Studies on Dough Development. II. Effects of Mixing Apparatus and Mixing Speed on the Rheological and Analytical Properties of Heated Dough

S. ENDO, K. TANAKA, and S. NAGAO[1]

Cereal Chem 62(4): 272–275

ABSTRACT

Factors affecting the formation of two major peaks (at 75 and 85°C) in the Do-Corder curve for a dough developed in different mixers before heat treatment were studied. The shape of these peaks depended on both the type of mixing apparatus and the absorption level of the dough. The Do-Corder curves for doughs premixed to maximum consistency at a constant absorption level showed different patterns depending on the type of mixer. Premixing in the mixograph at water absorption levels of 70, 75, and 80% produced two peaks at 75 and 85°C. On the other hand, only one peak at 85°C was observed for doughs premixed in a farinograph at 70 or 75% water absorption; dough premixed at 80% absorption in a farinograph showed the usual two peaks. The type of mixing apparatus also influenced the contents of sulfhydryl groups and of free lipid extractable with ethyl ether from a premixed dough. The effect on free lipid was accentuated when a premixed dough was heated. Mixing speed, however, had little effect on the rheological properties of doughs.

Prolonged mixing of dough changes its rheological properties. The function of mixing in breadmaking is considered to be critical and has been studied by many workers. One approach is to investigate the flour components involved in mixing. An increase in the acetic acid-soluble protein was observed during dough mixing by Tsen (1968). Tanaka and Bushuk (1973a, 1973b) found that glutenin was converted from insoluble to soluble during prolonged mixing. As the result of reconstitution studies, Finney et al (1982) reported that mixing requirements and loaf volume were controlled by gel-glutenin proteins of the acid-soluble gluten proteins and gliadin proteins, respectively.

Despite much work on the changes of rheological properties of dough during mixing, the mechanism remains obscure. According to some workers, the dough must only be mixed long enough for it to reach maximum consistency (Bohn and Bailey 1936, Dulby 1960, Fortmann et al 1964); however, baking quality may vary with different types of mixers even for doughs developed to the optimum. Fisher et al (1949) found that rheological properties of doughs depended on mixing conditions. Kilborn and Tipples (1972) reported that both mixing intensity and the work imparted to the dough must be optimized to achieve proper dough development. Mecham (1968) suggested that the changes of rheological properties during dough mixing were due to the cleavage of disulfide bonds by the mechanical action of the mixer. The resulting increase in sulfhydryl (SH) content could be studied in a dough mixed under nitrogen.

On the basis of such results, dough development is now considered to be largely related to the production and oxidation of SH groups. We previously used a Brabender Do-Corder (Endo et al 1984) to investigate the relationship between dough development and activated SH groups. Our work described here was designed to study the effects of the type of mixing apparatus, the water absorption level, and the mixing speed on the rheological properties of dough, taking into account the effects of heat during baking.

MATERIALS AND METHODS

The flour used in this study was described previously (Endo et al 1984). All chemicals used were reagent grade.

Preparation of Premixed Dough

A Brabender farinograph with a 300-g mixing bowl and a mixograph with a 35-g bowl were operated according to the AACC farinograph testing procedure (constant flour weight procedure) (1962) and AACC mixograph testing procedure (1962), respectively, except that water absorption levels of 70, 75, and 80% were used. Doughs were mixed for the time needed to reach maximum consistency at the peak time by a farinograph or a mixograph.

A type SS Kantoh vertical mixer (Kantoh Kongoki Co., Japan) was also used to study the effect of mixing speed on dough development. Water absorption levels of 70, 75, and 80% were used for 300 g of flour at mixing speeds of 62 rpm (low) or 120 rpm (high).

At the end of each mixing time, a sample of dough was taken and quickly frozen by immersion in liquid nitrogen. The frozen dough was freeze-dried, pulverized in a mortar, and ground in a coffee-grinder finely enough for it to pass through a 100-mesh sieve.

Do-Corder Operation

A Brabender Do-Corder was operated as described by Tanaka et al (1980) at a constant water absorption level (70%) and a lever position of 1.5 throughout. The X-axis of the Do-Corder curves shows the range of temperatures.

