# THE DEVELOPMENT OF MICRO METHODS FOR THE QUALITY EVALUATION OF WHEAT AND FLOUR

by

MERLE DENNIS SHOGREN

B. S., Bethany College, Lindsborg, Kansas, 1951

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A THESIS

submitted in partial fulfillment of the
requirements for the degree

MASTER OF SCIENCE

Department of Flour and Feed Milling Industries

KANSAS STATE COLLEGE
OF AGRICULTURE AND APPLIED SCIENCE

1954

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# INTRODUCTION

The present methods of wheat breeding to produce new improved varieties are slow, costly, and painstaking procedures. Much time and space is utilized in the development of wheat crosses which are eliminated ultimately from further consideration for increase once milling and baking tests are applied. These tests require from 1500 to 2000 g. of wheat and therefore cannot be undertaken until about the eighth generation after the original cross is made.

Progress in wheat improvement depends upon the application of the laws of heredity and the science of genetics. Parental material possessing desirable characteristics must be selected and crossed. From the resultant hybrid populations from such crosses, promising material are chosen for further study and propagation. Observations are made on such characteristics as date of maturity, yield, test weight, height, vigor, resistance to disease, winter hardness, and strength of straw. The plant breeder selects from each generation plants with those quality characteristics that are best suited to a particular situation. Years of this type of tedious work are done before any knowledge is obtained of the milling and baking characteristics. It becomes apparent that the application of micro milling and baking tests at an early generation would be highly desirable.

Interest in micro milling and baking is relatively new. According to Van Scoyk (17), Werner did some unpublished work in 1932 using 25 g. flour doughs. This test was later used by Geddes and Aitken (10).

Van Scoyk in 1937 (16) having access to Werner's results developed further the test by adding sheeting rolls and a molder. Van Scoyk's principle interest was in fermentation time, loaf volume data, and other information of a similar nature. Particular interest was in the fact that large doughs could be mixed and then divided into equal parts thus eliminating variation due to mixing.

Harris and Sanderson in 1938 (11) made comparisons of the 100 g. and 25 g. flour dough procedures. They concluded that although the 25 g. procedure in their case did not accurately predict 100 g. loaf volume, nevertheless, from the information obtained with the 25 g. procedure weak wheat and strong wheat varieties would be differentiated.

In 1939 Van Scoyk (17) reported the use of 8-ounce covered jelly glasses for fermentation jars, and a Werner type volume meter capable of being read to 1 cc. He reported obtaining results with the 25 g. procedure that were as informative as those obtained with the 100 g. procedure. In addition, he had the advantages of smaller equipment, precision, and to some extent, elimination of variables.

The result of this work indicated that small doughs (25 g. flour doughs or less) would prove valuable in quality evaluation of wheat in early generations where a limited amount of the sample is available. Even though the smaller size loaves may not give a precise indication of quality, the ability to differentiate between relatively strong and weak varieties would be sufficiently useful to the plant breeder to warrant the use of micro methods.

It seemed impractical to test wheat samples from generations earlier than the fourth generation. The complete test was designed on the basis of 100 g. of wheat which is the amount available at the fourth generation.

# EXPERIMENTAL

## Development and Construction of Equipment

Bread Pans. Of the 100 g. of wheat available from the plant breeder, 5 g. were to be alloted for protein analysis. Of the remaining 95 g., approximately 60 g. of flour may be obtained. Since the Farinograph might readily use 30 g. to produce a farinogram, about 30 g. would be left for protein, ash, and moisture analyses and the baking test. Alloting 13 g. of flour for protein, ash, and moisture analyses would then leave about 17 g. for the baking test.

With these limitations in mind, experimental bread pans of different sizes were constructed similar to regular bread pans. Since 8 g. of flour allows for check bakes, the different pan sizes were tested with 8 g. flour doughs obtained by scaling 14 g. of dough from a large mix (8 g. of flour plus the other ingredients yields about 14 g. total weight). Criteria for rejecting a particular size bread pan were such considerations as overlapping of the dough over the sides and failure of the dough after full oven rise to come completely in contact with the sides.

Several bread pans of the size thus determined were made from 16 guage steel. They were cut from sheet metal using a pattern and formed over a block pattern. This manner of construction minimized variation in size. They were 2.7 cm. wide and 4.2 cm. long at the bottom; 3.3 cm. wide and 5.0 cm. long at the top; and 2.3 cm. deep.

Mixer. The National Manufacturing Company of Lincoln, Nebraska constructed for this project a mixer capable of properly mixing 8 g. flour doughs. Plate I, Fig. 2 shows the bowl and Plate II is a three-quarter view photograph. Plate I, Fig. 2 illustrates that this mixer employs only two pins in this bowl. This, of course, resulted in a mixing action different from the mixograph (15) which employs a bowl with three pins. The path of the moving pins depends upon the ratio of moving gears to the stationary gear in the mixing head. In making this mixer smaller, the diameter of the bowl was reduced. This necessitated bringing the moving pins closer to the center which resulted in smaller moving gears and hence a gear ratio requiring only two pins in the bowl.

In addition to the mixer and bowl it was convenient to have an aligning template. This is useful in properly aligning the gears in the mixing head with respect to the pins in the bowl should the mixing head ever have to be removed. Plate III, Fig. 1 is a full scale drawing of this template.

Fermentation Cabinet. The fermentation cabinet differs from the cabinet manufactured regularly by the National Manufacturing Company in that it is about one-third the usual size. Plate IV shows the cabinet constructed by the National Manufacturing Company. Each of the four openings is 34.5 cm. wide, 26.5 cm. high, and 56.5 cm. deep with dividing shelves in the lower three compartments.

For fermentation pans, clear plastic refrigerator dishes with lids were obtained. In order that one day's baking could be weighed prior to the first mix, these were also used for flour and shortening. They were especially adapted for this use because they were transparent, they could be stacked with the lids on, and they were wide enough at the mouth to facilitate easy removal of the dough. They were 5.2 cm. deep with a

EXPLANATION OF PLATE I

Fig. 1. Full scale drawing of the aligning template for the mixing blades of the 10 g. Farinograph mixing bowl.

Fig. 2. Full scale cutaway drawing of the micro mixing bowl.

PLATE I

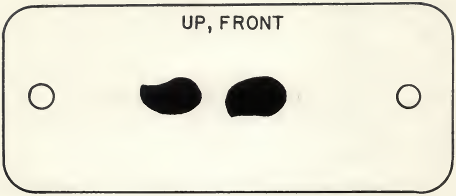



FIG. 1

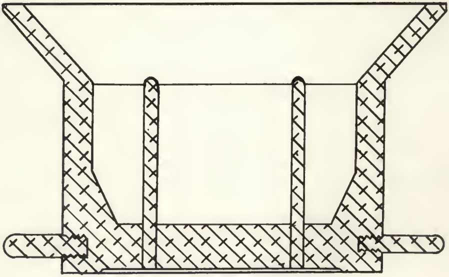


FIG. 2

EXPLANATION OF PLATE II

Photograph of the micro mixer showing the mixing bowl in position and the mixing head in a raised position.

PLATE II

EXPLANATION OF PLATE III

Fig. 1. Full scale drawing of the aligning template used to align the pins in the mixing head with respect to the pins in the mixing bowl.

B. Bowl pin
H. Mixing head pin

Fig. 2. Drawing illustrating the relationship of a bread pan with respect to the wire strips on an oven shelf.

PLATE III

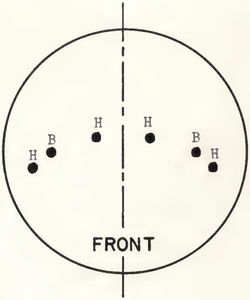



FIG. 1

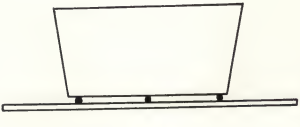


FIG. 2

## EXPLANATION OF PLATE IV

Photograph of the upper portion of the fermentation cabinet showing only two of the four compartments.

The top compartment contains the heating elements and the humidifier.

The control panel is at the right.

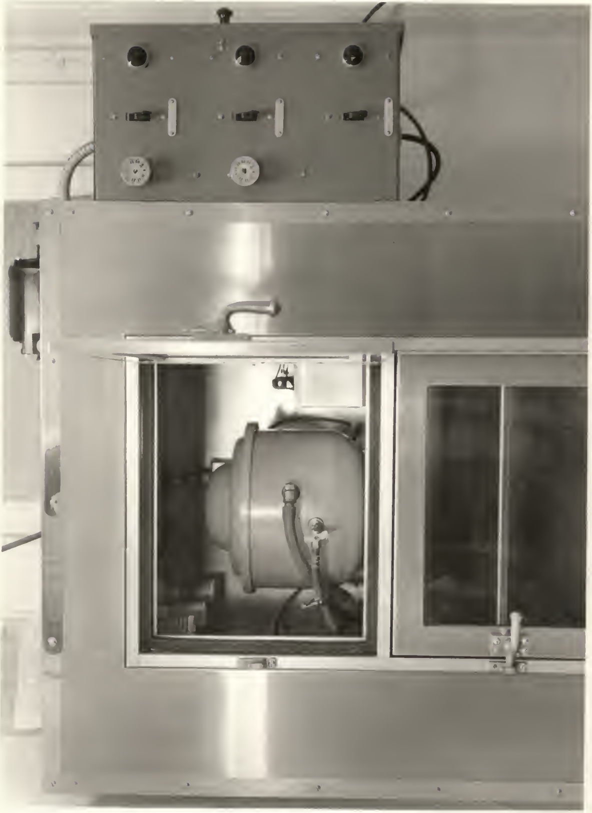


PLATE IV

diameter of 8.6 cm. at the top and 6.0 cm. at the bottom.

