NOTE

Effect of pH and Sodium Chloride on Wheat Flour Dough Properties: Ultracentrifugation and Rheological Measurements

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Salt linkages, electrostatic effects, and modified water structure are important for the properties of gluten, wheat flour dough, and baking (Belitz et al 1986). These effects have been studied at various levels of salt concentration, pH, and ion strength (Doguchi and Hlynka 1967; Salovaara 1982; Kinsella and Hale 1984; Holmes and Hoseney 1987; Preston 1989; He et al 1992). Sodium chloride usually shows a strengthening effect on dough properties and a decrease in farinograph absorption (Salovaara 1982; Preston 1989). The opposite effect was found for chaotropic anions at higher salt concentrations, when the effect of neutral salts of the lyotropic series was investigated (Kinsella and Hale 1984; Preston 1989). In baking experiments, these effects are not always observed, probably due to the adjustment of water content to a constant dough mixing resistance (Salovaara 1982). On the other hand, improved baking quality for sodium chloride supplemented doughs has been reported (He et al 1992). Doguchi (1967) reported a linear and moderately increasing relationship between farinograph maximum consistency of gluten and pH (4.5–6.0). In a later study, the loaf volume of baked bread also increased over the same pH region but decreased at higher pH values (Holmes and Hoseney 1987).

Earlier studies showed that the fractions obtained by ultracentrifugation of dough are sensitive to wheat cultivar, dough water content (Larsson and Eliasson 1996a), mixing time, ascorbic acid, and lipid content (Larsson and Eliasson 1996b). In the present study, the effect on dough properties of sodium chloride at concentrations related to baking and the effect of pH related to those observed in dough prepared with sour dough are reported. Dough properties are characterized by the fractionation of dough in ultracentrifugation and rheological measurements at small oscillating deformation.

MATERIALS AND METHODS

The wheat flour used was a commercial winter wheat mixture supplied by NordMills AB, Malmö, Sweden. This flour was a mixture of cvs. Tarso and Kosack (80:20) with protein 12.6% (N × 6.25), damaged starch 9.3%, falling number 328 sec, and ash 0.67%.

Flour doughs were prepared in a mixograph (Reomixer, Bohlin Reologi, Öved, Sweden). The mixing procedure followed the recommendations of the manufacturer. Flour (10 g) was mixed for 5 min at 30°C with distilled water to a dough water content of 47.0% (total basis).

The effect of pH was investigated using a solution with 1*M* lactic acid to reduce pH of the water used for dough mixing. The pH of the dough was measured with a pH-electrode punched directly into the dough. The effect of sodium chloride (NaCl) was studied using the appropriate amount dissolved in distilled water before adding to the flour.

The rheological behavior of the doughs was studied in a strain sweep test using a Bohlin VOR rheometer (Metric Analys, Stockholm, Sweden). The plate-plate geometry (diameter 15 mm, gap 2 mm) was used. The sample (≈0.45 g) was subjected to increasing strain at a frequency of 0.5 Hz. The dough tested was rested for 15 min at 30°C and sealed in plastic before it was fixed in the rheometer geometry. In the rheometer, the dough samples were covered with silicone oil to avoid water evaporation during the relaxation of residual stresses (15 min) and the measurement (3 min). For each measurement, 10 data points in the linear viscoelastic region were averaged. The data in the figures are each a mean value of at least three measurements on three different dough samples.

Doughs were centrifuged for 1 hr at 100,000 × *g* in a LE80 ultracentrifuge (Beckman Instruments, Stockholm, Sweden). The volume and the water content of the separated fractions were determined according to Larsson and Eliasson (1996a,b).

RESULTS AND DISCUSSION

An earlier study showed that the loaf volume of baked bread increased at pH 4.65–6.15 and decreased at higher pH values (Holmes and Hoseney 1987). The same study reports similar results for sodium chloride, with higher loaf volumes for concentrations ≤1.5–2.0%. The properties of wheat flour dough observed by ultracentrifugation, amount of dough fraction (liquid, gel, gluten, starch, and unseparated dough), and the water content of the individual fractions are influenced by factors important for baking and dough quality (Larsson and Eliasson 1996a,b), such as the effect of pH and sodium chloride.

