

# Bread-Making Test for 10 Grams of Flour<sup>1</sup>

M. D. SHOGREN and K. F. FINNEY<sup>2</sup>

## ABSTRACT

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A bread-making test for 10 g of flour was developed. Dough mixer, liquid-dispensing apparatus, shortening dispenser, dough molder, bread pans, and loaf volumeter are described. Comparisons of 10- and 100-g bread-making tests were made on fractionated and reconstituted flours, on two flour-protein series, one of station composites and the other of a single

variety, on loaf-volume responses to various concentrations of glucose, and on a flour that responded to various levels of oxidation. Correlations between the 10- and 100-g bread-making tests ranged from  $r = 0.976$  to  $r = 0.991$ .

Early fractionation and reconstitution studies conducted in our laboratory utilized a 100-g bread-making test. Preparation of gluten fractions eventually became too time-consuming for the 100-g test to be practical. Therefore, a bread-making test for 10 g of flour was developed (Shogren et al 1969). Subsequently, improvements in equipment have been made, but the basic concept of the 100-g method was retained. Details of 10-g procedures and improved equipment, together with comparisons of the 10- and 100-g methods, are reported here.

## MATERIALS AND METHODS

### Wheat and Flour Samples

Flour from the varieties Pawnee, Comanche, C.I. 12995, KS501097, and KS501099 were fractionated into gluten and starch plus water-solubles followed by fractional precipitation of the

gluten from a dilute lactic acid solution (Shogren et al 1969). Reconstituted flours contained the gluten fractions and the starch plus water-solubles.

Approximately 25 hard red winter wheat varieties were harvested at each of many stations throughout the Great Plains during the years 1977-1979 and composited by station. The station composites ranged in flour-protein content from 7.9 to 17.2% (14% mb).

The hard winter wheat variety Newton was harvested at 15 stations in 1979. Flour protein content ranged from 7.3 to 14.8%.

A regional bake standard (RBS-78) consisted of many hard winter wheats harvested throughout the Great Plains in 1978. RBS-78 flour had a protein content of 12.3%. It was baked with 0-10% glucose.

The hard winter wheat variety Payne was harvested at four locations in 1979. The blend had a flour-protein content of 13.4%, a medium-short mixing time, and a good loaf-volume response to oxidation. Loaf characteristics were determined at several levels of oxidation.

### Bread-making Equipment

The fermentation pans and cabinet were those used in the 100-g test. Oven temperature was raised from 215 to 232°C, and the shelf covering of sheet asbestos doubled to 1/8 in. Sheeting rolls were spaced at 0.0984 in. (2.50 mm) for all punches. Shortening (0.3 g) was added to the flour in the mixing bowl by means of a length of

<sup>1</sup>Mention of firm names or trade products does not imply that they are endorsed or recommended by the USDA over other firms or similar products not mentioned.

<sup>2</sup>Research food technologist and research chemist, respectively, U. S. Grain Marketing Research Laboratory, Agricultural Research Service, U.S. Department of Agriculture, Manhattan, KS 66502.

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glass tubing (7-mm o.d.) that was fitted with a glass extruder rod (5-mm o.d.). The tube, with the rod inserted, was plunged into semisolid shortening that was forced into the tube and then extruded to a calibrated mark, after which the calibrated amount of shortening was extruded into the mixing bowl containing the flour.

An apparatus to dispense liquids included a bank of three automatic pipettes and one burette. The pipettes delivered 0.6 g of sugar, 0.15 g of salt, and 0.025 g of malted barley extract in 3 ml; 50 ppm ascorbic acid in 1 ml; and 0.25 or 0.55 g of yeast in 2 ml. The burette delivered additional water up to 5 ml.

Two dough mixers and four mixing bowls were supplied by the National Manufacturing Co., Lincoln, NE. The mixers and inside dimensions of the bowls were identical to those of the 10-g mixograph (Finney and Shogren 1972), with four important exceptions. Each bowl was manufactured without the right rear bowl pin to facilitate pickup of flour and dough on the inside bowl surfaces and to improve visual determination of the point of minimum mobility of the dough. The diameter of the head and bowl pins of the mixer was 1/8 in., whereas that of the mixograph pins was 3/32 in. The dough mixer was nonrecording and was operated at 100 instead of 88 rpm. The diameter of head and bowl pins of current models of the 10-g mixer is 3/32 in.