Preparation of Heated Dried Dough

The premixed dough samples (freeze-dried and ground) were again mixed with water and were heated in the Do-Corder to 90°C. Dried-dough samples were prepared as described previously (Endo et al 1984).

Determination of SH Groups and Free Lipid Contents

The SH groups and free lipid contents of the samples were determined as reported previously (Endo et al 1984).

RESULTS AND DISCUSSION

Do-Corder Results

The Do-Corder curve generally showed two peaks at 75 and 85°C. Tanaka et al (1980) studied the effects of chemicals on the curves and suggested that these peaks were assigned to the consistency of gluten and starch, respectively.

Either a farinograph or mixograph was used to premix a dough before heat treatment in the Do-Corder. These mixers exert somewhat different effects on dough development. In a farinograph, dough is mixed with a pair of dough-mixing blades. The mixograph mixer has six pins, two of which are fixed to the mixing bowl while the others rotate.

The resistance offered by the dough during mixing is probably influenced by the differences in the mixing mechanisms of these two machines. Kilborn and Tipples (1973) indicated that discrepancies exist in the mechanical and mixing efficiencies of different types of

[1]Nisshin Flour Milling Co., Central Research Laboratory, 177 Tsurugaoka Ohi Iruma, Saitama 354 Japan.

mixers. In the present study, the mixing times required for doughs to develop to the point of maximum consistency in the mixograph were shorter than those in the farinograph at any water absorption levels (data not shown). More distinct discrepancies were observed as absorption levels increased. Because dough development involves the hydration of flour particles, physical development of gluten, and chemical changes in the flour components, it is possible that these processes may be delayed more in doughs mixed in the farinograph than in the mixograph.

The different effects caused by these two mixers were also obvious for heated doughs (Fig. 1). The Do-Corder curves for doughs premixed to the peak time at different absorption levels in a mixograph showed two peaks (75 and 85°C), and the major peak gradually shifted from 85 to 75°C as the absorption level increased from 70 to 75%. On the other hand, such a shift occurred between 75 and 80% absorption for equivalent doughs premixed by a farinograph.

In our study (Endo et al 1984), we showed that the shape of the Do-Corder curve was affected by the absorption level in the dough during premixing; however, different mixers also exerted distinct effects on the rheological properties of a dough. To further examine these effects, a dough was mixed in the farinograph continuously for 5 or 10 min after it had reached its maximum consistency; however, no additional effects were observed in the curve for this dough (data not shown). This result showed that the farinograph exerted a weaker mixing effect than the mixograph did. The mixograph thus appears to be more effective than the farinograph in developing a dough.

Effect of Mixing Apparatus on SH Content

Mixing decreased the SH content of a dough. As shown in Figure 2a, SH contents were lower in doughs mixed to peak consistency at various absorption levels than in the original flour. These results are consistent with the findings of Bushuk et al (1968). The decrease in SH content, however, depends on the types of mixing apparatus, too. Doughs mixed in a mixograph showed somewhat larger decreases in SH content than those mixed in a farinograph.

Results were similar for the heated doughs (Fig. 2b). The decrease in SH content related to heating was similar for doughs premixed in a mixograph or a farinograph at 70% absorption level. At higher absorption levels, however, the decrease in SH content of the dough mixed in a mixograph was greater than that in a farinograph.

Previously (1984), we suggested that dough mixing may produce unmasked SH groups, which could in turn be easily oxidized. If this is so, the mixograph is more effective than the farinograph in unmasking SH groups judging from the results in Figure 2. Further evidence favoring this concept is shown by the similarity of the Do-Corder curve for a dough mixed in a farinograph and that of the original flour (Fig. 1).

