Effect of Certain Salts on Bread Loaf Volume and on Soluble Nitrogen of Wheat Flour and Nonfat Dry Milk Slurries[1]

R. R. ROACH,[2] C. S. LAI,[2,3] and R. C. HOSENEY[2]

ABSTRACT

The amount of soluble nitrogen (SN) in a slurry containing wheat flour and nonfat dry milk (NFDM) was less than the sum of the SN in slurries that contained only the individual components. The addition of sodium chloride to a flour-milk mixture caused the amount of SN to increase to near the level of the sum of the SN of the two components. Possibly, this resulted from a reduction in an interaction between NFDM and flour proteins by charge shielding. The effect of sodium chloride on improving bread loaf volume when NFDM is present may be related to its effect on the NFDM-flour interaction. Sodium iodide also improved loaf volume and increased the SN of the composite slurry. Calcium chloride did not increase the amount of SN in the composite slurry nor did it improve bread loaf volume.

Cereal Chem. 69(5):574–576

Neutral salts have long been known to affect protein solubility (Hofmeister 1888). At low salt concentrations, protein solubility tends to increase and can be explained by the Debye-Hückel theory as an electrostatic event (Arakawa and Timasheff 1985). However, Preston (1981) showed that solubility of wheat gluten proteins decreased rather than increased at low salt concentration. This was suggested to be caused by charge shielding of the protein's ionized groups.

As salt concentrations increase, the specific ion present becomes important, and its effect on protein solubility is related to more than the valency and charge density of the ions (Hofmeister 1888). Hofmeister established the lyotropic series that relates ions according to their effect on proteins. Preston (1981) found wheat gluten protein solubility at high salt levels ($>0.5M$) to be affected in agreement with this relationship. The salt commonly used in breadmaking, sodium chloride, was shown to decrease solubility of the proteins as its concentration increased, as predicted by the lyotropic series.

Sodium chloride influences wheat flour dough properties (i.e., mixing requirements, optimum absorption, and ease of processing) and bread quality (loaf volume). These changes may be related to the effect of sodium chloride on protein solubility.

Another ingredient used in bread that has been found to influence characteristics of dough and bread is nonfat dry milk (NFDM) (Moore and Herman 1942, Pyler 1988). Further, it has been suggested (Skovholt and Bailey 1932) that sodium chloride influences the effect that NFDM has on increasing optimum absorption. Skovholt and Bailey (1932) reported that the presence of sodium chloride was necessary to achieve the maximum increase in absorption that occurs with the inclusion of NFDM. The addition of sodium chloride with NFDM increased the optimum absorption about twice as much as NFDM did alone. For example, 4% flour weight basis NFDM increased absorption by 2%, but the addition of 1.75% sodium chloride with the NFDM increased the absorption by 4%. However, Hlynka (1962) reported that sodium chloride (with no NFDM) actually decreased optimum absorption. Moore and Herman (1942) showed that sodium chloride, at the levels used in bread (1.5–2.0%), did not greatly affect the optimum absorption.

Holmes and Hoseney (1987a,b) reported evidence that indicates an interaction between flour and NFDM. They showed that NFDM had a negative effect on loaf volume when sodium chloride was not included in the bread formula. Bread containing NFDM and no sodium chloride had a smaller loaf volume than did bread with neither ingredient. The addition of sodium chloride to bread containing NFDM improved loaf volume. For maximum loaf volume, the optimum level for salt was about 1.5% flour weight basis. Bread without NFDM had an optimum sodium chloride level of 0–0.5%. Thus, NFDM had a negative effect on bread loaf volume when used alone, but when used in combination with sodium chloride, a positive effect occurred.

Although NFDM seldom is used in the baking industry today, it remains a part of official methods. In addition, the action of NFDM may be a good model for many milk replacers (soy flour or soy flour-whey blends) that are used in the industry. The effect of NFDM on bread and the influence of sodium chloride on this effect may involve the wheat flour proteins. Measurements of soluble nitrogen (SN) were made with flour and NFDM alone and combined in slurries with and without salt in an attempt to better understand the role sodium chloride plays in bread.