Volume Meter. To determine the size requirements of the loaf volume meter, portions of as much as 15 g. of dough were taken from large mixes and baked. The use of 15 g. rather than 14 g. of dough would, to some extent, account for extra strong flours. Volumes were determined by coating with paraffin (3) and submerging in water. The displaced water was a measure of the volume. On the basis of these volumes, the volume meter shown in Plate V was constructed.

At the bottom of the burette tube B is a sliding gate which controls the flow of lead shot from compartment A to compartment C. Compartment C contains the loaf being measured and may be opened by means of the latch and swinging the top part of the loaf volume meter out and down. In this operation, the pivot point is a hinge at the back of compartment C. If the top part is swung out and down with the compartment C closed, the pivot point is the pointed rods.

The bottom of compartment C rests on the desk top (in the position shown) which is to the left of the loaf volume meter in the side view.

Rape seed commonly used for loaf volume measurements was unsatisfactory for this volume meter due to the static electricity produced by the rape seed flowing against the glass (5). However, lead shot (about 441/sq. in.) had the desired qualities.

Standardization of the volume meter was accomplished by using a standard brass block of known value (30.09 cc.). Its dimensions were 1.9 cm. by 3.6 cm. by 4.4 cm.

Oven. The National Manufacturing Company constructed a small oven

EXPLANATION OF PLATE V

Detailed drawing of the front view and side view of the loaf volume meter and an exploded view of the stand.

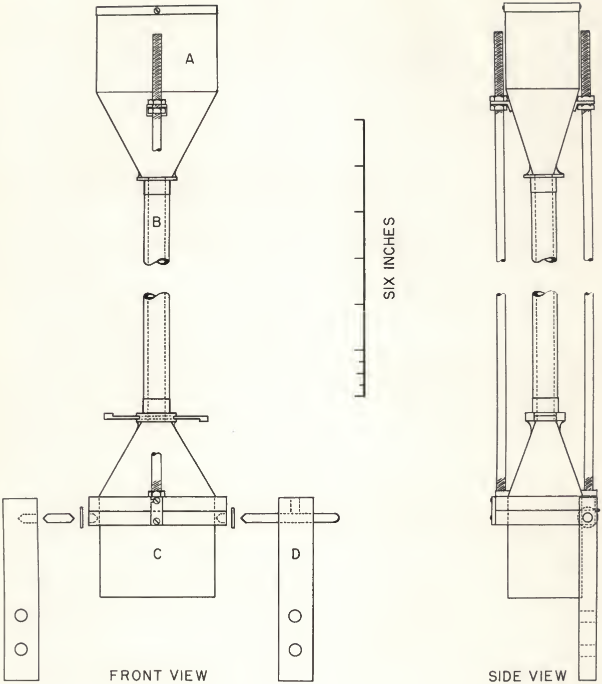
A - Compartment serving as a reservoir for the lead shot.

B - 50 ml. burette tube.

C - Compartment containing the loaf being measured.

D - The loaf volume meter stand.

PLATE V



according to specifications supplied. The oven is illustrated in Plate VI. It is a reel type electric oven designed to handle twelve micro baking pans. The oven also has the facilities for use of steam to provide the desirable humidity.

Bread baked in this oven had large holes in the corners near the top of the loaf (essentially separating the crust from the interior of the loaf) and had no break and shred. It seemed a possibility that too slow a rate of gas production might be a factor affecting the formation of break and shred. Increasing yeast (up to 3%), sugar (up to 7%), and malt, and combinations of yeast and sugar did not produce the break and shred desired.

To check the possibility that the oven, being electric, might be the factor involved, eight doughs were scaled from one large mix. Four of these were baked in a gas oven and the other four in the small electric oven. The bour baked in the gas oven had break and shred while the four baked in the electric oven had none.

Two differences of possible consequence were considered; the lack of moisture in the electric oven and a difference in the types of shelves employed.

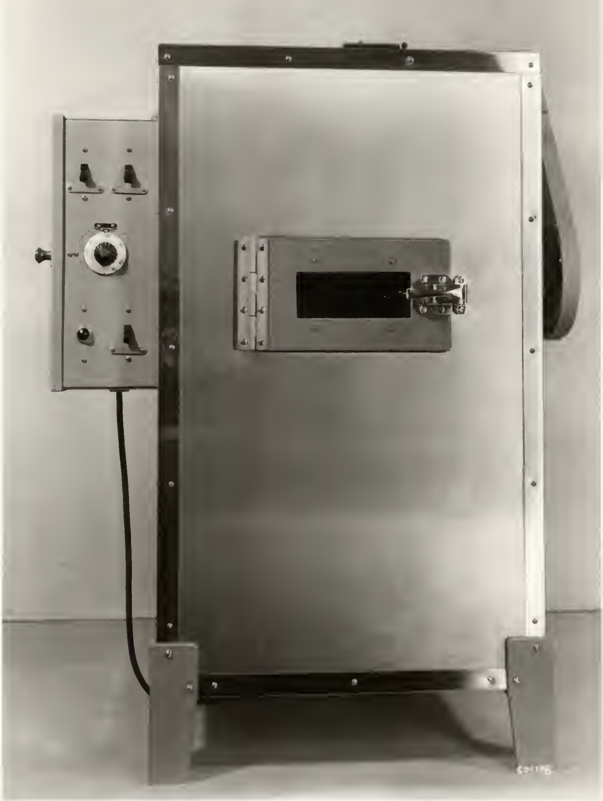
To eliminate the difference in moisture, a steam generator was assembled using a flask and a bunsen burner. Since condensations in the steam line resulted in the formation of water drops a steam condenser or water trap, as shown in Plate VII was made and inserted in the steam line next to the oven. The use of varying amounts of steam improved crust color but did not produce any break and shred.

The electric oven had heavy metal shelves as contrasted to the

EXPLANATION OF PLATE VI

Photograph of the micro oven. The control panel is at the left.

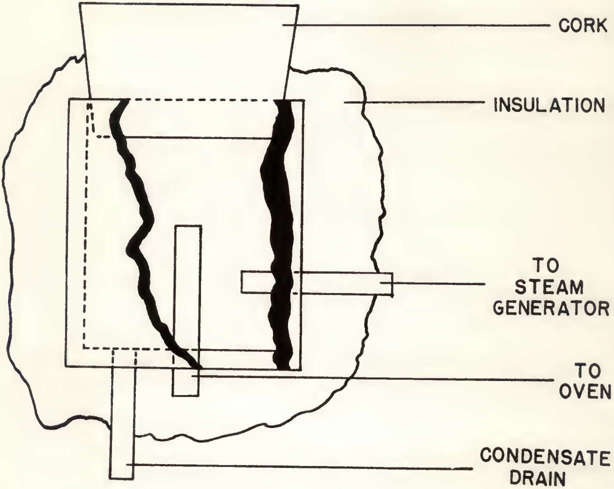
PLATE VI



EXPLANATION OF PLATE VII

Full scale drawing of the steam condenser or water trap.

PLATE VII


CORK
INSULATION
TO
STEAM
GENERATOR
TO
OVEN
CONDENSATE
DRAIN

perforated shelves of the gas oven. An improvement in break and shred was noted when an asbestos pad was placed on the shelf. Apparently the heat capacity of the shelf and the rate at which this heat was conducted to the bread pan affected the formation of break and shred. To vary the heat capacity and rate of conduction, the following combinations of materials were used:

1. On heavy metal shelves:
   - A. Transite.
   - B. Hardware cloth.
   - C. Metal grillwork.

2. On shelves made of grillwork:
   - A. Transite.
   - B. Hardware cloth.

3. On shelves made of transite:
   - A. Metal grillwork.
   - B. Hardware cloth.
   - C. Wire strips.

Most of the arrangements showed some improvement but the wire strips on the transite shelves seemed to give the most consistent results. Plate III, Fig. 2 shows the arrangement of the wire strips on the shelf and the position of a bread pan in relationship to the strips.

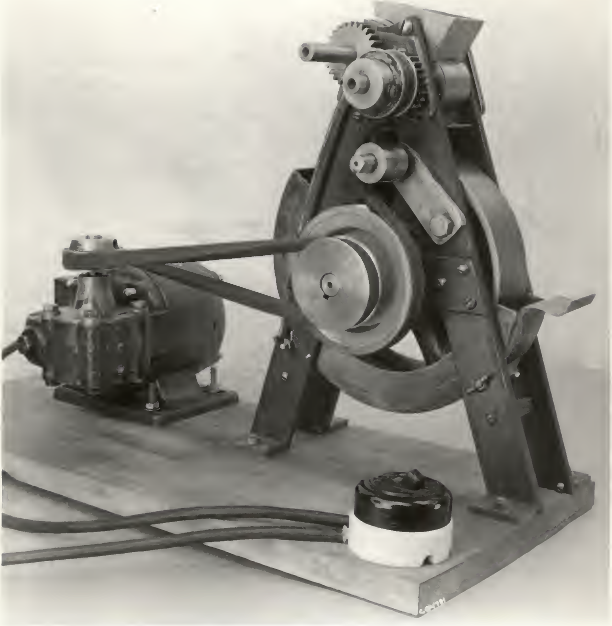
Sheeting Rolls and Molder. The sheeting rolls and molder were combined into one machine. Plate VIII is a photograph of the complete unit. Plate IX is a detailed drawing. Plate X, Fig. 2 is a schematic diagram of the sheeting rolls and molder showing the path of the dough during the molding operation and during the sheeting process.

