5.20	46
3.0	4.80	49	4.91	51	5.13	47	5.12	50
3.5	4.70	51	4.88	54	5.01	49	5.03	53
4.0	4.53	52	4.77	56	4.97	53	5.01	54

* 0.5% Arkady used as yeast food.

** After addition of two per-cent salt.

*** Titratable acidity in ml's 0.01N NaOH.

Dough machinability decreased with increasing bran levels. As bran increased the dough became much harder to pan, and was much shorter with an undermixed appearance when optimum mixing was reached.

Effect of different factors on the baked product: A statistical analysis of the data obtained from each granulation of bran was performed. The specific volumes of four loaves were determined. One representative loaf out of these four was selected to determine internal and total loaf score. Results of the statistical analysis is shown in tables 15 through 26. Individual analyses were performed on specific loaf volume in cc/lb., internal loaf score, and total loaf score.

Tables 15, 17, 19, 21, 23, and 25 of the effect of bran granularity on specific volume, total loaf score and internal loaf score indicated that at the 3 percent level of bran, the fine granulation produced bread with greater specific volumes and higher scores. At the 6 and 9 percent levels of bran, the medium granulation produced the best scores.

Increasing the bran in the formula produced deleterious effects on specific volumes and loaf scores, tables 16, 18, 20, 22, 24, and 26. Mixing tolerance was reduced as the bran level increased. Oxidation requirements were not consistent in relation to increasing bran level or bran granulation.

A summary of the second and third order interaction effects in the bran granulation experiments is shown in table 27. Analysis of variance tables for the bran granulation experi-

TABLE 15. EFFECT OF BRAN GRANULATION, AND DOUGH OXIDANT ON TOTAL LOAF SCORE.(100 MAX.)

	Bran Level (%)								
	3			6			9		
	Bran Granulation								
p.p.m.	Fine	Medium	Coarse	Fine	Medium	Coarse	Fine	Medium	Coarse
45	81.2*	74.2 *	75.2	67.5*	78.2 *	73.7	67.7*	64.0 *	47.0
75	81.2*	76.5 *	74.0	61.7*	74.7	74.5	58.0*	71.0 *	43.5
105	81.7	82.0	84.0	60.0*	80.7 *	77.7	57.0*	71.0 *	47.7

LSD = 2.0, 5% Level of Significance (Oxidation level)

LSD = 2.0, 5% Level of Significance (Bran Granulation)

* = Significantly different than adjacent value

TABLE 16. EFFECT OF BRAN LEVEL, AND DOUGH OXIDANT ON TOTAL LOAF SCORE.(100 MAX.)

	Bran Granulation														
	Fine					Medium					Coarse				
	Bran Level (%)														
p.p.m.	3		6		9	3		6		9	3		6		9
45	81.2	*	67.5		67.7	74.2	*	78.2	*	64.0	75.2		73.7	*	47.0
			*		*	*		*		*					*
75	81.2	*	61.7	*	58.0	76.5		74.7	*	71.0	74.0		74.5	*	43.5
						*		*			*		*		*
105	81.7	*	60.0	*	57.0	82.0		80.7	*	71.0	84.0	*	77.7	*	47.7

LSD = 2.0, 5% Level of significance (Oxidation Level)

LSD = 2.0, 5% Level of significance (Bran Level)

* = Significantly different than adjacent value

TABLE 17. EFFECT OF BRAN GRANULATION, AND DEVELOPER R.P.M. ON TOTAL LOAF SCORE (100 MAX.).

	Bran Level %								
	3			6			9		
	Bran Granulation								
r.p.m.	Fine	Medium	Coarse	Fine	Medium	Coarse	Fine	Medium	Coarse
81	82.0	82.7 *	77.0	79.7*	86.3 *	82.3	70.7*	80.3 *	59.3
	*	*		*		*		*	*
102	90.3*	86.0 *	77.0	66.7*	85.7 *	79.0	70.0*	75.7 *	52.0
	*	*	*	*	*	*	*	*	*
125	82.3*	78.7 *	83.0	57.0*	75.3 *	72.3	54.3*	63.0 *	41.3
	*	*	*	*	*	*	*	*	*
146	71.0	73.0 *	76.7	49.0*	64.3 *	67.7	48.7*	55.7 *	31.7

LSD = 2.4, 5% Level of significance (Mixing Speed)

LSD = 2.0, 5% Level of significance (Bran Granulation)

* = Significantly different than adjacent value

TABLE 18. EFFECT OF BRAN LEVEL, AND DEVELOPER RPM ON TOTAL LOAF SCORE.(100 MAX.)

