Do-Corder Studies on Dough Development. I. Interactions of Water Absorption, Sulfhydryl Level, and Free Lipid Content in Heated Dough

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ABSTRACT

A Brabender Do-Corder was used to study factors affecting the rheological properties of doughs in terms of dough development. The major peak of the Do-Corder curve for a dough, developed in another mixing apparatus before heat treatment, shifted from 85 to 75°C, compared with that for a control flour. The shift was influenced by mixing time and absorption level. The shift in this peak was promoted by an increase in the water absorption level. There was a rapid decrease in the content of sulfhydryl and free lipid extracted with ethyl ether at an early stage of mixing. However, the decrease in sulfhydryl content for a control flour after heat treatment in the Do-Corder was small compared with that for a premixed dough. Free lipid in a premixed dough increased greatly as a result of heat treatment in the Do-Corder, despite a slight decrease in free lipid observed in a control flour after heating. Flour protein was responsible for the rheological changes of doughs during prolonged mixing, judging from the changes in sulfhydryl content and lipid binding. On the other hand, little response was shown in Do-Corder curves for doughs containing *N*-ethylmaleimide.

Dough mixing, one of the most critical steps in the bread-making process, is the main testing method for evaluating baking quality in bread flour. The farinograph and the mixograph have been used for this purpose in most cereal research laboratories. Previous studies on dough mixing can be classified into two types. One was aimed at studying the chemical changes in flour components related to dough development, and the other was designed to establish the best mixing conditions to achieve optimal baking quality for a particular flour sample.

In spite of many research studies, the rheological changes in dough during mixing remain obscure. As the result of an extensigraph study, Fisher et al (1949) reported that the elasticity and extensibility of mixed dough changed during prolonged mixing. After studying the correlation between the baking performance and stress-relaxation time of a mixed dough, Frazier et al (1975) concluded that loaf volume increases when relaxation time is extended.

All of these rheological changes in mixed doughs have been demonstrated at room temperature. The research described in this article was designed to study these changes at elevated temperatures, together with the factors affecting these properties when the Do-Corder was used. In previous studies (Tanaka et al 1980, Nagao et al 1981a, Nagao et al 1981b), we used this machine to evaluate the bread-making potential of a dough.

MATERIALS AND METHODS

Materials

The flour used for this study was produced by milling No. 1 Canada western red spring wheat on an experimental Buhler mill to 60% extraction. Its protein content was 13.1%, its moisture 14.7%, and its ash 0.43%. All chemicals used were of reagent grade.

Preparation of Premixed Dough Samples

A mixograph with a 35-g bowl (National Mfg. Co., Lincoln, NE) was operated according to the AACC mixograph testing procedure (1962), except that water absorption levels of 70, 75, and 80% were used for 35 g of flour. In the test for defatted flour and the dough that contained *N*-ethylmaleimide (NEMI) (1,200 ppm), 75% water absorption level was used. Doughs were mixed to the peak time (PT), and mixing was continued for another five or 10 min. 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 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 of 70%. The lever position was 1.5 throughout. The *x*-axis of the Do-Corder curves shows the range of temperatures.

Testing of Dried-Dough Samples in the Do-Corder

The premixed dough samples (freeze-dried and ground) were again mixed with water and heated in the Do-Corder to 90°C. For comparison, a flour sample was mixed in the same way. Dough samples, taken at various times, were quickly frozen by immersion in liquid nitrogen, freeze-dried, pulverized, and ground as described in the preparation of premixed dough samples to pass through a 100-mesh sieve. These samples were used to determine sulfhydryl (SH) and free lipid contents.

Determination of Sulfhydryl Contents

The SH contents of the samples were determined by amperometric titration. The method used was developed by Sokol et al (1959) and modified by Tsen and Anderson (1963). The change in SH content of premixed doughs or Do-Corder-heated doughs was calculated by the following formulas: (1) change in SH content of premixed doughs (%) = (SH content per 1 g of protein in premixed dough at appropriate mixing time) × 100/(SH content per 1 g of protein in flour); and (2) change in SH content of Do-Corder-heated doughs (%) = (SH content per 1 g of protein in heated dough) × 100/(SH content per 1 g of protein in premixed dough). When flour is mixed in the Do-Corder, the words "premixed dough" should be read "flour."

