Technologies of salt reduction in bread: issues, problems and solutions

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Outline:

• Salt in bread
  – Content
  – Bread as source of sodium
• The rationale: effects of salt in bread
  – Technological
  – Sensory
• Salt reduction and replacement
• Notes and conclusions
Main messages:

- Bread is a major source of salt (25-35%)
- Salt (NaCl) has many roles in bread
- **Taste** is the critical issue
  - Other (technological) problems in salt reduction can be solved

- Rapid reduction (taste reduction) is a challenge
  - because of competition between bakers, and within the food sector

- The bread salt reduction in Finland: 1.3 - 1.5% $\rightarrow$ 1.0 - 1.2%
  (2.0-2.2% $\rightarrow$ 1.5-1.8%, on flour basis)
  - has taken time (30 years)
  - consensus in the food & health sector
Sources of salt in the Finnish diet 1980–1999

- Milk products
- Fats
- Bread
- Sweet baked
- Meat products
- Fish products
- Prepared foods
- Catering
- Table salt
- Other


Sources of salt: UK

Figure 1 A pie chart to show sources of salt intake from various foods (a total of 76% of daily salt intake) (Henderson et al. 2003 and FSA 2003).
### Sources of sodium (%) in the diet

<table>
<thead>
<tr>
<th>Food sector</th>
<th>Ireland(^1)</th>
<th>UK(^2)</th>
<th>USA(^3)</th>
<th>Finland(^4)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cereals and cereal products</td>
<td>35</td>
<td>38</td>
<td>27</td>
<td>35</td>
</tr>
<tr>
<td>Meat &amp; meat products</td>
<td>21</td>
<td>21</td>
<td>21</td>
<td>30(^5)</td>
</tr>
<tr>
<td>Soups &amp; sauces</td>
<td>7</td>
<td>13</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td>Processed vegetables</td>
<td>4</td>
<td>9</td>
<td>7</td>
<td>9</td>
</tr>
<tr>
<td>Milk and cream</td>
<td>9</td>
<td>5</td>
<td>7</td>
<td>10</td>
</tr>
<tr>
<td>Fish dishes</td>
<td></td>
<td></td>
<td></td>
<td>10</td>
</tr>
</tbody>
</table>

\(^1\)FSAI (2005); \(^2\)SACN (2003); \(^3\)Engström et al. (1997); \(^4\)Findiet 2002; \(^5\)included meat dishes
# Salt intake from various foods

Finnish food balance sheets from 1980 to 1999

<table>
<thead>
<tr>
<th></th>
<th>1980</th>
<th>%</th>
<th>1991</th>
<th>%</th>
<th>1997–1999</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>g/day</td>
<td>%</td>
<td>g/day</td>
<td>%</td>
<td>g/day</td>
<td>%</td>
</tr>
<tr>
<td>Table salt</td>
<td>3.8&lt;sup&gt;a&lt;/sup&gt;</td>
<td>30</td>
<td>2.6&lt;sup&gt;b&lt;/sup&gt;</td>
<td>21</td>
<td>2.3&lt;sup&gt;b&lt;/sup&gt;</td>
<td>21</td>
</tr>
<tr>
<td>Meat products</td>
<td>1.8</td>
<td>14</td>
<td>2</td>
<td>17</td>
<td>2.2</td>
<td>21</td>
</tr>
<tr>
<td>Bread</td>
<td>2</td>
<td>16</td>
<td>1.7</td>
<td>14</td>
<td>1.3</td>
<td>12</td>
</tr>
<tr>
<td>Milk products</td>
<td>1.2</td>
<td>9</td>
<td>1.1</td>
<td>9</td>
<td>1.2</td>
<td>11</td>
</tr>
<tr>
<td>Catering</td>
<td>1</td>
<td>8</td>
<td>1.2</td>
<td>10</td>
<td>1.1</td>
<td>10</td>
</tr>
<tr>
<td>Sweet baked</td>
<td>0.8</td>
<td>6</td>
<td>0.9</td>
<td>7</td>
<td>0.8</td>
<td>7</td>
</tr>
<tr>
<td>Prepared foods</td>
<td>—</td>
<td>—</td>
<td>0.8</td>
<td>7</td>
<td>0.8</td>
<td>7</td>
</tr>
<tr>
<td>Fats</td>
<td>0.9</td>
<td>7</td>
<td>0.7</td>
<td>6</td>
<td>0.6</td>
<td>5</td>
</tr>
<tr>
<td>Fish products</td>
<td>1</td>
<td>8</td>
<td>0.9</td>
<td>7</td>
<td>0.4</td>
<td>4</td>
</tr>
<tr>
<td>Other</td>
<td>0.2</td>
<td>2</td>
<td>0.3</td>
<td>2</td>
<td>0.4</td>
<td>2</td>
</tr>
<tr>
<td>Total</td>
<td>12.7</td>
<td>100</td>
<td>12.2</td>
<td>100</td>
<td>11.1</td>
<td>100</td>
</tr>
</tbody>
</table>