Effect of Mixing Apparatus on Free Lipid Content

Doughs mixed in either a mixograph or farinograph decrease in free lipid content. The decrease leveled off at about 30% of the original lipid content (Fig. 3a); however, heat treatment in the Do-Corder mixer increased free lipid content (Fig. 3b). Doughs premixed in a farinograph showed an almost linear increase as the water absorption level increased. A slight increase occurred at 75%

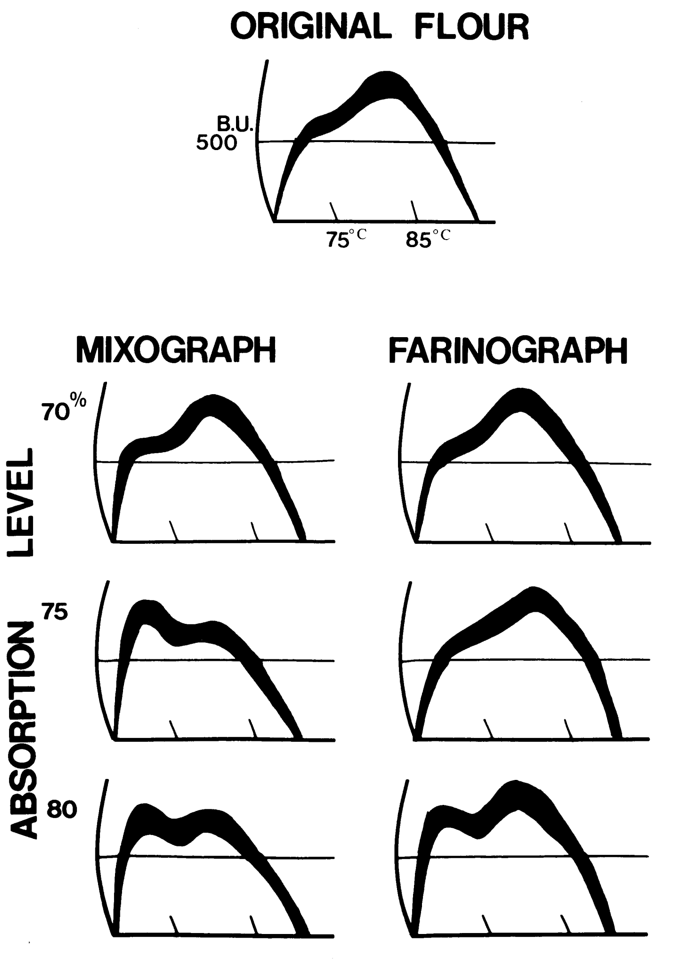

Fig. 1. Do-Corder curves for powdered freeze-dried doughs premixed in a mixograph or a farinograph at absorption levels of 70, 75, and 80%. Doughs were premixed until they reached maximum consistency at the peak time.