In determining the size of the drum roll and clearance between the pressure plate and the drum roll, a simple gadget was used. This gadget was a board with runners along each edge on the flat side. The dough was hand curled and placed on a table. The board was then pushed along the

EXPLANATION OF PLATE VIII

Photograph of the sheeting rolls and molder.

PLATE VIII



## EXPLANATION OF PLATE IX

Detailed drawing of the sheeting rolls and molder.

A - Drum roll

B - Sheeting roll

C - Sheeting roll

D - Lever arm

E - Drive gears for sheeting rolls

F - Drive pulley for sheeting rolls

G - Belt idler

H - Power take-off for pulley F

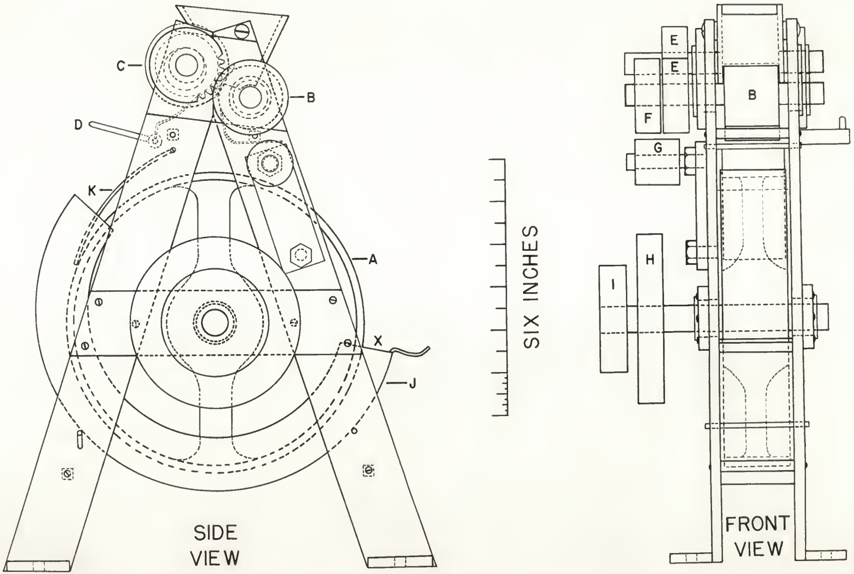
I - Main drive pulley

J - Pressure plate

K - Curler

X - Exit point for dough

PLATE IX



EXPLANATION OF PLATE X

Fig. 1. Schematic diagram of the board molder.

Fig. 2. Schematic diagram of the sheeting rolls and molder.

PLATE X

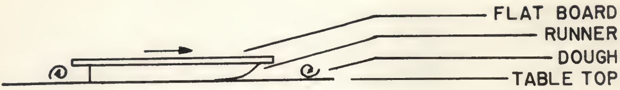



FIG. 1

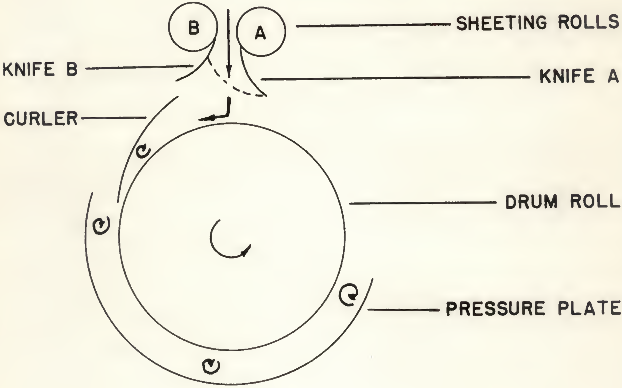



FIG. 2

table top, riding on the runners, with the dough rolling between it and the table. Plate X, Fig. 1 is a schematic diagram illustrating this procedure. The distance between the runners was indicative of the drum roll width and runner thickness indicative of the distance between the drum roll and the pressure plate.

The length of the board represented the length of the pressure plate and the distance the dough traveled on the table represented the distance it would travel along the circumference of the drum roll. The diameter of the drum roll was not considered to be critical since it would not alter the molding process if a slightly smaller or slightly larger drum roll were used. The drum roll size was dependent upon the surface speed of the drum roll at the circumference, the speed of the sheeting rolls, and the speed reduction mechanism necessary using an electric motor. The resulting surface speeds at their circumferences were: drum roll - 72 rpm = 1563 in./minute; sheeting rolls = 164.5 rpm = 774.8 in./minute. The drum roll surface speed is faster than the surface speed of the sheeting rolls in order that the ribbon of dough will be carried along and not bunch up during the molding process. The electric motor used had a built-in reduction gear which gave a drive speed of 90 r.p.m.

Farinograph Mixing Bowl. The Farinograph is useful in determining the amount of water required to make a dough of a certain consistency. This information is essential in estimating the amount of water required in the baking formula.

From the farinogram one may also estimate the mixing tolerance of a flour sample and get an idea of its general strength characteristics (4) (13).

Farinograph mixing bowls that use 300 g. and 50 g. of flour are available. However, it was desired to obtain a mixing bowl using 10 g. of flour. Accordingly, a micro Farinograph mixing bowl was supplied by the Brabender Corporation of Rochelle Park, New Jersey. The accessory equipment included an aligning template for the mixing blades, a special scale head (range 0 to 200 grams), a special dynamometer arm stop assembly, and a special drilled piston (for the damper system). The mixing bowl and stand are shown in Plate XI. Plate I, Fig. 1 shows the aligning template. The mixing bowl and the accessory equipment (with the exception of the drilled piston and the template) are illustrated in Plate XII.

The template is necessary to properly align the mixing blades should the blades ever have to be removed.

The smaller mixing bowl required a more sensitive balance system. The added sensitivity was incorporated into the special scale head.

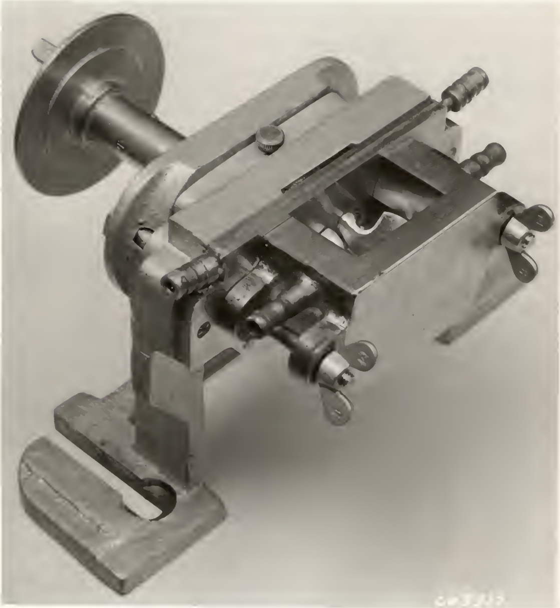
When the motor was turned on, the dynamometer arm was deflected more than 200 g. The special scale head could not absorb that amount of deflection. The dynamometer arm stop assembly was mounted in such a manner that it absorbed the initial deflection of the dynamometer arm.

The damper system also had to be changed since adjustment of the system to give the least amount of dampening resulted in virtually no curve amplitude (the curve amplitude is a function of the dampening). The use of a less viscous liquid (kerosene) did not give the desired amplitude. Holes drilled in the piston lessened the dampening permitting sufficient amplitude to be obtained with the oil normally used in the system.

EXPLANATION OF PLATE XI

Photograph of the micro Farinograph mixing bowl and stand.

PLATE XI



## EXPLANATION OF PLATE XII

Photograph of the Farinograph with the micro mixing bowl and accessories attached.

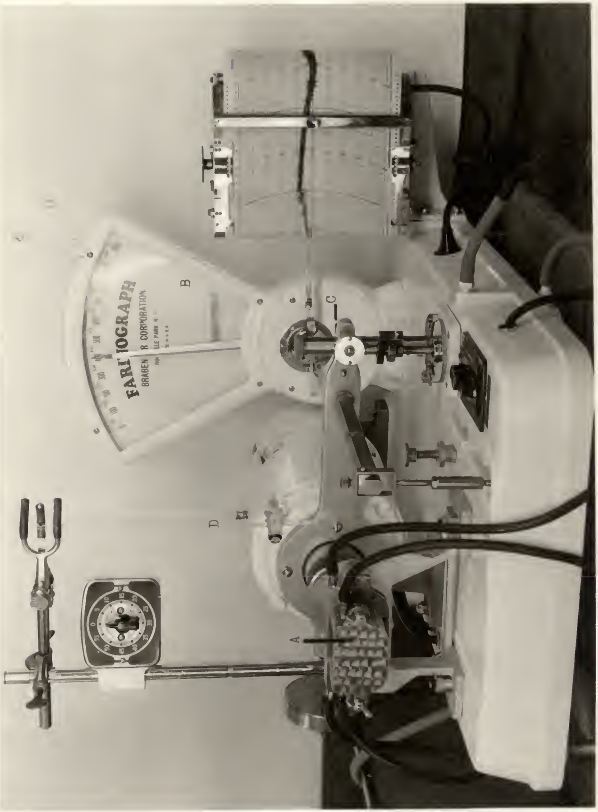
A. 10 g. mixing bowl

B. Special scale head

C. Dynamometer bumper arm (almost hidden)

D. Burette

PLATE XII



## Development of Micro Methods

Baking. Several different medium strong flours were used in developing the optimum micro baking method. The flours used were blends made from the Kansas Experiment Station Environment Series of samples for the year 1951 (14). The blend consisted of six varieties in the protein range of 11.1 percent to 12.4 percent. The Farinograph absorption of the blend was 68.5 percent and the mixograph mixing time was 3 minutes.

