

# Investigate the effect of partial replacement of NaCl with KCl on salty perception and preference in Vietnamese pumpkin soup and tomato soup

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## ABSTRACT

Salt (NaCl) reduction is currently a critical problem. High salt consumption leads to the excessive amount of Na<sup>+</sup> in bloodstream, which negatively affects human health by increasing the risks of getting hypertension, cardiovascular and other diseases. Among the prospective substances for replacing NaCl, potassium chloride (KCl) is one of the most promising one. However, KCl at high concentration was reported to impart the metallic taste and bitterness in food, so research on the optimal replacement of NaCl by KCl is an ongoing endeavour. This research was therefore conducted to investigate the effect of replacing NaCl by KCl on the saltiness perception and the acceptance level in two soups: Vietnamese pumpkin soup and tomato soup. The visual analog scale (VAS) was used to measure the saltiness perception, while the hedonic 9 – point scale was used to evaluate the customer's acceptance level. Each soup was prepared with 5 different combinations of KCl and NaCl: 2 NaCl samples with no KCl added (0.65% and 0.75%), 3 samples with the NaCl concentration remained at 0.65% and different levels of KCl (0.1%, 0.133%, and 0.167%). Overall, all three samples with KCl added had higher salty intensity than the 0.65% NaCl, but these samples' saltiness did not reach that of sample with 0.75% NaCl in both Vietnamese pumpkin soup and tomato soup. For the hedonic scores, the results showed that adding KCl did not have significant effects on the acceptance of the consumers, since there were no significant differences between those samples in both soups. It can be concluded that KCl, at the concentration in this research, effectively enhance the saltiness in Vietnamese pumpkin soup and tomato soup without leaving any undesirable sensory properties that affected the consumers. Therefore, KCl can be considered as a good solution in reducing NaCl.

**Key words:** potassium chloride, salt replacement, pumpkin soup, tomato soup

## INTRODUCTION

The habit of using table salt (NaCl) as an additive in daily meals and food processing industry has become familiar for centuries due to its several functions such as saltiness enhancer, food preservatives, etc. Although NaCl is an indispensable component, high salt consumption has become a worldwide concern due to health risks.

The salt intake of countries has been reported to increase rapidly, and this intake were much higher than the recommended salt intake of 5g/day from the World Health Organization (WHO). According to the results of several studies, Vietnam was listed as one of the countries with very high salt consumption. Specifically, on average, Vietnamese people consumed about 9.4g of salt per day<sup>1</sup>, two times higher than the amount of salt recommended by WHO (5g/day)<sup>2</sup>. This high salt consumption greatly increased health risks. Research has showed a strong link between high NaCl consumption and high blood

pressure. Furthermore, the high consumption of salt can lead to number of consequences related to human health, including high blood pressure, cardiovascular diseases, etc.<sup>3,4</sup>.

This situation of high salt consumption has led to the recommendation by WHO to lower NaCl intake in foods by 35% by the year of 2025<sup>5</sup>. Therefore, salt reduction methods have been investigated throughout the world. Over four years, nutritional program in United Kingdom has successfully reduced approximately 16% of NaCl daily intake with the achievement that individuals did not recognize the salt level has been gradually reduced<sup>6</sup>, while in Japan, they have successfully reduced the amount of salt in daily food from 14.5 to 9.5 grams in the period of 1993 – 2017<sup>7</sup>. Furthermore, many researches have focused on raising customer awareness towards the high level of salt intake to encourage people to reduce their daily NaCl usage<sup>8,9</sup>. However, reducing NaCl did have some disadvantages. Research reported that decreas-

