Mini Review

Differences in Salt Bittern Components and Effects on Rice Porridge Taste

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Summary Salt is an important seasoning that adds a salty taste to enhance or suppress other tastes in cooking. Porridge is treated with salt, even with the addition of a small amount of salt to tighten its taste. This salty taste intensity is also influenced by the amount of bittern component contained in the salt because not only the bittern component but also the change of pH affects the degree of swelling and penetration into rice. However, excessive salt intake causes lifestyle-related diseases. For that reason, salt intake reduction is recommended. When salt and citric acid are added to the porridge simultaneously, the contrasting effects of acidity and saltiness enhance the salty flavor, allowing for the reduction of salt intake.

Key Words bittern component, reduced salt, rice gruel, salt, salty taste

When preparing rice porridge, even a small amount of added salt can increase saltiness. Even a small amount of added salt plays an important role in compensating other tastes. Salt (sodium chloride), a fundamentally important seasoning for cooking, affects not only the food taste but also its texture because of its penetration and dehydration of foods. In recent years, it has become possible to use salt containing bitter components effectively. A recent report has described that, when treating food with salt of high bitterness, the influence on taste might derive from bitterness, not from salt (1). As presented herein, we introduce results of examination of the influence on taste by making rice porridge using salts with different bitterness contents. Reducing salt intake is recommended because excessive salt uptake causes disease. Research on low-salt food technology with excellent palatability is progressing actively to strengthen saltiness by adding aroma and flavors to foods and creating alternative structures of foods (2–6).

From this perspective, we are investigating the possibility of reducing salt intake using interaction between salty taste and other taste ingredients (7, 8). We also report salty taste enhancement based on the contrast effect of acidity and saltiness with rice porridge (8).

Commercial Salt Samples Containing Bitter Components

Currently, salts of many kinds are sold in Japan. These salts, whether deriving from local seawater or reprocessing from imported salt, etc., are produced using various methods. Commercially available salts are classifiable into six types (groups A–F) depending on the production method as follows (9): A, reprocessed imported solar salt; B, salt produced by boiling seawater; C, salt made by adding a bittern component to the surface of ion exchange membrane salt; D, salt dried by direct spraying of seawater at room temperature; E, salt produced by adding an umami component such as sodium glutamate; and F, imported salt (9). Imported salts are further segmented by differences of raw materials and manufacturing methods (10): whether solar salt or rock salt, whether they were used as salt, whether they were dissolved in water and reproduced, and so on (10). The main salt components actually include six: contain chloride ion, sodium ion, sulfate ion, magnesium ion, calcium ion, and potassium ion. Moreover, the component composition changes because the precipitation behavior of crystals differs depending on the salt production method. Commercially available salts of 30 kinds were collected and analyzed to ascertain their salt components, which were then compared and examined according to the manufacturing method (9). Results show that group D salts have more magnesium, calcium, potassium, and sulfate ion than other salts. Group B salts also have more bittern components than those produced using other methods. The bitter ingredient amount affects the salt taste. Earlier reports describe that it is identifiable by a taste sensor (11). Therefore, the salty taste quality was evaluated by taste sensor measurement and sensory evaluation (9). Furthermore, principal component analysis was applied by combining the inorganic component content, the taste sensor measurement value, and the sensory evaluation result. Eventually, 30 commercially available salts were classified. Consequently, results demonstrated that the salt is an unrelated group produced by boiling seawater and by direct spraying of seawater. Group E salts were also different from the others. However, salts produced by other methods have similar properties. The findings above indicate that commercially available salts are classifiable into four groups because of different production methods, ingredients, and taste, as shown in Fig. 1 (9).
Differences in Salt Bittern Components and Effects on Rice Porridge Taste