The validity of the results obtained by the use of the micro baking test was based on a comparison with the results obtained from the present standard baking test (1) (2). For the preliminary comparison of baking results, tests were made using the Kansas Experiment Station Environment Series of samples for the year 1951.

It was desired to make the micro baking test as nearly like the standard baking test as possible. The formula used in the standard test was as follows:

| | |
|---|---|
| flour | 100.0 parts |
| salt | 2.0 " |
| sugar | 5.0 " |
| yeast | 2.0 " |
| dry milk solids | 4.0 " |
| malted wheat flour | 0.25 " |
| arkady | 0.5 " |
| shortening | 3.0 " |

The formula used in the micro test was the same except for the following three ingredients: arkady, salt, and malt. In place of arkady, 1 mg. percent of potassium bromate was used, salt was reduced from 2 percent to 1.5 percent, and malted wheat flour was replaced by a malt syrup (120° Lintner).

The salt and sugar were made into a solution containing 13.64 g. of salt, 45.45 g. of sugar, and 64.72 ml. of water per 100 ml. of solution. For a flour weight of 10 g., 1.1 ml. of solution were added. Each 1.1 ml. portion contained 0.15 g. of salt, 0.5 g. of sugar, and 0.71 ml. of water. It was found that this concentration of salt and sugar did not crystallize nor did it exhibit mold growth on standing at room temperature. Therefore it could be prepared in a large enough quantity to supply salt and sugar for several days of baking.

The concentration of the potassium bromate solution was 10 mg. percent. A 1 ml. portion of this solution contained 0.1 mg. of potassium bromate or 1 mg. percent based on 10 g. of flour. Since the amount of water displaced by 10 mg. percent of potassium bromate is very small, the amount of water added with each ml. of solution was considered to be 1 ml.

To 120 g. of dry milk solids was added 528 ml. of water, making a total volume of 600 ml. A 2 ml. portion of this solution contained the equivalent of 0.4 g. of dry milk solids and 1.7 ml. of water. A fresh solution was prepared for each bake.

The malt solution contained 2.5 g. of malt syrup per 100 ml. of solution. Displacement of the syrup was considered to be zero and therefore a 1 ml. portion of the solution contained the equivalent of 0.025 g. of malt syrup and 1 ml. of water. A fresh solution was prepared for each bake.

A yeast suspension of 100 ml. was made using 20 g. of yeast and 83.8 ml. of water. A 1 ml. portion of this suspension contained 0.2 g. of yeast and 0.838 ml. of water. A fresh suspension was prepared for each bake.

Maximum homogeneity of the yeast suspension was obtained by thoroughly shaking prior to taking a portion.

The total water added with the various ingredients was:

| | |
|---|---|
| salt and sugar | 0.71 ml. |
| potassium bromate | 1.0 |
| milk | 1.7 |
| malt | 1.0 |
| yeast | 0.84 |
| Total | 5.25 ml. |

Additional water was added to bring each dough to the proper absorption.

The shortening was melted and added with the aid of a special pipette, calibrated in such a manner that 14 drops weighed 0.3 g. The shortening was added to the flour at such a time as to allow cooling to room temperature before mixing.

For all preliminary work such as determination of optimum fermentation time and optimum proof time, the flour samples used were mixed to optimum as determined by the appearance of the dough, using the mixograph mixing time as a guide. The resulting mixing times of the flour samples were approximately the same as that given by the mixograph.

Using one of the medium strong flours mentioned previously, a fermentation time series was baked. From one large dough mixed in the Hobart A-200 were scaled six 13-g. doughs. With a fermentation cabinet relative humidity near 100 percent and an oven temperature of 400° F, these six doughs were handled in pairs, the first pair fermented 1.5 hours after mixing to the first punch; the second pair fermented 1.75 hours; the third 2.0 hours after mixing. The average loaf volumes of the pairs of loaves were: 47.4 cc., 48.0 cc., and 45.0 cc. respectively. This series was also made with another flour sample yielding average volumes of 42.8 cc., 47.0 cc., and 46.2 cc. for 1.5, 1.75, and 2.0 hours fermentation time respectively.

Thus, both flours exhibited maximum loaf volume after 1.75 hours fermentation time.

In determining the optimum proof time, a series similar to that used in determining optimum fermentation time was used. Proof time was varied from 50 to 70 minutes in increments of 5 minutes. This series required five sets of duplicate doughs. The results are shown in Table 1.

Table 1. Effect of proof time on loaf volume, grain and texture.

| Proof time (minutes) | Average volumes (cc.) | Grain and texture |
|---|---|---|
| 50 | 52.9 | 90 |
| 55 | 54.5 | 100 |
| 60 | 56 + | 90 |
| 65 | 56 + | 85 |
| 70 | 56 + | 80 |

The grain and texture score decreased after 55 minutes proof time. As a result of these tests a proof time of 55 minutes was used.

Loaf color and crust thickness were the basis on which the proper oven temperature was determined. Baking times were varied using different oven temperatures to study the effect of temperature on loaf color and crust thickness. A temperature of 400° F for a period of 11 minutes in the oven proved to be the most suitable conditions.

The optimum baking conditions thus determined were:

| Operation | Time |
|---|---|
| first punch | 105 min. |
| second punch | 45 min. |
| molding | 30 min. |
| pan proof | 55 min. |
| oven | 11 min. |
| Conditions | |
| oven temperature | 400° F |
| Fermentation cabinet relative humidity | near 100 % |

Baking Results. Of the available 1951 Kansas Experiment Station Environment Series of samples, 191 samples were baked conforming to the above conditions. Volumes were measured and recorded. Break and shred and interior qualities were judged and the scores recorded. No attempt was made to correlate these scores with those of the standard test.

The 191 samples were baked during a ten-day period and each day three control loaves were baked. The average volume for the thirty loaves was found to be 50.7 cc. The volumes of the control loaves for each day were averaged and the difference in one day's average from the total average was added to or subtracted from the sample loaf volumes on that particular day. This procedure would tend to minimize day to day variations.

The correlation between the micro loaf volumes and the corresponding loaf volumes obtained from the standard test was $r = 0.538$. This is significant beyond the 1 percent level.

Although a significant correlation was obtained, it seemed likely a higher correlation should exist. This would indicate that some technique used in the micro method could be modified to give a higher correlation. The baking techniques were rechecked in an effort to obtain optimum conditions. Since the Environment Series included varieties grown at different locations, there existed samples of the same variety having different levels of protein. The volumes of the samples of several varieties were plotted against percent protein. In all cases, the loaf volume change with increased flour protein showed only a slight relationship and this was substantiating evidence that some technique was affecting the micro loaf volumes because loaf volume should increase with increased flour protein content (8).

A combination oxidation-reduction and mixing time series was made using the control flour. The redox potential was varied using cystiene and potassium bromate as follows: 3 mg. percent, 2 mg. percent, and 1 mg. percent of cystiene, one level with neither cystiene nor potassium bromate, and potassium bromate at 1 mg. percent, 2 mg. percent, and 3 mg. percent levels. Four mixing times were used as follows: 1.5, 2.0, 2.5, and 3.0 minutes. The results are shown in Plate XIII.

The results of this experiment brought out three important considerations; 1. the random loaf volume response to increased redox potential, 2. the average volume of each group increased with longer mixing time, and 3. the randomness of each redox series decreased with increased mixing time.

These three facts indicate first, that the samples were not baked under optimum conditions, second, the need for baking in triplicates to determine optimum conditions, and third, the necessity for harsher treatment of the dough. Three-minutes mixing time (the optimum for this flour was three minutes as indicated by the mixograph) gave the highest loaf volumes and yet the response to increased redox potential was random.

To remove any doubt that yeast inhibiting factors were not present (9) several experiments on gas production and gas retention were made. Doughs from the Hobard A-200 and from the micro mixer were tested for both gas production and gas retention. The results compared favorably. Next, dough samples having gone through all steps up to and including molding from both methods, were tested for gas production and gas retention. These results also compared favorably.

## EXPLANATION OF PLATE XIII

A graph of the loaf volume data (in cc.) obtained from a combination oxidation-reduction and mixing time series.

The levels of cystiene used (1 mg. %, 2 mg. %, and 3 mg.%) are represented by -1, -2, and -3 respectively.

I The effect of varying the redox potential in a dough mixed for 1.5 minutes.

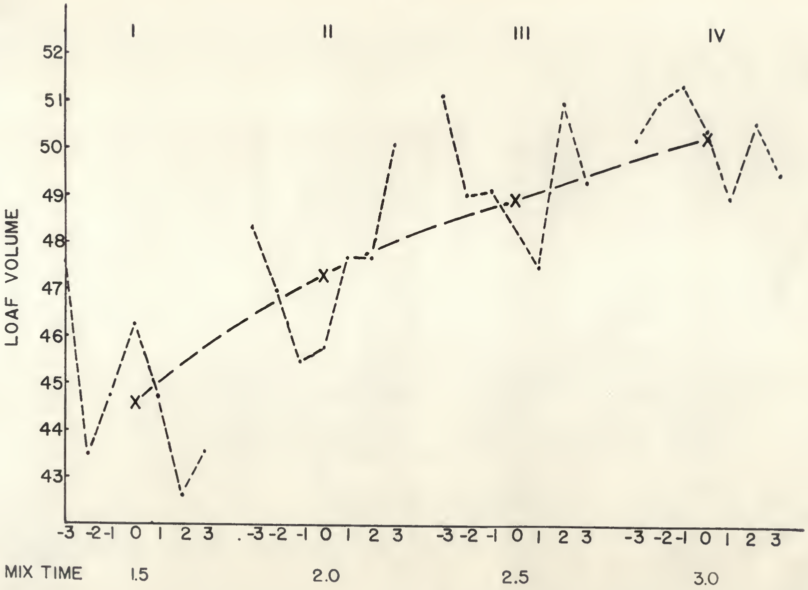
II The effect of varying the redox potential in a dough mixed for 2.0 minutes.