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ing the amount of NaCl in food resulted in negative effects on consumers' appetizer and sensory properties<sup>10</sup>. As a result, maintaining the sensory properties by replacing NaCl with other salt compounds is currently the preferred approach. Among these salt compounds, potassium chloride (KCl) is one of the most potential salt substitutes that has similar characteristic to NaCl, in addition to its lesser impact on human health. This can be considered to be one of the most common NaCl reduction compounds despite the fact that at high concentration, KCl may have metallic or bitterness flavor<sup>11, 12</sup>. Approaches have succeeded in replacing NaCl partially by KCl in some type of foods. Juan et al. concluded that a ratio of 60 NaCl:40 KCl could be considered as a possible solution for salt replacement in cow's milk cheeses<sup>13</sup>. While in the fermented pork sausages, Zampouni et al. revealed that the formulated products with KCl salt replacement demonstrated comparable fermentation and ripening behavior to the sample with NaCl<sup>14</sup>. In case of wheat bread products, for the 50% NaCl substitution by KCl, it was reported that no significant differences were recognized compared to the control sample (100% NaCl)<sup>15</sup>. From the above literature review, this research was conducted with the aim of investigating salty intensity and the customer acceptance level of NaCl replacement method by using KCl. The research was conducted on two food products: pumpkin soup and tomato soup. Soup making involves minimal processing steps, so soup is an appropriate choice to examine the effects of replacement of NaCl by KCl on taste and preference. Pumpkin soup was chosen because this is a popular soup in Vietnam and the soup has a neutral taste, so the effects of KCl on taste is more pronounced for participants to evaluate. Tomato soup was chosen to compare the results of this study with other research about NaCl replacement, since there are many pieces of research about NaCl replacement on tomato soup.

## MATERIALS AND METHODS

### Participants and test condition

In total, 100 participants were recruited from Ho Chi Minh University of Technology, Ho Chi Minh City, Vietnam. The age of the subjects ranged from 18 to 25. The recruitment criteria included absence of any diseases or disorders related to the taste perception and the interest in joining the study.

### Sample preparation

We conducted this research on two food products: pumpkin soups and tomato soups. The materials for

preparing the soups are presented below. The soups were prepared on the day of testing and served to the participants at 60°C. Each sample contained 20 ml of soup and was served in a disposable paper cup with a cover lid.

All the tests were performed at the Sensory Laboratory of Food Technology Department of Ho Chi Minh City University of Technology. The environmental conditions were controlled at air-conditioned temperature (25°C) under the white light. The laboratory was designed with individual partitioned booths.

### Vietnamese pumpkin soup

Cucurbita pepo L. pumpkins and herbs (cilantro and rice paddy herb) were purchased at the supermarket. The herbs were used to reflect the similar flavor profile of original soup that most Vietnamese people usually eat.

Pumpkins after purchased would be washed to eliminate dust and the skin of pumpkin was removed. The pumpkin seeds were then removed and the pulp was chopped into small pieces. The small pieces were washed before cooking. The Vietnamese pumpkin soup was prepared with ratio of 500 grams of chopped pumpkin and 1L of water. The temperature and time for heating process is 95°C for 10 minutes. Monosodium glutamate (MSG) was added 1g/1L soup, then at the end of cooking the herbs (cilantro and rice paddy herb) were added at 5g/1L soup. After finishing the heating step, the pumpkin pulps were removed since the samples with pulps may distract the participants from evaluating the salty intensity. Different salt concentrations were then added into the pumpkin soup (Table 1).

### Tomato soup

We followed the procedure in the research of L. Pilic et al. for preparing tomato soup<sup>16</sup>. The tomato puree that used in this experiment is called Passata Rustica which come from Luce, Italy. This puree made of mostly raw tomatoes, therefore it has a distinctive fresh tomato flavor compared to the other tomato sauces.

Firstly, the tomato puree and water were weighted at the ratio 1:1, then mixed, then heated at 95°C for 5 minutes. After heating, the soup was then poured out into six bottles and measured according to the pre-calculated volumes, the salt concentrations that shown in Table 1 are sequentially put into the soup bottles to complete the test samples.

**Table 1: Percentage of NaCl and KCl in evaluated samples**

Sample	1	2	3	4	5
% NaCl/soup (w/w)	0.65%	0.75%	0.65%	0.65%	0.65%
% KCl/soup (w/w)	0%	0.1%	0.133%	0.167%	0%

[Source: Authors]

### Sensory testing procedure

In the first session, participants were presented with the saline solution on the VAS scale to familiarize with the intensity evaluation. They were asked to taste the three saline solutions with the order from the lowest to the highest concentration, then tried to remember the salt intensity of each concentration. The VAS is a type of line scale, which facilitates the use of non-parametric statistics. Besides, biases from using numerical scales can be lowered by applying VAS. The VAS scale was used to quantify the intensity of salty taste. The VAS scale used in this experiment was anchored at 3 points shown in Figure 1. These anchor points equaled to the intensity of three saline solutions (0.5%, 0.65% and 0.8%)<sup>16</sup>.

