Study of Gas Production and Retention in Doughs with a Modified Brabender Oven-Rise Recorder[1]

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ABSTRACT

The Brabender Oven-Rise Recorder was adapted to study the changes in volume of dough during fermentation. The recorded curve gives an indication of gas-production and gas-retention capacity of the dough. The effects of yeast, malt, sugar, salt, potassium bromate, and potassium iodate concentrations, and variable mixing rates and times on fermentation, were studied. Increase in yeast concentrations increased gas-production and -retention capacity. Salt decreased production and retention. Malt had a slight negative effect on production but essentially no effect on retention. Sugar at low concentrations increased gas production, but decreased it at levels above 5%. Sugar had very little effect on gas retention. Potassium bromate and potassium iodate below 40 p.p.m. had no effect on rate of production but increased the amount of retention. Higher levels of iodate decreased the retention but had little effect on rate of production. Increasing mixing time and rate had no effect on the rate of production but increased the retention capacity. Gas production is independent of flour strength but retention increased with increasing strength.

Gas production in a fermenting dough can be measured as an increase in pressure in an airtight container of known volume, as an increase in volume at constant pressure, or as increase in buoyancy of a dough immersed in a suitable liquid. Gas retention is somewhat more difficult to measure although, in principle, the methods used for measuring total gas production can also be modified to measure gas retention. This is usually achieved by absorbing the carbon dioxide that escapes in alkali. This principle for measuring gas production and retention has been successfully utilized in an instrument such as the Chopin Zymotachygraph. The methods for measuring gas production and retention were recently reviewed by Bloksma and Hlynka (1).

The early literature on baking quality contains numerous references on studies of gas production and retention. These properties were extremely important in evaluating flour for long fermentation baking processes. In recent years the trend in baking technology has been to replace long fermentation by mechanical development, and hence the significance of gas production and retention has somewhat diminished. However, as will be noted from the results to be presented, gas retention is related to mechanical development and hence remains as an important property in modern baking technology.

The present work is a part of a detailed study of the fundamental processes that occur in dough during the breadmaking process. The Brabender Oven-Rise Recorder (ORR), which was originally designed to measure the change in volume of a piece of dough during the baking phase, was adapted and used to measure the production and retention of carbon dioxide during fermentation. In its original design, as shown by Fig. 1, the instrument records the oven phase or oven-rise phase of baking in the form of a

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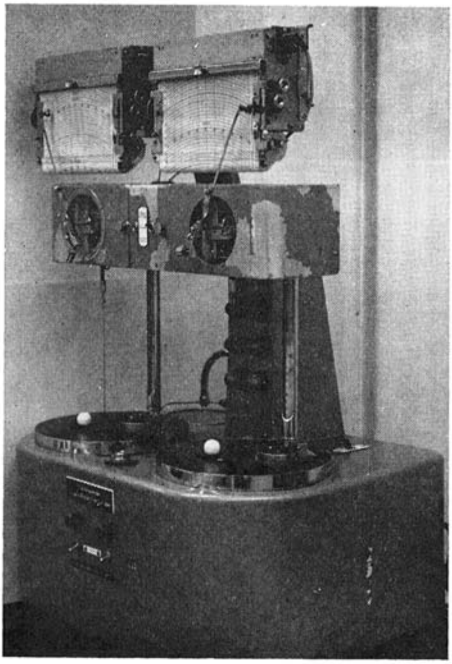

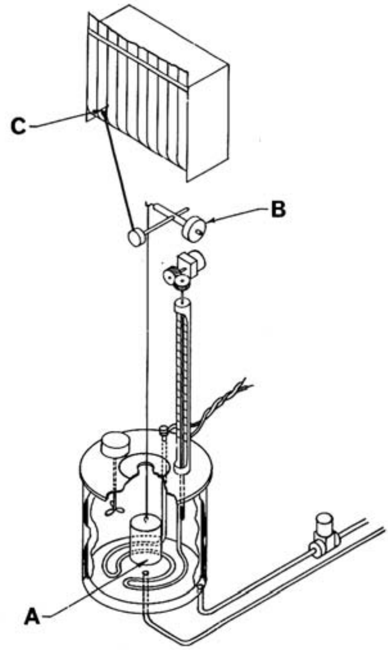

Fig. 1 (left). The C. W. Brabender Oven-Rise Recorder (ORR).
Fig. 2 (right). Schematic diagram of the ORR.

