The Effect of Acid and Salt on the Farinogram and Extensigram of Dough

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ABSTRACT

In the farinograph test, the consistency of dough was increased by decreasing the pH with acetic acid in the absence of salt (sodium chloride), but contrarily, it tended to decrease from a lower value to the lowest, in the presence of salt. With the extensigraph, the resistance showed a fixed lower level at the pH range 5.9–4.3 without salt; however, with salt it was increased from a low level to the highest value by decreasing the pH from 5.8 to 4.2. The extensibility showed a marked decrease in both cases with or without salt.

There is considerable variation in the effects of pH upon the farinogram of dough as reported by two groups of workers.

Watanabe, Watanabe, and Uemura (1) used McIlvaine's, Michaelis's, and Sørensen's buffer (pH 2 to 12) as mixing water, and observed marked weakening after peak time and a decrease of development time with lower pH value. However, no distinct change of maximum consistency at low pH was detected.

On the contrary, Bayfield and Young (2), using the same shift in pH environment, found no increment of weakening, an increase of development time, and a marked decrease in consistency.

As for the effect of pH on extensibility of dough, earlier work by Bailey and LeVesconte (3) can be cited. A recent study on the effect of pH by Bennett and Ewart (4) with the Simon Research extensometer indicated a marked decrease of extensibility and resistance at low pH, though both had a small peak of increment at acid level lower than 10 m*M* of acetic acid per 280 g. flour. It should be noted that 2.5% sodium chloride solution was used as mixing water in this experiment.

Regarding the effect of salt, Hlynka (5) showed that 1% salt decreased the consistency of dough by 70 B.U. and 2% salt decreased it by 90 B.U. He and Bushuk (6) explained this effect in relation to the hydration capacity of dough.

The salt effects on the extensigram were shown by Fisher, Aitken, and Anderson (7) in comparison with the effect on the farinogram. They found that a raised salt level caused an increment of both extensibility and resistance.

In the theoretical consideration of these effects, the report by Grogg and Melms (8) indicated the effect of the salt level on viscous properties of flour, and that by Knyogrnichev and Komarov (9) showed the relation between swelling properties and salt varieties; these provided the authors with some references.

However, no paper could be found which dealt with the comparison of the combined effects of acid and salt on the physical properties of dough.

These experiments were undertaken to consider the behavior of dough in which the pH was lowered with acetic acid in the environment of various salt concentrations. The role of ionic groups of wheat proteins in the physical properties of dough seems to be clarified to some extent by the results of these experiments.

MATERIALS AND METHODS

The flour in this study was a bleached commercial blend from hard red winter and hard red spring wheats imported from North America. It was provided by Nisshin Flour Mills, Japan. The content of protein was 11.8%, moisture 15.0%, and ash 0.38%. Farinograph absorption was 61.5% (14% moisture basis).

Normal acetic acid was added to obtain the desired pH values of 4.2, 4.8, and 5.2 during incorporation of water into flour. The salt was also mixed in the dough as a solution in ratios of 0, 1, and 3% salt in flour by a method similar to that for the acid.

Farinograms were recorded by the procedure specified by Brabender, OHG (10). The thermostat was maintained at 30°C. and a large mixing

