EFFECT OF BLEACHING ON FLOUR AS MEASURED BY STRUCTURAL RELAXATION OF DOUGH[1]

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ABSTRACT

Differences in structural relaxation of a hard red spring wheat flour dough were measurable when bleached with 3.3 and 5.5 p.p.m. of chlorine dioxide in the presence of 200 p.p.m. benzoyl peroxide. The increase of the relaxation hyperbola semiaxis constant caused by increased chlorine dioxide concentration and measured at a 3-hour reaction time was approximately constant for doughs mixed in air for 2.5 minutes and 10 minutes. The increase of the semiaxis constant caused by the farinograph mixing time difference of 2.5 minutes and 10 minutes was also approximately constant at different concentrations of chlorine dioxide. The combination of higher chlorine dioxide level and longer mixing time in air caused a larger increase in the asymptotic load than was expected by considering bleaching and mixing separately.

The technique of measuring structural relaxation of dough (2) provides the investigator with a tool that not only describes the relaxation phenomena in quantitative terms, but also enables one to postulate a model of the structure of dough and thus obtain a better understanding of the behavior of the system (5). With this technique the action of bromate (5) under various conditions (2,4,7) and of other agents (1) has been studied and measured in dough. In order to employ the technique for quality-control purposes, it is necessary to know the effect of flour bleaching on structural relaxation. Also it is necessary to choose a mixing time for the dough preparation. Consequently, the action of bleaching with chlorine dioxide and the effect of mixing time on dough structural relaxation were investigated.

Materials and Methods

The flour used in this study was commercially milled from North Dakota hard red spring wheat. The flour had a protein content of 11.9% and ash content of 0.41% on a 14% moisture basis.

Relaxation of dough was measured in a procedure using the unbleached flour and flour bleached with two concentrations of bleaching agent. The lower concentration consisted of 3.3 p.p.m. of chlorine dioxide and 200 p.p.m. benzoyl peroxide; the higher concentra-

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tion employed 5.5 p.p.m. of chlorine dioxide and 200 p.p.m. of benzoyl peroxide. These two concentrations are characteristic of the upper and lower limits of commercial treatment. The method of flour bleaching employed was essentially the acetic anhydride method described by Parker and Fortmann (9).

The relaxation procedure employed was essentially the one outlined by Dempster *et al.* (1,2). The dough was mixed in a standard farinograph mixer under room conditions. To 300 g. of flour, 2% of sodium chloride was added in solution plus enough water to make the absorption 60.8% on a 14% moisture basis. After 2.5 minutes of mixing, the dough had a consistency of 500 farinograph units. The dough was mixed for 2.5, 5, 10, or 20 minutes. A 0- or a 3-hour reaction time was given to the dough, which is the time between mixing in the farinograph and shaping with the extensigraph. Extensigrams were obtained after rest times ranging from 5 to 120 minutes.

From the extensigram the load at 5-cm. extension was measured. The extension recorded at 5 cm. on the chart was corrected for vertical movement of the dough holder. The extensigraph was calibrated at 2 extensigraph units per gram force.

Results and Discussion

Figures 1 and 2 show dough relaxation curves for unbleached flour at 0- and 3-hour reaction time with different mixing times. At a 1-hour reaction time the relaxation curves which are not shown fell in between the corresponding curves of 0- and 3-hour reaction time. Since the farinograph mixer was operated under room conditions, Figs. 1 and 2 show the total effect of the mechanical mixing action and oxygen incorporation into the dough.

Relaxation curve changes caused by varying mixing time are very slight for a zero reaction time as shown in Fig. 1. From 2.5 minutes to 10 minutes a slight increase can be noted in asymptotic load and relaxation constant for the hyperbolic curves. Increasing mixing time beyond 10 minutes to 20 minutes shifted the hyperbolic relaxation curve back down to the position of the 5-minute mixing time curve. The upward shift between 2.5- and 10-minute mixing is to be expected, assuming increasing oxygen incorporation with longer mixing time (3). The downward shift of the 20-minute mixing curve must be caused by mixing *per se*.