Determination of Free Lipid Extracted by Ethyl Ether

Free lipid contents of the samples were determined according to the AACC method (1962) by exhaustive extraction with ethyl ether in a Soxhlet. The change in free lipid contents of premixed doughs or Do-Corder heated doughs was calculated by the following formulas: (1) change in free lipid content of premixed doughs (%) = (free lipid content in premixed dough at appropriate mixing time) × 100/(free lipid content in flour); and (2) change in free lipid content of heated doughs (%) = (free lipid content in heated dough) × 100/(free lipid content in premixed dough). When flour is mixed in the Do-Corder, the words "premixed dough" should be read "flour."

Preparation of Defatted Flour

Free lipids were removed from flour by exhaustive extraction with petroleum ether (bp 35–60°C) in a large Soxhlet.

RESULTS AND DISCUSSION

Do-Corder Results with Premixed Doughs

The various levels of water absorption differed in the extent of their effects on dough development. In proportion to the increase of absorption level, elasticity in doughs decreased and its extensibility increased. This may be related to the increase of free water in doughs. Using the concept of dough mobility, Hlynka (1959) reported a method to determine moisture content. This term refers to the reciprocal of the maximum consistency of a dough in

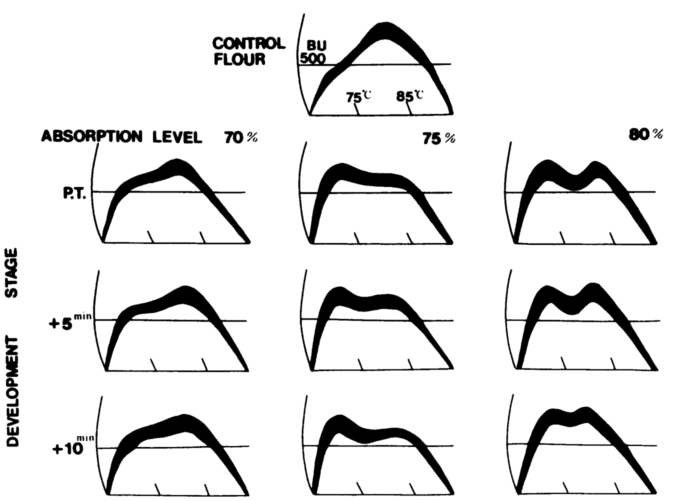

Fig. 1. Do-Corder curves for a control flour and powdered freeze-dried doughs premixed in a mixograph for the appropriate times at various absorption levels (70, 75, and 80%). Doughs were mixed until they reached maximum consistency, and then for another 0 (peak time), 5, and 10 min.

the farinograph.

An increase in water absorption delayed dough development. Peak time was reached after 3.8 min of mixing at 70% absorption, and after 4.9 or 8.2 min at 75% or 80%, respectively. Bakers generally consider that the largest loaf can be baked from dough developed to maximum consistency (mixed to peak time). Endo et al (1981) observed that the major peak of the Do-Corder curve gradually shifted from 85 to 75°C for doughs during prolonged mixing. A similar change was seen in the curve for bromated doughs (Tanaka et al 1980). These two results showed that both chemical and mechanical development can have similar effects in doughs.

As shown in Fig. 1, however, the shift of the major peak from 85 to 75°C and the shape of the Do-Corder curve depended on the water absorption levels in premixed doughs. No shift of the peak at 85°C was observed after prolonged mixing at 70% absorption, although the height of the peak decreased slightly. Finney et al (1945), Finney et al (1972), and Hoseney et al (1972) reported that oxidation requirement is related to mixing requirement and protein content. Besides this scientific evidence, bakers know from experience that the amount of oxidizing agent required to develop dough varies with the amount of water added, even though constant flour may be used. The results shown in Fig. 1 support this. At lower absorption levels, a larger amount of oxidizing agent might be needed, considering that two peaks appeared for bromated dough at such absorption levels (Tanaka et al 1980). The combination of mechanical and chemical dough development helps to increase the amount of water that might be added while retaining similar dough properties. Because Henika (1965) reported that absorption levels in doughs increased with mixing speed,

