Enhancing Effects of Herbs on the Salty Taste Perception of Saline

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(Received February 23, 2020)

Summary In many countries, excessive consumption of sodium chloride (salt) has become a serious social problem and reducing salt has been required. Herbs have been reported to enhance the saltiness of food; however, few studies have focused on the numerical evaluation of the degree of saltiness enhancement by herbs. The purpose of this study was to quantify the degree of saltiness enhancement by herbs via human sensory evaluation using a visual analog scale (VAS). The sensory evaluation was conducted on 69 students who were able to arrange the five different saline concentrations in order. The sensory salt concentration of herb-added 0.4 wt% saline solutions were perceived in comparison with the saltiness of 0.2 to 0.6 wt% reference saline solutions. The results were recorded by an arrow on a VAS. Hot-water extracts of the herbs basil, rosemary, parsley, anise, and oregano were used. The sensory salt concentration of a 0.175 wt% herb-added saline was equivalent to the actual salt concentration (0.4 wt%). However, the sensory salt concentrations of salines with 0.35 wt% herb extracts were significantly higher (p<0.001). There were no significant differences in the saltiness-enhancing effects depending on the species of, preference for, and familiarity with a particular herb. It was estimated that the addition of 0.35 wt% herb extracts enhanced the salty taste of the saline by 1.13 to 1.22 times.

Key Words salt, herb, reduce salt intake, saltiness enhancement, sodium, hypertension

The World Health Organization recommends a sodium chloride (salt) intake of less than 5 g/d; however, the populations of most countries have a long-standing history of high salt intake, resulting in an average global dietary salt intake of around 10 g/d (1). Sodium chloride is the only substance that evokes a salty taste response (2). Therefore, salt is essential for cooking and food processing.

However, an excessive intake of salt is known to be a main risk factor for high blood pressure (3), and hypertension is known to increase the risk of cardiovascular events (4), stroke (5), and gastric cancer (6). Salt intake by the Japanese is high by global standards, and excessive salt intake is considered the number four risk factor for death (7). According to the Japanese National Health and Nutrition Survey 2017, the average salt intake is 11.8 g/d by adult males and 9.1 g/d by adult females; the values have been declining in recent years but still far exceed the recommended daily allowance (8). It is, therefore, necessary to further reduce salt intake.

Simply decreasing the amount of salt used in dishes and processed foods causes an insufficient salty taste, reduced flavor, and impaired palatability (9). One way to circumvent these challenges is to use salt enhancers, i.e., ingredients that enhance the perception of saltiness. For example, acidic substances and umami have been reported to be saltiness enhancers. Hamajima (10) showed that the addition of 0.01 wt% acetic acid to saline enhanced its salty taste perception. Hatae et al. (11) reported that the addition of a low concentration of vinegar into a saline lowered its salty taste detection threshold and cognition threshold levels. Kemp et al. (12) reported that monosodium glutamate (MSG) had no influence on the saltiness at threshold levels, although a high concentration of MSG enhanced the saltiness of sodium chloride.

Recently, it has been suggested that spices and herbs, which have long been used as flavor enhancers, can be used as saltiness enhancers (13). It is thought that the flavor components of herbs and spices enhance salty taste perception (14). Moreover, herbs and spices can also impart a desirable flavor, color, and texture to the finished food product and thus minimize any flavor deficits arising from salt reduction (15). However, there has been little research reporting the degree of saltiness enhancement by spices and herbs as a numerical value.

The purpose of this study was thus to quantify the degree of saltiness enhancement by herbs using a human sensory test. Based on salty taste perception of 0.2–0.6 wt% saline solutions, the degrees of saltiness
of 0.4 wt% saline solutions containing herb extracts at two different concentrations were evaluated using a visual analog scale (VAS). In addition, a questionnaire was administered to investigate the dietary and exercise habits of the participants that may affect their salty taste perception.

**MATERIALS AND METHODS**

**Test solution.** NaCl (purity ≥99 wt%; National Foundation of Salt) was dissolved in pure water to prepare 0.2, 0.3, 0.4, 0.5, and 0.6 wt% saline solutions.