Figure 2 illustrates the effect of varying dough mixing time at a 3-hour reaction time. The upward shift with increasing mixing time was considerably greater for the curves at a 3-hour reaction time than it was at the 0-hour reaction time. At the 3-hour reaction time

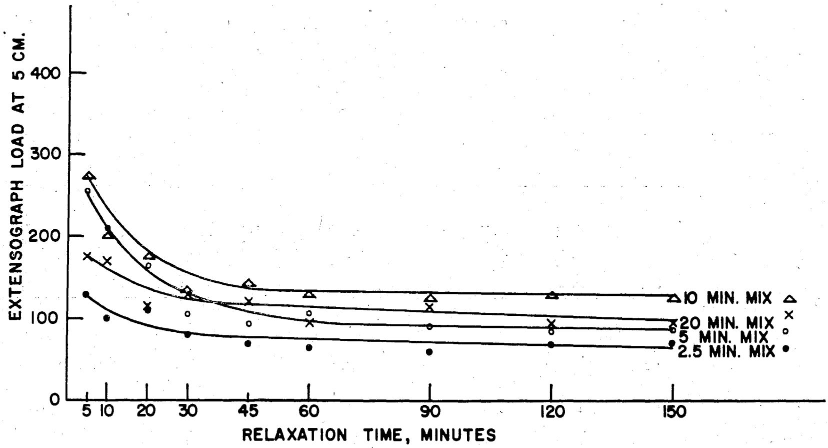

Fig. 1. Structural relaxation curves for dough mixed in air for 2.5, 5, 10, and 20 minutes in a farinograph mixer with a reaction time of 0 hours.

the increase of asymptotic load with longer mixing time held true up to 20 minutes of dough mixing in the farinograph mixer. At all the mixing times tested, the relaxation curves shifted upward with increasing reaction time. The upward shift probably means that the oxygen incorporated into the dough was beyond the level of 40% oxygen reported by Dempster *et al.* (3).

Relaxation curve parameters were calculated for the mixing time

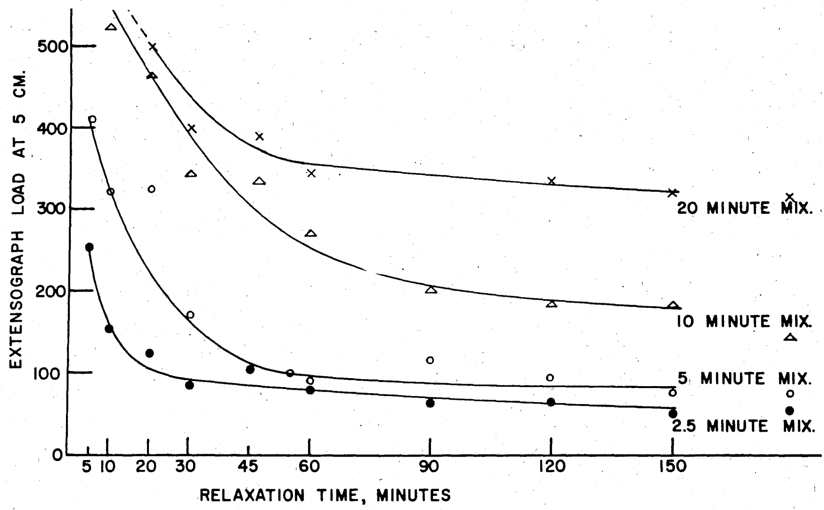

Fig. 2. Structural relaxation curves for dough mixed in air for 2.5, 5, 10, and 20 minutes in a farinograph mixer with a reaction time of 3 hours.

