Effects of Ascorbic Acid and Potassium Bromate on Viscous Properties of Dough Measured with a Hoeppler Consistometer

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ABSTRACT

Consistency curves were derived to express the dependence of consistency on the stress for doughs from strong, medium, and weak flours. The addition of 0.3% potassium bromate and 0.3% ascorbic acid showed different effects on the consistency of doughs depending on the strength of the flour. The effect of flour quality (strength) on the specific consumption of energy during mixing and on the consistency of doughs was considerably greater than the effect of potassium bromate or ascorbic acid. Additions of potassium bromate or ascorbic acid decreased the consistency more for the weaker flour than for the stronger flour. Fermentation changed the shape of the consistency curves. The range of consistency for the same range of stress was smaller for fermented doughs than for the nonfermented doughs, but the relative position of consistency curves was not affected by the strength of the flour.

The derivation of flow curves for dough from measurements with the Hoeppler consistometer was described previously (1). Because of the non-Newtonian behavior of dough, the consistency varies with stress. Experimental consistency curves show the actual relationship of these two variables. This paper deals with the effects of ascorbic acid and potassium bromate on the rheological properties measured with the Hoeppler consistometer.

From the data obtained with the Hoeppler consistometer, the consistency of dough can be calculated from the velocity of the ball falling through the dough and the applied force,

$$\eta = \frac{G}{v} \cdot K$$

where η is consistency in c.g.s. units $\cdot\ 10^2$,
G is weight of the ball in g.,
v is velocity of the ball in cm. sec.$^{-1}$,
K is an instrument constant in cm.$^{-1}$

This equation is recommended by the manufacturer of Hoeppler consistometer (2). The value of constant K is determined by calibration with a material of known viscosity. The dimensions of this constant, determined by dimensional analysis, are cm.$^{-1}$ The magnitude of the constant depends on the diameter of ball; for the ball used in the present study (16 mm.) the value of K was 100 cm.$^{-1}$

MATERIALS AND METHODS

Three types of flour were used. The flours and some pertinent properties are shown in Table I.

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TABLE I. DESCRIPTION OF FLOURS

Flour	F_1	F_2	F_3
Strength	strong	weak	medium
Ash content (% dry basis)	0.75	0.72	0.70
Moisture (% dry basis)	14.3	14.3	14.3
Wet gluten (% dry basis)	41.1	21.1	34.3
Berliner value (ml.)	19	16	11
Farinograph			
Absorption (%)	60.8	54.6	56.6
Dough development time (min.)	22	1.5	2.5
Stability (min.)	10	0.5	6.5

Doughs containing 1.5% salt, 1.5% sugar, 1.25% yeast, and 0.75% fat (all on flour basis) were mixed on the farinograph with variable amounts of water to give a farinographic consistency of 500 Brabender Units.

The electric current required by the mixer was recorded by a recording amperometer and was used to calculate the consumption of energy for mixing to optimum consistency. The power in watts was calculated by multiplying the current by the voltage (220 v.). The consumption of energy was calculated from the power input, multiplied by the time of mixing in seconds divided by the weight of dough. All doughs were mixed to maximum energy consumption. Mixing time for dough from flour F_1 was 11 min.; for F_2, 2 min.; and for F_3, 6 min. Immediately after mixing, a portion of the dough was loaded into the consistometer cell. The consistency was measured at 6 min. after mixing. This relaxation time was adequate to ensure good reproducibility. A second portion of the same dough was allowed to ferment for 45 min. at 30°C. Its consistency was then measured as with the nonfermented dough.

Three doughs from each flour were tested: 1) control dough; 2) control plus 0.3% potassium bromate; and 3) control plus 0.3% ascorbic acid (percentages based on flour).

RESULTS AND DISCUSSION

Effect of Flour Quality, Potassium Bromate, and Ascorbic Acid on Energy Consumption

Table II gives the specific energy consumption during mixing of doughs from

TABLE II. EFFECT OF FLOUR QUALITY AND POTASSIUM BROMATE AND ASCORBIC ACID ON ENERGY CONSUMPTION DURING MIXING TO MAXIMUM CONSISTENCY

Flour	Treatment	Energy consumption $J.g.^{-1}$	Difference %
F_1	None	29.5	0
	Bromate (0.3%)	32.3	+9.5
	Ascorbic acid (0.3%)	25.2	−14.6
F_2	None	6.7	0
	Bromate (0.3%)	6.4	−4.6
	Ascorbic acid (0.3%)	5.8	−13.9
F_3	None	20.4	0
	Bromate (0.3%)	24.2	+18.6
	Ascorbic acid (0.3%)	19.2	−5.9