MATERIALS AND METHODS

Materials

Two lots of hard red winter wheat flours were used in this study (donated by Cargill, Wichita, KS). The protein, ash, and moisture contents were 12.0, 0.48, and 11.4 for lot A and 11.5, 0.47, and 12.8 for lot B, respectively. NFDM (high heat treated) was supplied by Galloway West, Fond-du-Lac, WI, and Knudsen, Visalia, CA. Sodium chloride, sodium iodide, and anhydrous calcium chloride were reagent grade.

Soluble Nitrogen

Distilled water (100 ml) was added to the appropriate dry ingredients. The ingredients and levels used are as follows: wheat flour, 20 g; NFDM, 0.8 g; sodium chloride, 0.3 g; sodium iodide, 0.77 g; and calcium chloride, 0.285 g. The salts were added to equivalent anion content. The capped bottle was shaken vigorously by hand 50 times to blend the dry ingredients and water. An additional 100 ml of distilled water then was added and the bottle was shaken 10 times. The capped bottle was placed on a wrist-action shaker (Burrell Corp., Pittsburgh, PA) for 1 hr at high speed. The resultant mixture was centrifuged for 15 min at $1,000 \times g$. The supernatant was filtered through glass wool with suction. Two replicate samples of each treatment were prepared, and 50 ml of the filtrate from each was analyzed for nitrogen by the Kjeldahl method.

Pup Loaf Baking Procedure

The straight-dough baking procedure followed was described by Finney (1984). The formula included 6.0% sugar, 4% NFDM, 3.0% shortening, 1.5% salt, optimum water, and $KBrO_3$. All percentages are based on 100 parts of malted flour (14% mb). The dough was mixed to optimum (minimum mobility) in a National Special 100-g pin mixer (National Manufacturing Co., TMCO, Lincoln, NE). The dough was fermented in a proof cabinet (National) at 30°C and 90–95% rh for 180 min. During fermentation, the dough was sheeted at a gap of 4.76 mm (3/16 in.) after 105 and 155 min. At the end of fermentation, the dough

[1]Contribution 91-8-J, Kansas Agricultural Experiment Station, Manhattan 66506.

[2]Graduate research assistant, graduate research assistant, and professor, respectively, Department of Grain Science and Industry, Kansas State University, Manhattan 66506-2201.

[3]Present address: General Mills, Inc., Minneapolis, MN.

was sheeted at a gap of 7.94 mm (5/16 in.) and then molded in a drum molder (Thomson Machine Co., Beltsville, NJ). The dough piece was placed in a pan (77 × 142 mm top, 62 × 126 mm bottom, 57 mm depth) and then proofed at 30°C and 90–95% rh for 55 min. The proofed dough was baked at 218°C for 24 min. Immediately upon removal from the electric reel oven (National), the loaf was weighed and the volume was determined by rapeseed displacement.

As individual salts were evaluated, sodium chloride was removed from the formula. Removal of NFDM also was as indicated.

Statistical Analysis

Data were evaluated by analysis of variance with *t* tests (LSD) using the Statistical Analysis System (SAS Institute 1985).

RESULTS AND DISCUSSION

The sum of SN found in a flour slurry plus that in an NFDM slurry was greater than the SN when the two were combined into a single system (Fig. 1). The presence of sodium chloride did not increase the amount of SN in the individual protein sources (Fig. 1). However, when sodium chloride was added to the slurry containing flour and NFDM, the SN was increased to near that of the sum of the SN of the components. In this case, the sodium chloride acted to solubilize protein, which it did not do with the individual components. The solubilizing action of sodium chloride may have been caused by charge shielding on both proteins. This then may have stopped the desolubilizing interaction between the flour and the NFDM proteins. It is not clear whether the NFDM protein interacts with the soluble or the insoluble flour protein. However, at the pH of dough (~ 5.0–6.0), the gluten proteins have a net positive charge and NFDM proteins have a net negative charge. Thus, we assume that the NFDM proteins are interacting with the gluten proteins and not with the water-soluble proteins from flour. The prevention of this interaction may be related to the effect that sodium chloride has in improving bread that contains NFDM (Fig. 2). Clearly, the addition of NaCl to a dough containing NFDM greatly improves the loaf volume. This confirms the findings of Holmes and Hoseney (1987b). The decrease in loaf volume at higher levels of salts is undoubtedly attributable to the effect of a high level of salt on fermentation.