The dough molder consisted of a sledlike apparatus that was pushed along a wood runner (Fig. 1). A scale drawing (Fig. 2) does not show the wood runner that was 0.5 × 4.1 × 110 cm. The sides of the sled and the runner were made of close-grained maple wood and the curling and pressure plates of Plexiglas. A steel weight (100 g) was mounted at the rear of the curling plate. The curling plate was free to be raised by the dough (6 mm at the front, 9 mm at the rear) and to fall as the dough passed under it. The underside of the

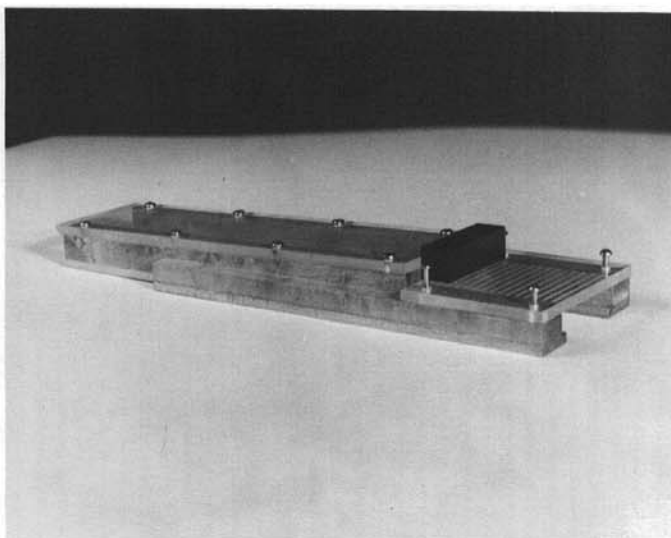


Fig. 1. Molder for bread dough that contained 10 g of flour (wood runner not shown).

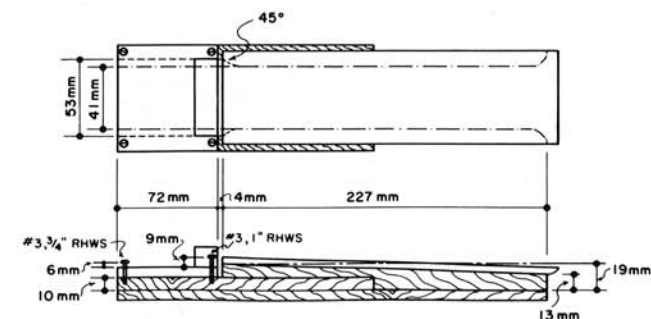


Fig. 2. Scale drawing of molder for bread dough that contained 10 g of flour (wood runner not shown).

curling plate had grooves perpendicular to the length of the molder (Fig. 1). The curling plate of the molder contributed to better replicability and crumb grain than those for an earlier model.

Bread pans (Fig. 3) were made from tin plate 0.009 in. (0.2286 mm) thick. Inside measurements were: bottom, 24.6 × 52.8 mm; top, 32.1 × 61.2 mm; and height, 23.5 mm. Construction was facilitated by using an aluminum template. Aluminum sheet (3/16 in. or 4.76 mm thick) was clamped to the bed of a vertical end mill

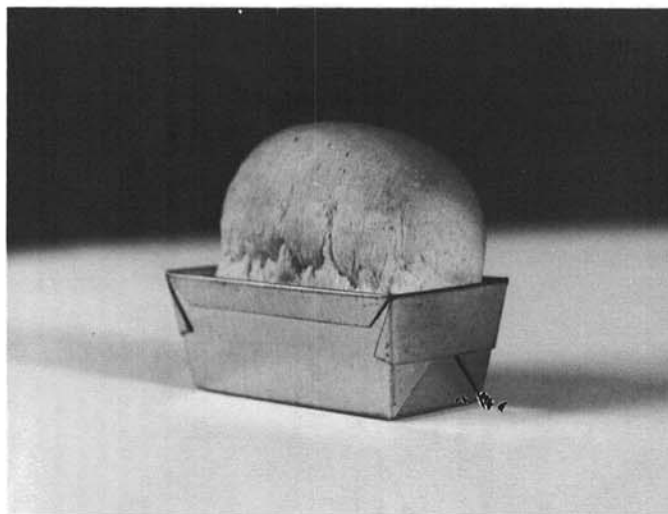


Fig. 3. Baking pan for bread dough that contained 10 g of flour.