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**Sodium in the Finnish diet:**

II Trends in dietary sodium intake and comparison between intake and 24-h excretion of sodium

Data for 1982 and 1992 are from systematically collected and analysed samples; those for 1996 are from a few major bakery companies and represents their major products.
The rationale: Why salt?

Role of salt in bread

- Technological
- Sensory
The rationale: The roles of salt in bread

3 reasons to add salt (1/3):

1) Salt improves bread flavour and other sensory properties

- Salt-free bread is tasteless, ‘pasteboardy’, not stimulating saliva
- Optimal salt content for taste 1.0-1.4 % (by panels in the 1980’s)
- Salt improves sensation of bread freshness?
- Salt-free bread perceived older and drier
- Salt-free bread was evaluated oldest, although was softest
- Salt-free and low salt breads crumblier
The rationale: The roles of salt in bread

3 reasons to add salt  (2/3):

2) Salt improves dough handling properties (machinability)

- Enables higher dough yield (compensating for the reduced water absorption found in the farinograph)
- Dough development time increased, stability improved
- Resistance to extension/extensibility improved
The rationale: The roles of salt in bread

3 reasons to add salt (3/3):

3. **Shelf-life (mold-free time) extended**

Example:  
- salt-free bread: 4 d until mold appearance  
- 2% salt (on flour): 7 d

\[ a_w \text{ value: } 0.97 \text{ at 1.0% salt} \]  
\[ 0.96 \text{ at 1.6% salt} \]

Note! Salt also retards fermentation  
- low salt (0.5% on flour) may stimulate yeast  
- at 2% addition fermentation reduction ca 20%  
  \( \rightarrow \) or 20% longer proof time needed  
- may be a stabilising effect
Technological role of salt in breadmaking

Typical farinograms of unsalted and salted wheat doughs (% salt on flour)

With 1 or 2% salt:
- Peak time increased (= dough strength increased)
- Water absorption decreased (= water binding decreased)
Salt occupying sites in gluten proteins where water would go.

(Salovaara 1984)
Technological role of salt in breadmaking

Mixograms of wheat doughs (% salt on flour)

With 0.5 - 5% salt:
- longer mixing time,
- wider bandwidth,
- lower rate of breakdown
  (= dough strength increased)

(Danno & Hoseney 1982)


Technologies of salt reduction in bread: issues, problems and solution
Gluten has a small net (+) charge.

The small net (+) charge is suppressed by salt. Protein becomes more compact.

At low pH the gluten has a sizeable net (+) charge → repulsion forces due to the excessive (+) charges.

With salt the net (+) charge of the proteins are suppressed → a compact structure.

Fig. 2. Schematic diagram showing possible effects of pH and salt on wheat gluten proteins.

Galal et al. (1978)
Salt free bread tastes like pasteboard

White bread

Besides saltiness, overall palatability and a saliva stimulating sensation were increased by salt.