In the following sessions, participants evaluated the intensity of salt and the overall liking of 5 pumpkin soups (second session) and of 5 tomato soups (third session). Participants had to rinse their mouths with distilled water before and after tasting every sample. For the salty intensity, the visual analogue scale (VAS) with 3 marks (0.5, 0.65 and 0.8) was used to record the salt concentration that the participants perceived. Participants were asked to compare the saltiness of the soup samples with the references and then put a mark on the VAS. For the hedonic evaluation part, participants needed to rate the sample using the 9-point liking scale. The 9-point liking scale, which is also known as the degree of liking scale, is the most commonly used hedonic scale and is considered simple and easy to use<sup>17</sup>. In this type of scale, preference acts as the baseline for evaluation and can be categorized according to like and dislike. The 9 terms used in this scale typically include dislike extremely, dislike very much, dislike moderately, dislike slightly, neither like nor dislike, like slightly, like moderately, like very much and like extremely. Normally, the labels are corresponding to the value from 1 to 9, with 1 referring to dislike extremely and 9 assigning to? like extremely.

### Data analysis

For the data analysis of saltiness intensity, we filtered out participants who did not give higher intensity for sample 0.75% than that of sample 0.65% because these participants had low discrimination threshold

and might dilute the results. Analysis of variance (ANOVA) and post hoc least significant difference (LSD) test were then used on the data of the filtered participants to evaluate the intensity difference between samples.

For the data analysis of hedonic liking, we considered all of the participants, since we wanted to study the general liking trend of consumers. ANOVA and LSD test were used to evaluate the liking difference between samples. The data analysis was done using Rstudio software.

## RESULTS AND DISCUSSIONS

### Vietnamese pumpkin soup

After filtration, 65 participants could discriminate 0.65% and 0.75% NaCl samples and thus the data for these 65 people were used to analyze the saltiness intensity (see section 2.5). The pumpkin soups with 0.167% KCl and 0.1% KCl were showed to have an intensity of saltiness greater than the sample with 0.65% NaCl (Table 2). These 2 samples were not statistically different, but were found to have significant differences with the remaining soup containing 0.133% KCl. Statistical analysis revealed that participants generally perceived a saltier taste in samples with KCl, compared to the 0.65% NaCl sample without adding KCl. However, soups containing KCl had significantly lower intensity of saltiness than soups with 0.75% NaCl. The salty taste is perceived by electrically charged ions that pass into and out of cells through specialized protein pores, called sodium ion channels, which are embedded within cell membranes of taste cells. The K<sup>+</sup> ion had similar size to Na<sup>+</sup> ion, so K<sup>+</sup> ion can also pass through the sodium ion channels to induce salty taste. However, the saltiness of KCl only equals to 0.6 the saltiness of NaCl. Thus, when replacing NaCl with up to 1.67 times KCl (0.167% KCl compared to the reduce amount of 0.1% NaCl), the intensity of salty taste was not the same as before reducing NaCl. For these reasons, it could be concluded that KCl did enhance the salty taste in pumpkin soup, but the replacement ratio needed to be higher than 1.67. The result was different from that of Crouch et al. in which 62% of the participants indicated that they sensed the same level of saltiness at the replacement ratio of 1:1<sup>18</sup>.