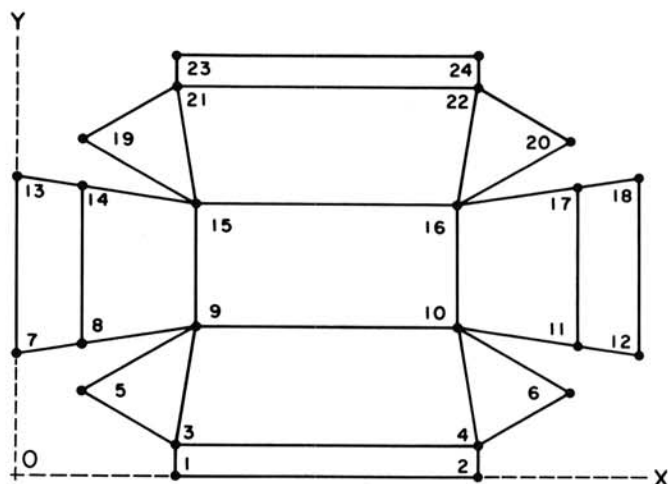


Fig. 4. Layout of template for the construction of the 10-g bread pan.

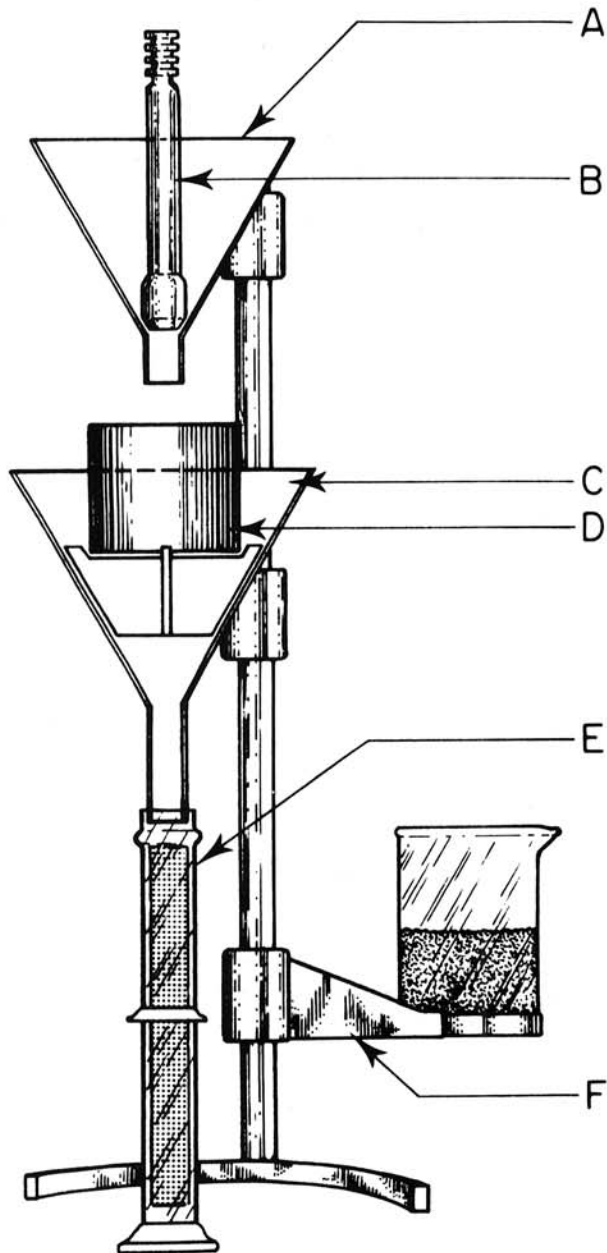
TABLE I  
X and Y Coordinates (in mm) for Points on Bread-Pan Template