Sodium chloride is a nonchaotropic salt that improves the loaf volume when NFDM is present (Fig. 2). Sodium iodide is a

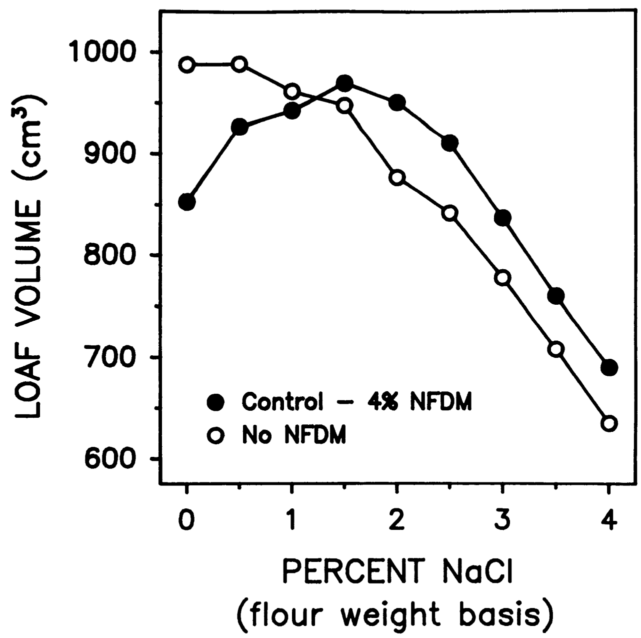

Fig. 2. Effect of sodium chloride on loaf volume of bread with and without nonfat dry milk (NFDM).

TABLE I
Effect of Sodium Iodide on Loaf Volume, Flour B

Treatment	Loaf Volume[a] (cm^3)	Proof Height (cm)
Control	987 a[b]	. . .
No salt	953 b	7.9 a
Sodium iodide		
0.25%	955 b	7.9 a
1.00%	963 b	7.9 a
1.50%	980 a	7.9 a
2.00%	960 b	7.8 b

[a] Average of at least two observations.
[b] Values within columns followed by different letters indicate statistically significant differences at the 5% level.

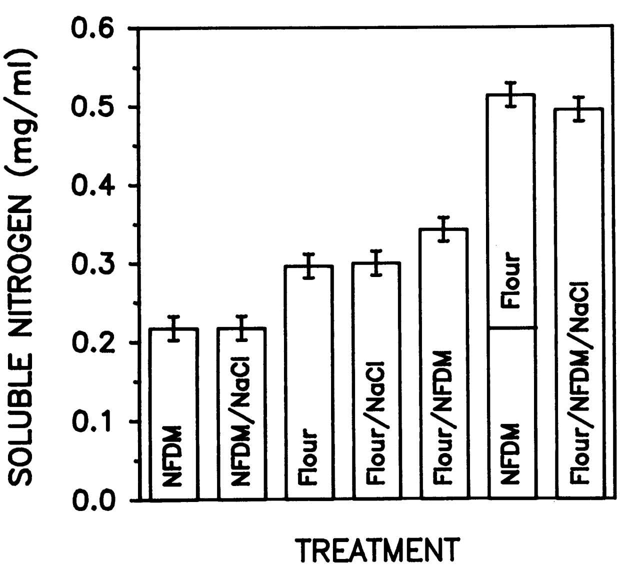

Fig. 1. Effect of sodium chloride on soluble nitrogen of nonfat dry milk (NFDM), flour, and NFDM-flour slurries. NFDM was used at 4% and sodium chloride at 1.5% flour weight basis when either or both were included in a slurry. Error bar represents LSD value for statistically significant differences at the 5% level.