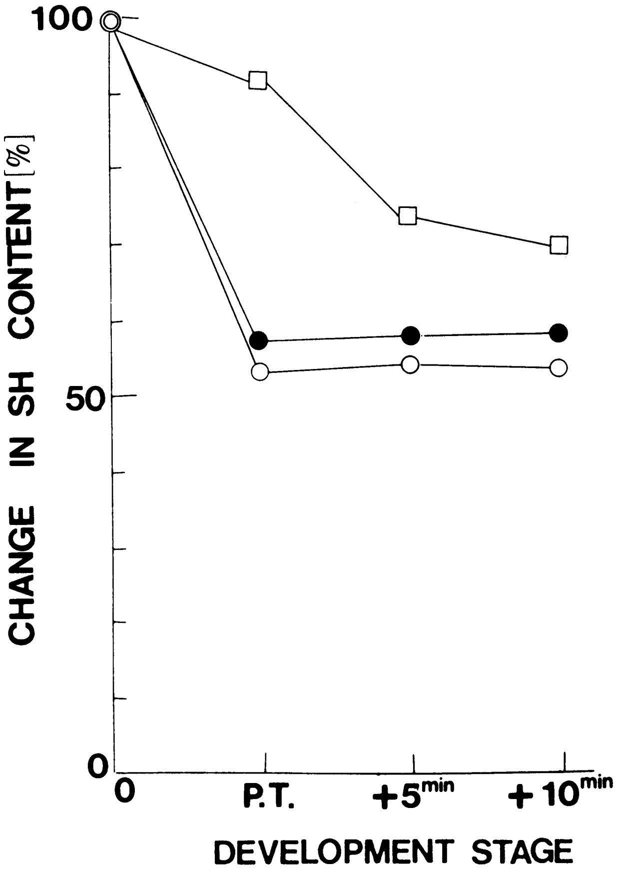

Fig. 2. Decrease in sulfhydryl content of a dough during prolonged mixing. Doughs were mixed in a mixograph for the appropriate times at various absorption levels. The results are shown as a percentage of the sulfhydryl content of a mixed dough compared to that of a control flour. ◎ = control flour, o——o = 70% absorption, ●——● = 75% absorption, and □——□ = 80% absorption.

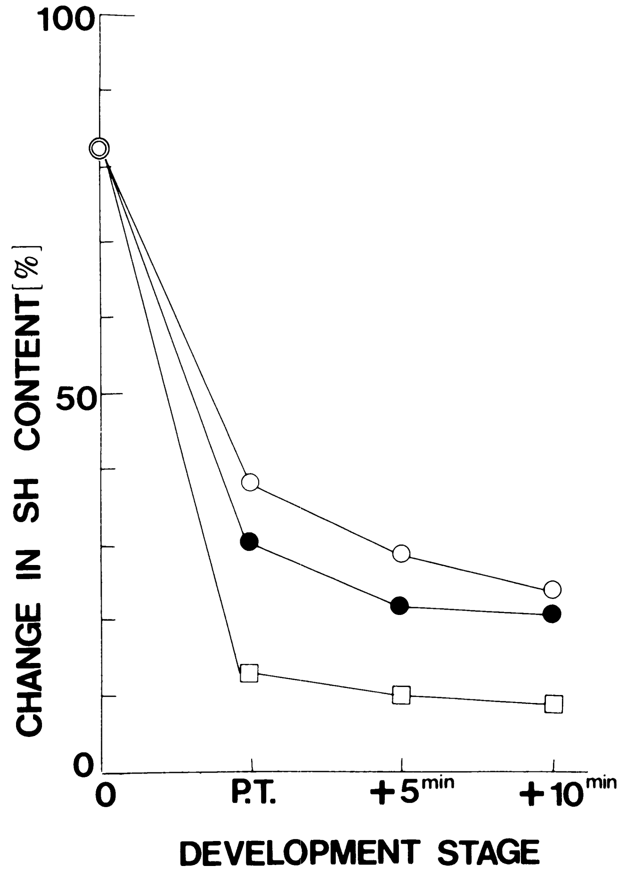

Fig. 3. Effects of Do-Corder heat treatment on the sulfhydryl content of a control flour and of powdered freeze-dried doughs premixed in a mixograph for the appropriate times at various absorption levels. The results are shown as a percentage of the sulfhydryl content of a heated dough compared to that of a premixed dough (or flour). ◎ = control flour, o——o = 70% absorption, ●——● = 75% absorption, and □——□ = 80% absorption.

correlations between mixing speeds and absorption levels should also be studied.