Differences in taste were compared when four kinds of commercial salt with different properties were used for cooking (1). The four salts are the following: A, sodium chloride only; B, reprocessed imported solar salt; C, salt produced by boiling seawater; and D, salt dried by direct spraying of seawater at room temperature. The respective inorganic component contents of these salts are shown in Table 1. These components are shown as solid contents remaining after water is extracted from the salt solution. To investigate the taste characteristics of these salts, we demonstrated taste discrimination using a saline solution in the following manner. After each salt was dissolved to 1% sodium chloride content in 1,500 mL of deionized water, the salt solution was kept at 70˚C. These solutions were used as samples for sensory evaluations. Saline evaluation was conducted by 38 panelists. We conducted experiment procedures and analyses using Scheffe’s paired comparison method (modified Haga’s method), investigated the saltiness, bitterness, and preferences for the saltwater solutions. Table 2 and Fig. 2 respectively portray the intensity of taste in sensory evaluation and the significant difference for each combination of salts. The salty taste intensity was found to be almost identical as the sodium chloride content, as shown in Fig. 2, but a significant difference was found between sample B and sample D, as shown in Table 2. The bitterness intensity was felt strongly for Sample D, as shown in Fig. 2. No marked difference was observed from other salts, as indicated at Table 2. These results are interpreted as explained below. The following concentrations of the salts were used: Sample B has 0.0056% of magnesium chloride and 0.0089% of mag-

Table 1. Composition of inorganic ions in the four salt samples (1). (%)

<table>
<thead>
<tr>
<th></th>
<th>Ca</th>
<th>K</th>
<th>Mg</th>
<th>Na</th>
<th>Cl</th>
<th>SO_4</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>39.3</td>
<td>60.7</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>B</td>
<td>0.09</td>
<td>0.11</td>
<td>0.28</td>
<td>38.7</td>
<td>60.75</td>
<td>0.04</td>
</tr>
<tr>
<td>C</td>
<td>0.36</td>
<td>0.11</td>
<td>0.31</td>
<td>38.2</td>
<td>59.40</td>
<td>1.58</td>
</tr>
<tr>
<td>D</td>
<td>0.80</td>
<td>1.06</td>
<td>3.34</td>
<td>30.5</td>
<td>54.90</td>
<td>5.84</td>
</tr>
</tbody>
</table>

Table 2. Results of sensory evaluation of the salty taste of sample pairs (1).

<table>
<thead>
<tr>
<th>Taste Profile</th>
<th>Combination of pairs</th>
<th>Intensity of salty taste</th>
</tr>
</thead>
<tbody>
<tr>
<td>Saltiness</td>
<td>Sample A Sample B</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Sample A Sample C</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Sample A Sample D</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Sample B Sample C</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Sample B Sample D</td>
<td>**</td>
</tr>
<tr>
<td>Bitterness</td>
<td>Sample A Sample B</td>
<td>**</td>
</tr>
<tr>
<td></td>
<td>Sample A Sample C</td>
<td>**</td>
</tr>
<tr>
<td></td>
<td>Sample A Sample D</td>
<td>**</td>
</tr>
<tr>
<td></td>
<td>Sample B Sample C</td>
<td>**</td>
</tr>
<tr>
<td></td>
<td>Sample B Sample D</td>
<td>**</td>
</tr>
<tr>
<td></td>
<td>Sample C Sample D</td>
<td>**</td>
</tr>
</tbody>
</table>

**p < 0.01.
nesium sulfate, the magnesium chloride concentration contained in Sample C is 0.013%, as shown in Table 1. However, the aqueous solution prepared using sample D containing many bittern components contained 0.12% of magnesium chloride and 0.06% of magnesium sulfate. The amounts thereof were more than 10 times those of other edible salts, as shown in Table 1. In general, salt with a high bittern component has strong bitterness. The bitterness of the sample pairs with sample D was evaluated as strong because the bitter component of sample D was greater than that of the other salts, as shown in Table 2 and Fig. 2. Evaluation of palatability was lower for Sample D than those of other salt pairs, as shown in Table 2 and Fig. 2. Therefore, results demonstrate that the bittern component amount strongly affects the salt taste (1).