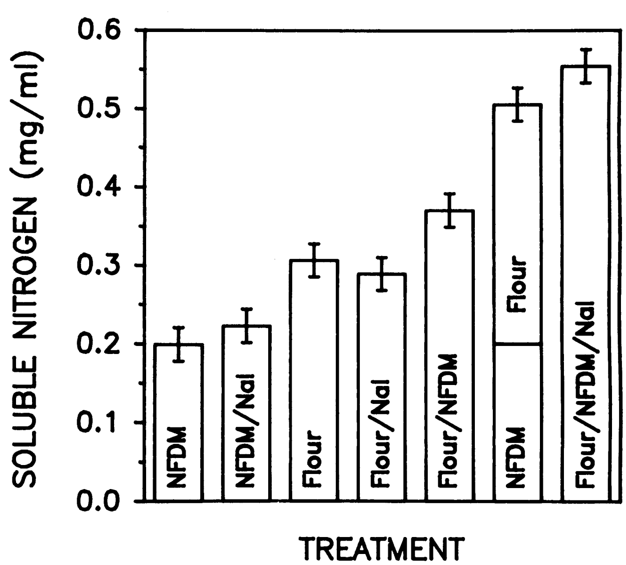

Fig. 3. Effect of sodium iodide on soluble nitrogen of nonfat dry milk (NFDM), flour, and NFDM-flour slurries. NFDM was used at 4% flour weight basis when included in a slurry. Sodium iodide, when present in a slurry, was used at a level (3.85%) to provide anionic strength equivalent to 1.5% sodium chloride. Error bar represents LSD value for statistically significant differences at the 5% level.

chaotropic salt that also improves the loaf volume in the presence of NFDM (Table I). The effect of this salt on SN (Fig. 3) was shown to be similar to the effect of sodium chloride on SN. It had little effect on SN of flour and NFDM when slurried separately. The increase of SN in the composite slurry was similar to the increase when sodium chloride was used. Thus, the action may have been a charge-shielding effect similar to that of sodium chloride.

Calcium chloride is a chaotropic salt that does not improve loaf volume (Table II). Therefore, its effect on SN also was studied (Fig. 4). Calcium chloride did not affect the SN of NFDM, but it did increase the amount of SN of the flour above that when no salt was present, indicating a solubilizing effect on the flour proteins. This in agreement with the action of this salt on proteins as found by Gortner et al (1929). Calcium chloride, in combination with flour and NFDM, also increased SN but only by an amount equal to that in flour alone. That increase did not equal the sum

TABLE II
Effect of Calcium Chloride on Loaf Volume

Treatment	Loaf Volume[a] (cm^3)	Proof Height (cm)
Control	890 a[b]	. . .
No salt	835 b	7.6 a
Calcium chloride		
0.5%	773 c	7.3 b
1.0%	705 d	6.5 c
1.5%	695 de	6.5 c
2.0%	675 e	6.2 d
2.5%	622 f	5.8 e
3.0%	625 f	5.5 f
3.5%	610 fg	5.2 c
4.0%	593 g	4.8 h
5.0%	515 h	4.4 i

[a] Average of at least three observations.
[b] Values within columns followed by different letters indicate statistically significant differences at the 5% level.

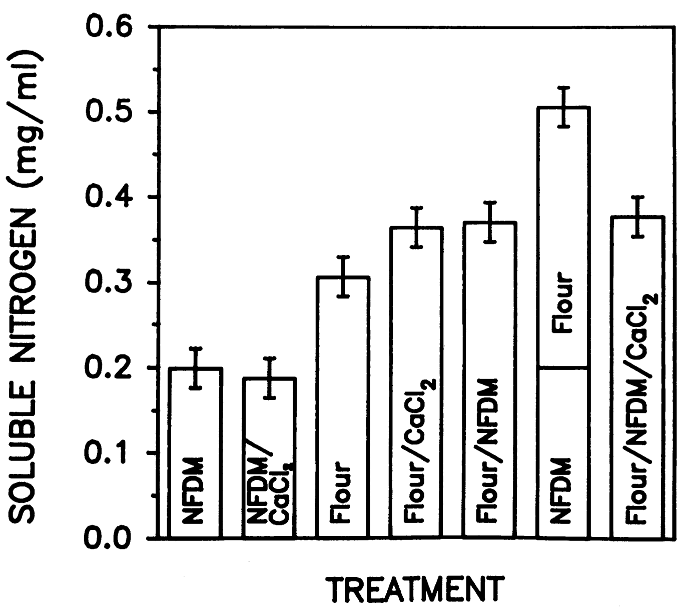

Fig. 4. Effect of calcium chloride on soluble nitrogen of nonfat dry milk (NFDM), flour, and NFDM-flour slurries. NFDM was used at 4% flour weight basis when included in the slurry. Calcium chloride, when present in the slurry, was used at a level (1.425%) to provide anionic strength equivalent to 1.5% sodium chloride. Error bar represents LSD value for statistically significant differences at the 5% level.

of the SN of both components, as with sodium chloride or sodium iodide. Therefore, calcium chloride did not show the apparent protecting effect of sodium chloride, at least to the same extent, and this may relate to the fact that it does not improve loaf volume for bread containing NFDM.