Figure 1: VAS with 0.5, 0.65 and 0.8 marks. [Source: Authors]

Table 2: Saltiness and liking of Vietnamese pumpkin soup with KCl (mean ± standard deviation)

Sample	0.65% NaCl	0.75% NaCl	0.65% NaCl and 0.1% KCl	0.65% NaCl and 0.133% KCl	0.65% NaCl and 0.167% KCl
Saltiness (N=65)	61.800 <sup>c</sup> ± 7.758	70.723 <sup>a</sup> ± 7.201	66.169 <sup>b</sup> ± 8.994	63.723 <sup>c</sup> ± 7.841	67.292 <sup>b</sup> ± 7.909
Liking (N=100)	6.090 <sup>ab</sup> ± 1.371	5.750 <sup>c</sup> ± 1.610	6.060 <sup>abc</sup> ± 1.448	6.270 <sup>a</sup> ± 1.413	5.900 <sup>bc</sup> ± 1.459

<sup>a-c</sup> Means within a row with different letters are statistically different (p ≤ 0.05).

[Source: Authors]

For liking, pumpkin soup samples with 0.65% NaCl and 0.133% KCl received the greatest liking (Table 2). However, the post-hoc test revealed that this sample was not significantly different from the sample of 0.65% NaCl and the soup of 0.65% NaCl and 0.1% KCl, which placed second and third in hedonic scores, respectively. In addition, the liking of 0.75% NaCl sample was the lowest among the 5 soups and was significantly different than the best-liked samples. In summary, adding KCl to pumpkin soup did not decrease the liking of consumers. Therefore, from the hedonic point of view, it could be acceptable to use KCl as a replacement for NaCl reduction in Vietnamese pumpkin soup. However, at high concentration, KCl imparts bitter and metallic taste which lower the liking of consumers. Therefore, KCl cannot replace 100% NaCl used in food.

### Tomato soup

For tomato soups, the participants perceived the soups with KCl as saltier like the pumpkin soup. This was verified by the higher salty intensity for KCl-contained soups in ANOVA results and the significant difference between these samples and the sample of 0.65% NaCl in the post-hoc test (Table 3). Accordingly, it could be concluded that KCl also enhanced the saltiness of tomato soup, which had high acidity and sourness compared to the neutral flavor profile of pumpkin soup. The results were consistent with the study of Hooge et al. which confirmed that there was an increase in salty taste intensity when raising the concentration of KCl<sup>19</sup>. However, the participants perceived similar salty intensity for the 3 samples containing different amount of KCl. This could be explained by the sourness of the tomato soups masking the saltiness, thus perceiving saltiness in small increment proved difficult for naïve consumers. On the other hand, the salty taste intensity of soups with KCl was significantly lower than the sample containing only 0.75% NaCl. Therefore, when replacing 0.1% NaCl (on the basis of total soup weight) by the equal and higher amounts of KCl, the salty taste intensity was decreased. It could be assumed that the taste given by KCl might not be as salty as that given by NaCl even with high acidity food like tomato soups.

Regarding the liking scores of participants towards tomato soups with addition of KCl (Table 3), sample 0.65% NaCl with no added KCl, sample 0.65% NaCl with 0.133% KCl and sample 0.65% NaCl with 0.167% KCl had the highest liking scores (these 3 samples showed no significant difference when compared to each other). The soups containing KCl were not statistically different from each other, illustrating that adding KCl 0.1% - 0.167% showed no difference in hedonic trend of consumers for tomato soup. In summary, the addition of KCl had no significant effect on preference of saltiness in tomato soup. This leads to the conclusion that KCl can be potentially used as a NaCl replacement solution since it is able to increase the salty taste without compromising the liking of consumers. However, it is important to note that KCl at high concentration impart the metallic and bitter taste. Even though sodium in NaCl was said to have the ability to suppress bitterness<sup>20</sup>, it could only mask the bitter taste to a certain level of KCl and this level depends on the food matrices.

**Table 3: Saltiness and liking of tomato soup with KCl (mean ± standard deviation)**

Sample	0.65% NaCl	0.75% NaCl	0.65% NaCl and 0.1% KCl	0.65% NaCl and 0.133% KCl	0.65% NaCl and 0.167% KCl
Saltiness (N=65)	60.380 <sup>c</sup> ± 7.504	69.360 <sup>a</sup> ± 7.333	65.360 <sup>b</sup> ± 8.821	66.520 <sup>b</sup> ± 8.273	65.880 <sup>b</sup> ± 8.128
Liking (N=100)	5.660 <sup>a</sup> ± 1.712	5.160 <sup>b</sup> ± 1.818	5.190 <sup>b</sup> ± 1.679	5.470 <sup>ab</sup> ± 1.623	5.370 <sup>ab</sup> ± 1.715

<sup>a-c</sup>Means within a row with different letters are statistically different (p ≤ 0.05).