Five commercially used dry herbs, basil, rosemary, parsley, anise, and oregano (Hachi Foods Co., Ltd.), which are popular and easily available in Japan (16), were subjected to testing. Herb extracts of basil, parsley, and oregano were prepared by grinding the herbs in a mortar, placing 1.75 g of ground herbs on filter paper (No. 1, 185 mm; Tokyo Roshi Kaisha, Ltd.), and slowly pouring 400 mL of pure water at 95°C over them. Anise and rosemary (1.75 g) were put in tea bags without grinding; the tea bags were placed in a beaker, steamed in 400 mL of pure water at 95°C, and allowed to stand for 5 min to prepare extracts. Next, 2 g of salt was added to each herb extract, and the volume was finally adjusted to 500 g with pure water. This mixture was used as a 0.35 wt% herb-added 0.4 wt% saline. Further, a part of this solution was double diluted with 0.4 wt% saline to obtain a 0.175 wt% herb-added 0.4 wt% saline.

A soup stock was prepared by dissolving 5 g of Dashi (Japanese soup stock made from fish and kelp), with no salt added (Sozairyoku-Dashi; Riken Vitamin Co., Ltd.), in 750 g of pure water at 95°C. Next, 9.5, 11.3, and 16.4 g of miso (Takeya Miso Co., Ltd.) were dissolved in 200 g of the soup stock to prepare miso soups, which were adjusted to 0.6, 0.8, and 1.0 wt% salt concentrations, respectively.

**Subjects.** Eighty students (29 men and 51 women) between the ages of 19 and 24, who were enrolled in Kindai University, participated in the sensory evaluation. This study was conducted in October 2015 with the approval of the Kindai University Faculty of Agriculture life ethics committee (No. 2015-6) and in accordance with the Declaration of Helsinki.

**Sensory evaluation.** Sensory evaluation was carried out using samples at the room temperature of 23–24°C. The reason for carrying out at the room temperature is to minimize temperature fluctuation of the samples. The subjects were prohibited from eating and drinking for 1 h before the start of the sensory evaluation.

A salt concentration difference discriminability test was conducted as follows: 5 mL of each of 0.2, 0.3, 0.4, 0.5, and 0.6 wt% saline solutions was poured into a clear plastic cup of a 20-mL capacity, and the cups were randomly labeled A to E. Sensory evaluation was performed using a ranking method, wherein the subjects were allowed to taste and arrange the cups in the order of concentration. It should be noted that the mouth was rinsed with pure water before tasting each sample, and the same sample could be tasted more than once. Subjects who correctly arranged the solutions were chosen for this study because they were able to distinguish a 0.1 wt% difference in salt concentrations.

Saltiness evaluation of the herb-added 0.4 wt% saline solutions was conducted as follows. The subjects tasted the 0.2, 0.3, 0.4, 0.5, and 0.6 wt% reference saline solutions, with the salt concentrations disclosed, to evaluate the saltiness of the test samples. Next, the subjects tasted the 0.175 and 0.35 wt% herb-added 0.4 wt% saline solutions while being blinded to the salt concentrations. The perceived sensory salt concentration for each herb-added 0.4 wt% saline solution was recorded by an arrow on a VAS, with numerical values of 0.2 to 0.6 wt%, based on the comparison with the perceived saltiness of 0.2 to 0.6 wt% saline, with disclosed salt concentrations (Fig. 1). This VAS-based method can detect subtle changes in clinical fields and has been reported to have good reproducibility (17). VAS has already been applied as a taste evaluation method (18). Considering the subjects’ possible fatigue, sensory evaluation was performed using up to three different herbs per person a day. Some subjects were participated for 2 d to evaluate five different herbs at their own will.

It has been reported that there is a relationship between salty taste preference and salt concentration in miso soup (19). A preference survey regarding the salt level in miso soup was conducted as follows. Miso soups prepared with salt concentrations of 0.6, 0.8, and 1.0 wt% were tasted, and the soup closest to a subject’s preference was chosen by each subject. The relationship between the salt concentration of preference in the miso soup and the salty taste perception of herb-added 0.4 wt% saline solutions was investigated.

A questionnaire survey was conducted regarding the basic characteristics of the subjects (sex, age, height, weight, and time elapsed after meal) and their dietary habits of the participants that may affect their salty taste perception.