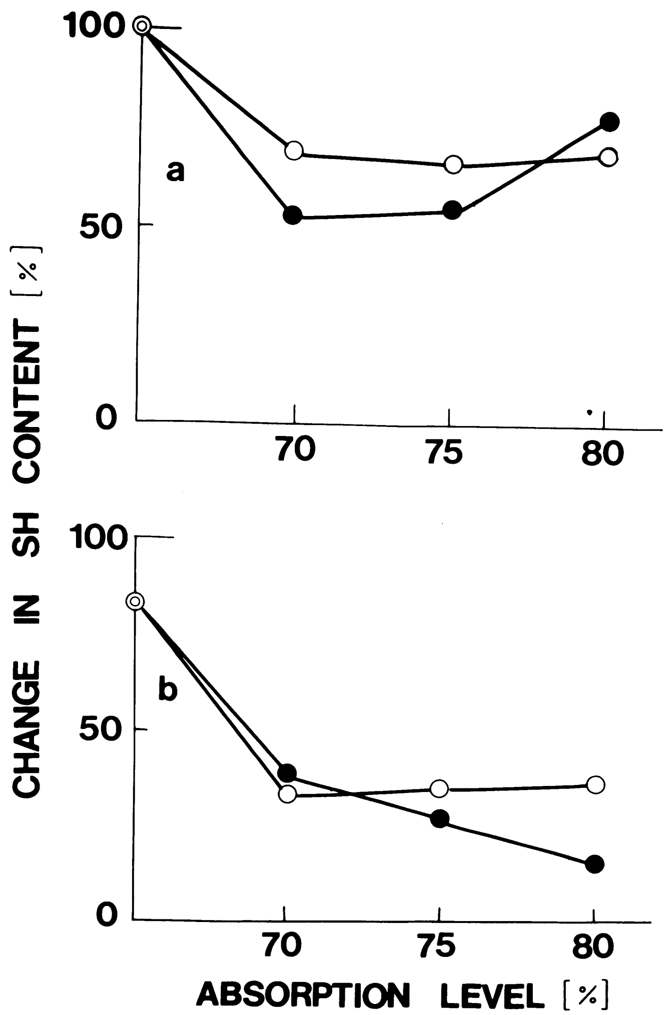

Fig. 2. Effects of mixing apparatus on the sulfhydryl content of dough **a,** premixed appropriately for the time to reach maximum consistency at absorption levels of 70, 75, and 80% and **b,** heated in the Do-Corder. ◎ = original flour, ○—○ = premixed in a farinograph, ●—● = premixed in a mixograph.

absorption for doughs premixed in a mixograph. These results demonstrated the influence of mixing apparatus on the content of free lipid for heated doughs.

Effect of Mixing Speed

The effects of mixing speed on the rheological properties of doughs have been demonstrated by many workers (Chamberlain et al 1965, Marston 1971, Kilborn and Tipples 1972). Despite these studies, little information is available on the entire mechanism involving rheological changes of a dough mixed at different speeds. Our study was done to investigate the effect of mixing speed on the rheological properties of doughs using a vertical mixer. Figure 4 shows the Do-Corder curves for the doughs premixed in a vertical mixer for 5 min at either 62 rpm (low) or 120 rpm (high).

In contrast to the results obtained in a mixograph or a farinograph, doughs premixed in a vertical mixer showed a shift of two peaks in the Do-Corder curve at any absorption level. This shift was delayed as absorption level increased. The effect of mixing speed on the curve was not significant at the 70 and 80% absorption levels, but premixing at the 75% absorption level produced a shoulder at 85° C in place of a peak as mixing speed increased from low to high.

Figure 5a shows the decrease in SH content of a dough during mixing. The decrease was more rapid as mixing speed increased. Doughs premixed at a higher mixing speed showed lower SH content (Fig. 5a,b). In contrast to the results obtained for heated doughs premixed by a mixograph or a farinograph, the loss of SH content was the greatest at the absorption level of 70% for the vertically mixed doughs.

The free lipid content of a dough extracted with ethyl ether was also affected by mixing speed. Doughs showed a somewhat lower free lipid content as mixing speed increased (Fig. 6a); this paralleled the decrease in SH content. The largest difference in free lipid content of heated doughs in the Do-Corder occurred between doughs premixed at low and high speed at the 75% absorption level, where the maximum increase was observed at high mixing speed (Fig. 6a). The increase of free lipid content in a heated dough leveled off at the 75% absorption level when premixed at low mixing speed.

The phenomena observed for doughs premixed in different mixers and at different mixing speeds may well be related to the activation of SH groups, resulting in changes in the binding of lipid to protein. More activated SH groups might be produced as mixing speed and intensity increase. However, this change is also affected by the absorption level of the dough.

CONCLUSION

The changes of rheological or analytical properties during prolonged mixing were observed in Do-Corder curves by varying the type of mixing apparatus, the absorption level, and the mixing time. The changes relating to mixing speed were affected by the absorption level of the dough. Doughs developed to the optimum stage underwent a critical change in rheological properties when they were remixed and heated in the Do-Corder mixer. Our results suggest that mechanical dough development is related to the unmasking of SH groups, some of which may be involved in the binding of lipid to protein.