Bread flavour profile

**Rye bread**

'Salt free bread tastes like pasteboard'


Besides saltiness, overall palatability, a saliva stimulating sensation and sourness were increased by salt in rye bread.
Table 2 Parameters of wheat bread baking process and selected loaf properties at various sodium chloride levels

<table>
<thead>
<tr>
<th>Salt concentration (%)</th>
<th>0</th>
<th>0.8</th>
<th>1.7</th>
<th>1.7</th>
<th>2.5</th>
<th>2.5</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0 (salt-free)</td>
<td>0.6 (low salt)</td>
<td>1.2 (normal salt)</td>
<td>1.8 (high salt)</td>
<td>2.5 (high salt)</td>
<td></td>
</tr>
<tr>
<td><strong>Baking process</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Baking absorption (^a)</td>
<td>56.8</td>
<td>55.5</td>
<td>54.9</td>
<td>54.2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mixing time (^b) (min)</td>
<td>10.5</td>
<td>13.5</td>
<td>15.0</td>
<td>17.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fermentation time (^c) (min)</td>
<td>88</td>
<td>90</td>
<td>105</td>
<td>124</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Loaf properties</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Specific volume (ml/g)</td>
<td>4.35</td>
<td>4.57</td>
<td>4.52</td>
<td>4.41</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Quality scores: (^d)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Volume</td>
<td>14</td>
<td>15</td>
<td>15</td>
<td>15</td>
<td></td>
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<tr>
<td>Other external</td>
<td>19</td>
<td>20</td>
<td>19</td>
<td>19</td>
<td></td>
<td></td>
</tr>
<tr>
<td>characteristics</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Internal characteristics</td>
<td>28</td>
<td>31</td>
<td>34</td>
<td>35</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aroma and taste</td>
<td>17</td>
<td>20</td>
<td>25</td>
<td>22</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total score</td>
<td>78</td>
<td>86</td>
<td>93</td>
<td>91</td>
<td></td>
<td></td>
</tr>
<tr>
<td>pH</td>
<td>5.9</td>
<td>5.8</td>
<td>5.7</td>
<td>5.7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Titratable acidity (ml)</td>
<td>2.5</td>
<td>2.8</td>
<td>3.0</td>
<td>3.1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Crumb moisture (%)</td>
<td>38.7</td>
<td>38.1</td>
<td>37.2</td>
<td>37.1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Water activity (a_w)</td>
<td>0.98a</td>
<td>0.97ab</td>
<td>0.97ab</td>
<td>0.96b</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

\(^a\) At a dough consistency of 500 BU. \(^b\) Time required for mixing until a 10 Brabender unit drop was observed after reaching maximum development (500 BU). \(^c\) Time required to produce 425 ml of gas in a 150 g dough sample in the fermentograph (30°C). \(^d\) Maximum scores: volume (sp. vol. × 3.33) 20, other external characteristics 20 (crust colour, 10; break and shred, 5; symmetry 5), internal characteristics 35 (character of crust, 5; crumb colour, 10; grain, 10; texture, 10), aroma and taste 25 (aroma, 10; taste, 15). Total maximum score 100. Means followed by the same letter in rows showed no significant difference at \(p = 0.01\)
High salt retards fermentation, CO\textsubscript{2} production → proof times shorter

Effect of NaCl on relative production of CO\textsubscript{2} in wheat dough in 2 hours.

Fermentation time needed for a given volume in unsalted and salted dough.

(Salovaara 1984)
Salt content had no effect on crumb hardening.

Salt-free rye bread: impossible to measure compressibility - slices disintegrated, crumbled.