| Points | Coordinates   |   | Points | Coordinates   |   |
|--------|---------------|---|--------|---------------|---|
|        | x             | y |        | x             | y |
| 0      | (0.0, 0.0)    |   | 13     | (0.0, 60.5)   |   |
| 1      | (32.3, 0.0)   |   | 14     | (12.7, 58.5)  |   |
| 2      | (93.5, 0.0)   |   | 15     | (36.5, 54.8)  |   |
| 3      | (32.3, 6.4)   |   | 16     | (89.3, 54.8)  |   |
| 4      | (93.5, 6.4)   |   | 17     | (113.2, 58.5) |   |
| 5      | (12.7, 16.9)  |   | 18     | (125.9, 60.5) |   |
| 6      | (113.2, 16.9) |   | 19     | (12.7, 68.0)  |   |
| 7      | (0.0, 24.4)   |   | 20     | (113.2, 68.0) |   |
| 8      | (12.7, 26.4)  |   | 21     | (32.3, 78.6)  |   |
| 9      | (36.5, 30.2)  |   | 22     | (93.5, 78.6)  |   |
| 10     | (89.3, 30.2)  |   | 23     | (32.3, 84.9)  |   |
| 11     | (113.2, 26.4) |   | 24     | (93.5, 84.9)  |   |
| 12     | (125.9, 24.4) |   |        |               |   |

**TABLE II**  
**Formulation for 10- and 100-Gram Straight Dough**

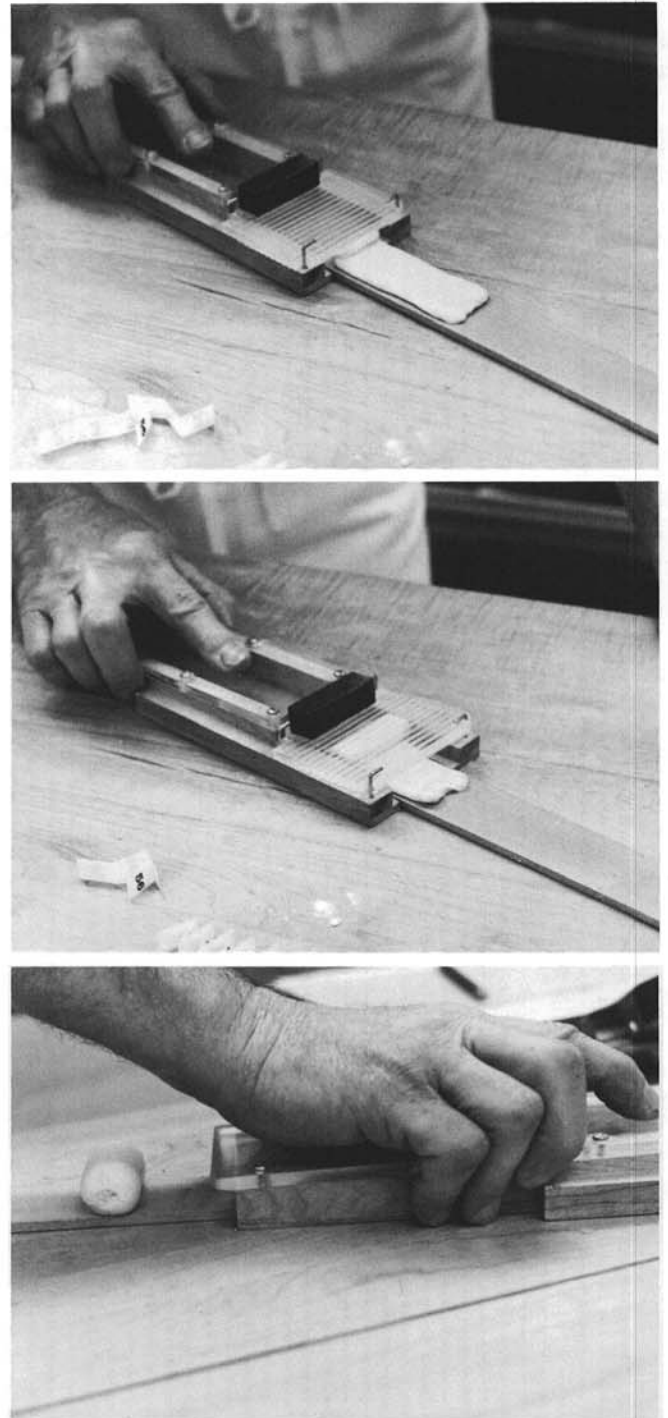
| Ingredient        | Amount of Ingredient |                       |
|-------------------|----------------------|-----------------------|
|                   | (g)                  | (%)                   |
| Flour             | 10.0                 | 100.0                 |
| Sugar             | 0.6                  | 6.0                   |
| Salt              | 0.15                 | 1.5                   |
| Shortening        | 0.3                  | 3.0                   |
| Yeast             | 0.235-0.55           | 2.35-5.5 <sup>a</sup> |
| Malted barley     | 0.025                | 0.25                  |
| Ascorbic acid     | 0-50 ppm             |                       |
| Potassium bromate | 0-10 ppm             |                       |
| Water             | as needed            |                       |

<sup>a</sup> Varied according to length of fermentation and gas-producing capability of yeast.