curve. Figure 2 shows the schematic diagram of the ORR. In the original purpose, the instrument was used as follows: A wire basket containing the dough test piece is immersed into the oil bath which is at 30°C. The wire basket *A* is suspended on a small balance *B* which is connected to a recording pen *C*. As the temperature of the oil bath rises from 30° to 100°C., the buoyancy of the dough test piece increases as the volume increases. The buoyancy is measured by the balance system, and the volume changes are recorded on a kymograph as a continuous curve. The heating-up period takes about 22 min. After the temperature of 100°C. has been reached, at which point the test is finished, the recorder stops automatically. The recorded curve gives the volume after proofing and the change in volume during baking. By using the ORR at a constant temperature of 30°C., the only modification from the original procedure, the changes in volume of a piece of dough during fermentation can be measured. These volume changes give a direct indication of the gas-production or -retention ability of the dough, whichever is the controlling factor. A sudden change in buoyancy in the region of constant gas production is assumed to reflect indirectly changes in gas-retention capacity.

With the above technique, the effects of the main constituents of a typical bread formula—e.g., flour, yeast, malt, sugar, salt, and improvers—were investigated. The effects of variable mixing rates and times were examined also.

MATERIALS AND METHODS

The flour used was a commercial straight-grade flour milled from Canadian hard red spring wheat. It was unbleached and free from improvers. The protein and ash contents were 13.5 and 0.45% respectively. A soft wheat flour containing 7.9% protein and 0.42% ash was used to examine the effect of flour strength. The basic bread formula comprised 100 g. flour, 3 g. yeast, 0.3 g. malt syrup (250° Lintner), 2.5 g. sugar, 1 g. salt, and 40 p.p.m. potassium bromate. The doughs were mixed in the GRL mixer (2) for 5 min. at 68 r.p.m. When one of the ingredients or the mixing time was varied, the others remained constant as given here. The doughs were taken from the mixer and 33-g. test pieces scaled and immersed in the mineral oil of the ORR. The buoyancy curves taken were usually recorded over a period of 5 hr.

RESULTS

First, it was necessary to determine if the fall-off in ORR curve did indeed reflect a change in gas retention which was not complicated by a decrease in gas production, by comparing the ORR curve with the gas production curve as measured by the pressuremeter method (3). Such a comparison is made in Fig. 3 for a dough from the basic formula. It is seen that gas production over the 5-hr. period is indeed linear, and therefore, the drop-off in the ORR curve reflects a decrease in retention capacity. The ORR

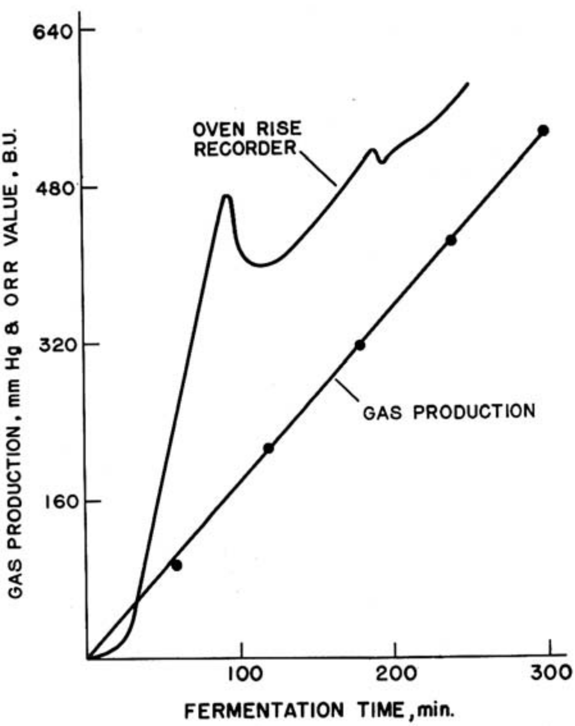

Fig. 3. ORR and gas-production curves for a dough from the basic formula.

curve shows an induction period not shown by the gas production curve. This is probably a direct result of the principle of the method; a definite pressure must be built up in the dough to overcome the pressure of the surrounding liquid. No further significance will be attributed to the induction period. At the 5% yeast level, the highest used in this study, the gas production curve showed a slight decrease in rate of gas production between 4 and 5 hr. of fermentation; however, this was not serious enough to affect markedly the interpretation of the ORR results.