Salovaara et al. (1986)
Salt decreased crumbliness (sieving test)

Salovaara et al. (1986)

Fig. 4  Effect of salt level on the crumbliness of wheat (a) and rye bread (b) in a sieving test
Salt content had no significant effect on mastication time

<table>
<thead>
<tr>
<th>Salt concentration (%) (in bread)</th>
<th>0 (salt-free)</th>
<th>0.6 (low salt)</th>
<th>1.2 (normal salt)</th>
<th>1.8 (high salt)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average mastication time(^a)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>One-day-old bread</td>
<td>29</td>
<td>31</td>
<td>25</td>
<td>29</td>
</tr>
<tr>
<td>Three-day-old bread</td>
<td>32</td>
<td>40</td>
<td>33</td>
<td>32</td>
</tr>
<tr>
<td>Time until swallowed(^a) (sec)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>One-day-old bread</td>
<td>26.4</td>
<td>25.3</td>
<td>24.1</td>
<td>22.5</td>
</tr>
<tr>
<td>Three-day-old bread</td>
<td>26.3</td>
<td>33.3</td>
<td>28.9</td>
<td>27.6</td>
</tr>
</tbody>
</table>

\(^a\) No significant differences at \(p = 0.05\) between values in rows. Significant differences at \(p = 0.05\) between one-day-old and three-day-old bread in each column except values for salt-free bread

Salovaara et al. (1986)
Do consumers want to use low salt bread? In long term?
- 15-week study; free choice; 4 types of bread; free bread to be used at their families at home; 813 choices, 61 persons

At start:
50-60% chose low-salt

At the end:
20-30% chose low-salt

Decreasing trends

Tuorila-Ollikainen et al. 1986.
Appetite 7:127-139
Do consumers accept low salt bread? Will they notice?
- 12-week study; lunch restaurant; 3 types of bread freely available; bread salt content was changed; any difference in amounts consumed or will it or will it go unnoticed?

Reduction of salt content did not reflect in bread amount consumed.

At return to original salt content only wheat bread consumption increased.

High acidity, high acetic acid in particular, can be perceived as salty in rye bread. However, the acidity itself can become a problem.

Hellemann et al (1991)
Outline:

- Salt in bread
  - Content
  - Bread as source of sodium

- The rationale: effects of salt in bread
  - Technological
  - Sensory

- Salt reduction and replacement
# Periodic Table of Elements

![Periodic Table Image](image-url)

### Legend - click to find out more...

- **H**: gas
- **Li**: solid
- **Br**: liquid
- **Tc**: synthetic

- **Non-Metals**
- **Transition Metals**
- **Rare Earth Metals**
- **Halogens**
- **Alkali Metals**
- **Alkali Earth Metals**
- **Other Metals**
- **Inert Elements**
Replacing NaCl? An 'artificial salttener'?

Table 1. Some essentially pure salty, salty and bitter, and essentially bitter salts

<table>
<thead>
<tr>
<th>Pure salty taste:</th>
<th>NaCl, LiCl</th>
</tr>
</thead>
<tbody>
<tr>
<td>Salty and bitter:</td>
<td>KCl, RbCl, NH Cl, NaBr, LiBr, NaJ, LiJ, Na SO , K SO , NaNO</td>
</tr>
<tr>
<td></td>
<td>2 4 2 4 3</td>
</tr>
<tr>
<td>Bitter:</td>
<td>CsCl, MgCl , MgSO , RbBr, CsBr, KJ, RbJ, CsJ, CaCl</td>
</tr>
<tr>
<td></td>
<td>2 4 2</td>
</tr>
</tbody>
</table>

Sources: AMERINE et al. (1965), DeMAN (1979), NEY (1979)
Taste qualities of salts

van der Klaauw & Smith 1995
Mineral salts

- Na partially replaced by K and Mg

Mineral salts (examples)