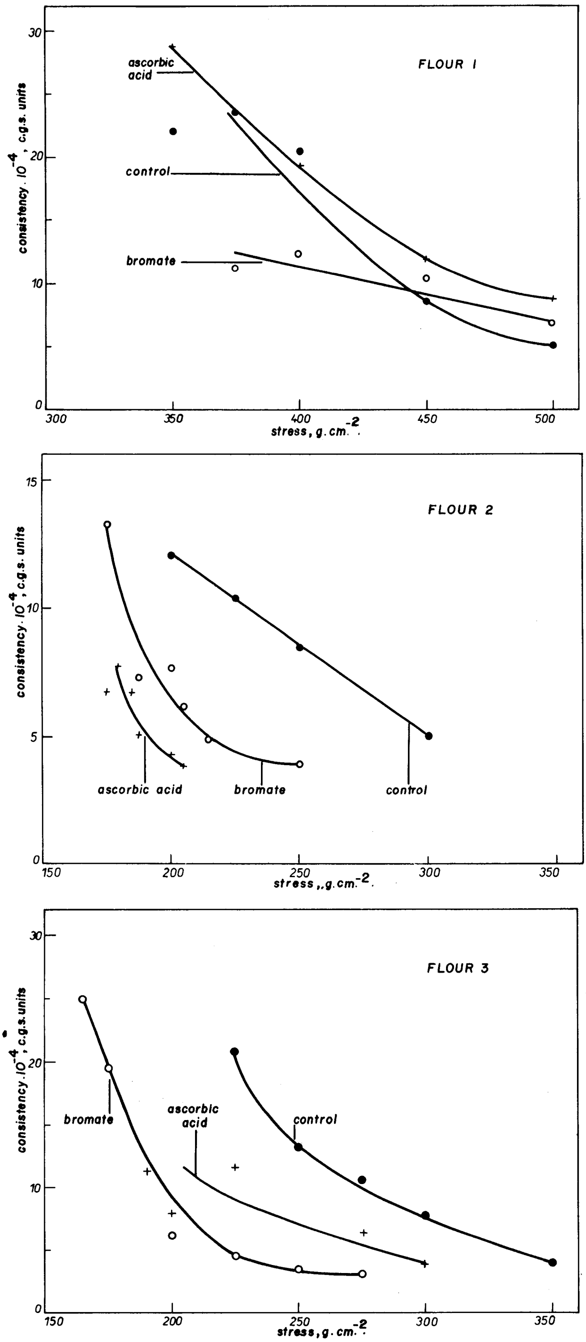

Fig. 1. Consistency curves showing the effects of potassium bromate and ascorbic acid for doughs from flours (A) F_1, (B) F_2, and (C) F_3.

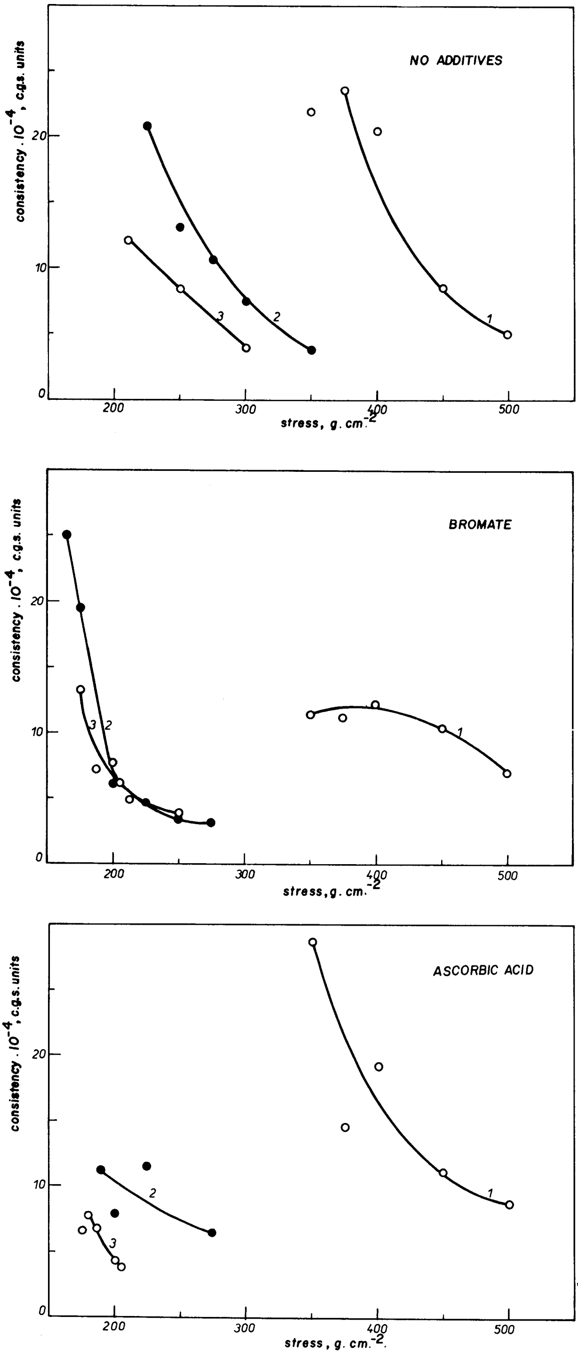

Fig. 2. Consistency curves for doughs from flours F_1, F_2, and F_3 with (A) no additives, with (B) 0.3% potassium bromate, and with (C) 0.3% ascorbic acid.