The ORR curve is characterized by a relatively linear initial phase for the period where all the gas produced is retained by the dough. After about 1½ hr. of fermentation, the dough seems to have reached an optimum in retention capacity, and there is a sudden collapse with release of a relatively large amount of gas. This is shown as a relatively sharp peak in the buoyancy curve. After the first marked collapse occurs, some of the retention is recovered and further fermentation is characterized by an increase in buoyancy at a decreasing rate. In some cases, as will be seen later, this phase shows alternate decreases and increases in buoyancy rather than a unidirectional change. From a comparison of the ORR curve and the gas-production curve, it is inferred that the maximum height of the buoyancy curve reflects the gas-retention capacity of the dough.

Figure 4 shows the effects of mixing time and rate. Initial rate of gas production is not affected by longer time or higher rate of mixing. However, the retention capacity is increased quite markedly by increase in mixing time and rate. The effect on retention is twofold. First, the length of fermentation time, during which all of the gas produced is retained, is extended; and second, the over-all retention, as reflected by the leveling-off

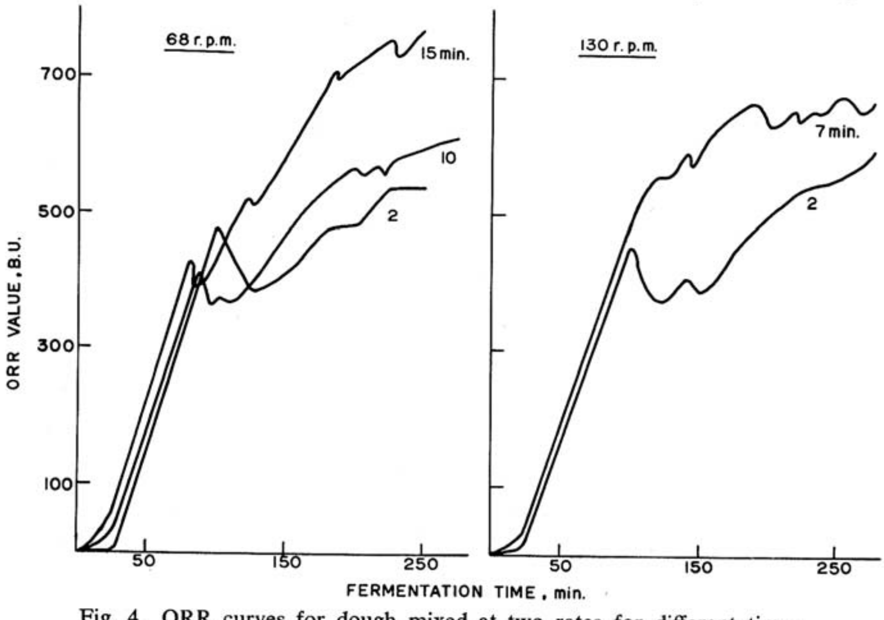

Fig. 4. ORR curves for dough mixed at two rates for different times.

of the ORR curve, is increased. Indeed, for the 15-min. mixing time at a slower rate (68 r.p.m.), almost all of the gas produced is retained throughout the 5-hr. fermentation period. The effect of doubling the mixing rate is not very evident after 2 min. of mixing, but becomes quite marked at longer