**Table 1. Characteristics of the subjects who passed the salt concentration difference discriminability test.**

| Test passer | Mean (SD)% |
|------------|------------|
| Men $n=25$ |            |
| Women $n=44$ |           |
| Age (y) | 20.6 (1.4) | 21.2 (1.2) |
| Height (cm) | 172.1 (7.8) | 156.3 (5.6) |
| Weight (kg) | 62.0 (9.3) | 47.7 (5.1) |
| BMI (kg/m²) | 20.9 (2.1) | 19.5 (1.7) |
| Time elapsed after meal (h) | 3.4 (2.8) | 2.4 (1.0) |
Herbs Enhance Salty Taste Perception

Table 2. Sensory salt concentrations in herb-added 0.4 wt% saline and ratio to the actual concentration.

| Herbs     | 0.175 wt% added herb extract | 0.35 wt% added herb extract |
|-----------|------------------------------|-----------------------------|
|           | Sensory salt conc. | Ratio to actual conc. | Sensory salt conc. | Ratio to actual conc. |
| Basil     | 0.40 (0.10) | 1.00 (0.25) | 0.48 (0.10)** | 1.21 (0.24)** |
| Parsley   | 0.39 (0.09) | 0.97 (0.23) | 0.45 (0.10)** | 1.13 (0.24)** |
| Anise     | 0.39 (0.10) | 0.97 (0.25) | 0.45 (0.12)** | 1.13 (0.29)** |
| Rosemary  | 0.39 (0.11) | 0.97 (0.27) | 0.48 (0.08)** | 1.19 (0.20)** |
| Oregano   | 0.40 (0.10) | 0.99 (0.25) | 0.49 (0.09)** | 1.22 (0.22)** |

***p<0.001: 0.175 wt% added vs. 0.35 wt% added (paired t-test).

RESULTS

Salt concentration difference discriminability test

 Among the students, 44 women and 25 men passed the test. There was no sex difference in the pass rate (86%). The data for the subjects who passed the test were analyzed; Table 1 shows the basic characteristics of the subjects.

and exercise habits that may affect the degree of sensory evaluation. The questions included were whether home cooking involved deep seasoning, whether seasoning was added in meals, whether salty foods were consumed frequently, whether eating out was frequent, whether delicatessens were eaten frequently, and whether exercise was frequent. The answers were provided using option 1 (No), 2 (Sometimes), or 3 (Yes). In addition, the flavor preference and familiarity with each herb used in the evaluation were marked as 1 (Yes) or 2 (No).

Statistical analyses. The data were analyzed for the 69 students who passed the salt concentration difference discriminability test. There was no sex difference in the saltiness evaluation after the addition of herbs; therefore, data analyses were performed without sex distinction. All statistical analyses were performed using the IBM Statistical Program for Social Sciences ver. 24.0.

Continuous variables were expressed as the mean and standard deviation. A paired Student’s t-test was used to compare the average values of the sensory salt concentrations and the ratios of the actual salt concentration between the two groups for different concentrations of the added herbs. An unpaired Student’s t-test was used to compare the average sensory salt concentrations classified according to herb preference and familiarity.

An unpaired one-way analysis of variance was performed to compare the average sensory salt concentrations and average ratios of the sensory salt concentrations to the actual salt concentrations among groups classified by herb type. The same method was used to compare the average values of the sensory salt concentrations classified by the preference of miso soups and by eating and exercise habits (data not shown).

Categorical variables are expressed as a proportion (%) or number. p<0.05 was considered statistically significant.

### Table 3. Sensory salt concentration of 0.35 wt% herb-added 0.4 wt% saline classified by the preferred salt concentration (0.6, 0.8, 1.0 wt%) in miso soup. Mean (SD) wt%

| Herbs     | Number of preference of salt conc. in miso soup | Sensory salt conc. of 0.35 wt% herb-added 0.4 wt% saline |
|-----------|-----------------------------------------------|--------------------------------------------------------|
| Basil     | 69 0.6 wt% n=23 0.8 wt% n=30 1.0 wt% n=16 | 0.49 (0.09) 0.50 (0.11) 0.44 (0.07) |
| Parsley   | 69 0.6 wt% n=23 0.8 wt% n=30 1.0 wt% n=16 | 0.46 (0.10) 0.46 (0.10) 0.43 (0.10) |
| Anise     | 56 0.6 wt% n=15 0.8 wt% n=17 1.0 wt% n=11 | 0.41 (0.12) 0.47 (0.10) 0.48 (0.10) |
| Rosemary  | 56 0.6 wt% n=11 0.8 wt% n=14 1.0 wt% n=6  | 0.52 (0.08) 0.45 (0.07) 0.46 (0.07) |
| Oregano   | 56 0.6 wt% n=11 0.8 wt% n=14 1.0 wt% n=6  | 0.52 (0.09) 0.47 (0.08) 0.47 (0.09) |

Preferred salt concentration in miso soup 0.6 wt% vs. 0.8 wt% vs. 1.0 wt%: n.s. (ANOVA).