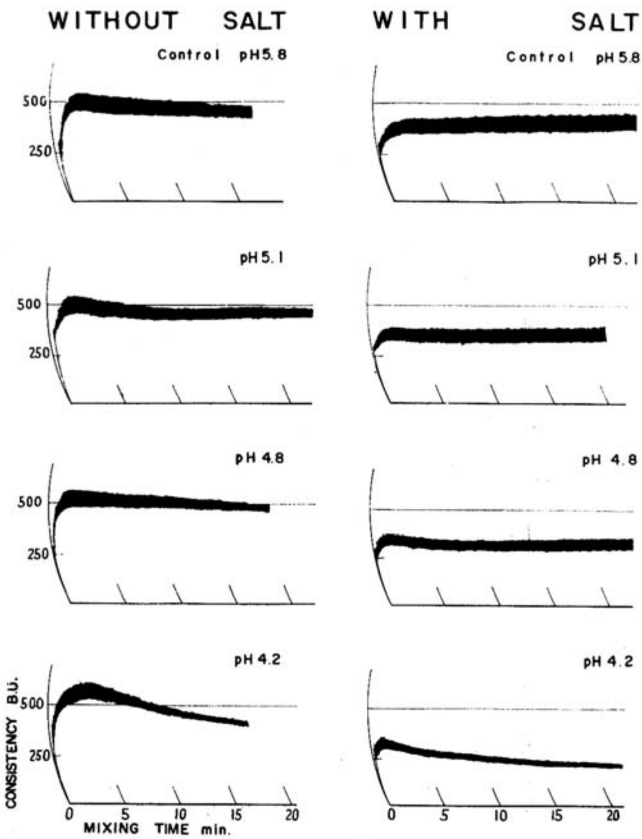


Fig. 1. Farinograms at pH 5.8, 5.1, and 4.2 with or without salt (NaCl). pH was adjusted with 1N-acetic acid, 5 ml. (pH 5.1), 10 ml. (pH 4.8), and 30 ml. (pH 4.2) per 300 g. flour. NaCl, 3% flour basis. Absorption: 61.5%.

bowl was used, employing 300 g. flour. All farinograms were recorded at the same absorption level as that in the control experiment, 61.5%.

Extensigrams were made according to the instructions supplied by Brabender, OHG, for the use of their instrument (11), with one exception, that is, no salt was used unless otherwise stated. All doughs were mixed in the large farinograph (stainless-steel) bowl to 500 B.U. consistency. Flour, water, and reagents were mixed for 1 min., followed by a 5-min. reaction period, and then mixed to 500 B.U. for 3 min. An extension test was carried out after the rest period for 45 min. Repeat tests on the same dough piece were made at 45-min. intervals after remoulding. In the figure, however, only the third extensigram in 135 min. was used.

RESULTS AND DISCUSSION

The farinograms and the maximum consistency of dough at various pH values and salt levels are illustrated in Fig. 1 and Fig. 2. The tendencies of the curves were quite different between doughs with and without salt; that is, the consistency was increased with decreasing pH in the absence of salt, and decreased in the presence of salt. The former result is a new finding, and the latter results coincide with those by Bayfield and Young (2).

The result without salt may be brought about by low ionic strength of flour itself, which is assumed as low as 0.05 mol. equivalent (12), and the tendency with salt may come from 1–3% of salt used by the present authors and 2% of salt plus 0.25% monocalcium phosphate used by Bayfield *et al.*

The deviation of the data by Watanabe *et al.* (1) from those of Bayfield and Young (2) may be due to the difference in the ionic strength of the medium or the difference in the acid buffers they used. The present authors detected various effects on the farinogram with different acids, even at the same pH (13).

The data in Fig. 2 cover both relatively low and relatively high ionic strength.

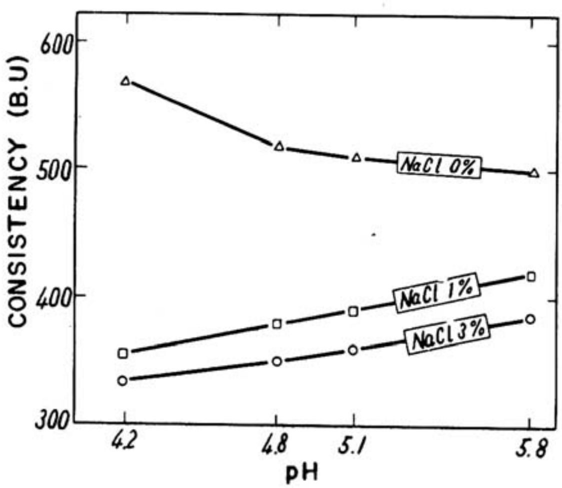
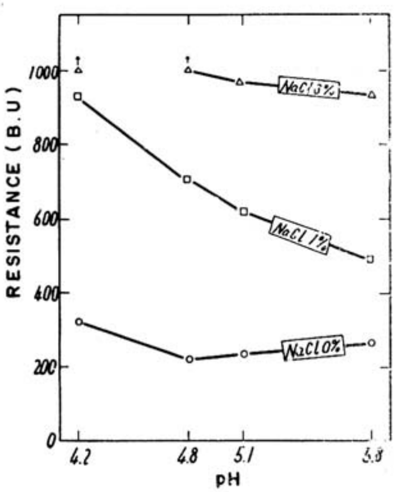


Fig. 2. The maximum consistency of dough at various pH values, containing 0, 1, and 3% sodium chloride.