	Bran Granulation														
	Fine					Medium					Coarse				
	Bran Level (%)														
r.p.m.	3		6		9	3		6		9	3		6		9
81	82.3	*	79.7	*	70.7	82.7	*	86.3	*	80.3	77.0	*	82.3	*	59.3
	*		*			*				*			*		*
102	90.3	*	66.7	*	70.0	86.0		85.7	*	75.7	77.0		79.0	*	52.0
	*		*		*	*		*		*	*		*		*
125	82.3	*	57.0	*	54.3	78.7	*	75.3	*	63.0	83.0	*	72.3	*	41.3
	*		*		*	*		*		*	*		*		*
146	71.0	*	49.0		48.7	73.0	*	64.3	*	55.7	76.7	*	67.7	*	31.7

LSD = 2.4, 5% Level of significance (Mixing speed)

LSD = 2.0, 5% Level of significance (Bran Level)

* = Significantly different than adjacent value

TABLE 19. EFFECT OF BRAN GRANULATION, AND DEVELOPER RPM ON INTERNAL LOAF SCORE.(65 MAX.)

	Bran Level (%)														
	3					6					9				
	Bran Granulation														
r.p.m.	Fine		Medium		Coarse	Fine		Medium		Coarse	Fine		Medium		Coarse
82	58.7	*	53.7		53.7	55.3	*	61.3	*	58.0	47.3	*	49.0	*	38.3
	*		*			*				*			*		*
105	66.3	*	61.7	*	55.7	45.0	*	60.7	*	54.0	45.7	*	51.7	*	34.7
	*		*		*	*		*		*	*		*		*
125	59.0	*	56.7	*	58.7	36.0	*	50.3	*	48.7	33.3	*	41.3	*	27.7
	*		*		*	*		*		*	*		*		*
146	49.3		52.0	*	55.3	30.7	*	42.0	*	44.0	28.7	*	35.0	*	21.7

LSD = 2.1, 5% Level of significance (Mixing speed)

LSD = 1.5, 5% Level of significance (Bran Granulation)

* = Significantly different than adjacent value

TABLE 20. EFFECT OF BRAN LEVEL, AND DEVELOPER RPM ON INTERNAL LOAF SCORE. (65 MAX.)

	Bran Granulation														
	Fine					Medium					Coarse				
	Bran Level (%)														
r.p.m.	3		6		9	3		6		9	3		6		9
81	58.7	*	55.3	*	47.3	53.7	*	61.3	*	49.0	53.7	*	58.0	*	38.3
	*		*			*				*			*		*
102	66.3	*	45.0		45.7	61.7		60.7	*	51.7	55.7	*	54.0	*	34.7
	*		*		*	*		*		*	*		*		*
125	59.0	*	36.0	*	33.3	56.7	*	50.3	*	41.3	58.7	*	48.7	*	27.7
	*		*		*	*		*		*	*		*		*
146	49.3	*	30.7	*	28.7	52.0	*	42.0	*	35.0	55.3	*	44.0	*	21.7

LSD = 2.1, 5% level of significance (Mixing speed)

LSD = 1.5, 5% level of significance (Bran level)

* = Significantly different than adjacent value

TABLE 21. EFFECT OF BRAN GRANULATION, AND DOUGH OXIDANT ON INTERNAL LOAF SCORE. (65 MAX.)

	Bran Level (%)								
	3			6			9		
	Bran Granulation								
p.p.m.	Fine	Medium	Coarse	Fine	Medium	Coarse	Fine	Medium	Coarse
45	57.7 *	53.2	52.0	46.0 *	54.2 *	49.7	45.2 *	43.2 *	31.2
75	58.5 *	55.0 *	53.2	40.0 *	50.7	50.0	35.8 *	47.0 *	30.6
105	58.7	59.7	62.2	39.2 *	55.7 *	53.7	35.2 *	42.5 *	30.0

Oxidation level nonsignificant by prior F test

LSD = 1.5, 5% level of significance (Bran granulation)

* = significantly different than adjacent value

TABLE 22. EFFECT OF BRAN LEVEL, AND DOUGH OXIDANT ON INTERNAL LOAF SCORE. (65 MAX.)

	Bran Granulation								
	Fine			Medium			Coarse		
	Bran Level (%)								
p.p.m.	3	6	9	3	6	9	3	6	9
45	57.7	* 46.0	45.2	53.2	54.2	* 43.2	52.0	49.7	* 31.2
75	58.5	* 40.0	* 35.8	55.0	* 50.7	* 47.0	53.2	* 50.0	* 30.6
105	58.7	* 39.2	* 35.2	59.7	* 55.7	* 42.5	62.2	* 53.7	* 30.0

Oxidation level not significant by prior F test

LSD = 1.5, 5% level of significance (Bran Level)

* = Significantly different than adjacent value

TABLE 23. EFFECT OF BRAN GRANULATION, AND DOUGH OXIDANT ON BREAD LOAF VOLUME.