Saltiness evaluation of herb-added 0.4 wt% saline

The perceived sensory salt concentrations of the herb-added 0.4 wt% saline solutions with two different concentrations of the added herbs were indicated on the VAS, using the perceived saltiness of 0.2 to 0.6 wt% as a reference. The results are shown in Table 2. The sensory salt concentrations of the 0.175 wt% herb-added 0.4 wt% saline solutions were significantly higher than those of the 0.175 wt% herb-added 0.4 wt% saline solutions (p<0.001) and were estimated 1.13 to 1.22 times higher than the actual salt concentration.

Relationship between the preferred salt concentration in miso soup and sensory salt concentration of 0.35 wt% herb-added 0.4 wt% saline

The subjects were divided into three groups based on the preferred salt concentration (0.6, 0.8, or 1.0 wt%)
in miso soup, and the mean values of the sensory salt concentrations of the 0.35 wt% herb-added 0.4 wt% saline in each group were calculated (Table 3). Regardless of the kind of herb, the sensory salt concentrations of the 0.35 wt% herb-added 0.4 wt% saline solutions were similar among the three groups.

**Table 4. Sensory salt concentration classified by herb preference and familiarity.**

| 0.35 wt% herb extracts added | Preference (%) | Familiarity (%) |
|------------------------------|----------------|-----------------|
| Basil \( (n=69) \)           | 88.4 (0.09)    | 73.9 (0.08)     |
| Parsley \( (n=69) \)          | 63.2 (0.10)    | 79.4 (0.10)     |
| Anise \( (n=43) \)            | 38.1 (0.14)    | 7.1 (0.13)      |
| Rosemary \( (n=31) \)         | 56.7 (0.08)    | 36.7 (0.08)     |
| Oregano \( (n=31) \)          | 20.0 (0.07)    | 10.0 (0.02)     |

Like vs. Dislike; n.s. (unpaired t-test).
Familiar vs. Unfamiliar; n.s. (unpaired t-test).

![Fig. 2. Percentages of the dietary and exercise habits in the subjects.](image)

**DISCUSSION**

There are two ways to reduce salt intake: 1. replacing the salty taste with other tastes and maintaining the acceptability of foods, even when saltiness is reduced, and 2. enhancing saltiness using other ingredients (15). The latter method, employing herbs, was evaluated in this study.

It is difficult to perceive a purely salty taste in soups and other dishes because they contain many compo-
nents, such as carbohydrates, lipids, and amino acids, in addition to salt. Therefore, the salty taste-enhancing effects of selected herbs were evaluated in the present study using a saline solution, which contains only salt.

The average salt concentration in reduced-salt foods has been reported to be approximately 0.4 to 0.5 wt% (2). In this study, to evaluate the salty taste-enhancing effects of herbs, saline, at a concentration of 0.4 wt%, which is lower than the generally preferred salt concentration (approximately 0.9 wt%), was used as a stock solution.

Subjects were recruited from general students, believed to have a general taste sensation. To eliminate any bias, the concentration of saline used in the herb addition test was not disclosed to the subjects. The subjects were asked to evaluate the salt concentration of the herb-added saline solutions using a VAS, by comparing the salty sensations of these solutions with those of the 0.2 to 0.6 wt% saline solutions with disclosed concentrations. Results indicated that adding 0.35 wt% herb extracts to 0.4 wt% saline resulted in a salty taste equal to that of 0.45 to 0.49 wt% saline being perceived. It was estimated that the herbs enhanced the salty taste by 1.13 to 1.22 times and can be expected to reduce the salt usage by approximately 10 to 20%.

Five herbs commonly used in Japan were tested and found to not significantly differ in their ability to enhance salty taste. Furthermore, there were no significant differences in the saltiness-enhancing effects of herbs depending on the preference for and familiarity with the herbs. When assessing the saltiness enhancement in a dish, the subjects have to distinguish between the saltiness enhancement effect of a herb and the improvement of dish palatability by the herb. However, through the use of saline, the evaluation can be focused on the salty taste enhancement, without any other factors influencing taste. This may have contributed to the absence of any differences associated with herb preference and familiarity in our study.