<table>
<thead>
<tr>
<th></th>
<th>Seltin (Cederroths)</th>
<th>PAN-salt (Oriola)</th>
</tr>
</thead>
<tbody>
<tr>
<td>NaCl</td>
<td>65</td>
<td>57</td>
</tr>
<tr>
<td>KCl</td>
<td>25</td>
<td>28</td>
</tr>
<tr>
<td>MgSO$_4$·7H$_2$O %</td>
<td>10</td>
<td>12</td>
</tr>
<tr>
<td>L-lysine hydrochlorid %</td>
<td>-</td>
<td>2</td>
</tr>
<tr>
<td>Anticaking substance</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Na content %</td>
<td>25,4</td>
<td>22,8</td>
</tr>
<tr>
<td>Equimolarity coefficient*</td>
<td>1,15</td>
<td>1,22</td>
</tr>
<tr>
<td>Price € /kg (25 kg) (ca)</td>
<td>3</td>
<td>5</td>
</tr>
</tbody>
</table>

*Coefficient needed for multiplication to compensate for lower molecular weight, hydrate etc.

E.g. 22% more PAN-salt needs to be weighed to get same amount of moles.
Relative saltiness, mineral salt in vegetable broth
(paired comparisons of different concns of mineral salt against 0.5% NaCl, n = 34, each panelist performed 5 paired comparisons)

0.75% mineral salt corresponds to 0.5% NaCl, thus relative saltiness = 0.67

University of Helsinki, unpublished
Farinograms at 20% replacement level

Technologically, 20% replacements cause no major problems

Salovaara (1982)
Lyotropic series (Hofmeister series) of anions and cations

Cations and anions can be arranged in a series based on their effects in many chemical and technological systems (such as retrogradation):

Cations: $\text{Ba}^{2+}, \text{Sr}^{2+}, \text{Ca}^{2+}, \text{K}^+, \text{Na}^+, \text{Li}^+$

Anions: $\text{CNS}^-, (\text{PO}_4^{3+}, \text{CO}_3^{=}), \text{I}^-, \text{NO}_3^-, \text{Br}^-, \text{Cl}^-, \text{C}_2\text{H}_3\text{O}_2^-, \text{F}^-, \text{SO}_4^=$.

$\text{NaCl}$ replacement at 20% and 40% level in wheat dough also followed the lyotropic series (farinograph peak time and stability, extensigraph resistance and extension):

$\text{CaCl}_2, \text{MgCl}_2, \text{KCl}, \text{NaCl}, \text{Mg(OAc)}_2, \text{MgSO}_4, \text{NaSO}_4$

$\text{Na}^+$ and $\text{K}^+$ are close to each other in the lyotropic series, both strengthen wheat dough.

$\text{Ca}^{2+}$ and $\text{Mg}^{2+}$ have a weakening effect compared to $\text{Na}^+$. 
Role of mineral salt on composition of bread (highest replacement levels with K and Mg salts that went unnoticed in sensory panel test) in comparison with dark wheat and whole meal rye bread

Salovaara (1982)
Role of mineral salt on composition of bread
(highest replacement levels with K and Mg salts that went unnoticed in sensory panel test) in comparison with dark wheat and whole meal rye bread

Salovaara (1982)
General notes on salt reduction

- preference for salt assumingly inherited
- salty/savoury taste is an essential part of the western food culture
- salt supports other *flavours* of foods and is essential for the *texture* of many foods

- salt preferences can be changed
- rapid changes in sensory properties of products may be a risk in the market – long term trend in the food industry needed
- salt substitutes (mineral salts) are of little value in flavour improvement but may be helpful for texture of reduced-salt foods

(partly modified from Hely Tuorila, 27.03.2007)
Conclusions on salt reduction in bread

- Bread is a major source of salt (25-35%)
- Salt (NaCl) has many roles in bread
- **Taste** is the critical issue
  - Other (technological) problems in salt reduction can be solved

- Rapid reduction (taste reduction) probably does not work
  - because of competition between bakers, and within the food sector

- The bread salt reduction in Finland: 1.3 - 1.5% → 1.0 - 1.2%
  - (2.0-2.2% → 1.5-1.8%, on flour basis)
  - has taken 30 years
  - consensus in the food & health sector has been helpful, including
    labelling requirement for ‘high in salt’
  - further progress requires actions also elsewhere in Europe
References


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