	Bran Level (%)														
	3					6					9				
	Bran Granulation														
p.p.m.	Fine		Medium		Coarse	Fine		Medium		Coarse	Fine		Medium		Coarse
45	2639	*	2539	*	2653	2582	*	2817	*	2693	2619	*	2522	*	2279
	*		*		*			*		*	*		*		*
75	2622	*	2556		2556	2573	*	2788	*	2727	2599	*	2628	*	2171
	*		*		*	*		*			*		*		*
105	2735	*	2602	*	2519	2548	*	2957	*	2724	2576	*	2687	*	2381

LSD = 15.0, 5% Level of Significance (Oxidant Level)

LSD = 15.0, 5% Level of Significance (Bran Granulation)

* = Significantly different than adjacent value

TABLE 24. EFFECT OF BRAN LEVEL, AND DOUGH OXIDANT ON BREAD LOAF VOLUME. (cc/lb.)

	Bran Granulation														
	Fine					Medium					Coarse				
	Bran Level (%)														
p.p.m.	3		6		9	3		6		9	3		6		9
45	2639	*	2582	*	2619	2539	*	2817	*	2522	2653	*	2693	*	2279
	*				*	*		*		*	*		*		*
75	2622	*	2573	*	2599	2556	*	2788	*	2628	2556	*	2727	*	2171
	*		*		*	*		*		*	*				*
105	2735	*	2548	*	2576	2602		2957		2687	2519	*	2724	*	2381

LSD = 15.0, 5% Level of Significance (Oxidant Level)

LSD = 15.0, 5% Level of Significance (Bran level)

* = Significantly different than adjacent value

TABLE 25. EFFECT OF BRAN GRANULATION AND DEVELOPER R.P.M. ON LOAF VOLUME.

	Bran Level (%)														
	3					6					9				
	Bran Granulation														
r.p.m.	Fine		Medium		Coarse	Fine		Medium		Coarse	Fine		Medium		Coarse
81	2648	*	2463	*	2633	2731	*	3062	*	2796	2656	*	2769	*	2504
	*		*		*	*		*			*		*		*
102	2792	*	2671	*	2538	2917	*	2981	*	2812	2712	*	2671	*	2368
	*		*		*	*		*		*	*		*		*
125	2644	*	2599	*	2576	2542	*	2775	*	2644	2535	*	2565	*	2190
	*		*		*	*		*		*	*		*		*
146	2576	*	2531	*	2607	2436	*	2591	*	2606	2823	*	2512	*	2044

LSD = 16.3, 5% Level of Significance (Mixing Speed)

LSD = 15.0, 5% Level of Significance (Bran Granulation)

* = Significantly different than adjacent value

TABLE 26. EFFECT OF BRAN LEVEL, AND DEVELOPER R.P.M. ON LOAF VOLUME.

	Bran Granulation														
	Fine					Medium					Coarse				
	Bran Level (%)														
r.p.m.	3		6		9	3		6		9	3		6		9
81	2648	*	2731	*	2656	2463	*	3062	*	2769	2663	*	2796	*	2504
	*		*		*	*		*		*	*				*
102	2792	*	2917	*	2712	2671	*	2981	*	2671	2538	*	2812	*	2368
	*		*		*	*		*		*	*		*		*
125	2644	*	2542		2535	2599	*	2775	*	2565	2576	*	2644	*	2190
	*		*		*	*		*		*	*		*		*
146	2576	*	2436	*	2823	2531	*	2591	*	2512	2607		2606	*	2044

LSD = 16.3, 5% Level of Significance (Mixing Speed)

LSD = 15.0, 5% Level of Significance (Bran Level)

* = Significantly different than adjacent value

Table 27. Summary of Interaction Effects; Bran Granulation Series

	Specific Loaf Volume	Internal Loaf Score	Total Loaf Score
AXB	S	S	S
AXC	S	S	S
AXD	S	S	S
BXC	S	S	N
BXD	S	S	S
CXD	S	S	S
AXBXC	S	N	N
AXBXD	S	N	N
AXCXD	S	N	N
BXCXD	S	S	S

A = Method of grinding

B = Level of whole wheat

C = Level of oxidant

D = Developer speed

S = Significant interaction by prior F test

N = Nonsignificant interaction by prior F test ments are presented in the appendix. As with the whole wheat experiments, no attempt was made to analyze the third order interactions, other than showing significance with the F test. This was because no meaningful postulations could be made.

In figures 15 through 26 the results of the bran granulation experiments are illustrated. As with increasing levels of whole wheat, increasing levels of bran produced bread with a more open grain and thicker cell walls. Granulation of the bran also effected the cellular structure. With the fine granulation, the cells were more open and the walls were thicker than in the medium and coarse granulations. The coarse granulation produced a relatively fine cell structure but cell coalescence produced large holes in the structure of the bread.