III The effect of varying the redox potential in a dough mixed for 2.5 minutes.

IV The effect of varying the redox potential in a dough mixed for 3.0 minutes.

The average loaf volume for each set is represented by X and the line X -- X illustrates the general increase in loaf volume with the increased mixing time.

PLATE XIII


I
II
III
IV
LOAF VOLUME
52
51
50
49
48
47
46
45
44
43
-3 -2 -1 0 1 2 3
-3 -2 -1 0 1 2 3
-3 -2 -1 0 1 2 3
-3 -2 -1 0 1 2 3
MIX TIME
1.5
2.0
2.5
3.0

Optimum fermentation time was again determined using the control flour. Triplicates were used, mixing them three minutes and scaling 14 g. of dough rather than 13 g. (larger dough size seemed to give better break and shred). Changes in fermentation time were distributed proportionally among the periods between operations. Fermentation times of 170, 180, 190, and 200 minutes were used. Table 2 shows the results.

Table 2. Effect of fermentation time on loaf volume and break and shred.

| Fermentation time (min.) | Loaf volumes ( cc.) a | b | c | Average loaf volume | Deviation of volumes | Break and shred |
|---|---|---|---|---|---|---|
| 170 | 49.0 | 40.0 | 48.5 | 49.1 | 1.5 | poor |
| 180 | 49.5 | 49.3 | -- | 49.4 | 0.2 | good |
| 190 | 50.3 | 49.7 | 49.5 | 49.8 | 0.8 | very good |
| 200 | 49.4 | 48.4 | 48.7 | 48.7 | 1.2 | good |

The differentiation was not great but 190 minutes fermentation time gave the largest loaf volumes and the best reproduc ibility.

Using the newly established optimum fermentation time, a series of baking tests was made to determine the most suitable oven temperature. Temperatures of 300, 350, 400, 450, and 475 degrees F were used and triplicate bakes were made at each temperature. Table 3 shows the results.

Table 3. Effect of oven temperature on loaf volume and break and shred.

| Oven temperature (degrees F) | Loaf volumes ( cc.) a | b | c | Average loaf volume | Deviation of volumes | Break and shred |
|---|---|---|---|---|---|---|
| 300 | 48.6 | 53.7 | 50.7 | 50.8 | 1.6 | very good |
| 350 | 48.9 | 49.3 | 50.4 | 49.5 | 1.5 | fair |
| 400 | 53.1 | 50.5 | ---- | 51.8 | 2.6 | fair |
| 450 | 53.1 | 52.0 | 52.3 | 52.5 | 1.1 | poor |
| 475 | 51.8 | 52.5 | 53.0 | 53.0 | 1.2 | none |

The loaves were baked for varying lengths of time depending upon the oven temperature. At 400° F, the bake time was 15 minutes. This was an increase of four minutes over the bake time used previously at the same temperature. A slightly thicker crust was obtained and the sides and ends of the loaf were firmer and conceivably would hold up better during volume measurement. The largest volumes were obtained at a temperature of 450° F but 400° F gave nearly the same volumes with better break and shred. The higher temperatures tended to dry the bread more than was desirable. Hence, 400° F was considered the optimum temperature at which to bake the micro loaves.

A new proof time series was baked in triplicate, varying the time from 45 to 60 minutes in increments of 5 minutes. Table 4 shows the results.

Table 4. Effect of proof time on loaf volume and break and shred.

| Proof time (min.) | Loaf volumes (cc.) a | b | c | Average loaf volume | Deviation of volumes | Break and shred |
|---|---|---|---|---|---|---|
| 45 | 50.9 | 53.6 | 50.7 | 51.7 | 2.9 | very good |
| 50 | 54.0 | 52.9 | 54.0 | 53.6 | 1.1 | good |
| 55 | 56.1 | 55.1 | 55.0 | 55.5 | 1.1 | good |
| 60 | 54.5 | 58.3 | 56.0 | 56.3 | 3.8 | very good |

The mixing times of the micro mixer and the mixograph were compared, using the control flour (with a mixograph mixing time of 3 minutes) and conforming to the established optimum baking conditions. Mixing time was varied from 3 to 5 minutes in increments of 0.5 minutes and triplicate bakes were made for each mixing time. Table 5 shows the results.

Table 5. Effect of mixing time on loaf volume and break and shred. (Flour with mixograph mixing time of 3 minutes.)

| Mixing time (min.) | Loaf volumes (cc.) a | b | c | Average loaf volume | Deviation of volumes | Break and shred |
|---|---|---|---|---|---|---|
| 3.0 | 49.8 | 52.0 | 52.8 | 51.5 | 3.0 | fair |
| 3.5 | 51.6 | 53.5 | 53.5 | 52.8 | 1.9 | good |
| 4.0 | 54.1 | 54.6 | 53.6 | 54.1 | 1.0 | good |
| 4.5 | ---- | 56.6 | 56.8 | 56.7 | 0.2 | very good |
| 5.0 | 56.4 | 56.2 | 55.9 | 56.2 | 0.5 | good |

Both break and shred and the interior qualities were optimum at the 4.5 minute mixing time in addition to obtaining maximum volume and maximum reproducibility. In Table 5 as in Plate XIII, an increase in reproducibility was observed with a longer mixing time.

A flour exhibiting a mixograph mixing time of four minutes was used in a mixing time series. Using triplicate bakes the mixing time was varied from 3.5 to 5.5 minutes in increments of 0.5 minutes. Table 6 shows the results.

Table 6. Effect of mixing time on loaf volume and break and shred. (Flour with a mixograph mixing time of 4 minutes)

| Mixing time (min.) | Loaf volumes (cc.) a | b | c | Average loaf volume | Deviation of volumes | Break and shred |
|---|---|---|---|---|---|---|
| 3.5 | 52.2 | 52.2 | ---- | 52.2 | 0.0 | poor |
| 4.0 | 53.0 | 51.7 | 53.1 | 52.6 | 1.4 | fair |
| 4.5 | 54.6 | ---- | 54.8 | 54.7 | 0.2 | fair |
| 5.0 | ---- | 56.3 | 54.7 | 55.5 | 1.6 | good |
| 5.5 | 50.5 | ---- | 55.5 | 51.4 | 1.8 | very good |

A maximum volume was obtained at a mixing time of 5 minutes. Good break and shred and good loaf volume reproducibility were also obtained at this mixing time.

The control flour exhibited a mixing time increase of 50 percent over the mixograph mixing time. The latter flour showed an increase of 25 percent. The apparent under-development during mixing when the micro method was used first on the 1951 Kansas Experiment Station Environment Series undoubtedly accounts for the lack of high correlation between the standard and micro loaf volume results.

Since there were large loaf volume variations caused by increasing the mixing time, and since mixograph data would not be available before starting a bake, optimum development of the dough was determined by the appearance and feel of the dough (6).

Techniques and Procedures. The flour and shortening were transferred from the plastic dish to the mixing bowl using a brush to remove any flour remaining in the plastic dish or on the edge of the bowl. The solutions and additional water were pipetted into the bowl. The bowl and its contents were then placed on the mixer and contents mixed to optimum. Some practice and careful observations were required to properly determine the point of optimum development of the dough.

Upon completion of the mixing process, the dough was removed with the aid of a narrow spatula, rounded and placed in a plastic dish. The dish was covered with a numbered lid and placed in the fermentation cabinet. The fermentation cabinet was set for 86° F and a relative humidity near 100 percent. The cabinet was allowed at least one and one-half hours to come to constant temperature and humidity.

To punch the dough, the sheeting rolls were used. The dough was carefully removed from the plastic dish using a scraping motion with the fingers to loosen the dough. The piece of dough was then gently elongated and sent through the sheeting rolls (Plate X, Fig. 2). To remove the dough as it came through the rolls, the thumb of the right hand, pointing towards roll B, was held against roll A. At the moment of contact of the dough with the thumb, the dough was pulled away from the roll.

The resulting ribbon of dough was then rolled or curled by hand (as it would be in the molding process), replaced in the plastic dish, covered and returned to the fermentation cabinet.

This procedure was repeated for the second punch.

The dough was similarily handled in the molding process except that a knife was placed against roll A by holding the lever on the right side of the molder in a downward position, thus causing the dough to be curled and molded rather than go through the sheeting process.

In some cases, sticky doughs would adhere to the drum roll going on past the point where the dough emerges from the molding process. To eliminate this, the motor was turned off when the dough appeared at the exit point.

Immediately after being molded, the dough was placed in a bread pan with the seal down and with the dough touching one side of the pan. A numbered piece of paper was also placed in the bottom of the pan (number down), prior to panning the dough. This numbered paper would adhere to the loaf and serve later to identify the loaf.

After panning the dough, the pan and dough in the covered plastic dish were returned to the fermentation cabinet.

