Role of Salt in Baking

The general term salt in baking formulas refers to sodium chloride. Salt is one of the four essential ingredients in bread (flour, salt, yeast, and water). The functions of salt in baking include stabilizing yeast fermentation rate, strengthening the dough, enhancing the flavor of the final product, and increasing dough mixing time.

Increased mixing time can be explained as follows. In a flour-water system at a normal pH (~6.0), the gluten protein has a net positive charge. These positive charges repulse each other. This allows the gluten to hydrate faster (shorter mixing time) and keeps the protein chains from interacting with each other, resulting in a weaker dough. Low levels of salt shield the charges (19) allowing the protein chains to approach each other. This causes the dough to hydrate more slowly (longer mixing time) and allows the protein chains to react more tenaciously to form a stronger dough (3,4,29). Danno and Hoseney (4) showed that doughs that had been overmixed to the point that they had lost their elastic character could be returned to a normal elasticity by the addition of salt. They also showed that at high levels of salt (>10%), dough did not form in the time frame of the experiment (Fig. 1).

It is well known in the baking industry that salt lengthens the mixing time of dough (Fig. 1). This has been well documented by the farinograph (7,13,17, 21,22,27,29) and in the mixograph (4, 12,24). The longer mix time slows the rate of production in large bakeries that are on tight production schedules and increases the energy cost of mixing. Therefore it is common practice to delay salt addition until the dough has reached the clean-up stage (when the dough forms into a continuous mass and no longer sticks to the sides of the mixer). At this stage the dough is essentially hydrated and the added salt does not affect the time required to finish mixing.

Farinograph studies have also shown that salt decreases water absorption (7,13, 21,22,27,29). This effect was not reported in mixograph or baking studies.

It is well known that salt has a strengthening effect on dough. This has been documented in the farinograph (7,13,17,22, 27,29), mixograph (4,12,24), extensigraph (21,27), and baking studies (5,6,9).

The effect of salt on mixing time and dough strengthening is explained as follows. In a flour-water system at a normal pH (~6.0), the gluten protein has a net positive charge. These positive charges repulse each other. This allows the gluten to hydrate faster (shorter mixing time) and keeps the protein chains from interacting with each other, resulting in a weaker dough. Low levels of salt shield the charges (19) allowing the protein chains to approach each other. This causes the dough to hydrate more slowly (longer mixing time) and allows the protein chains to react more tenaciously to form a stronger dough (3,4,29). Danno and Hoseney (4) showed that doughs that had been overmixed to the point that they had lost their elastic character could be returned to a normal elasticity by the addition of salt. They also showed that at high levels of salt (>10%), dough did not form in the time frame of the experiment (Fig. 1).

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In addition to sodium chloride, there are other salts that are important in baking, especially in chemically leavened products such as cake, biscuits, pancakes, etc.

It has been reported that cereal products contribute about 25% of the sodium intake in Western diets.

Potassium chloride is widely used as a partial salt substitute.

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The flavor-enhancing function of salt is well known. Omitting salt from the formula results in baked products that are quite tasteless. At the level used, salt does not impart a salty taste to the product but rather brings out the other flavors in the system. It is also known to increase sweetness and mask metallic, bitter, or other off flavors. The reasons and mechanism of this function of salt are outside the expertise of the authors and will not be discussed further in this manuscript.

An important function of salt in breadmaking is its stabilizing effect on fermentation. In dough made without salt, the yeast ferments excessively resulting in gassy, sour dough and baked products with open grain and poor texture (14). Salt inhibits or “controls” fermentation rate by decreasing the rate of gas production (6), which results in longer proof times (18,25). This appears to be the result of increased osmotic pressure and the action of the sodium and chloride ions on the membrane of the yeast cells (14). Salt gives the baker a tool to control the production of carbon dioxide gas and the other products of fermentation, especially in the warm summer months if temperature control is a problem in the bakery.

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Although salt increases dough strength, levels of salt above the optimum level of 1.5–2% for bread (5) do not necessarily improve loaf volume. Holmes and Hoseney (9) observed a substantial decrease in volume of loaves at elevated salt levels. They also observed that salts other than sodium chloride had a deleterious effect on loaf volume (on Fig. 2).