Changes in SH Content of a Dough

During prolonged mixing, the SH content of a dough decreases linearly (Bushuk et al 1968), but such studies need to be extended to investigate the effects of elevated temperatures. The SH content of dough was therefore determined during dough development in both the mixograph and the Do-Corder. At any absorption level, SH content decreased as a result of mixing (Fig. 2). The decrease depended upon water absorption levels, however. A more rapid decrease was observed in the early stages of mixing at 70 or 75% than at 80%. These results with the mixograph may be related to results from the Do-Corder, since little change in SH content was observed with prolonged mixing after PT, at least at lower absorption levels.

A more rapid decrease in SH content was observed as a result of heating doughs, especially at higher absorption levels (Fig. 3). This fall in SH content was also greater than that for heated dough, not premixed, in which the SH content fell to about 80% of its initial value. The SH groups that remain unchanged after prolonged mixing are interpreted to be those that are protected or masked from chemical interaction. Mixing and heating thus appear to be critical steps in producing unmasked SH groups. This unmasking of SH groups is analogous to heat denaturation.

The activation of SH groups also depends on water-absorption levels. At lower absorption levels, the activated SH groups were rapidly oxidized to disulfide groups. As absorption levels increased, however, the oxidation of activated SH groups decreased in unheated premixed dough. The increase in SH oxidation caused by heating was most dramatic for the 80% absorption dough, which changed from having the least SH oxidation (Fig. 2) to the greatest (Fig. 3), with few (10%) SH groups remaining unreactive. Presumably, both activation and oxidation of SH in premixed doughs contribute to dough development. Activation and oxidation apparently are restricted by absorption levels, resulting in different degrees of development in mixed doughs.

Changes in Free Lipid Content

A rapid decrease in free lipid content of doughs was observed to be due to premixing without heating, as shown in Fig. 4. The decrease leveled off at 30% of the original lipid content. This change in free lipid content is presumably due to the lipid becoming bound, probably to protein.

In contrast to these results, there was a dramatic increase in free lipid during heating in the Do-Corder (Fig. 5). Under the same conditions, the free lipid content of heated dough (not premixed) decreased to 60% of its initial value; therefore, free lipid that had changed into bound lipid during premixing was again changed into free lipid in heated doughs. These results may be compared to the changes in SH content (Figs. 2 and 3), which suggested that protein denaturation increased in heated dough as mixing time increased.

Do-Corder Results with Defatted Flours

The mixing time requirements for defatted flours increased when compared to normal flours (data not shown). Chung et al (1980) reported that the changes in wheat flour components due to the defatting process delayed dough development. Figure 6 shows Do-Corder curves for doughs premixed to various stages of development, using flour defatted with ethyl ether. Extraction of free lipid from the flour had little effect on the curves (compare with

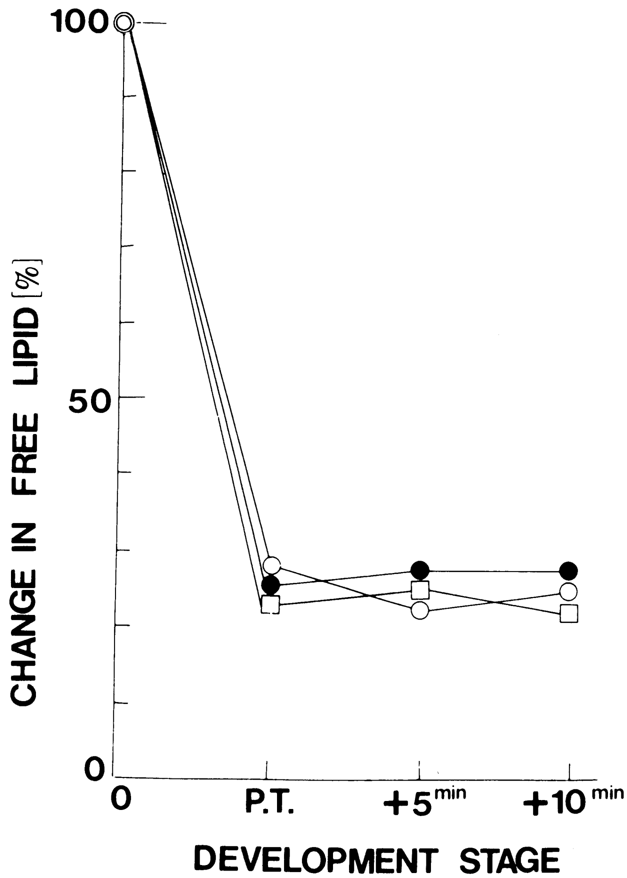

Fig. 4. Decreases in the free lipid content of doughs during mixing. Doughs were mixed in a mixograph for the appropriate times at various absorption levels. The results are shown as a percentage of the free lipid content of a mixed dough compared to that of a control flour. ◎ = control flour, o——o = 70% absorption, •——• = 75% absorption, and □——□ = 80% absorption.