The increment of consistency caused by the acid is presumed to come from specific combinations of wheat gluten with acetic acid which is estimated by dilatometry (unpublished data). It also may originate from swelling which is brought about by positive net charge of ionized group of protein at a low pH. The effect of salt to depress the raised consistency caused by acid can be explained by the function of salt which decreases bound water, as indicated by Bushuk and Hlynka (6). The competitive effect of salt against acid could be caused by replacing the region occupied by acid with salt. This hypothesis can be supported by the results of Cunningham, Geddes, and Anderson (14) in which precipitation of gluten dispersion by salt is shown.

However, the hypothesis should be considered that salt may shield the electric field of ionic groups in a limited distance by increasing ionic strength (12). In the experiment reported by Tarr (15) with fish meat, the effect of salt and acid on swelling was quite different from that of wheat protein. This may be due to the fact that meat contains larger amounts of salt-soluble proteins than wheat.

The extensibility and the resistance with the extensigraph are shown in Figs. 3 and 4. Salt has been known to increase both extensibility and



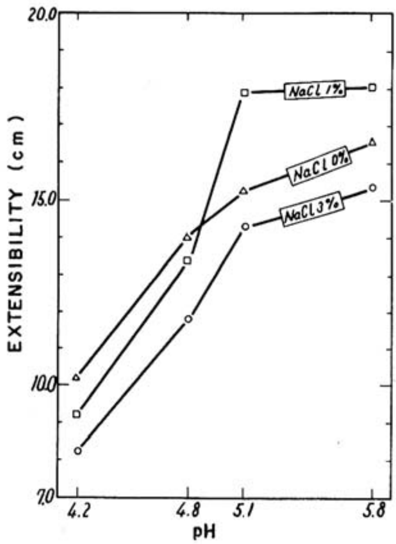


Fig. 3 (left). Resistance of dough at various pH values, containing 0, 1, and 3% sodium chloride.

Fig. 4 (right). Extensibility of dough at various pH values, containing 0, 1, and 3% sodium chloride.

resistance at normal conditions without acid. This is also shown at a point (pH 5.9) on the curve with 1 and 3% salt in Fig. 3. The increment of resistance with salt was more characteristic when the pH was lowered with acetic acid. On the other hand, the resistance of dough without salt remained low at any pH values lower than normal. A remarkable drop in extensibility was observed in all doughs, in the presence or absence of salt at low pH.

The results obtained with acetic acid in the presence of salt are in agreement with those obtained by Bennett and Ewart (4) with the extensometer. They used an acid level from 0 to 135 m*M* per 280 g. flour, and detected a peak increment of resistance at about 10 m*M* acetic acid.

This high resistance of the extensigram brought about by the salt and the acid can be explained by the slight denaturation of gluten which brings inside polar group to the outside through unfolding, and which results in network formation. Acetic acid may accelerate the denaturation with salt, and cause a specific increment of resistance at low pH values, as shown in Fig. 3.

The high resistance of the extensigram at low pH may also be caused by difficulties of the sulfhydryl-disulfide exchange reaction as shown by Tsen (16); however, the constant resistance at low pH in the cases without salt cannot be explained by this hypothesis.

Some contradictions are present in the fact that salt with acetic acid decreases the consistency of the farinogram, though it increases the resistance. The consistency of the farinogram and the resistance of the extensigram may not be synonymous rheological values which progress in parallel. For example, the reducing reagents which bring about higher consistencies at an initial stage of mixing are known to cause very low resistances on the extensigram. Similarly, higher consistencies caused by acids without salt resulted in very low resistance of the extensigraph in this experiment.

