Impact of capsaicin on salt release and salt perception during consumption of salt and salt-capsaicin solutions

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Abstract

The mechanism on how capsaicin could affect salt release in the mouth and its saltiness perception was unknown. This is the first study designed to investigate the impact of capsaicin on salt release in the tongue and correlate with its perception during and after consumption. A simple 1% NaCl solution was used without or with 5 ppm capsaicin as CTR or CAP solution, respectively. Thirty panellists were recruited and trained to score salt and spicy intensity when holding the sample in the mouth for 10 s, then for every 10 s after swallowing till 60 s. Swab analysis was used to investigate the level of salt released after consumption of CTR or CAP solution every 10 s till 60 s. The results indicated that the saltiness rating was significantly reduced by 13% as the result of capsaicin ($P < 0.05$), which could be due to the dilution effect by extra capsaicin-stimulated saliva. Individual panellists varied on their saltiness and spiciness scores, but there was a positive Pearson's correlation between saltiness and spiciness scores ($P < 0.05$), that is, the higher the spiciness ratings, the higher the saltiness ratings. This indicated a potential multimodal interaction between trigeminal and taste sensation.

Keywords: chilli, spicy, capsaicin, salt, perception

Introduction

Excessive salt intake in our diet has been linked with the onset of hypertension and its cardiovascular complications [1], and a large cohort study (over 13,000 Chinese adults followed for 9 years) revealed that chilli intake was inversely associated with the risk of developing hypertension [2]. Another study [3] indicated that enjoyment of spicy food may significantly reduce individual salt preference, daily salt intake and blood pressure by modifying the neural processing of salt taste in the brain. However, the mechanism on how spicy food could affect salt release in the mouth and its saltiness perception was unknown. Capsaicin, as one of the major functional components in spicy food, is known to trigger the trigeminal sensation in the mouth [4]. This study was designed to investigate the impact of capsaicin on salt release and perception from a simple matrix- 1% sodium chloride solution.

Experimental

Sample solution preparation

Capsaicin stock solution (1%) was prepared by dissolving capsaicin (0.1 g) with food-grade ethanol (10 g). Salt stock solution (1 L) of 1% NaCl was prepared with pure water (Purite Ltd, Oxon, UK), then half of the stock solution (0.5 L) was used as control solution (CTR), and 250 µL of 1% capsaicin was added to another 0.5 L to make 5 ppm capsaicin solution (CAP).

Panel recruitment

Thirty panellists (age 22-35, 8 males, 22 females) at the University of Nottingham were recruited. The frequency of their chilli consumption was recorded and varied between 0-7 times per week (37% consumed less than 3 times, 43% had 3-5 times, and 27% more than 5 times). Every panellist attended two separate sessions: one for salt release analysis, and another for sensory analysis.

Swab analysis

According to an established protocol [4], every panellist firstly rinsed their mouth with 10 mL water, and swab at the top of their tongue with a pre-weighted cotton bud (regard at 0 s). Then they received a randomised sample solution (10 mL) with a 3-digital code, and they swallowed the solution after holding for 10 s, the second swab was taken at 10 s, and they swabbed every 10 s till 60 s. They took 5 min break between samples to rinse their mouth with water, and triplicates samples were given for each solution. All the swabs were extracted by 10 mL of methanol/water (50/50) solution, and their sodium levels were measured by Flame Photometry (Sherwood Scientific Ltd., Model 410, Cambridge, UK), followed a standard method [5].

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Sensory analysis

Sequential profiling in this study used a similar protocol as the previous chilli study [6], and the perceived intensity of saltiness and spiciness was recorded by Compusense™ (Guelph, Canada). A training session was given for every panellist to practice the scoring method using trial samples following a similar procedure as swab analysis: i) holding 10 mL of solution for 10 s, scoring its salty and spicy intensity; ii) swallowing at 10 s, and scoring salty and spiciness every 10 s till 60 s. There was 5 min break between samples to rinse their mouth with water and each solution was measured in triplicates with a randomised order.

Data analysis

A total of 1260 data were collected from swab analysis (30 pp x 3 reps x 7 time-points x 2 solutions), and sensory analysis collected 2520 data (30 pp x 3 reps x 7-time points x 2 solutions x 2 attributes). All the statistical data analysis was done by SPSS (IBM® SPSS® Statistics version 25) and XLSTAT Software ©-Pro (2020.1.3, Addinsoft, Inc). Analysis of variance analysis (ANOVA) was conducted to confirm any significant differences ($P < 0.05$).