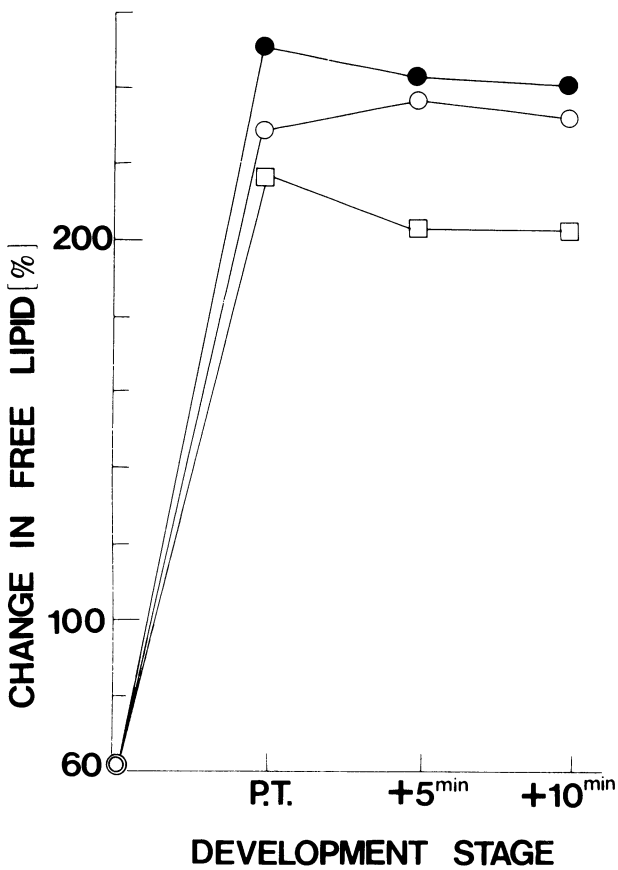

Fig. 5. Effects of Do-Corder heat treatment on free lipid content of a control flour and of powdered freeze-dried doughs premixed in a mixograph for the appropriate times at various absorption levels. The results are shown as a percentage of the free lipid content of a heated dough compared to that of a mixed dough (or flour). ◎ = control flour, o——o = 70% absorption, •——• = 75% absorption, and □——□ = 80% absorption.

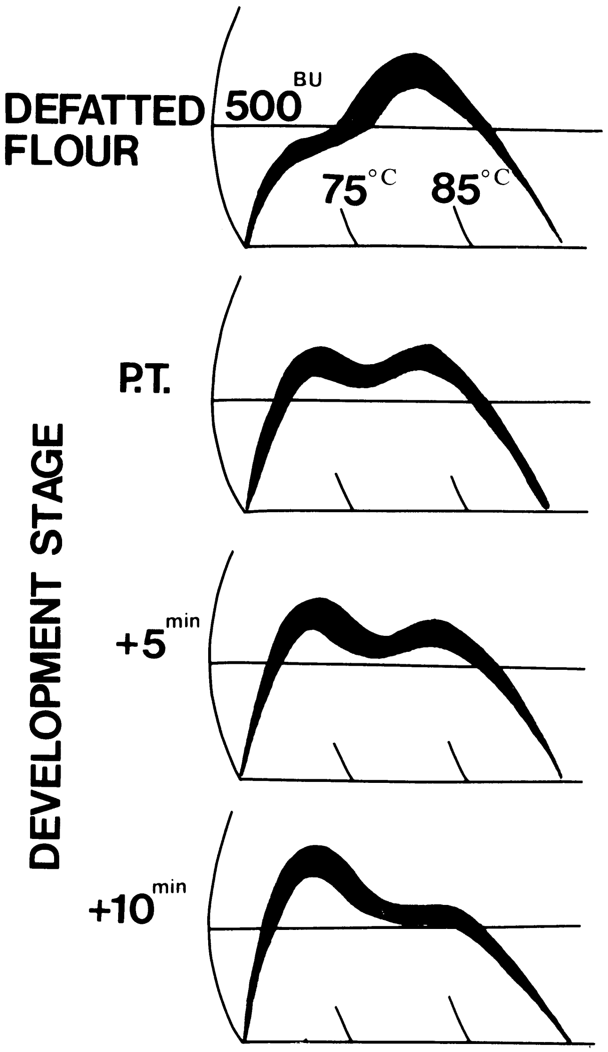

Fig. 6. Do-Corder curves for a defatted flour and powdered freeze-dried doughs prepared from defatted flour and premixed in a mixograph for the appropriate times at a water absorption of 75%.