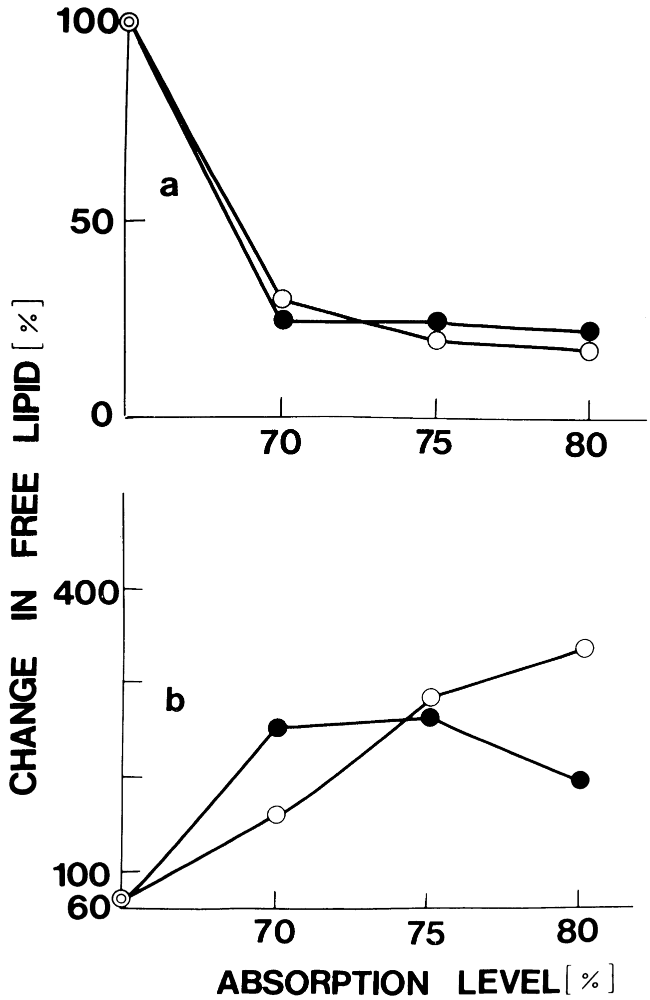

Fig. 3. Effects of mixing apparatus on free lipid content of doughs **a**, premixed for the time to reach maximum consistency at absorption levels of 70, 75, and 80% and **b**, heated in the Do-Corder. ◎ = original flour, O—O = premixed in a farinograph, ●—● = premixed in a mixograph.

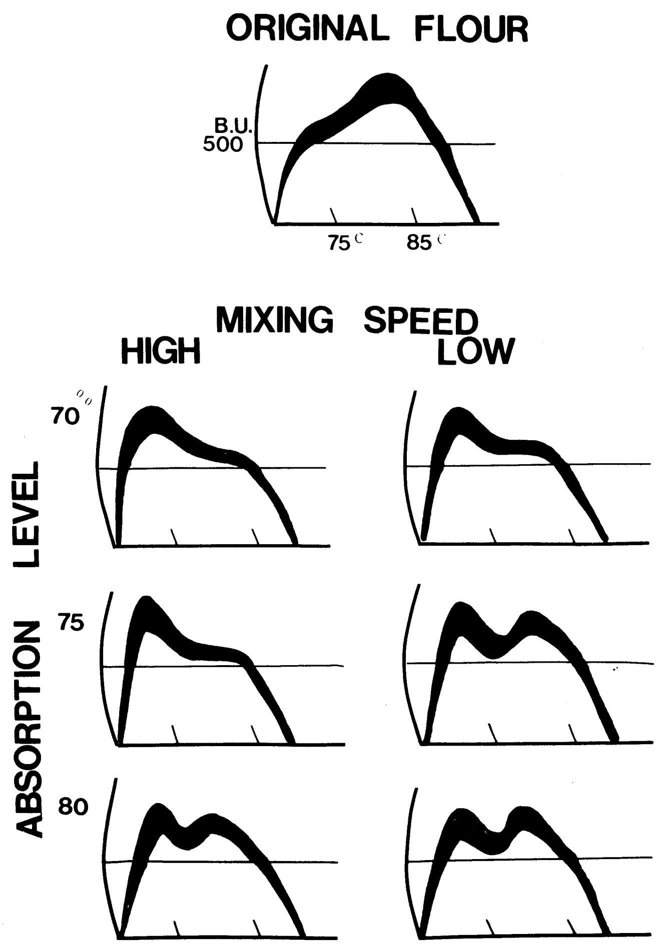

Fig. 4. Do-Corder curves for doughs premixed in a vertical mixer for 5 min at the mixing speed of 62 rpm (low) or 120 rpm (high) at water absorption levels of 70, 75, and 80%.