After the proper proof time, the pan and dough were placed in the oven. One hour was allowed for the oven to come to the desired temperature and fifteen minutes were allowed for the development of the proper humidity. A cotton glove was used to handle the bread pans.

After baking, the bread was removed from the pan and allowed to cool. In about fifteen minutes the pan was sufficiently cool to be used again. Rarely did a loaf stick to the bread pan enough to warrant the use of a spatula for removal but occasionally a slight rap of the bread pan against the desk top facilitated removal of the loaf.

Prior to use, the volume meter was standardized (1) (12). This was accomplished by placing the brass block, with the area of least surface down, in compartment C of the loaf volume meter (Plate V). The gate was opened and the lead shot allowed to fill the remainder of the compartment and the burette tube up to a reading of 10 cc. In the event that too high a reading (too much lead shot) was obtained, a lid at the top of the meter was removed and a little lead shot removed by tipping the meter. Where too low a reading was obtained, the lid was removed and a little lead shot added. In actual volume measurement, 20 cc. was added to the reading obtained (30 cc. to account for the brass block minus 10 cc. to account for 10 cc. standardization reading).

The loaf volume was measured by placing the loaf in compartment C of the volume meter. The lead shot was allowed to fill the remainder of that compartment and up into the burette. Two measurements were made on each loaf with the average being recorded.

After about four hours, the loaves were scored for break and shred and grain and texture.

The procedures involved in changing the Farinograph to accomodate the 10 g. mixing bowl and its accessories were quite extensive. They are listed in step form.

1. The counter weights were removed from the threaded shaft on the left-hand side of the Farinograph.

2. The finger bolts, mixing bowl, and stand were removed from the Farinograph.

3. The burette was removed.

4. The pointer arm assembly was removed.

5. The chromium plated shaft cover was removed from the scale head assembly.

6. The white enamel cover was removed from the scale head mechanism.

7. The glass cover was removed from the scale head assembly.

8. The connecting linkage was unhooked from the metal band on the scale element and removed.

9. The securing plate was applied by attaching with screws to the scale head frame and to the tapped holes provided in the counter weight of the scale head sensing element. Care was taken not to damage the knife edges of the scale element.

10. A protective roll of tissue paper was applied to the scale head pointer.

11. The glass cover of the scale head assembly was replaced.

12. The enamel cover plate was replaced with one-inch bolts and approximately one-half inch thick separators (made from 0-1 hole stoppers). This provided sufficient clearance for the attachment of the pointer shaft protector.

13. A gasket was made (from paper) to fit the pointer arm shaft protector cover.

14. The pointer arm shaft protector cover was secured with the screws from step 5. The paper gasket from step 13 was placed between the cover and the enamel.

15. The feet of the Farinograph were adjusted to insure efficient working clearance.

16. The scale head securing bolts were removed from below. Care was taken not to damage the knife edge at the end of the lever system.

17. The scale head assembly was removed and stored in a box constructed for it.

18. The special scale head assembly was attached to the Farinograph.

19. The protective paper cover was removed from the glass on the scale head and placed on the original scale head glass.

20. The pointer arm shaft protective cover was removed.

21. The enamel scale assembly cover was removed.

22. The glass scale head cover was removed.

23. The protective roll of tissue paper was removed from the scale head pointer.

24. The securing plate attached to the scale head frame and to the counter weight of the scale sensing element was removed.

25. At this point, any accumulation of dust or other material was removed from the assembly with a camel hair brush.

26. The lever arm linkage was moved to the outer-most position.

27. The scale arm linkage was attached with the adjustment nut downward and the upper hook with open part toward the scale head element.

28. The 0 stop bumper and the 1000 limit bumper were adjusted so that the scale head pointer would fall slightly below 0 and above 1000 (in case the pointer did not fall below 0, the lever arm linkage would have been lengthened).

29. The glass cover on the scale head was replaced.

30. The white enamel scale cover was replaced.

31. The chromium plated cover was replaced.

32. The screw from the dash pot to the dynamometer arm linkage was removed. The dash pot cover was unscrewed and removed, the linkage slipped off the dynamometer arm, and the assembly removed from the dash pot. The recessed nut at the bottom of the piston was unscrewed and the special drilled piston put on. The dash pot piston assembly was replaced, adjusting the ports to a wide open position.

33. The smaller of the two counter weights was replaced and secured with the lock nut.

34. The scale pointer arm was replaced. This was done with the pen attached and the pointer arm at a position where the pen just touched the recording paper.

35. The 10 g. bowl and stand were placed in position. The set screw on the drive shaft was loosened and the drive shaft adjusted to engage the Farinograph motor drive shaft.

36. The pen was adjusted to coincide with the scale head pointer. This was done by setting the 1000 limit bumper at 500 (as indicated by the pointer when lifting the lever arm against the limit bumper) and adjusting the pen to 500 on the recording paper. The 1000 limit bumper was then readjusted.

37. The mixing blades were checked to see that they were not stuck by dough accumulation.

38. A burette (made to drain 7.0 ml. in 16 to 20 seconds) was adjusted to drain in the right front corner of the mixing bowl.

39. The two rear bolts which held down the dash pot top to the base were removed. The dynamometer arm bumper assembly was positioned and secured with two special bolts. In operation, the cushioned arm was placed over the end of the dynamometer arm before starting the Farinograph motor and twisted clear immediately after the motor had started. The arm was made to be adjusted by loosening the Allen set screw at the base and sliding the shaft upwards. To shorten the shaft, 1/8 th inch may be removed from the bottom of the post or another arm hole tapped in at a lower position.

40. The electrical plug was replaced.

41. A clean up flour was weighed (10 g.) and placed in the mixing bowl. Approximately 6.5 ml. of water was run into the bowl. The dough was allowed to mix for 20 minutes, a pinch of salt added, and enough flour added to obtain approximately 700 units of consistency. The instrument was stopped, the mixing bowl stand moved enough to disengage the mixing bowl shaft from the motor shaft, and the bowl cleaned.

42. The stand was repositioned, the dynamometer arm bumper placed in position, the instrument started, the bumper twisted out of position and the running zero adjusted by means of the counter weight. This was done with the pen filled with ink.

43. The water hoses were attached starting at the back wall and through the bowl.

Prior to determining the absorption of a flour sample, the dash pot was allowed from two to four hours to come to constant temperature and the Farinograph was run for twenty minutes, mixing a clean-up flour. Ten grams (on a 14 percent moisture basis) of the flour sample was weighed and placed in the mixing bowl and the motor started. The dynamometer bumper arm was twisted out of position immediately thereafter. The stopcock on the burette was opened at the same instant the motor was started and allowed to drain in the right front corner of the mixing bowl until about 6.5 ml. had been added. Any flour or dough on the upper inside walls of the mixing bowl was scraped down with a spatula (of soft material) and the mixing bowl covered with a piece of glass. The pen was kept well-inked at all times. The paper was brushed flat when bulges occurred and a minimum of paper allowed beyond the tear-off knife. After twenty minutes of mixing, the mixing bowl was cleaned, following the procedure in step 41.

To determine accurately the absorption of a flour sample, the peak of the curve must center on the 500 consistency line. If the curve fell above or below the 500 line, another 10 g. sample was weighed and more or less water was added depending on the position of the peak of the curve. Near the 500 line, 0.05 ml. of water shifted the curve about 20 units (or one division line). The amount of water required to center the peak of the curve on the 500 consistency line was recorded in pencil on the graph along with the sample number.

## RESULTS

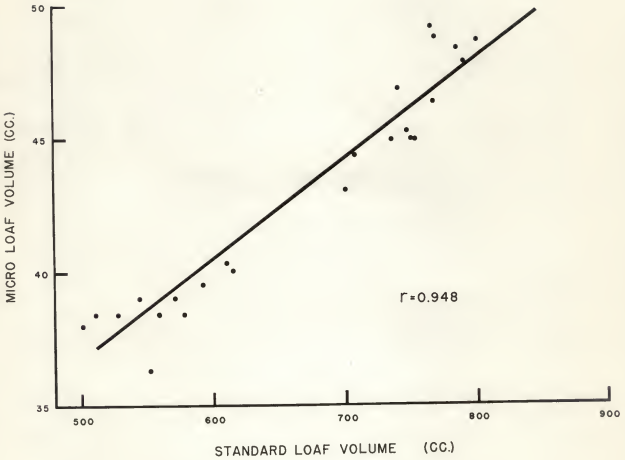
### Comparisons of Micro and Standard A.A.C.C. Baking Methods

A comparison of the micro with the standard baking method was made using a group of special samples harvested in Manhattan, Kansas in 1952 (7). Twenty-four samples were selected including the variety Tenmarq and progeny of a cross between Tenmarq and Chiefkan. The standard loaf volumes ranged from 511 cc. to 800 cc. with an average loaf volume of 665.3 cc. The micro loaf volumes ranged from 36.3 cc. to 49.1 cc. with an average loaf volume of 42.9 cc. The loaf volumes (Appendix, Table 1) obtained by the two methods were plotted as shown in Plate XIV and the correlation found to be r = 0.9485.

EXPLANATION OF PLATE XIV

Reqression graph of micro loaf volume and standard loaf volume.

PLATE XIV


50
45
40
35
MICRO LOAF VOLUME (CC.)
r=0.948
500
600
700
800
900
STANDARD LOAF VOLUME (CC.)