When the level of bran in the formula was increased, a decrease in developer speed was required to produce optimum results. A wider range of developer speeds was possible with the medium granulation of bran compared with the fine and coarse granulations. Increasing levels of oxidation resulted in finer grain and texture and a slight increase in mixing tolerance.

The bread crumb became increasingly dark as the amount of bran in the formula was increased. In figure 27 a linear decrease in reflectance, with increasing levels of bran was noted.

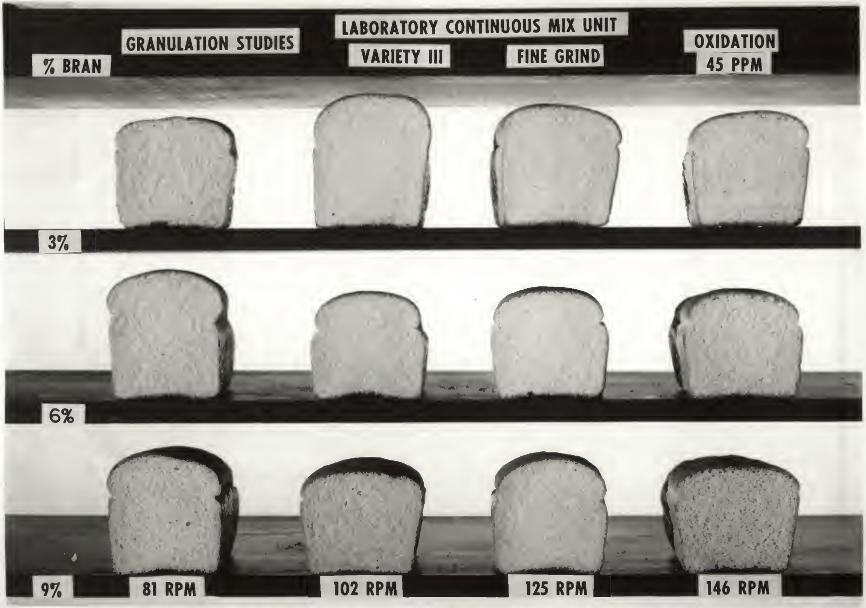

Figure 15. Bran Granulation Series (Fine Grind)

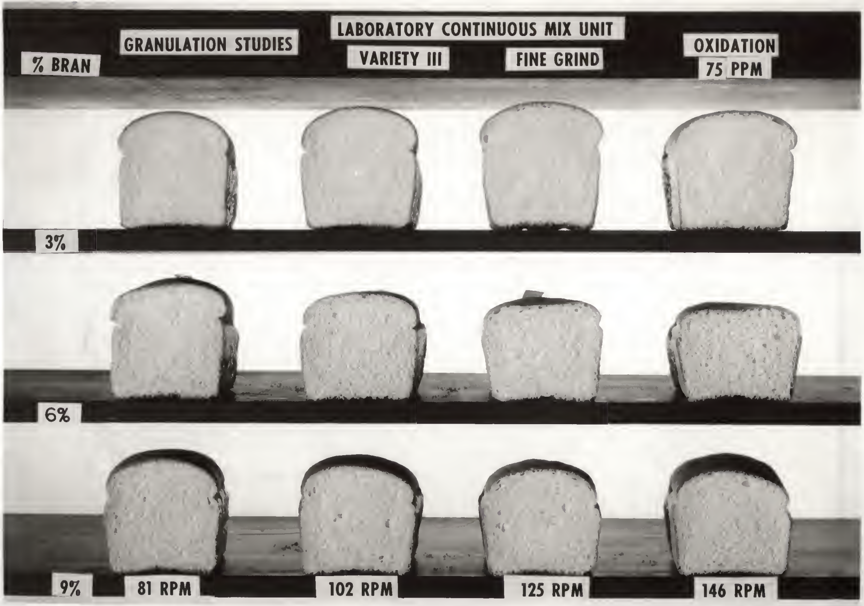

Figure 16. Bran Granulation Series
(Fine Grind)

Figure 17. Bran Granulation Series
(Fine Grind)