[Source: Authors]

## CONCLUSIONS

In conclusion, KCl can be used to replace NaCl in Vietnamese pumpkin soup and tomato soup without significant effects on the consumer's acceptance. However, KCl have significant lower salty taste than that of NaCl, even at replacement ratio of 1.67:1 KCl:NaCl. Therefore, the substitution of NaCl by KCl can be a potential solution to tackle the problem of high NaCl consumption which can lead to some negative health effects such as cardiovascular and kidney diseases.

## LIST OF ABBREVIATIONS USED

ANOVA Analysis of Variance  
 LSD Least Significant Difference  
 VAS Visual analog scale  
 WHO World Health's Organization

## COMPETING INTERESTS

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

## AUTHORS' CONTRIBUTIONS

My Tien Nguyen, Trang Minh Hong Pham: Methodology, Investigation, Funding acquisition. Thinh Huu Pham: Formal analysis. Dzung Hoang Nguyen, Hien Thi Nguyen: Formal analysis, Supervision.

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# Nghiên cứu ảnh hưởng của việc thay thế một phần NaCl bằng KCl đến cảm nhận vị mặn và mức độ ưa thích trong súp bí đỏ và súp cà chua

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## TÓM TẮT

Giảm muối (NaCl) hiện đang là một vấn đề mang tính cấp bách. Việc tiêu thụ nhiều muối dẫn đến dư thừa lượng Na<sup>+</sup> trong máu, ảnh hưởng tiêu cực đến sức khỏe con người do làm tăng nguy cơ mắc bệnh cao huyết áp, tim mạch và các bệnh khác. Trong số các chất có tiềm năng thay thế NaCl, kali clorua (KCl) là một trong những chất có triển vọng nhất. Tuy nhiên, KCl ở nồng độ cao được cho là mang lại vị kim loại và vị đắng trong thực phẩm, vì vậy nghiên cứu về sự thay thế tối ưu NaCl bằng KCl là một nỗ lực đang được tiến hành. Vì vậy, nghiên cứu này được thực hiện nhằm khảo sát ảnh hưởng của việc thay thế NaCl bằng KCl đến cảm nhận độ mặn và mức độ chấp nhận trong hai món súp: canh bí đỏ và súp cà chua. Thang đo tương tự trực quan (VAS) được sử dụng để đo lường cảm nhận về độ mặn, trong khi thang đo độ yêu thích 9 điểm được sử dụng để đánh giá mức độ chấp nhận của người tiêu dùng. Mỗi loại súp được chuẩn bị với 5 hỗn hợp KCl và NaCl khác nhau: 2 mẫu NaCl không thêm KCl (0,65% và 0,75%), 3 mẫu có nồng độ NaCl duy trì ở mức 0,65% và các mức KCl khác nhau (0,1%, 0,133%, và 0,167%). Nhìn chung, cả 3 mẫu bổ sung KCl đều có nồng độ mặn cao hơn mẫu NaCl 0,65%, tuy nhiên độ mặn của các mẫu này không đạt được độ mặn của mẫu bổ sung NaCl 0,75% ở cả mẫu canh bí đỏ và súp cà chua. Đối với điểm số ưa thích, kết quả cho thấy việc bổ sung KCl không có tác động đáng kể đến sự chấp nhận của người tiêu dùng vì không có sự khác biệt đáng kể giữa các mẫu đó trong cả hai loại súp. Có thể kết luận rằng KCl ở nồng độ trong nghiên cứu này có tác dụng tăng cường độ mặn trong canh bí đỏ và súp cà chua của Việt Nam một cách hiệu quả mà không để lại bất kỳ đặc tính cảm quan không mong muốn nào ảnh hưởng đến người tiêu dùng. Vì vậy có thể coi KCl là loại muối thay thế tốt trong việc giảm lượng NaCl.

**Từ khóa:** KCl, thay thế muối, súp bí đỏ, súp cà chua

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