A comparison of the micro baking method with the standard baking method was made using 82 samples of the 1952 Kansas Experiment Station Environment Series (14). The loaf volumes (Appendix, Table 2) obtained by the two methods were plotted as shown in Plate XV and the correlation found to be r = 0.749. Two control loaves were baked on each of the seven days required to bake this series of samples. The average loaf volume of the control loaves was 53.0 cc. The loaf volumes of the control loaves for each day were averaged and the difference in one day's average from the total average was added to, or subtracted from, the sample loaf volumes on that particular day. The standard loaf volumes ranged from 683 cc. to 1047 cc. with an average loaf volume of 852 cc. The micro loaf volumes ranged from 37.4 cc. to 61.8 cc. with an average loaf volume of 48.0 cc.

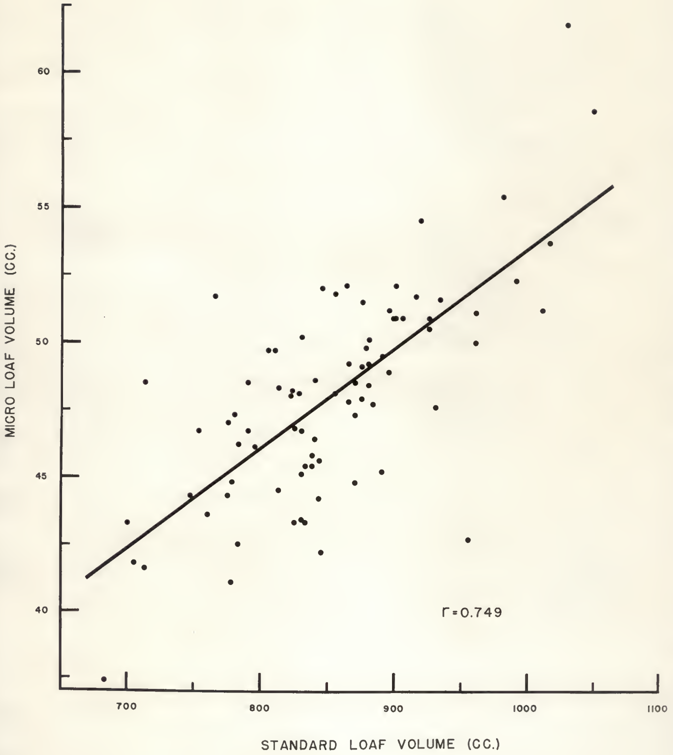
## Comparison of Farinograms of 10, 50, and 300 g. Bowls

To make a comparison of the 10, 50, and 300 g. Farinograph mixing bowls, four flours varying in absorption, mixing time, mixing tolerance, and general strength characteristics were used. The four flours were: a baker's winter wheat flour, a baker's spring wheat flour, a family flour, and a pastry flour. Plate XVI compares the curves of the 10, 50, and 300 g. mixing bowls for each of the four flours.

EXPLANATION OF PLATE XV

Regression graph of micro loaf volume and standard loaf volume.

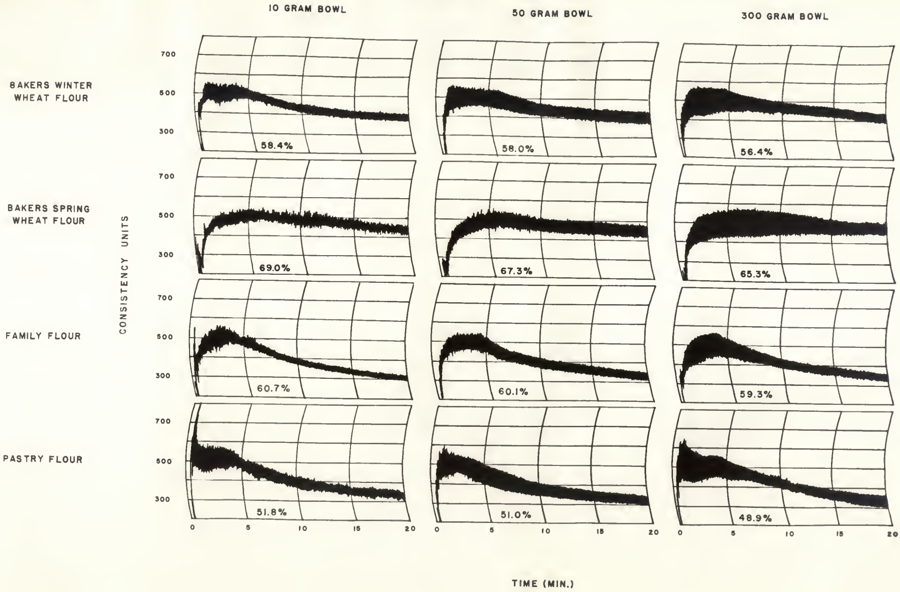
PLATE XV


60
55
50
45
40
MICRO LOAF VOLUME (CC.)
700
800
900
1000
1100
STANDARD LOAF VOLUME (CC.)
r=0.749

## EXPLANATION OF PLATE XVI

Comparison of the farinograms obtained by the use of the 10, 50, and 300 g. Farinograph bowls.

PLATE XVI


10 GRAM BOWL
50 GRAM BOWL
300 GRAM BOWL
BAKERS WINTER WHEAT FLOUR
BAKERS SPRING WHEAT FLOUR
FAMILY FLOUR
PASTRY FLOUR
CONSISTENCY UNITS
700
500
300
58.4%
58.0%
56.4%
69.0%
67.3%
65.3%
60.7%
60.1%
59.3%
51.8%
51.0%
48.9%
0
5
10
15
20
TIME (MIN.)

### Comparison of External Characteristics of Micro, Standard, and One-pound Loaves

Plate XVII, Fig. 1 shows the relative sizes of the micro, standard, and one-pound loaves.

Plate XVII, Fig. 2 compares the external characteristics of the micro method and the standard method using three flours. The micro loaf volumes were 38.7 cc., 46.8 cc., and 53.5 cc. respectively. The standard loaf volumes were 658 cc., 750 cc., and 830 cc. respectively.

## DISCUSSION

The standard A.A.C.C. baking test (1) used to evaluate the special plant breeder's samples, employed a mixer designed for 100 g. flour doughs. Hence, all of the dough resulting from 100 g. of flour and the other ingredients (a total weight of about 175 g.) was used to make one loaf. Duplicates were mixed separately.

The baking test, used to evaluate the Kansas Experiment Station Environment Series, employed a mixer with a minimum capacity of about 300 g. flour doughs. With this mixer, two 175 g. flour doughs were scaled from one mix.

The micro method was altered to simulate each situation. To simulate the former method, 8 g. flour doughs were mixed (total weight of about 14 g.) and all the dough was used. To simulate the latter method, 10 g. flour doughs were mixed and one 14 g. dough was scaled. The mixer

## EXPLANATION OF PLATE XVII

Fig. 1. Comparison of micro, standard, and one-pound loaves.

Fig. 2. Comparison of micro and standard loaves.

PLATE XVII


Fig. 1

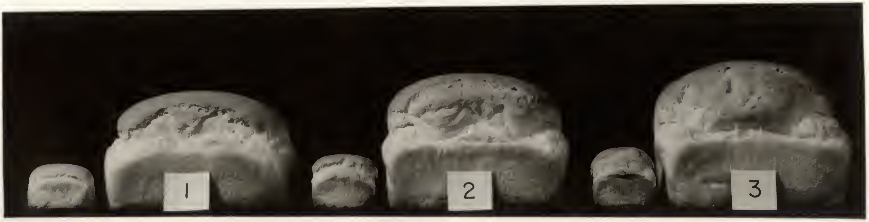



Fig. 2

did not have sufficient capacity to permit making duplicate doughs from the same mix.

The results of the micro and standard baking methods obtained from the two comparisons indicates that the micro method is suited for testing early generations of wheat hybrids where a differentiation of relatively weak and strong wheat varieties is desired. Many varieties exist in the early generations and a large volume of tests is necessary. For this reason, and because of difficulties in scoring for internal and external characteristics, not too much emphasis was placed on the comparisons of the break and shred and the grain and texture. Furthermore, the main interest is in flour strength which is indicated by loaf volume.

The equations of the regression lines in Plates XIV and XV are $\hat{Y} = 17.63 + 0.0380X$ and $\hat{Y} = 16 + 0.0375X$ respectively. Of interest, is the fact that the slopes of both lines are nearly identical. From the mean loaf volumes in the first comparison, 1 cc. micro loaf volume is equivalent to 17.75 cc. of the standard loaf volume. From the mean loaf volumes in the second comparison, 1 cc. micro loaf volume is equivalent to 15.5 cc. of the standard loaf volume.

The comparison of the micro, standard, and one-pound loaves in Plate XVII, Fig. 1 shows clearly the relative sizes. The micro loaf was one which was baked on the heavy metal oven shelves that were originally in the oven. This loaf may be compared to one of the loaves in Plate XVII, Fig. 2. These micro loaves were baked in the micro oven with the transite shelves and wire strips.

From Plate XVII, Fig. 2 a striking similarity of external characteristics and relative size exists between the micro loaves and the standard loaves. The wide variation of flour strength (hence, loaf volume) explains in part this similarity since flours with less variation in strength usually did not show that degree of similarity.

Roughly, the 10 g. Farinograph mixing bowl is to the 50 g. bowl as the 50 g. bowl is to the 300 g. bowl. Without fail, as the bowl size decreased, the absorption increased. The least variation in absorption was obtained with the family flour (1.4 percent) and the largest variation with the spring wheat flour (3.7 percent). There was a tendency too, of a harsher action with the smaller bowl as indicated by the consistency at 20 minutes. The mixing time varied somewhat but the mixing tolerance and general curve characteristics were very similar in all the comparisons. In fact, the comparison of the 10 g. and 300 g. bowls was better than the comparison of the 50 g. and 300 g. bowls using the pastry flour.