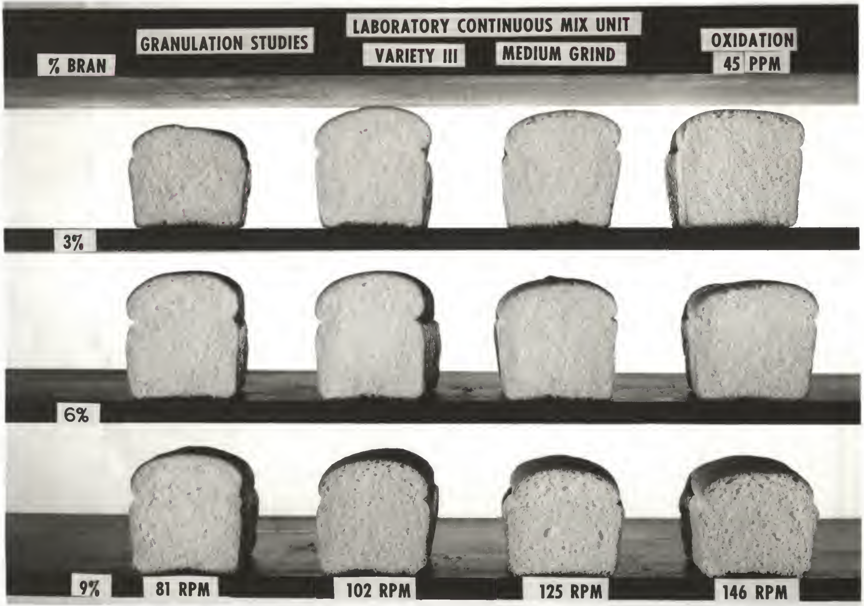

Figure 18. Bran Granulation Series
(Medium Grind)

Figure 19. Bran Granulation Series
(Medium Grind)

Figure 20. Bran Granulation Series
(Medium Grind)

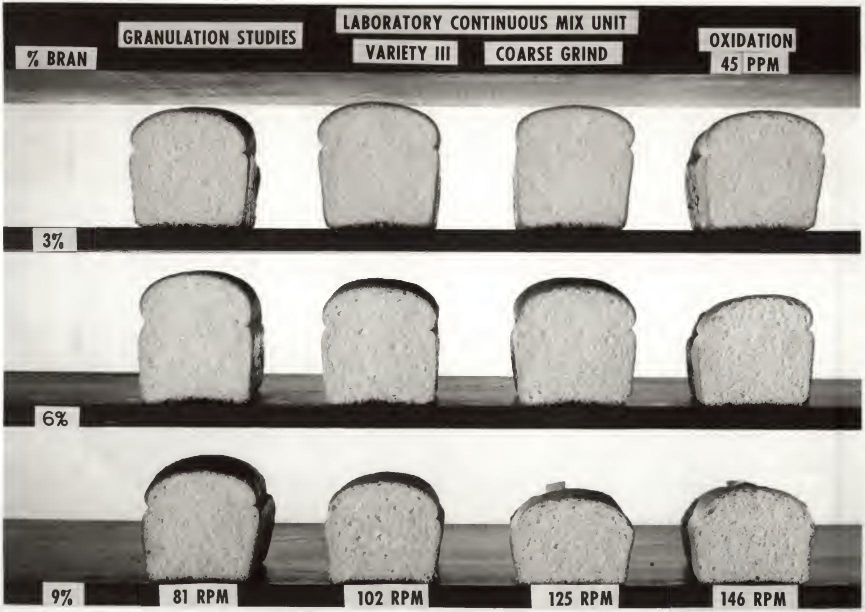

Figure 21. Bran Granulation Series
(Coarse Grind)

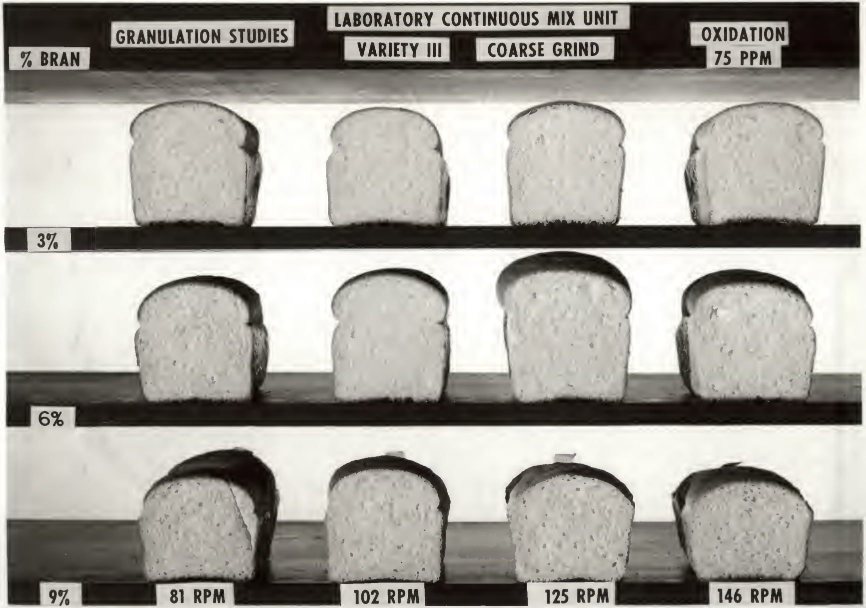

Figure 22. Bran Granulation Series
(Coarse Grind)