Results and discussion

The average sodium level during the 60 s observation period was calculated for both CTR and CAP solutions (Figure 1a). The results indicated that there was a 14% lower level in CAP than CTR, which could be due to the saliva dilution effect. It was reported that 5 ppm capsaicin solution could stimulate an extra 92% saliva over 60 s period [6], so additional saliva could dilute any salt on the tongue before and after swallowing the solution.

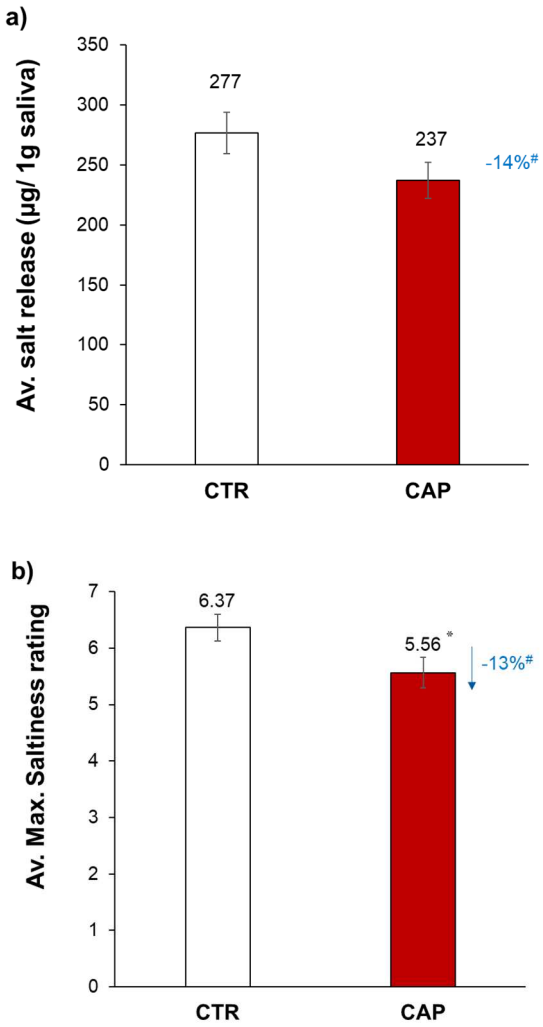

Figure 1*: a) average salt release (µg/ 1g saliva) and b) average of the maximum saltiness rating for CTR (white bar) and CAP (red bar) with standard error bars (30 panellists, 3 reps, 7-time points).* # *indicated % change as (CAP-CTR)/CAP *100%;* * *indicated a significant difference at p < 0.05.*

Additionally, the maximum saltiness rating was averaged between all the panellists (Figure 1b). A similar reduction of 13% in saltiness perception was found, which might correlate to the lower level of salt released during this period. Statically, there is a significant reduction in saltiness perception for CAP, compared to the CTR ($p < 0.05$).

Dynamic profile for salt release was summarised in Figure 2a). The maximum sodium level was reached at 10 s immediately after swallowing the solution, and then the level decreased with time. Generally, CAP had a lower level than CTR after swallowing, which might be caused by the dilution effect by extra saliva secreted by capsaicin.

The perceived saltiness also decreased with time (Figure 2b), and the maximum saltiness perception for CTR reached 10 s when swallowing, but the maximum salty perception for CAP was at 0 s when holding the solution. Saltiness ratings were significantly lower in CAP than in CTR ($p < 0.05$), so capsaicin in salt solution significantly reduced its saltiness perception.

The spiciness rating over 60 s (Figure 2c) illustrated a significant difference between CTR and CAP ($p < 0.05$). Spiciness rating for CAP reached its maximum at 20 s, that is, 10 s after swallowing the solution, so the results illustrated the delayed effect of spiciness perception. Then the spiciness perception reduced gradually with time till 60 s, but the rating at 60 s remained much higher than the maximum spicy rating for CTR, which indicated a long-lasting spicy sensation by capsaicin stimulation. Interesting, CTR solution without any capsaicin had an average spiciness score ~2 at 0 s, which may be due to the panellists were forced to make a choice and some of them might consider 1% salt solution as irritation and scored its spiciness when holding the salt solution. There might also be a "halo" effect as both attributes (spiciness and saltiness) were scored at the same time, so some panellists were likely to rate spiciness the same way as they rated saltiness.