The pH of dough was reduced to 5.5 and 4.5. The pH of the reference dough, to which no acid had been added, was 5.9. An effect on the ultracentrifugation behavior was observed only in dough at pH 4.5. Slightly smaller amounts of liquid, gel, gluten, and unseparated phases resulted (Fig. 1A). The water content of the liquid and gel phases decreased moderately, but it decreased significantly when pH was reduced to 4.5 (Table I). Note that the water content of the gluten phase was not affected, nor was a significant effect of pH observed on the viscoelastic properties determined at small deformations (results not shown). This may be compared with a moderate increase in farinograph maximum consistency, but there was no effect on peak development time of mixed gluten at pH 4.5–6.0 as reported earlier by Doguchi (1967).

A smaller amount of gluten and a larger amount of liquid phase were both detected when 0.5% NaCl (fwb) was added (Fig. 1B). The gluten phase contained less water after centrifugation (Table I).

TABLE I
Water Content of Separated Phases

	Liquid	Gel	Gluten	Starch	Unseparated
pH					
5.90[a]	85.0±0.2	79.8±0.3	55.3±0.3	28.5±0.4	30.4±0.2
5.52	85.0±0.2	79.8±0.3	55.3±0.3	28.5±0.4	30.4±0.2
4.52	82.5±0.4	77.5±0.4	56.1±0.4	29.8±0.0	30.1±0.1
NaCl[b]					
0.0[a]	85.0±0.2	79.8±0.3	55.3±0.3	28.5±0.4	30.4±0.2
0.5	85.1±0.4	78.9±0.1	53.6±0.7	30.5±0.4	31.1±1.6
1.0	85.1±0.3	79.4±0.1	53.1±0.4	31.0±0.2	31.1±0.8

[a] Reference.
[b] Flour weight basis (%).

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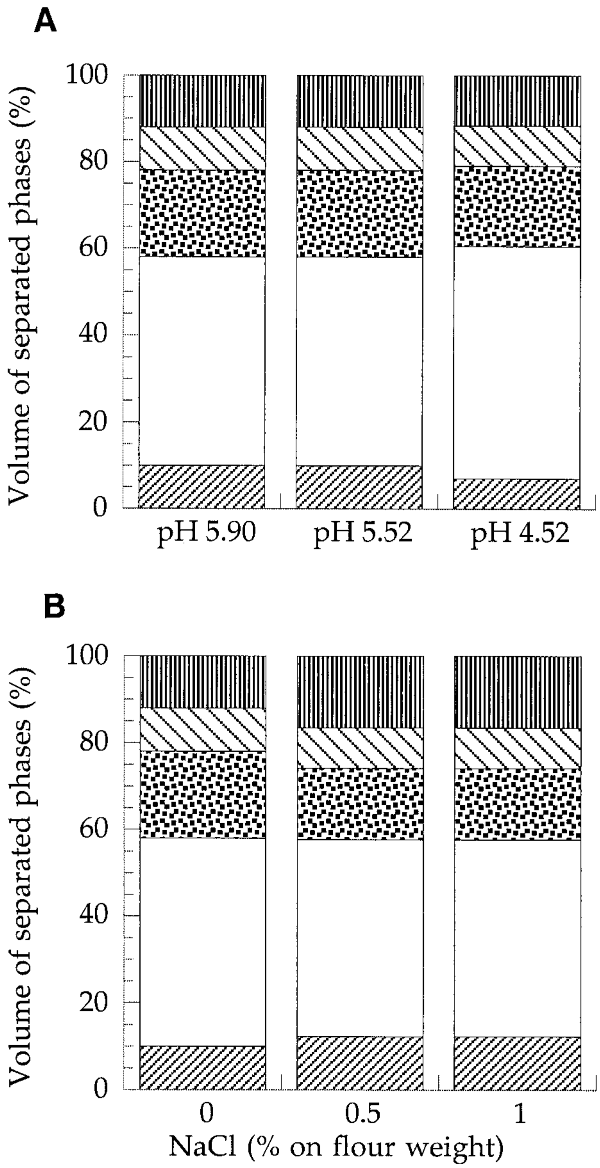

Fig. 1. Effect of pH (**A**) and NaCl at pH 5.90 (**B**) on the separation of wheat flour dough by ultracentrifugation. Dough fractions (top to bottom) are: liquid, gel, gluten, starch, and unseparated dough.