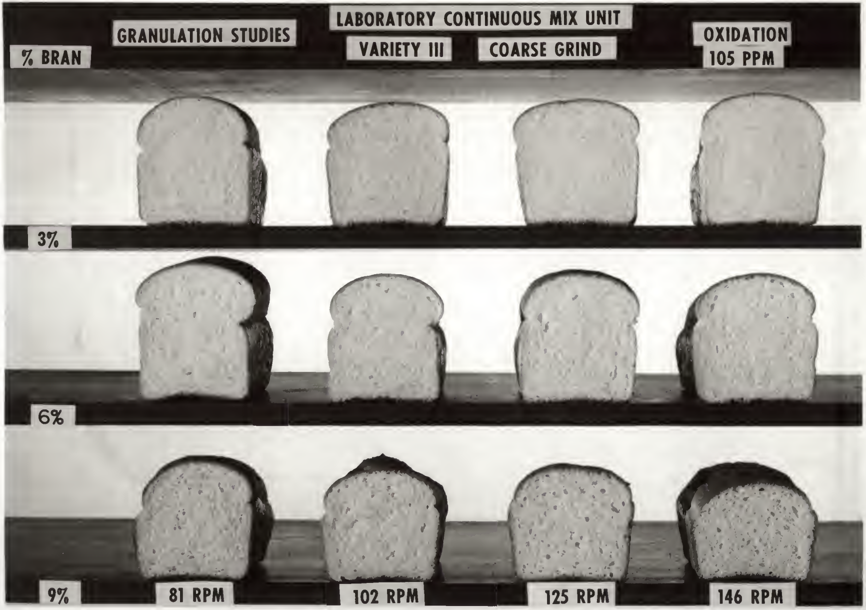

Figure 23. Bran Granulation Series
(Coarse Grind)

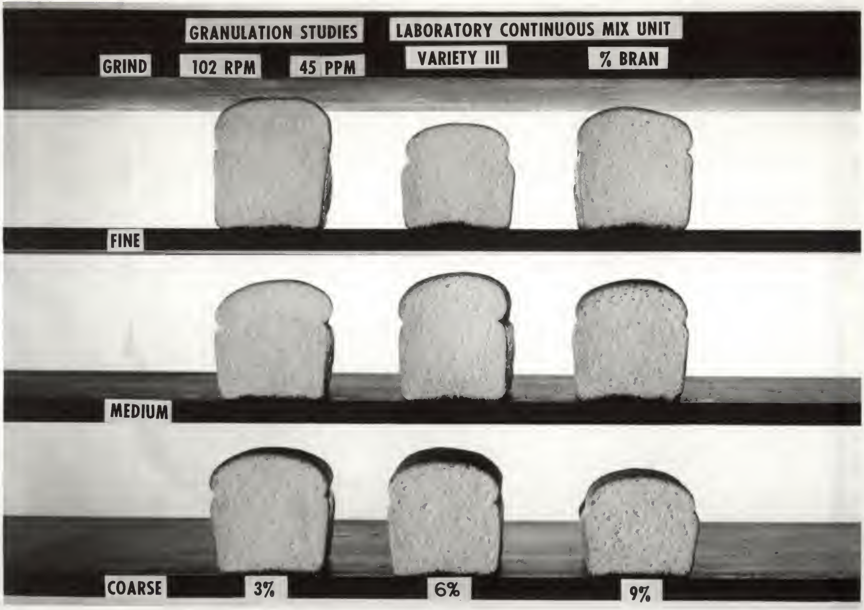

Figure 24. Bran Granulation Series
(45 Parts Per Million)

Figure 25. Bran Granulation Series
(45 Parts Per Million)

Figure 26. Bran Granulation Series
(45 Parts Per Million)

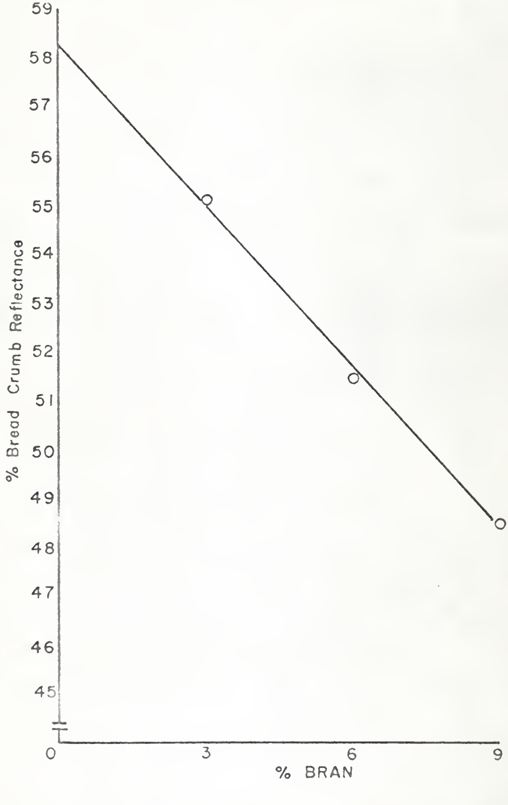

Figure 27. Effect of Percent Bran on Bread Crumb Color.