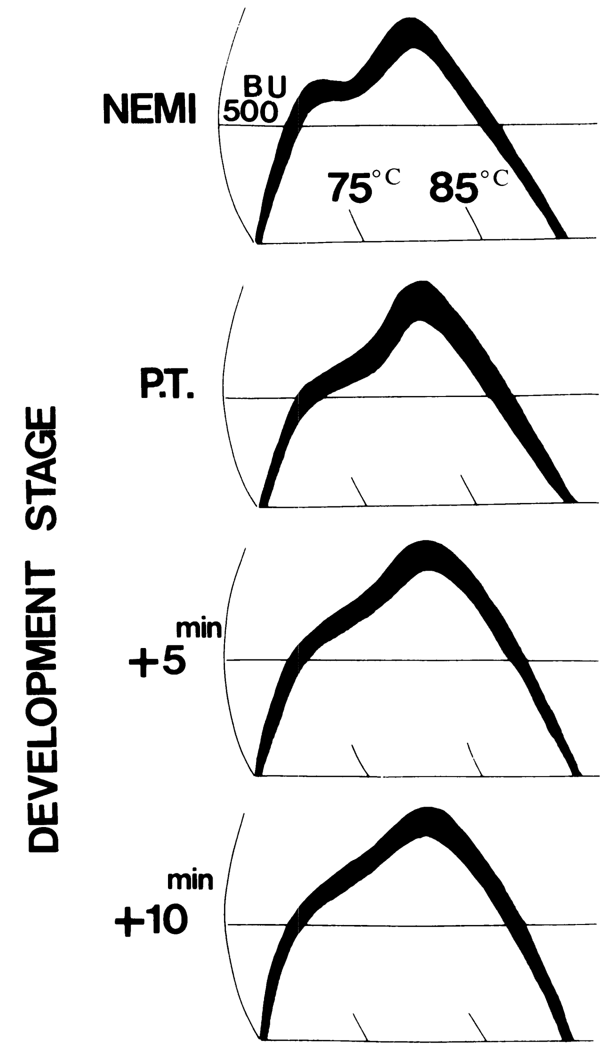

Fig. 7. Do-Corder curves for doughs premixed in a mixograph for the appropriate times with 1,200 ppm *N*-ethylmaleimide (NEMI) at a water absorption of 75%. No NEMI was added in Do-Corder testing of premixed doughs, but 1,200 ppm NEMI was added to the flour samples in the Do-Corder (top curve).

Fig. 1 at 75% absorption level). Therefore, a decrease of free lipid content in mixed dough was not considered to be detrimental to development. Such a decrease might be produced as a result of changes in flour components, particularly protein during mixing.

Do-Corder Results in the Presence of NEMI

The addition of NEMI (1,200 ppm) to a normal dough produced an increase in the Do-Corder peak at 75° C, as shown by comparing curves for control flour samples in Fig. 1 at 75% absorption level and Fig. 7 (Tanaka et al 1980). This peak disappeared with prolonged mixing (Endo et al 1981). As shown in Fig. 7, however, the curve for dough premixed with NEMI to PT was very similar to that of flour. That is, the dramatic effect of NEMI in the mixograph was not transferred to the Do-Corder in premixed doughs. Moreover, the change of the Do-Corder curves during prolonged mixing was restricted with the addition of NEMI to a normal dough.

CONCLUSIONS

The mechanism of dough development has been studied with respect to chemical and mechanical aspects. The results obtained in this study suggested that mechanical development also affects the characteristics of the dough at an early stage of baking. The chemical factors affecting development observed in the Do-Corder are thought to involve the protein fraction, particularly its SH groups and its ability to bind lipid. This possibility is supported by the fact that, in the presence of NEMI, the curves showed little development regardless of prolonged mixing.

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