On the other hand, remarkably a higher water content was observed for the starch fraction after centrifugation. A moderate but significant increase in the value of the storage modulus (G') was detected in small deformation rheological measurements when 1–2% NaCl was included in the dough (Fig. 2). The lower water content of the gluten fraction obtained after centrifugation and the increase in G' of dough may be compared with the reported observations of a decrease in farinograph absorption and increased dough strength for doughs mixed with NaCl (Salovaara 1982; Preston 1989).

Considering the different effects caused by reducing pH and adding NaCl, it may be interesting to compare the results with the protein classes present in different fractions separated by ultracentrifugation. The proteins dominating the liquid and gel phases are mainly albumin and globulin type proteins, and most of the proteins in the gluten phase are storage (gluten) proteins. However, all other protein classes were detected as traces in all phases (R. Kuktaite, H. Larsson, and E. Johansson, *unpublished*). In conclusion, reduced pH mainly influenced the liquid and gel phases, and the gluten phase was most affected by adding NaCl. Considering protein as the primary component affected by pH and salt, it seems that pH influences mainly albumins and globulins and NaCl has the greatest effect on gluten proteins. Moreover, the results reported indicate that ultracentrifugation is a sensitive tool to detect small effects, such as water distribution in dough, that are caused by conditions influencing baking behavior. The main advantage of the technique is that fresh dough samples are used.

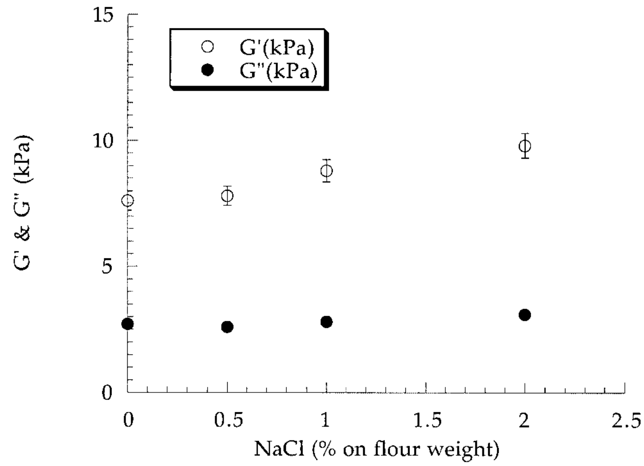

Fig. 2. Effect on storage and loss modulus (G' and G'') of wheat flour dough by increasing concentration of NaCl.

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LITERATURE CITED

Belitz, H.-D., Kieffer, R., Seilmeier, W., and Weiser, H. 1986. Structure and function of gluten proteins. Cereal Chem. 63:336-341.

Doguchi, M., and Hlynka, I. 1967. Rheological properties of crude gluten mixed in the farinograph. Cereal Chem. 44:561-575.

He, H., Roach, R. R., and Hoseney, R. C. 1992. Effect of nonchaotropic salts on flour bread-making properties. Cereal Chem. 69:366-371.

Holmes, J. T., and Hoseney, R. C. 1987. Chemical levening: Effect of pH and certain ions on bread making properties. Cereal Chem. 64:343-348.

Kinsella, J. E., and Hale, M. 1984. Hydrophobic associations and gluten consistency: Effect of speciffic anions. J. Agric. Food Chem. 32:1054-1056.

Larsson, H., and Eliasson, A.-C. 1996a. Phase separation of wheat flour dough studied by ultracentrifugation and stress relaxation I. Influence of water content. Cereal Chem. 73:25-31.

Larsson, H., and Eliasson, A.-C. 1996b. Phase separation of wheat flour dough studied by ultracentrifugation and stress relaxation II. Influence of mixing time, ascorbic acid, and lipids. Cereal Chem. 73:18-24.

Preston, K. R. 1989. Effects of neutral salts of the lyotropic series on the physical dough properties of a Canadian red spring wheat flour. Cereal Chem. 66:144-148.

Salovaara, H. 1982. Effects of partial sodium chloride replacement by other salts on wheat dough rheology and breadmaking. Cereal Chem. 59:422-426.

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