Summary and Conclusions

These experiments were designed to study wheat bread production by the continuous mix process. The production of a commercial variety bread with a commercial wheat bread premix was investigated. The production of wheat breads with various levels of whole wheat flour in the formula with two methods of grinding the whole wheat, and also the effects of using bran of different granulations at various levels in the formula were studied.

It was found that the method involved in grinding the whole wheat effected the quality of the bread. It was found that a gradual reduction of the stock produced bread of improved quality when compared to that produced by a quicker reduction of the stock. Acceptable bread could be produced with up to 25 percent whole wheat flour in the formula. Above 25 percent, the mixing speed was critical and loaf volumes were reduced. Increasing oxidation had an improving effect at the higher whole wheat levels.

It was found that the granularity of the bran fraction had a definite effect on bread quality. At the 3 percent level of bran in the formula, the fine granulation produced the best bread. At the 6 percent and 9 percent levels, the medium granulation produced the best bread. The deleterious effect of fine grinding at higher levels in the formula may have been due to the release of some material that effected the gluten structure. This material may have been causing a reducing effect on the

S-S bonds of the protein matrix causing a slackening of the dough. It is possible that this substance may have been glutathione. However, these deleterious effects of the fine grind could also have been a strictly physical phenomena or a combination of both chemical and physical effects. With the coarse granulation, the effect was thought to be due to the large bran particles rupturing the gluten network resulting in cell coalescence and an overall weakening of the dough.

From the results of the work with the wheat bread premix, it was concluded that an acceptable wheat type variety bread could be made both on a continuous mix laboratory unit and on a commercial continuous mix unit. With both units, controlled methods of production were required. It was observed in the setting of the liquid sponges that care was required to prevent washing-out the gluten, and that in wheat bread production, the branny material should be placed in the liquid sponge. Developer speed was critical, and since dough temperature had a tendency to be higher with increasing levels of whole wheat or bran, a cooling of the liquid sponge just prior to entering the incorporator was desirable. In wheat bread production by the continuous mix process, an acceptable product can be made providing controlled steps of production are followed.

APPENDIX

Analysis of Variance Tables

1. A.O.V. of Whole Wheat Total Leaf Scores

Source	D.F.	Ss	Ms	F
A	1	924.5	924.5	*
B	2	5843.5	2921.7	*
C	2	343.1	171.5	
D	3	2459.2	819.7	*
AXB	2	412.7	206.3	
AXC	2	474.3	237.1	*
AXD	3	512.6	170.9	
BXC	4	1382.0	345.5	*
BXD	6	1174.6	195.8	*
CXD	6	32.8	5.5	
AXBXC	4	391.5	97.9	
AXBXD	6	590.5	98.4	
AXCXD	6	957.9	159.6	
BXCXD	12	595.2	49.6	
AXBXCXD	12	727.0	60.6	
Error	0	0	0	

*Denotes significance at 5% level.

A = Whole wheat: type of grinding.
B = Whole wheat level.
C = Oxidant level.
D = Mixing speed.

2. A.O.V. of Whole Wheat Internal Loaf Scores

Source	D.F.	Ss	Ms	F
A	1	1112.4	1112.4	*
B	2	3540.4	1170.2	*
C	2	351.8	175.9	*
D	3	1845.2	615.1	*
AXB	2	294.7	147.3	*
AXC	2	161.9	80.9	*
AXD	3	521.4	173.8	*
BXC	4	592.1	148.0	*
BXD	6	331.0	55.2	
CXD	6	44.2	7.4	
AXBXC	4	495.8	123.9	*
AXBXD	6	259.9	43.3	
AXCXD	6	230.8	38.5	
BXCXD	12	113.8	9.5	
AXBXCXD	12	220.6	18.4	
Error	0	0	0	

* Denotes significance at 5% level.

A = Whole wheat: type of grinding.
B = Whole wheat level.
C = Oxidant level.
D = Mixing speed.