TABLE I

DOUGH STRUCTURAL RELAXATION PARAMETERS OBTAINED FOR UNBLEACHED AND BLEACHED FLOUR

MIXING TIME	REACTION TIME	HARD RED SPRING FLOUR, UNBLEACHED			HARD RED SPRING FLOUR BLEACHED WITH 3.3 P.P.M. CHLORINE DIOXIDE AND 200 P.P.M. BENZOYL PEROXIDE			HARD RED SPRING FLOUR BLEACHED WITH 5.5 P.P.M. CHLORINE DIOXIDE AND 200 P.P.M. BENZOYL PEROXIDE		
		Asymptotic Load	Relaxation Constant	Semiaxis Constant	Asymptotic Load	Relaxation Constant	Semiaxis Constant	Asymptotic Load	Relaxation Constant	Semiaxis Constant
minutes	*hours*									
2.5	0	75	2.0	2.0	89	2.9	2.4	115	2.4	2.2
2.5	3	79	1.1	1.5	106	3.7	2.7	141	6.4	3.6
10	0	111	2.6	2.3	138	2.0	2.0	144	2.0	2.0
10	3	146	10.4	4.6	225	15	5.5	300	19.4	6.2

data shown in Figs. 1 and 2. However, because of the considerable experimental error involved, the calculated relaxation parameters could be used only in a qualitative way to substantiate the observations already made from Fig. 1 and Fig. 2. The relaxation constant and asymptotic load increased with higher reaction time, this increase being larger for the longer mixing times.

The effects of flour bleaching on structural relaxation of doughs is shown in Table I for dough-mixing times of 2.5 and 10.0 minutes and reaction times of 0 and 3 hours. The asymptotic load, the relaxation constant, and the hyperbola semiaxis were calculated from regression equations.

Table I shows that physical changes of dough caused by commercial bleaching and a 3.3- to 5.5-p.p.m. change of concentration of chlorine dioxide can be measured by structural relaxation techniques. The asymptotic load increases with increasing concentration of bleaching agent for all four combinations of mixing time and reaction time. The bleaching effect, as measured by the increase in asymptotic load at 3-hour reaction time, is larger for the 10-minute mixing time than for the 2.5-minute mixing time.

The relaxation constant shows no pattern of change at 0-hour reaction time. It is probable that at 0-hour reaction time the relaxation constant which has a mean value of 2.3 is not affected by the concentration of bleaching agent. At 3-hour reaction time, however, the relaxation constant increases with increasing chlorine dioxide concentration. The increasing relaxation constant shows that the reaction caused by the bleaching is dependent on the concentration of bleaching agent. The reaction also is time-dependent, since it requires a reaction time, 3 hours in this case, to become measurable.

Table I shows that the effects of bleaching and mixing are not additive when measured by the relaxation constant. For example, the relaxation constant difference caused by the change of chlorine dioxide concentration is for the 2.5-minute mixing time 6.4−3.7 or 2.7 units. For 10-minute mixing, it is 19.4−15 or 4.4 units.

To obtain an additive index, the dough relaxation hyperbola semiaxis constants were calculated as proposed for the bromate reaction by Hlynka and Matsuo (8). The semiaxis difference between the doughs with the two chlorine dioxide concentrations was approximately the same regardless of mixing time. At 2.5-minute mixing, it was 0.9 units; at 10-minute mixing it was 0.7 units. Similarly, it was found that the semiaxis difference caused by the 2.5- to 10-minute difference in mixing time is the same, regardless of the bleach level used. The 2.5- to 10-minute difference in mixing time results in a semiaxis difference of 2.9, 2.8, and 2.6 for the three chlorine dioxide levels identified in Table I.

The approximately constant semiaxis constant difference means that bleaching effects were independent of effects produced by mixing under atmospheric conditions. Although relaxation rate differences as characterized by the hyperbola semiaxis were independent of mixing time, asymptotic load differences were not independent of mixing time. Thus, it was found that bleaching to the 5.5-p.p.m. level of chlorine dioxide caused an asymptotic load difference of 141−79=62 extensigraph units at 2.5-minute mixing, while at 10-minute mixing the difference is 300 − 146 = 154 units. Similarly, the asymptotic load increase due to the mixing time difference between 2.5 minutes and 10 minutes was 300−141=159 extensigraph units at the high chlorine dioxide concentration whereas it was 146−79=67 for the unbleached flour.

These results show that, using the farinograph mixer under room conditions, dough structural changes caused by bleaching may be measured as semiaxis differences at any mixing time. Asymptotic load changes due to bleaching will, however, be dependent on farinograph mixing time.

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