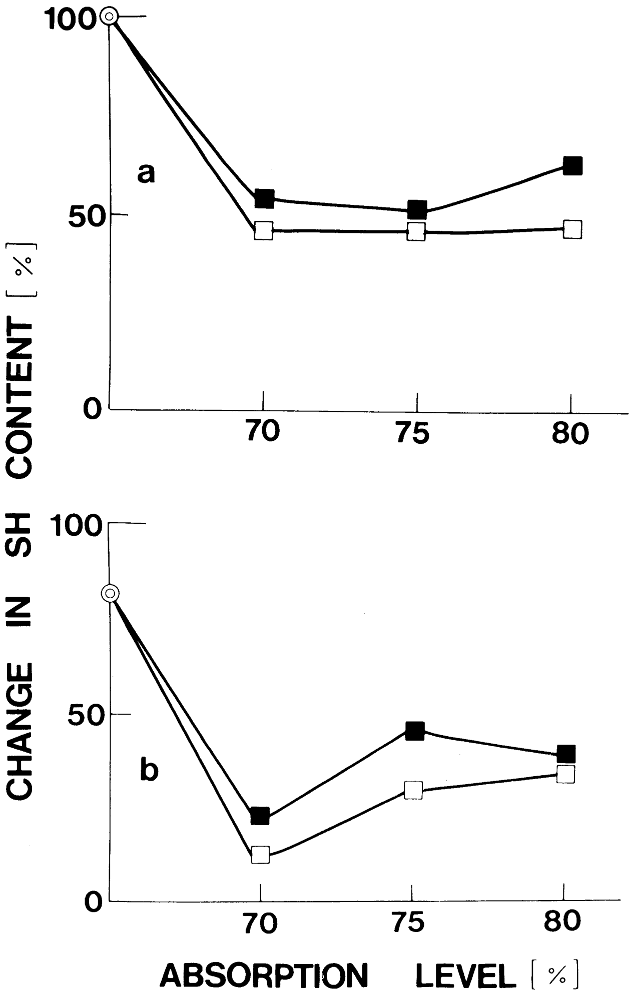

Fig. 5. Effect of mixing speed on sulfhydryl content of doughs **a,** premixed in a vertical mixer for 5 min at absorption levels of 70, 75, and 80% and **b,** heated in the Do-Corder. ◎ = original flour, ■—■ = premixed at low mixing speed (62 rpm), □—□ = premixed at high mixing speed (120 rpm).