Lawrence et al. (20) reported that salty taste could be strongly perceived upon adding a flavor component that mimicked a salty food. Guichard et al. (21) reported links between taste descriptors and odor descriptors using gas chromatography/olfactometry analysis. For example, odors described as either toasted, potato, sulfur, or mushroom were associated with saltiness. Based on these reports, it is considered that aroma components of herbs contribute to the enhancement of the salty taste; however, identification of herb aroma components requires further study.

Saline solutions containing the herb extracts were colored lightly brown. Since transparent cups were used for the sensory evaluation, a slight difference in the color of these solutions could be observed compared with that of saline without added herb extracts. This coloring may have affected the salty sensation. A previous study found that sour, sweet, and bitter thresholds were altered by yellow, red, and green visual stimuli, although the salty threshold was not affected by these stimuli (22). It is unknown whether coloring affected the perception of the salty taste in this study, thus the effect of color on salty taste perception is another subject for further study.

In a study examining the relationship between dietary habits and salty sensations, it has been reported that people who frequently eat out have a reduced ability to discriminate between different salt concentrations (23). In this study, the preference for a certain salt concentration in miso soup and dietary habits were not related to the perceived saltiness-enhancing effects of herbs. We believe that saltiness enhancement by herbs could be perceived by persons with any dietary habits.

Saltiness enhancement could not be confirmed in this study when the herb content in the saline was 0.175 wt%. Mitchell et al. (2) reported that adding 0.15 wt% rosemary to a vegetable soup with the salt concentration reduced from 0.93 to 0.45 wt% could preserve the taste of the soup. However, this report did not suggest that the addition of the herb enhanced the saltiness of the soup. The reason why the addition of 0.175 wt% herb (including rosemary) did not have a saltiness-enhancing effect in our study may have been the use of hot-water herb extracts. Hot-water extracts of herbs may be less flavorful than herbs themselves are when added to food. Herb aroma components are known to be present in herb essential oils (24). Soups and other dishes contain oils, and the essential oils of herbs are thus easily dissolved in such dishes. However, in the case of hot-water extracts, it is possible that oil-soluble herb essential oils are not extracted enough. If unprocessed herbs are added to a dish, saltiness enhancement effects may be obtained using herb amounts of less than 0.35 wt%.

Several limitations of this study should be acknowledged. Sensory evaluation is often performed by a small number of trained panelists, but the panelists employed in the present study were general students. Therefore, the accuracy of the sensory evaluation conducted herein could be low, although the opinions of panelists with a general taste sense may be suitable for such evaluations (25). To keep the quality of the results, a 0.1 wt% salt concentration difference discrimination test was administered to the panelists, and only those who passed the test were selected (Table 1).

Since the all persons were not simultaneously evaluating the effects of the five herbs, the comparison accuracy of the saltiness-enhancing effects of different herbs may not be good.

The herb extracts added to the saline were obtained using methods developed by us; therefore, it is difficult to generalize the amounts of herbs used in this study. The temperature of the test solutions used for the sensory evaluation was 23–24°C. In many cases, foods are eaten at warmer or cooler temperatures than the room temperature; thus, the relationship between the temperature and the salty taste-enhancing effect needs to be examined in the future. Furthermore, we used herbs easily available in Japan. The degree of saltiness enhancement by other herbs and spices also needs to be evaluated in the future.
In conclusion, although it has previously been reported that the addition of herbs to dishes, such as soups, has a salt-reducing effect, this study showed the degree of such an effect in numerical values. It was estimated that the addition of a 0.35 wt% herb extract enhanced the salty taste of a 0.4 wt% saline by 1.13 to 1.22 times. Furthermore, even when there were differences in dietary and exercise habits of the participants, the salty taste-enhancing effects of herbs were found. Considering the problem of excessive salt intake in many countries, these findings can aid effective salt-intake reduction.

Authorship
Research conception and design: TK and RK; experiments and data collection: TK, RK, CM, and MK; statistical analysis of the data: TK and HT; interpretation of the data: TK and RK; writing of the manuscript: TK and RK.

Disclosure of state of COI
No conflicts of interest to be declared.

Acknowledgments
We would like to thank all the students who participated in this study and Editage (www.editage.com) for the English language editing of the manuscript.

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