**Fig. 5.** Cutaway view of volumeter for loaves of bread from 10 g of flour. **A**, movable, stainless steel funnel; **B**, metal stopper; **C**, stationary, stainless steel, overflow funnel; **D**, metal cup; **E**, 100-ml graduated cylinder; **F**, movable platform.

equipped with an optical measuring device. Holes were drilled at each of the points 0-24 (Fig. 4) according to the x and y coordinates in Table I. The template was placed over a sheet of tin plate, a pointed tool was inserted in each hole, and dents were made by exerting a slight pressure on the tool. After the template was removed, lines were scribed with an awl and straightedge (as in Fig. 4) to give cutting or bending references. Cuts were made with metal shears, and bends were made with locking sheet metal tools machined to fit the bottom end and side. Final forming was accomplished with the pan inverted over a forming block. Certain cuts that were made are not shown; ie, the cut on the line between points 5 and 3 was undercut at 3 (toward 9) to allow room for the bend on the line between 8 and 14. The right-angle corners at 1, 2, 23, and 24 were cut off along an extension of the imaginary lines



**Fig. 6.** Molding bread dough from 10 g of flour: initiating (top), curling step (center), and completing (bottom).

such as from 8 to 3. Rigid sides were obtained by avoiding sharp bends at 3-4 and 21-22. Points 7, 12, 13, and 18 held the sides together when bent at right angles along the sides (Fig. 3).

The finished pan was conditioned by coating with shortening, wiping nearly clean, and baking at 232°C for 15 min. That procedure was repeated twice.

Proof height of bread dough that contained 10 g of flour was measured with a proof-height meter for dough from 100 g of flour by inserting a metal block 3 cm high (Finney 1984).

Loaf volume was measured by dwarf rapeseed displacement. The volumeter (Fig. 5) contained a top funnel that held dwarf rapeseed and the metal stopper, and swung in or out of position. The bottom funnel held a metal cup that had an inside diameter of 8 cm and an inside height of 7 cm and held either standard aluminum alloy blocks or bread. The platform with beaker was swung into position under the bottom funnel to catch the seed after the volume was determined. Standard aluminum alloy blocks of 25, 53, 81, and 102 cc were each 5.2 cm high.

### Breadmaking

The 100-g straight-dough bread-making method was described in detail by Finney (1984). For the 10-g bread-making method, formulation amounts for the 100-g method were reduced by a factor of 10. Mixing requirements for the 10- and 100-g methods were about equal. Breadmaking was according to the formulation in Table II.

Flour samples (10 g, 14% mb) were weighed the day before into small plastic screw-cap jars. Additional ingredients in the form of powder or semisolids, other than those in the above formulation, were blended immediately with each flour. On the day of baking, the flour was transferred to the mixing bowl, shortening was dispensed with the rod and tube, and liquid ingredients added by means of the dispensing apparatus. Each dough was mixed to the point of minimum mobility, removed from the mixer, and placed in a bowl that was covered and then placed in the fermentation cabinet (30°C). Fermentation was 90 or 180 min followed by proofing  $36 \pm 2$  min or  $57 \pm 2$  min, respectively (the time required to proof the controls to 4.1 cm). Doughs were punched after 52, 77, and 90 min or 105, 155, and 180 min for the 90 and 180 min