The completed micro test includes the following information: wheat protein and moisture content, flour yield, flour protein, moisture, and ash, dough absorption, mixing time, Farinograph curve, baking properties, general strength characteristics, and loaf volume.

SUMMARY

Micro methods designed to evaluate the quality of wheat and flour at early generations in the plant breeding process to produce new improved varieties would save much time and space and make room for other plant breeding work.

Accordingly, micro baking equipment including bread pans, a micro mixer, fermentation cabinet, loaf volume meter, sheeting rolls and molder, and accessory equipment was designed and obtained. In addition, a micro Farinograph bowl requiring 10 g. of flour was secured.

Each piece of equipment obtained was tested and modified as necessary to give best results.

Optimum baking conditions were established using the micro equipment and the techniques and procedures developed and tested by a comparison with standard methods using a series of 191 flour samples.

Comparisons of the micro methods and the standard methods using a group of 24 flour samples and a group of 82 flour samples were made. Correlations of r = 0.948 and r = 0.749 respectively were obtained.

Visual comparisons of the loaves baked by the two methods and illustrating the relative sizes of the loaves and the similarity of external characteristics of loaves have been shown.

A comparison of the farinograms obtained with the 10 g., 50 g., and the 300 g. Farinograph bowls was made using a baker's winter wheat flour, a baker's spring wheat flour, a family flour, and a pastry flour. It was found that absorption increased as the bowl size decreased. The largest

increase was 3.7 percent between the 10 g. and the 300 g. bowls using the baker's spring wheat flour. Mixing tolerance and general curve characteristics were strikingly similar.

The complete test was designed to test samples from the fourth generation where 100 g. of wheat are available. The test provided for the determination of protein and moisture content of the wheat, the flour yield, the determination of the protein, moisture, and ash content of the flour, and gave dough absorption, mixing tolerance, general strength characteristics, and loaf volume.

## ACKNOWLEDGMENTS

The author wishes to express his grateful appreciation to Dr. John A. Shellenberger for the interest, advice, encouragement, and help extended by him throughout the course of this work. He also wishes to express great appreciation for the help received from the other members of the Department of Flour and Feed Milling Industries.

Special thanks for technical advice and assistance are due Mr. Karl Finney, Federal Hard Winter Wheat Quality Laboratory, U.S.D.A., and Mr. Duane A. Rittis of the Department of Physics, Kansas State College.

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# APPENDIX

Table 1. Comparison of the micro with the standard A.A.C.C. loaf volumes.

| Laboratory number | Standard A.A.C.C. loaf volume (cc.) | Micro loaf volume (cc.) |
|---|---|---|
| 1952-1901 | 753 | 44.0 |
| 1910 | 544 | 39.0 |
| 1911 | 511 | 38.4 |
| 1912 | 571 | 39.0 |
| 1913 | 501 | 38.0 |
| 1914 | 615 | 40.0 |
| 1915 | 578 | 38.4 |
| 1916 | 559 | 38.4 |
| 1917 | 528 | 38.4 |
| 1934 | 740 | 46.8 |
| 1935 | 750 | 44.9 |
| 1936 | 768 | 48.7 |
| 1937 | 800 | 48.6 |
| 1938 | 765 | 49.1 |
| 1939 | 790 | 47.8 |
| 1940 | 785 | 48.3 |
| 1941 | 767 | 46.3 |
| 1942 | 552 | 36.3 |
| 1943 | 592 | 39.5 |
| 1945 | 747 | 45.2 |
| 1946 | 735 | 44.9 |
| 1947 | 707 | 44.3 |
| 1948 | 700 | 43.0 |
| 1949 | 610 | 40.3 |

Table 2. Comparison of the micro with the standard A.A.C.C. loaf volumes for the 1952 Kansas Experiment Station Environment Series.

| Laboratory number | Standard A.A.C.C. loaf volume (cc.) | Micro loaf volume (cc.) |
|---|---|---|
| 1952-21 | 865 | 47.8 |
| 23 | 890 | 49.5 |
| 26 | 855 | 48.1 |
| 27 | 883 | 47.7 |
| 32 | 915 | 51.7 |
| 33 | 880 | 50.1 |
| 34 | 925 | 50.9 |
| 40 | 900 | 50.9 |
| 41 | 905 | 50.9 |
| 44 | 775 | 44.3 |
| 45 | 828 | 48.1 |
| 50 | 845 | 42.2 |
| 53 | 845 | 52.0 |
| 55 | 833 | 43.3 |
| 56 | 813 | 48.3 |
| 57 | 783 | 42.5 |
| 59 | 683 | 37.4 |
| 60 | 840 | 48.6 |
| 61 | 830 | 45.1 |
| 61 | 830 | 46.7 |
| 70 | 760 | 43.6 |
| 73 | 830 | 43.4 |
| 76 | 765 | 51.7 |
| 78 | 833 | 45.4 |
| 80 | 840 | 46.4 |
| 82 | 925 | 50.5 |
| 86 | 890 | 45.2 |
| 92 | 713 | 41.6 |
| 93 | 880 | 49.2 |
| 103 | 875 | 49.1 |
| 104 | 753 | 46.7 |
| 105 | 780 | 47.3 |
| 106 | 783 | 46.2 |
| 108 | 838 | 45.8 |
| 111 | 825 | 43.3 |
| 114 | 825 | 46.8 |
| 115 | 870 | 48.5 |
| 116 | 778 | 41.1 |
| 117 | 833 | 45.4 |
| 118 | 790 | 46.7 |
| 118 | 790 | 48.5 |

Table 2. (concl.)

| Laboratory number | Standard A.A.C.C. loaf volume (cc.) | Micro loaf volume (cc.) |
|---|---|---|
| 1952-119 | 875 | 51.5 |
| 120 | 898 | 50.9 |
| 121 | 855 | 51.8 |
| 122 | 863 | 52.1 |
| 123 | 895 | 51.2 |
| 126 | 838 | 45.4 |
| 127 | 795 | 46.1 |
| 129 | 865 | 49.2 |
| 130 | 700 | 43.3 |
| 131 | 778 | 44.8 |
| 132 | 830 | 50.2 |
| 133 | 878 | 49.8 |
| 134 | 875 | 47.9 |
| 135 | 805 | 49.7 |
| 136 | 880 | 48.4 |
| 137 | 870 | 44.8 |
| 139 | 713 | 48.5 |
| 142 | 822 | 48.0 |
| 143 | 870 | 47.3 |
| 145 | 900 | 52.1 |
| 147 | 990 | 52.3 |
| 148 | 980 | 55.4 |
| 149 | 1015 | 53.7 |
| 152 | 1047 | 58.6 |
| 153 | 895 | 48.9 |
| 154 | 930 | 47.6 |
| 155 | 705 | 41.8 |
| 158 | 1025 | 61.8 |
| 159 | 1010 | 51.2 |
| 160 | 955 | 42.7 |
| 162 | 775 | 47.0 |
| 163 | 813 | 44.5 |
| 170 | 843 | 44.2 |
| 173 | 810 | 49.7 |
| 174 | 843 | 45.6 |
| 178 | 823 | 48.2 |
| 185 | 747 | 44.3 |
| 187 | 918 | 54.5 |
| 195 | 960 | 51.1 |
| 198 | 933 | 51.6 |
| 199 | 960 | 50.0 |

# THE DEVELOPMENT OF MICRO METHODS FOR THE QUALITY EVALUATION OF WHEAT AND FLOUR

by

MERLE DENNIS SHOGREN

B. S., Bethany College, Lindsborg, Kansas, 1951

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AN ABSTRACT OF A THESIS

submitted in partial fulfillment of the
requirements for the degree

MASTER OF SCIENCE

Department of Flour and Feed Milling Industries

KANSAS STATE COLLEGE
OF AGRICULTURE AND APPLIED SCIENCE

1954

The purpose of this investigation was to design, construct and utilize micro methods for the quality evaluation of small samples of wheat. The objective was to develop testing methods that require no more than 100 g. of wheat. At present, new wheat crosses cannot be evaluated for quality until about the eighth and later generations because of the size of samples required. The techniques developed by this research should permit quality tests to be completed by the fourth generation.

The following equipment for micro testing was developed: 1. dough mixer, 2. fermentation cabinet, 3. over, 4. pans, 5. sheeting rolls and molder, 6. loaf volume meter, and 7. micro Farinograph bowl.

The optimum operating conditions and suitable procedures for each item of equipment as well as the formula had to be determined for the micro baking test.

It was found that 190 minutes fermentation time, 50 minutes proof time, an oven temperature of 400° F, and 15 minutes bake time were optimum.

Comparisons of the micro method with the standard A.A.C.C. baking test using a group of 24 flour samples and a group of 82 flour samples were made. Correlations of r = 0.948 and r = 0.749 respectively were obtained. Visual comparisons of the loaves baked by the two methods showed the similarity of the external and internal characteristics of the loaves.

A comparison of the farinograms obtained with the 10 g., 50 g., and the 300 g. Farinograph bowls was made using a baker's winter wheat flour, a baker's spring wheat flour, a family flour, and a pastry flour. It was found that absorption increased as the bowl size decreased. The largest increase was 3.7 percent between the 10 g. and the 300 g. bowls using the baker's spring wheat flour.

The completed test includes the following information: wheat protein and moisture, flour yield, flour protein, moisture, ash absorption, mixing time, baking properties, general strength characteristics, loaf volume, and the Farinograph curve.