**Taste Differences in Salts Produced Using Different Production Methods and Used for Cooking—Sensory Evaluation of Rice Porridge**

We have reported evaluation results of the taste of porridge prepared using the salt solution used for the experiment above (1). Rice porridge was prepared in the following manner: salt corresponding to about 0.56% of sodium chloride was dissolved in 1,400 mL of distilled water. The samples contained 9.00 g, 10.02 g, 9.36 g, and 11.12 g, respectively, of salts of Sample A, Sample B, Sample C, and Sample D. To 1,400 mL of distilled water containing each salt, 200 g of rinse-free rice was added and cooked (IH heat retainer RC-10 HY; Toshiba Corp.). The rice porridge was prepared as three-quarter porridge. After preparation, it was mixed thoroughly for 10 s, steamed for another 30 min, and mixed thoroughly for 10 s to prepare a sample for sensory evaluation. Table 3 and Fig. 3 respectively portray the taste intensity in sensory evaluation and the significant difference in each combination of salts. Sample pairs with sample A and sample D were judged respectively as having strong and weak salty tastes, as shown in Fig. 3. Significant differences were found between sample pairs with sample D and the other salts examined as shown in Table 3. Despite addition of the same amount of sodium chloride in the porridge, the salty taste intensity differs, as shown in Table 3 and Fig. 3. Apparently, ingredients other than sodium chloride influence the taste. Significant differences were found in the combinations of sample A and sample D, sample C and sample D for the intensity of taste other than saltiness, as shown in Table 3. In addition, among responses to the question of what tastes other than a salty taste were found for Sample D, one response cited sweetness instead of bitterness. Sample D showed a significant difference from all other salts in terms of palatability, as shown in Table 3. The deliciousness of the porridge prepared from sample D is attributable to the use of a salt that is preferred over other salts. For evaluation of the saline solution, a tendency of avoiding strong bitterness was noted, but it was a different response for porridge preparation. Rice porridge has a simple cooking method: it uses only rice, water, and salt as starting materials. However, the kind of salt and pH influence the rice swelling and water penetration into rice (12–15). In our experiments, the concentrations of the salt added to samples A–D were almost equal, but the pH levels of the aqueous solution were, respectively, 6.07, 6.25, 6.10, and 9.95. The pH of the porridge prepared from samples A, B, and C was shown to be almost equal to the pH of the aqueous solution, but the pH of the porridge prepared from sample D is shown as 6.89. Based on the results described above, we concluded that the bittern component in the salt influences the expression of taste based on interaction with other taste ingredients. It also affects cooking.

![Fig. 3. Sensory scores of the salty taste of rice porridges (1).](image-url)
processes such as penetration and elution, eventually affecting the food taste (1).

**Using a Contrastive Effect for Salt Taste Enhancement—Sensory Evaluation of a Salt Water Solution**

Salt can fundamentally determine the taste of prepared foods. Salt not only adds saltiness; it also interacts with other taste ingredients during cooking, enhancing or suppressing other tastes. Salt reduction not only weakens the salty taste, it also alters the balance of tastes in dishes, eventually decreasing taste overall. Therefore, some means of reducing salt contents while maintaining the taste of prepared foods must be considered. In contrast to suppression or enhancement of other tastes of salt, we assessed the functions of various taste components to enhance salty taste. A mixed solution with acidity and saltiness is known to suppress salty taste with a large amount of acidity or increase of salty taste by the addition of a small amount of acidity. Reportedly, salty taste enhancement has been done using acetic acid (16) and vinegar (17–20). We sought means of enhancing salty taste using citric acid in a saline solution (7, 8). For the experiments, several aqueous solutions were prepared by adding 0.013%, 0.0018%, and 0.0025% of citric acid to 0.234% and 0.584% saline solution. Those concentrations of solutions can be discriminated from water. In fact, 0.0018% citric acid is a concentration at which one can recognize a slight sourness; 0.0025% citric acid is a concentration at which one can recognize sourness clearly. Salty taste intensities of a citric acid containing salt water solution and a citric-acid-free salt water solution were evaluated using pair tests. Salinity evaluation was done by 23 panelists. Figure 4 shows sensory evaluation results when adding citric acid to 0.234% saline. Although the salty taste tended to be suppressed with 0.0013% citric acid added saline, the salty taste intensity was enhanced significantly at higher citric acid concentrations. The 0.234% saline has salty taste with some sweetness, but when 0.0018% and 0.0025% citric acid was added, a clear salty taste was discerned. Apparently, the citric acid decreases the detection threshold of a salty taste. Figure 5 shows the

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**Fig. 4.** Sensory evaluation of the salt solution at 0.234% (W/V) with citric acids. The ordinate shows the number of panelists who answered that the sample tasted saltier (7, 8).