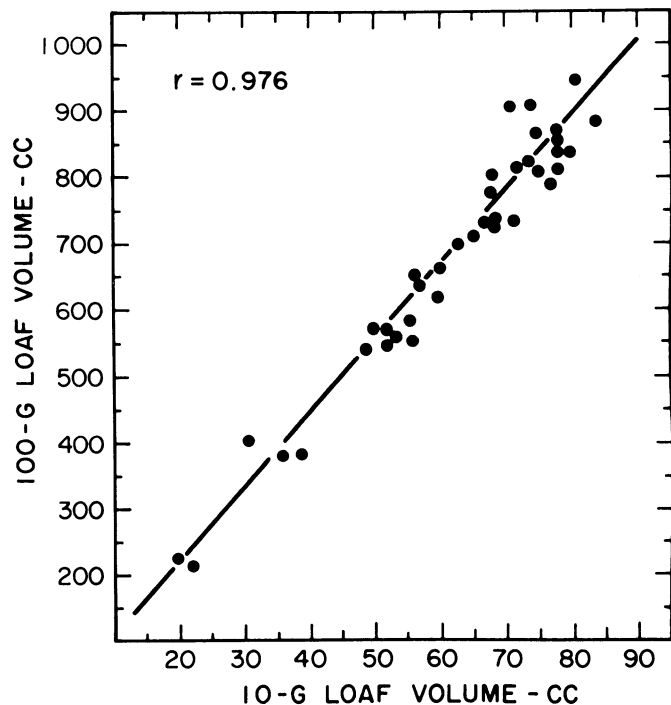


Fig. 7. Volumes of loaves from 10 and 100 g of the control flours, the reconstituted control flours, and reconstituted flours that contained certain protein fractions of Pawnee, Comanche, C.I. 12995, KS501099, and KS501097.

fermentation times, respectively. After the final punch, the ribbon of dough was placed on and toward one end of the runner and ahead of the molder. Then the end of the dough nearest the front of the molder was turned up to form an L that made contact with the curling plate. Molding was accomplished in about 2 sec by pushing the molder along the runner (Fig. 6). The molded dough was placed in a bread pan, returned to the fermentation cabinet, and proofed for the time required for the controls to proof to  $4.1 \pm 0.1$  cm. After adequate proofing, doughs were baked for 13 min at 232°C. After removing from the oven, loaves were immediately weighed and then placed on a wire grid for about 2 hr before volumes were determined.

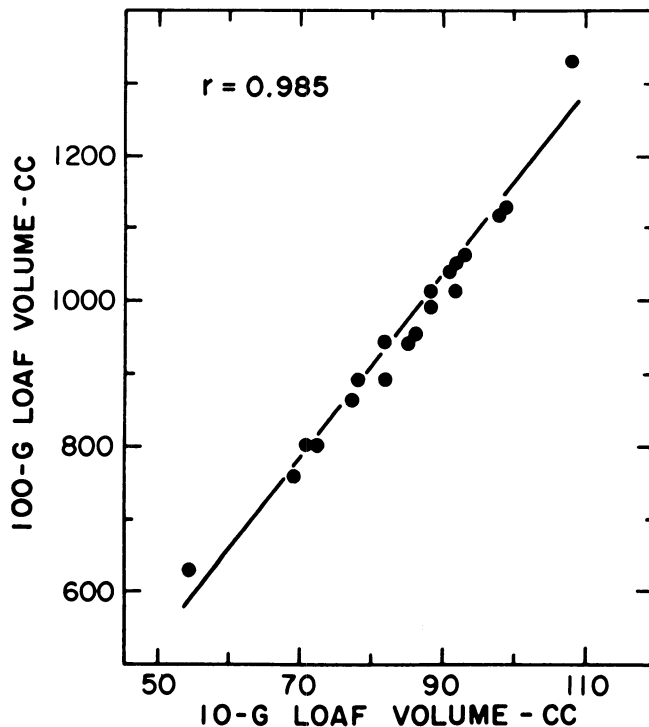


Fig. 8. Volumes of loaves from 10 and 100 g of flours that represented a protein series of station-composites.

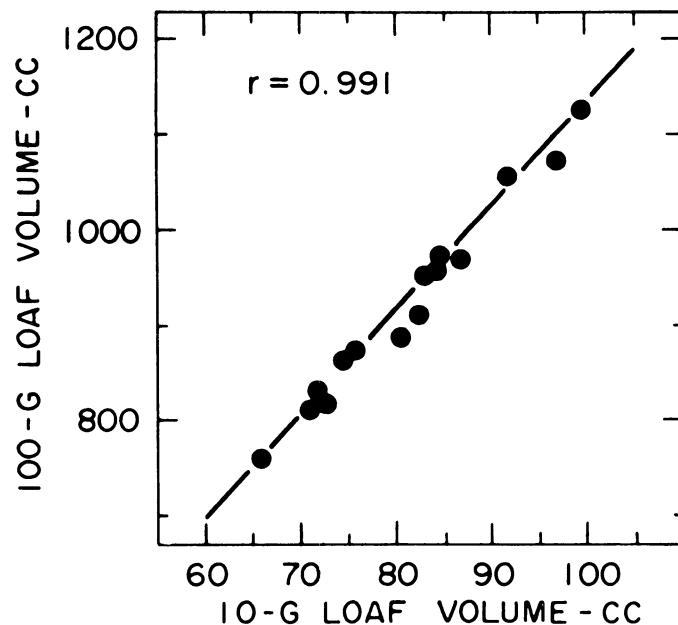


Fig. 9. Volumes of loaves from 10 and 100 g of flours that represented a protein series of Newton hard winter wheat.