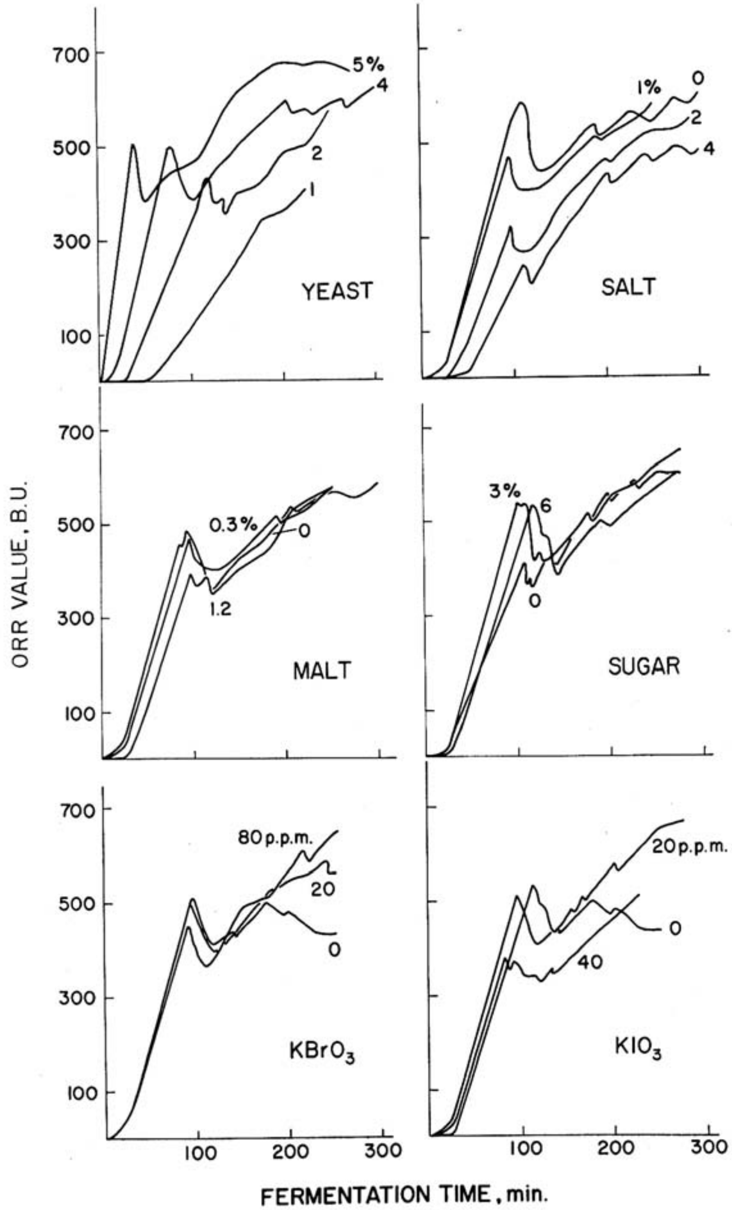

Fig. 5. ORR curves for dough containing various concentrations of yeast, salt, malt, sugar, and potassium bromate and iodate.

mixing time. The 7-min. curve at the higher rate indicates higher retention than the 10-min. curve at the slower rate.

The effects of yeast, salt, malt, sugar, and potassium bromate and iodate are summarized in Fig. 5.

Increase in the yeast level increases the rate of gas-production and -retention capacity until maximum gas-retention capacity has been obtained. Further additions of yeast will increase the rate of gas production but not retention, since any dough is able to expand only to a certain degree and no further. The time at which the initial loss of gas occurs becomes less as the level of yeast (or rate of gas production) increases. The effects of yeast observed here are in general agreement with the published information.

Salt tends to decrease the rate of gas production, probably by inhibiting yeast activity (4). Although 1% of salt had not much effect on retention capacity, higher levels had a negative effect. This is probably an indirect effect of the inhibition of yeast activity.

At the level normally used at the Grain Research Laboratory (0.3% of 250° Lintner syrup) malt has very little effect on the rate of gas-production or the gas-retention capacity. At much higher levels, the gas production is inhibited slightly.

Gas production and retention are affected very little by sugar. At 3% concentration, the rate of gas production was accelerated slightly. At 6% concentration, there was an indication of a slight negative effect on initial gas production.

Figure 5 shows the effect of two concentrations of potassium bromate, 20 and 80 p.p.m. During the first 3 hr., bromate has no effect on the fermentation process. The major effect occurs after this time period, when bromate markedly increases the gas-retention capacity of the dough.

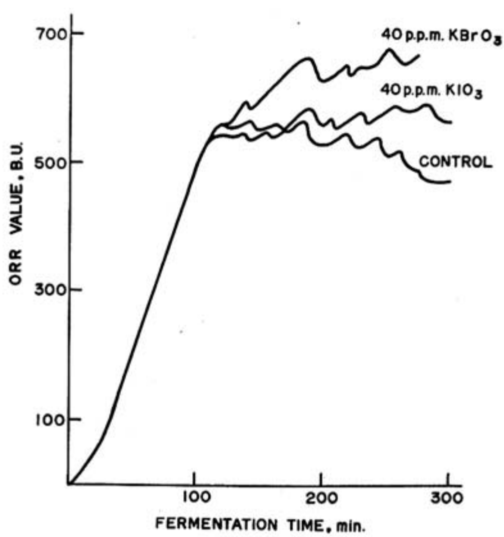

Fig. 6. ORR curves showing the effect of 40 p.p.m. potassium bromate and iodate in doughs mixed for 7 min. at 130 r.p.m.