From the observation of the extensigram, the effect of acid is a breakdown of dough. This breakdown may be caused by the action of the hydrogen ion or anionic acid residue which cleaves the inter or intra salt linkages of protein molecules. In breadmaking this destructive effect of acid in sour dough seems to be canceled by the addition of salt, and thus the lactic acid in brew appears rather to improve loaf quality as shown by Bayfield *et al.* (17,18).

Acknowledgment

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Literature Cited

1. WATANABE, C., WATANABE, T., and UEMURA, M. Researches on wheat milling and qualities of wheat flour. XI. On the effect of electrolyte on the rheological behavior of wheat flour dough. Preliminary Report: On the effect of pH. Shokuryo-Kagaku Kenkyusho Kenkyu-Hokoku No. 10: 15–19 (Apr. 1955).
2. BAYFIELD, E. G., and YOUNG, W. E. Flour brew studies. V. Effect of brew fermentation time. Baker's Dig. 38(1): 69–70, 72–73 (1964).
3. BAILEY, C. H., and LEVESCONTE, AMY M. Physical tests of flour quality with the Chopin Extensimeter. Cereal Chem. **1**: 38–63 (1924).
4. BENNETT, R., and EWART, J. A. D. The reaction of acids with dough proteins. J. Sci. Food Agr. **13**: 15–23 (1962).
5. HLYNKA, I. Influence of temperature, speed of mixing, and salt on some rheological properties of dough in the farinograph. Cereal Chem. **39**: 286–303 (1962).
6. BUSHUK, W., and HLYNKA, I. Water as a constituent of flour, dough and bread. Baker's Dig. 38(6): 43–46, 92 (1964).
7. FISHER, M. H., AITKEN, T. R., and ANDERSON, J. A. Effects of mixing, salt, and consistency on extensigrams. Cereal Chem. **26**: 81–97 (1949).
8. GROGG, B., and MELMS, DIANE. A method of analyzing extensigrams of dough. Cereal Chem. **33**: 310–314 (1956).
9. KNYOGRNICHEV, M. I., and KOMAROV, V. I. The effect of salts on the swelling of wheat flour. Zavedenii Pishchevaya Tekhnol **I**: 41–42 (1966).

10. BRABENDER. Farinograph operating and maintenance instructions, pp. 14–16. Brabender, OHG, Duisburg, Germany.
11. BRABENDER. Extensograph operating and maintenance instructions, pp. 5–13. Brabender, OHG, Duisburg, Germany.
12. BLOKSMA, A. H., and HLYNKA, I. Basic considerations of dough properties (p. 498). *In* Wheat: Chemistry and technology, ed. by I. Hlynka; Monograph Series, Vol. III. American Association of Cereal Chemists: St. Paul, Minn. (1964).
13. TANAKA, K., FURUKAWA, K., and MATSUMOTO, H. Effects of organic and inorganic acids on the physical properties of dough. J. Ferment. Technol. 566–569 (1967).
14. CUNNINGHAM, D. K., GEDDES, W. F., and ANDERSON, J. A. Precipitation by various salts of the proteins extracted by formic acid from wheat, barley, rye, and oat flours. Cereal Chem. **32**: 192–199 (1955).
15. TARR, H. L. A. Effect of pH and NaCl on swelling and drip in fish muscle. J. Fisheries Research Board Can. **5**: 411–427 (1942).
16. TSEN, C. C. A note on effects of pH on sulfhydryl groups and rheological properties of dough and its implication with the sulfhydryl-disulfide interchange. Cereal Chem. **43**: 456–460 (1966).
17. BAYFIELD, E. G., and YOUNG, W. E. Flour brew studies. II. Effects of acids, pH and oxidants upon brew fermentation and the resulting bread. Bakers' Dig. **36**(1): 34–38, 77 (1962).
18. BAYFIELD, E. G., LANNUIR, G. L., and YOUNG, W. E. Flour brew studies. IV. The importance of correct pH. Bakers' Dig. **37**(2): 55–58 (1963).

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