The volumeter was standardized by means of one or more standard blocks that had volumes within the range of the experimental loaves and a constant height equal to the average length of a loaf. The loaf was placed on end in the cylindrical cup in the lower funnel. Rapeseed in the stoppered upper funnel was swung into place directly over the loaf (or block when standardizing the volumeter). The stopper was removed quickly and seed allowed to fill the cup around the loaf or block and overflow into a 100-ml graduated cylinder. The seed that remained above the top plane of the cup also flowed into the 100-ml cylinder after it was systematically and carefully leveled off as in the determination of wt/bu of wheat. Volume was read directly from the cylinder. Duplicate determinations were made and averaged if within 0.5 cc. Additional determinations were made if duplicates did not agree within 0.5 cc. Loaves were cut and scored after loaf-volume determinations were made. Loaf volume differences of about 3 cc were significant at  $P = 0.05$ .

## RESULTS

### Fractionated and Reconstituted Flours

Volumes for loaves from 10 and 100 g of flour varied from 19 to 84 cc and 225 to 945 cc, respectively (Fig. 7). The baking method included 180 min of fermentation and about 2.25% compressed yeast.

The agreement between the two methods ( $r = 0.976$ ) for the controls and reconstituted flours of widely different loaf-volume potentials and mix times was the basis for adopting the 10-g baking system for research where sample size was limiting.

### Other Diverse Flours and Treatments

Volumes of bread from 10 and 100 g of flour were comparable for a protein series of station composites (Fig. 8); for a protein series of the variety Newton (Fig. 9); relative to the volume responses of the hard winter variety Payne to the oxidants ascorbic acid and potassium bromate (Fig. 10); and relative to the volume response to 0–10% glucose (Fig. 11). All volumes represented essentially optimum oxidation, except for those of Payne at 0 and 25 ppm of ascorbic acid. Loaf volume increased from the ratio of ascorbic acid to bromate of 0:0 through 25:0 and essentially leveled off (optimum) at 50:0, 50:5, and 50:10.

## DISCUSSION

Mixing and water requirements for 10 and 100 g of flour were similar, except that less water on a percentage basis generally was

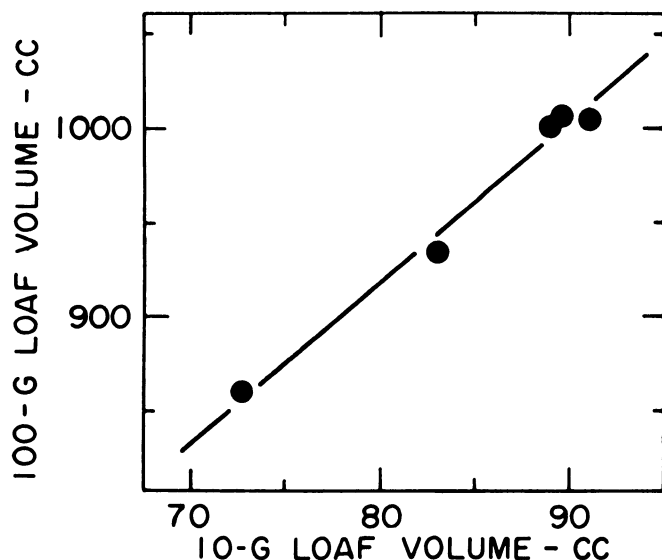


Fig. 10. Volume responses for loaves from 10 and 100 g of Payne hard winter wheat flour that contained ascorbic acid and bromate in the ratios of 0:0, 25:0, 50:0, 50:5, and 50:10 ppm from low to high volume, respectively.

required for 10-g doughs. For a flour with an average protein content and water requirement, 10 g of flour required one to two percentage points less water than 100 g.

Although the dispensing apparatus was not essential to the performance of the 10-g bread-making test, it facilitated consistency and an efficient routine that required a minimum of technicians.

The effect of yeast settling in the tubing from the reservoir to the pipette was minimized by keeping the volume of the tubing under 2 ml and by flushing the tubing between dispensings.