He et al. (6) studied the effect of different salts on the baking properties of flours that varied widely in baking quality. They reported that sodium sulfate greatly improved the rheological properties, loaf volume, and crumb grain of the poor-quality flour but made the good quality flour too elastic (bucky) for good breadmaking. The improvement of the poor quality flour was assumed to be by increasing the hydrophobic interactions between the gluten proteins. They also found that the improvement in baking quality of the poor quality flour by salts was limited. While the improvement was substantial, it did not improve the baking properties of the poor quality flour to the level produced using good quality flour and sodium chloride. This suggests that factors other than hydrophobic interactions affect the baking properties of flours.

In addition to sodium chloride there are other salts that are important in baking, especially in chemically leavened products such as cake, biscuits, pancakes, etc. In chemical leavening reactions, sodium bicarbonate is reacted with an acidic salt in the presence of moisture and heat to form carbon dioxide as the leavening agent. Water and salt are also produced in the reaction. Holmes and Hoseney (9) used a combination of yeast and chemical leavening to show that certain ions were detrimental to loaf volume. Both rheological (mixograph) and baking studies showed that the effect of the ions was related to their position in the anionic lyotropic series (Hofmeister series). The Hofmeister series ranks various ions on their ability to precipitate proteins from solution (8). The series lists both anions and cations in order from most stabilizing (nonchaotropic) to most destabilizing (chaotropic). The order for anions from nonchaotropic to chaotropic is $SO_4^2- > PO_4^{3-} > F^- > Cl^- > Br^- > I^- > NO_3^- > ClO_4^- > SCN^-$. The order for cations is $NH_4^+ > Cs^+ > Rb^+ > K^+ = Na^+ > H^+ > Ca^{2+} > Mg^{2+} > Al$. The anions have a much greater effect than do the cations. Although most agree that the series has its effect by its action on water, there is still debate about how it does this (for a discussion of current research on the topic, see Chemical & Engineering News, Nov. 28, 2007, p. 47). In general terms, the nonchaotropic salts cause the protein to be less hydrated, more structured, and less soluble. The chaotropic salts have the opposite effect with the protein being more hydrated and more soluble. The salts thus can have pronounced effects on both hydrogen bonding and on hydrophobic interactions between proteins.

Salt also affects the water phase of the dough system. Increased salt concentration generally increases the ordering of water structure. This ordering is highly dependent on the anion type, with nonchaotropic ions strongly promoting ordering. The increase in ordered water structure allows proteins to interact with each other through hydrophobic interactions (16,28).

Wheat gluten has been shown to contain about 35% hydrophobic amino acids (15). This is greater than the 28% that Kinsella (10) suggested could be accommodated in a hydrophobic core. Thus, wheat gluten has surface hydrophobicity, which promotes protein aggregation through hydrophobic interactions. Bernardin (2) suggested that these hydrophobic interactions play an important role in the rheological and baking properties of flours. The fact that neutral salts could alter the hydrophobic interactions between gluten proteins has been suggested by a number of workers (1,4,11,19–22, 29).

As shown above, different salts have widely different effects on dough rheology. At first glance it appears that by selecting the right salt one could obtain the rheology desired for baking. However, the effect of various ions on yeast activity and...
on human health must be kept in mind as well as the effect of the various salts on the taste of the final product.

Salt contains 39% sodium. Consumption of high levels of sodium has been linked to hypertension (high blood pressure). It has been reported that cereal products contribute about 25% of the sodium intake in Western diets (23). This has spurred interest in reducing the sodium chloride level or completely or partially replacing sodium chloride in baked product formulations with alternative salts.

Wyatt (30) reports that the salt content of white or whole wheat bread could be reduced by 50% with no change in flavor or overall acceptability. Sensory tests showed that 20% of the sodium chloride could be replaced with potassium chloride or 10% of the sodium chloride could be replaced with magnesium chloride or magnesium acetate without causing a deleterious effect on bread flavor (23). Takano et al. (26) suggest that sodium chloride in bread can be completely replaced with potassium gluconate with no effect on loaf volume or overall desirability. Potassium chloride is a widely used salt substitute. It has been shown to have an effect in baking similar to sodium chloride except that at high levels it imparts an undesirable off flavor often described as metallic, bitter, or chemical in nature (22). Mixtures of 50% sodium chloride and 50% potassium chloride have frequently been used with fair results in reduced-sodium products (14).

References