3. A.O.V. of Whole Wheat Specific Loaf Volumes

Source	D.F.	Ss	Ms	F
A	1	6000.0	6000.0	
B	2	5,382,000.0	2,691,000.0	*
C	2	35,000.0	17,500.0	
D	3	1,369,000.0	456,333.3	*
AXB	2	996,000.0	498,000.0	*
AXC	2	919,000.0	459,500.0	*
AXD	3	240,000.0	80,000.0	*
BXC	4	1,577,000.0	394,250.0	*
BXD	6	2,004,000.0	334,000.0	*
CXD	6	233,000.0	38,833.3	*
AXBXC	4	149,000.0	37,250.0	*
AXBXD	6	433,000.0	72,166.7	*
AXCXD	6	1,218,000.0	203,000.0	*
BXCXD	12	852,000.0	71,000.0	*
AXBXCXD	12	1,487,000.0	123,916.6	*
Error	216	1,747,000.0	8088.0	*

* Denotes significance at 5% level.

A = Whole wheat: type of grinding.
B = Whole wheat level.
C = Oxidation level.
D = Mixing speed.

4. A.O.V. of Ground Bran Total Loaf Scores

Source	D.F.	Ss	Ms	F
A	2	1354.1	677.0	*
B	2	7735.7	3867.8	*
C	2	159.0	79.5	*
D	3	5179.9	1726.6	*
AXB	4	3425.6	856.4	*
AXC	4	519.8	129.9	*
AXD	6	310.1	51.7	*
BXC	4	167.0	41.7	
BXD	6	1582.2	263.7	*
CXD	6	358.8	59.8	*
AXBXC	8	205.6	25.7	
AXBXD	12	394.7	32.9	
AXCXD	12	226.6	18.9	
BXCXD	12	1035.1	86.2	*
AXBXCXD	24	426.8	17.8	
Error	0	0	0	

* Denotes significance at 5% level.

A = Ground bran: granulation.
B = Ground bran level.
C = Oxidant level.
D = Mixing speed.

5. A.O.V. of Ground Bran Internal Loaf Scores

Source	D.F.	Ss	Ms	F
A	2	654.1	327.0	*
B	2	6460.3	3230.1	*
C	2	64.7	32.3	*
D	3	3178.1	1059.4	*
AXB	4	1465.7	366.4	*
AXC	4	321.9	80.5	*
AXD	6	316.8	52.8	*
BXC	4	331.8	82.9	*
BXD	6	918.3	153.0	*
CXD	6	274.7	45.8	*
AXBXC	8	130.2	16.3	
AXBXD	12	145.7	12.1	
AXCXD	12	205.5	17.1	
BXCXD	12	641.2	53.4	*
AXBXCXD	24	324.0	13.5	
Error	0	0	0	

* Denotes significance at 5% level.

A = Ground bran: granulation.
B = Ground bran level.
C = Oxidant level.
D = Mixing speed.

6. A.O.V. of Ground Bran Specific Loaf Volumes

Source	D.F.	Ss	Ms	F
A	2	1,697,000.0	848,500.0	*
B	2	3,236,000.0	1,618,000.0	*
C	2	262,000.0	131,000.0	*
D	3	3,236,000.0	1,078,666.7	*
AXB	4	4,074,000.0	1,018,500.0	*
AXC	4	248,000.0	62,000.0	*
AXD	6	142,000.0	23,666.7	*
BXC	4	40,000.0	10,000.0	*
BXD	6	1,116,000.0	186,000.0	*
CXD	6	59,000.0	9833.3	*
AXBXC	8	592,000.0	74,000.0	*
AXBXD	12	1,037,000.0	86,416.7	*
AXCXD	12	456,000.0	38,000.0	*
BXCXD	12	539,000.0	44,916.7	*
AXBXCXD	24	817,000.0	34,041.7	*
Error	324	1,361,000.0	4200.6	*

* Denotes significance at 5% level.

A = Ground bran: granulation.
B = Ground bran level.
C = Oxidant level.
D = Mixing speed.

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THE PRODUCTION OF WHEAT BREADS ON A LABORATORY CONTINUOUS MIX UNIT

by

ROBERT VON SCHANEFELT

B. S., Kansas State University, 1966

AN ABSTRACT OF A MASTER'S THESIS

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requirements for the degree

MASTER OF SCIENCE

Department of Grain Science and Industry

KANSAS STATE UNIVERSITY
Manhattan, Kansas

1967

Different aspects of wheat bread production were studied with a continuous mix laboratory unit. Different methods of milling whole wheat, effect of bran granulation, levels of whole wheat and bran, oxidation requirements and mixing requirements were included. Factorially designed experiments were used wherever applicable.

The method of grinding had significant effect on bread quality. Bran granulation also affected bread quality with a medium granulation producing the best results. Oxidation requirements were not consistent with either whole wheat grinding method or level of whole wheat in the formula. Bread quality decreased as whole wheat and bran level increased in the formula. Mixing requirements were reduced as the percent of whole wheat or bran was increased.

A commercial wheat bread premix was used to establish methodology. The methods developed have been applied to the commercial production of wheat bread with satisfactory results.