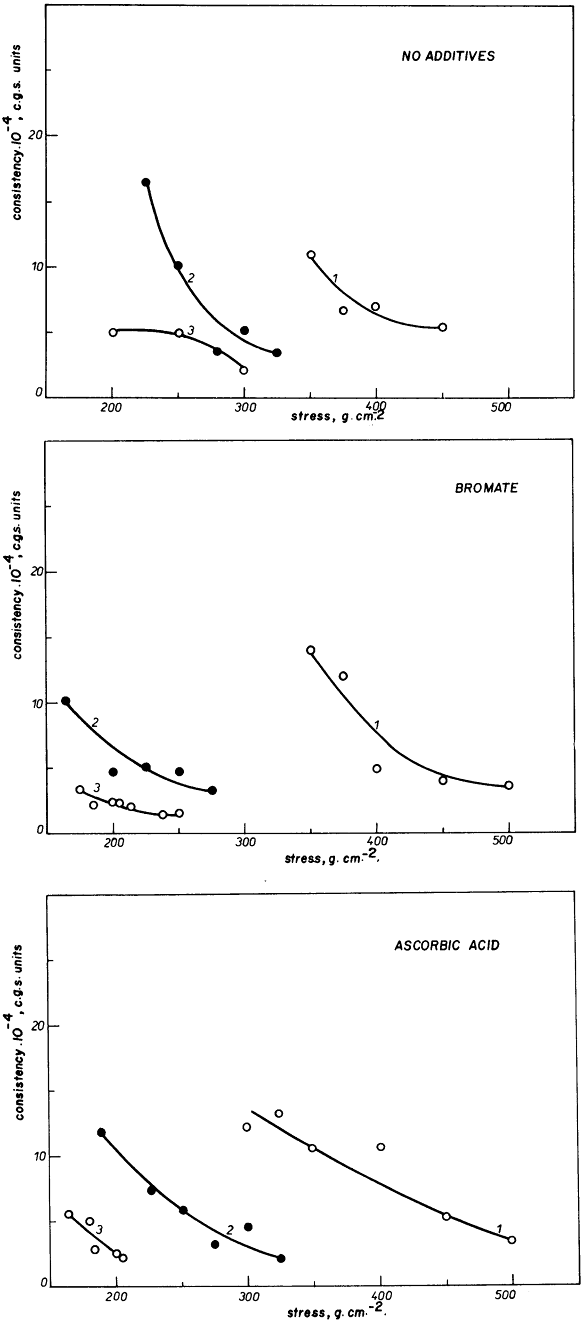

Fig. 3. Consistency curves for the doughs from flours F_1, F_2, and F_3, after 45 min. of fermentation with (A) no additives, with (B) 0.3% potassium bromate, and with (C) 0.3% ascorbic acid.

the three flours. The energy consumed depends primarily on flour quality. The stronger the flour, the higher the energy consumption. The energy increase results partly from the longer mixing time required and partly from the higher current required by the mixer. These differences are much greater than those caused by the addition of potassium bromate or ascorbic acid.

The effects of potassium bromate and ascorbic acid depend on flour strength. Addition of ascorbic acid produced a decrease in energy consumption for all three flours used, whereas the addition of bromate caused a decrease for doughs from weak flour and an increase for the two doughs from stronger flours.

Effect of Flour Quality and Bromate and Ascorbic Acid on Consistency Curves

Figure 1 shows consistency vs. stress for the three flours used. These results showed that the same amount of potassium bromate or ascorbic acid had the greater effect on the decrease of consistency in doughs from weak flour than in doughs from strong flour.

Figure 2 shows the consistency curves for the three types of dough: (a) without additives; (b) with added potassium bromate; and (c) with added ascorbic acid. The differences between the flours are accentuated by the addition of either potassium bromate or ascorbic acid.

Figure 3 shows curves analogous to those in Fig. 2, but for fermented doughs. The consistency was measured after 45 min. of fermentation. For all doughs, the consistency decreased with fermentation time. The differences between the flours were more pronounced after fermentation.

The consistency curves of the freshly mixed doughs are similar to curves for quasiplastic materials, i.e., materials that do not have a constant viscosity. For each dough fermentation decreased the slope of the curve, i.e., the consistency changed less with stress than for nonfermented doughs. This change was decreased further by the addition of potassium bromate or ascorbic acid. The consistency curves of treated doughs approached those of ideal plastic materials which have a constant viscosity. The effect of additives on the dough, immediately after mixing, was not apparent from the measurements with the Hoeppler consistometer. The curves were shifted into the range of lower stress, whereas their shape remained substantially unchanged.

DISCUSSION

The effects of ascorbic acid and potassium bromate on the consistency curves of dough varied with flour strength. In doughs from strong flour, the effects of the two maturing agents were small. On the other hand, the effects in doughs from weak flours were substantial. Both maturing agents produced a decrease in consistency determined at constant stress. The magnitude of the shift in consistency curves by ascorbic acid and bromate was accentuated by fermentation. This is not unexpected in view of the slow rate of reaction of these maturing agents in dough.

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