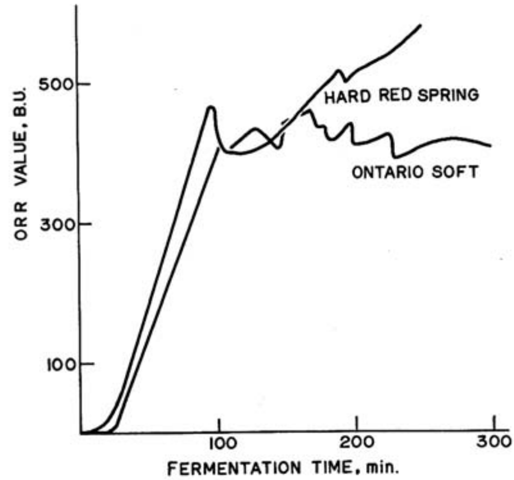

Fig. 7. ORR curves for doughs from strong and weak flours.

The effect of the fast-acting improver potassium iodate (which replaced the bromate in the formula) is quite different from that of bromate. The initial gas production is slightly inhibited at concentrations of 20 p.p.m. and higher. At 20 p.p.m. the effect of potassium iodate on retention was analogous to that of potassium bromate. However, the early gas retention was markedly decreased in doughs containing higher levels of iodate. This effect is eventually overcome by a longer fermentation period.

If the dough containing relatively high quantities of iodate (40 p.p.m.) is mixed more vigorously, the lowering of retention early in the fermentation period is not observed. The effects of bromate and iodate in doughs mixed for 7 min. at high speed (130 r.p.m.) are compared in Fig. 6. The effect of iodate on retention capacity becomes significant only after long fermentation times, whereas the effect of bromate is noticeable after about 2 hr.

The effect of flour strength on the fermentation curve as recorded by the ORR is shown in Fig. 7. At the level of yeast and salt used, there is very little difference in doughs from the two flours during the first 3 hr.; the strong flour showed a slightly higher rate of gas production. However, the behavior of the two doughs after 3 hr. of fermentation was quite different. The retention capacity of the dough from the weak flour reached its optimum after fermentation for about 100 min., whereas the retention of the dough from the strong flour continued to increase. This confirms the information obtained from practical observations that the main difference between a strong and a weak flour lies in their gas-retention capacity. These two samples of flour differed both in quantity and quality of their proteins. Further experiments are necessary to examine the role of quantity and quality factors separately.

DISCUSSION

The Brabender Oven-Rise Recorder was adapted to record changes in buoyancy of fermenting dough. The curve obtained gives information on production and retention of gas by the dough during fermentation. While an actual measure of the amount of gas produced and retained was not obtained in this method, the ORR curves reflect indirectly gas production and retention.

Gas production, as measured in the present study, is directly related to yeast activity and hence is readily affected by yeast concentration and to a lesser extent by ingredients which are yeast inhibitors, such as salt, high concentrations of sugar, and potassium iodate. This agrees in general with published information and practical observations.

Gas retention appears to be a more complex phenomenon, and is affected by a majority of the common bread ingredients. However, basically it seems to depend on gluten strength or the state of gluten development. Some evidence supporting this hypothesis has been obtained in this study.

Power-input studies (5,6) have shown that mixing for a longer period or at a higher rate tends to develop the gluten, and hence should improve the gas-retention properties of dough. This effect was directly measured in the present studies. It would be of interest to extend the present study to the point where breakdown occurs in the mixing curve, to determine if there is a parallel reversal in retention capacity.

It is well known that gluten development can also be accomplished by fermentation; hence, retention capacity increases with increasing yeast activity or fermentation time. This can only be accomplished to a level consistent with the intrinsic strength of the gluten (see Fig. 7). Salt not only inhibits gluten development by inhibiting yeast activity, but also inhibits gluten development during mixing (6). To obtain a required gluten development with increased salt concentrations, it would be necessary to use more mixing or a higher yeast concentration. Potassium iodate, a fast-acting improver, prevents the formation of a continuous gluten phase (7), and hence prevents gluten development. This effect can be offset by longer or more intense mixing (ref. 7 and Fig. 6). Potassium bromate, on the other hand, shows little interaction with mixing. Its value as an improver is clearly demonstrated by its effect on gas-retention capacity.

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