**Fig. 5.** Sensory evaluation of the salt solution at 0.584% (W/V) with citric acids. The ordinate shows the number of panelists who answered that the sample tasted saltier (7, 8).

**Fig. 6.** Salty taste intensity by sensory evaluation of rice porridge with sodium chloride (quantity) and citric acid (8).
sensory evaluation results obtained with addition of citric acid to 0.584% saline. Results show that salty taste suppression was recognized even at 0.0013% citric acid addition to 0.284% saline. The results described above demonstrate that interaction between sour and salty tastes when using citric acid exhibits both a contrastive effect and a suppressive effect depending on the target salt concentration, which are similar results to those obtained from studies examining acetic acid (16).

**Using Contrastive Effects to Reduce Salt Taste—Sensory Evaluation of Rice Porridge**

Mixed components of citric acid powder and salt (citric acid concentrations: 0.3, 0.5, 1, 2, 3, 5, 10%) were prepared and mixed with salt of 0.5% corresponding to the weight of porridge (8). Figure 6 shows that the salty taste intensities of salt porridge with and without citric acid were evaluated by pair testing (8). Because of the addition of citric acid, the salty taste of porridge tends to be felt strongly. Significant differences were also observed in porridge with 0.5%, 1%, and 5% added citric acid. The salty taste of porridge tends to be sensed strongly because of the addition of citric acid to the salt. Significant differences were also found among porridge samples using mixed salt to which citric acid had been added by 0.5%, 1%, and 5%. However, the saltiness intensity of the porridge treated with 10% citric acid mixed salt was the same as that in porridge treated only with citric acid without salt. Apparently, this result was obtained because the sourness of the mixed salt with 10% citric acid was so strong that the salty taste was sensed only weakly: the salty taste was difficult to discern. The results described above showed that salty taste enhancement by contrastive effects of acidity and salty taste were confirmed even when applied to foods. Additionally, the addition of citric acid at a concentration higher than that of saline was possible. Regarding the acidity necessary for saltiness enhancement, results show two types in which only the saltiness was felt strongly with no sense of acidity, and in which even a slight added amount led to a strong sensation of saltiness. In one case, the added amount elicited no sensation of acidity but only a strong salty taste. In the other case, the added amount which the salty taste is strongly sensed rather than salty with slight acidity (8). Eating foods with strong acidity presents limitations. Therefore, it is necessary to consider effects on palatability and salty taste enhancement (20). Nevertheless, these findings are expected to be applicable to the development of various reduced-salt foods.

**Conclusion**

Salt, a fundamentally important seasoning for cooking, affects not only the taste but also the texture of foods because the salt penetrates into the food and dehydrates it. Depending on the amount of bittern components in the salt, the effects of salt on food ingredients differ. Herein, we presented effects of adding salt to porridge, but when used for other cooking, salt effects might be different, indicating the necessity of considering how to use it for cooking according to the salt characteristics. Excessive salt intake causes lifestyle diseases. Therefore, salt uptake reduction is an important issue that must be addressed. Reportedly, salty taste enhancement by contrastive effects of other taste ingredients such as umami and acidity is effective for compensating taste insufficiency because of reduced salt. In conclusion, we presented an example using the contrastive effects of sourness and salty taste in porridge. The results might also be applicable to various dishes such as soup and simmered foods, with great effectiveness for reducing salt contents without reducing saltiness.

**Disclosure of State of COI**

No conflicts of interest to be declared.

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**REFERENCES**

sensor with lipid membranes. IEICE Trans Electron E83-C: 1040–1045.