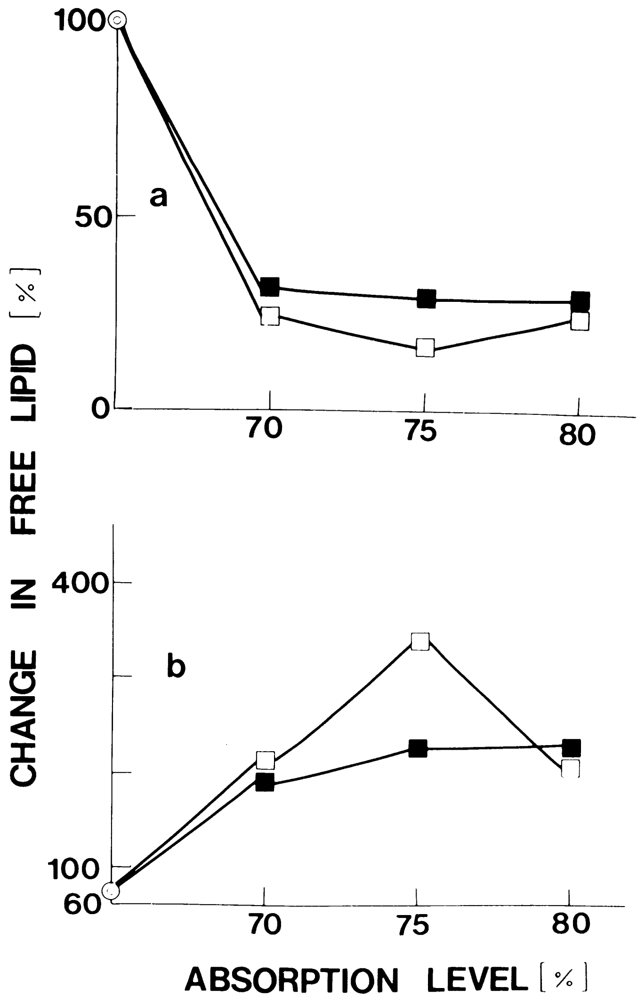

Fig. 6. Effect of mixing speed on free lipid content of doughs **a,** premixed in a vertical mixer for 5 min at absorption levels of 70, 75, and 80% and **b,** heated in the Do-Corder. ◎ = original flour, ■—■ = premixed at low mixing speed (62 rpm), □—□ = premixed at high mixing speed (120 rpm).

ACKNOWLEDGMENTS

We gratefully acknowledge the expert technical assistance of H. Hara, Y. Negishi, and K. Okano and the advice of C. W. Wrigley of the Wheat Research Unit of the Commonwealth Scientific and Industrial Research Organization (Australia) in the preparation of this manuscript.

LITERATURE CITED

AMERICAN ASSOCIATION OF CEREAL CHEMISTS. 1962. Approved Methods of the AACC. Methods 54-21 and 54-40, approved April 1961. The Association: St. Paul, MN.

BOHN, L. J., and BAILEY, C. H. 1936. Effect of mixing on the physical properties of dough. Cereal Chem. 13:560.

BUSHUK, W., TSEN, C. C., and HLYNKA, I. 1968. The function of mixing in breadmaking. Bakers Dig. 42(4):36.

CHAMBERLAIN, N., COLLINS, T. H., and ELTON, G. A. H. 1965. The Chorleywood bread process—recent developments. Cereal Sci. Today 10:412.

DULBY, G. 1960. The mixing of bread doughs. Bakers Dig. 34(4):34.

ENDO, S., TANAKA, K., and NAGAO, S. 1984. Do-Corder studies on dough development. I. Interactions of water absorption, sulfhydryl level, and free lipid content in heated dough. Cereal Chem. 61:112.

FINNEY, K. F., JONES, B. L., and SHOGREN, M. D. 1982. Functional (bread-making) properties of wheat protein. Fractions obtained by ultracentrifugation. Cereal Chem. 59:449.

FISHER, M. H., AITKEN, T. R., and ANDERSON, J. A. 1949. Effect of mixing, salt and consistency on extensograms. Cereal Chem. 26:81.

FORTMANN, K. L., GERRITY, A. B., and DIACHUK, J. A. 1964. Factors influencing work requirement for mixing white bread dough. Cereal Sci. Today 9(7):268.

KILBORN, R. H., and TIPPLES, K. H. 1972. Factors affecting mechanical dough work development. I. Effect of mixing intensity and work input. Cereal Chem. 49:34.

KILBORN, R. H., and TIPPLES, K. H. 1973. Factors affecting mechanical dough development. III. Mechanical efficiency of laboratory dough mixers. Cereal Chem. 50:50.

MARSTON, P. E. 1971. Chemical activation of dough development under slow mixing conditions. Bakers Dig. 45:16.

MECHAM, K. H. 1968. Changes in flour protein during dough mixing. Cereal Sci. Today 13:371.

TANAKA, K., and BUSHUK, W. 1973a. Changes in flour proteins during dough-mixing. I. Solubility result. Cereal Chem. 50:590.

TANAKA, K., and BUSHUK, W. 1973b. Changes in flour proteins during dough-mixing. II. Gel filtration and electrophoresis results. Cereal Chem. 50:597.

TANAKA, K., ENDO, S., and NAGAO, S. 1980. Effect of potassium bromate, potassium isodate, and L-ascorbic acid on the consistency of heated dough. Cereal Chem. 57:169.

TSEN, C. C. 1968. Oxidation of sulfhydryl groups of flour by bromate under various conditions and during breadmaking process. Cereal Chem. 45:531.

[Received October 10, 1984. Revision received February 7, 1985. Accepted February 10, 1985.]