At higher concentrations of all salts, the activity of yeast is affected. However, the negative effect of salt on yeast activity does not completely explain the effect of salts on loaf volume. Proof heights of dough containing sodium chloride or iodide were not significantly different between 0 and 2%. Over this same range of salt concentration, the loaf volume increased. Calcium chloride was more severe on yeast activity as shown by the proof heights (Table II).

CONCLUSIONS

The addition of NFDM to a bread formula that contains no salt caused a negative effect on loaf volume. This negative effect may arise through interactions between the proteins in NFDM and flour. Evidence of that interaction was the lower SN content of a system containing both NFDM and flour compared with the sum of the SN contents of separate slurries containing NFDM or flour. It is not clear which flour proteins are interacting with the NFDM. However, the gluten proteins would be most likely because, in a dough, they may have a charge opposite that of NFDM proteins.

The negative effect of NFDM is removed by the addition of certain salts to the bread formula. The salts, apparently by charge shielding, prevent a deleterious interaction of NFDM and flour proteins. This reduced interaction was shown by SN measurements. The addition of sodium chloride or iodide to a slurry containing both NFDM and flour increased SN to a level near that of the of the sum of the individual components. However, the presence of those salts did not increase the SN of slurries containing NFDM or flour separately.

LITERATURE CITED

ARAKAWA, T., and TIMASHEFF, S. 1985. Theory of protein solubility. Methods Enzymol. 114:49.

FINNEY, K. F. 1984. An optimized, straight-dough, bread-making method after 44 years. Cereal Chem. 61:20.

GORTNER, R. A., HOFFMAN, W. F., and SINCLAIR, W. B. 1929. The peptization of wheat flour proteins by inorganic salt solutions. Cereal Chem. 6:1.

GUY, E. J., VETTEL, H. E., and PALLANSCH, M. J. 1967. Effect of salts of the lyotropic series on the farinograph characteristics of milk-flour dough. Cereal Sci. Today 12:200.

HLYNKA, I. 1962. Influence of temperature, speed of mixing, and salt on some rheological properties of dough in the farinograph. Cereal Chem. 39:286.

HOFMEISTER, F. 1888. Zur Lehre von der Wirkung der Salze. Zweite Mittheilung. Cited in Guy et al (1967).

HOLMES, J. T., and HOSENEY, R. C. 1987a. Chemical leavening: Effect of pH and certain ions on breadmaking properties. Cereal Chem. 64:343.

HOLMES, J. T., and HOSENEY, R. C. 1987b. Frozen doughs: Freezing and thawing rates and the potential of using a combination of yeast and chemical leavening. Cereal Chem. 64:348.

MOORE, C. L., and HERMAN, R. S. 1942. The effect of certain ingredients and variations in manipulations on the farinograph curve. Cereal Chem. 19:568.

PRESTON, K. R. 1981. Effects of neutral salts upon wheat gluten protein properties. I. Relationship between the hydrophobic properties of gluten proteins and their extractibility and turbidity in neutral salts. Cereal Chem. 58:317.

PYLER, E. J. 1988. Baking Science and Technology, Vols. 1 and 2. Sosland Publishing Co.: Merriam, KS.

SAS INSTITUTE, INC. 1985. SAS User's Guide: Statistics. Version 5 ed. SAS Institute, Inc.: Cary, NC.

SKOVHOLT, O., and BAILEY, C. H. 1932. The effect of temperature and of the inclusion of dry skim milk upon the properties of doughs as measured with the farinograph. Cereal Chem. 9:523.

[Received October 15, 1990. Accepted March 23, 1992.]