Most flours had mixing requirements of 5 min or less, so that mixing, removing dough, and wiping the side of the bowl with a damp cloth and then drying with a cloth were accomplished in 6 min or less. With two mixers and four bowls, a mixing schedule of 3 min between each dough was easily attained.

Present bread pans were more uniform in metal thickness and overall dimensions than earlier models. Although slight differences in size may not significantly affect loaf volume, proof height would be altered. For instance, the larger the pan volume, the lower the proof height. Pan color affected loaf volume more than did pan weight. Pans that were too dark or too shiny lowered loaf volume. Therefore, it was important to apply an extremely thin coat of shortening on used pans and when conditioning new pans. Since the loss in volume due to coloration was probably relative, it was important to rotate extra pans from bake to bake.

A more automated volumeter than that shown probably would involve glass or plastic, impractical materials because of static electricity (Shogren and Shellenberger 1954). In the determination of volume, the distance between the outlet of the top funnel and loaf must be specific and constant. Standard blocks must be the same height as that of the average of loaves standing on end, which afforded an approximately constant loaf height irrespective of volume. After removal from the oven, loaves should stand for about 2 hr before volume is determined. Loaves from 10 g of flour will have erroneous volumes that are 1–4 cc low when determinations are made immediately after weighing the loaves from the oven. Once the loaf has cooled to room temperature, replicated volumes of a loaf will agree over a period of several hours, because shrinkage is negligible. That is not true for loaves from 100 g of flour. Their volumes should be determined immediately after weighing from the oven.

At first, crumb-grain evaluation of the 10-g loaf was more difficult than that of the 100-g loaf. As experience was gained, there were obvious differences in the crumb grains of loaves that had poor to good loaf-volume potentials, in the crumb grains of loaves with and without shortening, and in those of loaves that were under- or overoxidized.

The loaf-volume error introduced by wrong-side break and shred in loaves from 100 g of flour (Shogren and Finney 1984) generally was not significant in loaves from 10 g of flour. However, the crumb grains of wrong-side break and shred in loaves from 10 g of flour were readily identified as inferior to those of correct-side break and

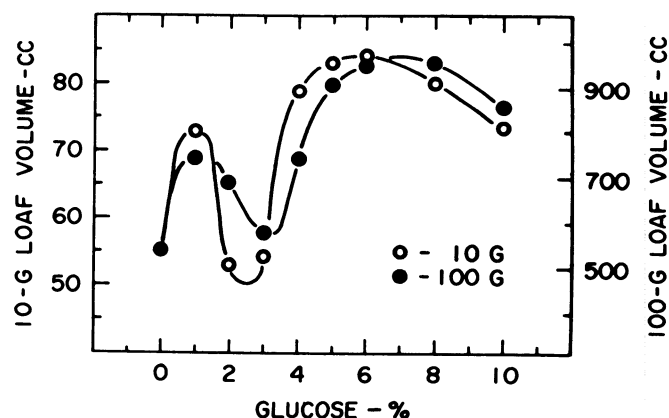


Fig. 11. Volume responses for loaves that contained 10 and 100 g of flour and an increasing concentration of glucose from 0 to 10%.

shred. The crumb grains of both-sides break and shred in loaves from 10 g of flour usually were inferior when the largest of the two breaks was a wrong-side break.

Holes in bread from 10 g as well as 100 g of flour were corrected for by the formula: volume of loaf (as received) minus 0.6 of the volume of the holes equals the corrected volume. The volumes of holes that were about 0.5 cc or greater in 10-g loaves and 5 cc or greater in 100-g loaves were determined by filling the holes level with dwarf rapeseed that was transferred for measurement to as small a graduated cylinder as feasible.

The bread-making method in the Hard Winter Wheat Quality Laboratory is optimized and balanced at a fermentation temperature of 30°C and a room temperature of 25°C. Dough-mixing time, flour absorption, chemical oxidation, and sheeter-roll and molder settings are optimized in a formula in which no ingredient is limiting. Gas production, fermentation time, chemical oxidation, and dough handling are balanced.

The method with either 100 or 10 g of flour has the flexibility to accommodate a wide range of flour characteristics. The comparisons of the 10- and 100-g methods (Figs. 7-11)

demonstrate that capability.

The 10-g method has been invaluable in fractionation and reconstitution studies and in other research on extremely limited materials.

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