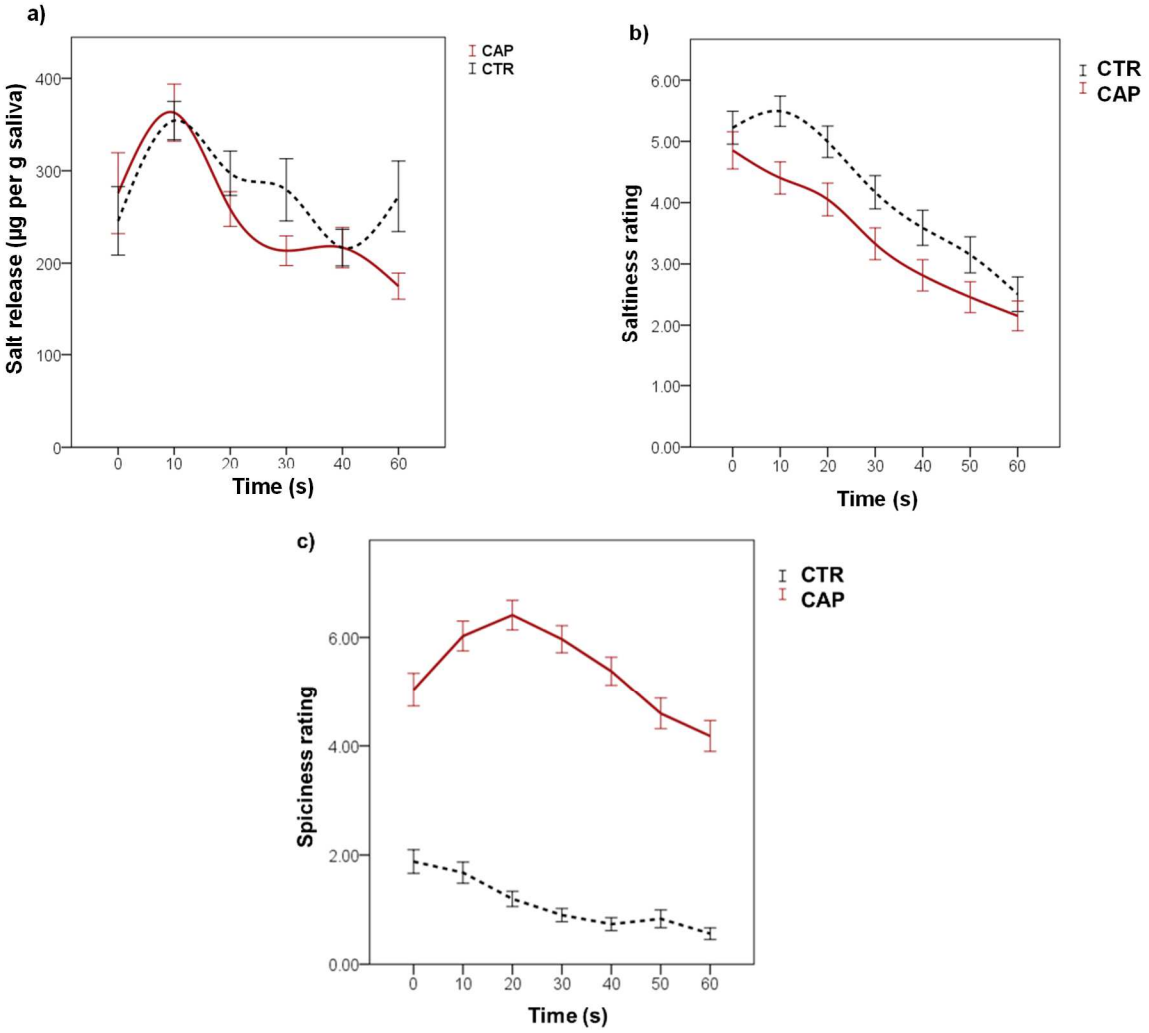

Figure 2*: a) salt release (µg/ 1g saliva), b) saltiness rating, and c) spiciness rating over 60 s for CTR (black dashed line) and CAP (red solid line) when solutions were held in the mouth for 10 s and swallowed after 10 s till 60 s. The standard error is shown as ± error bar (30 panellists, 3 reps).*

The average spiciness and saltiness scores for every panellist were calculated and plotted in Figure 3. The control samples (Figure 3a) indicated that the range of average saltiness ratings (y-axis) was from 1 to 8, so there was an individual difference in their saltiness perception. However, without adding any capsaicin, most people gave a relatively low spiciness rating (< 3). The spiciness scores (x-axis) of CAP samples (Figure 3b) illustrated a wide rating range (1-8), and there was a significant Pearson's correction ($p < 0.05$) between spiciness and saltiness ratings, i.e., the higher the spiciness rating, the higher the saltiness rating. This might indicate a multimodal interaction between trigeminal and taste sensation, as a recent study also reported a potential multisensory interaction between capsaicin-triggered trigeminal sensation and aroma perception [6].

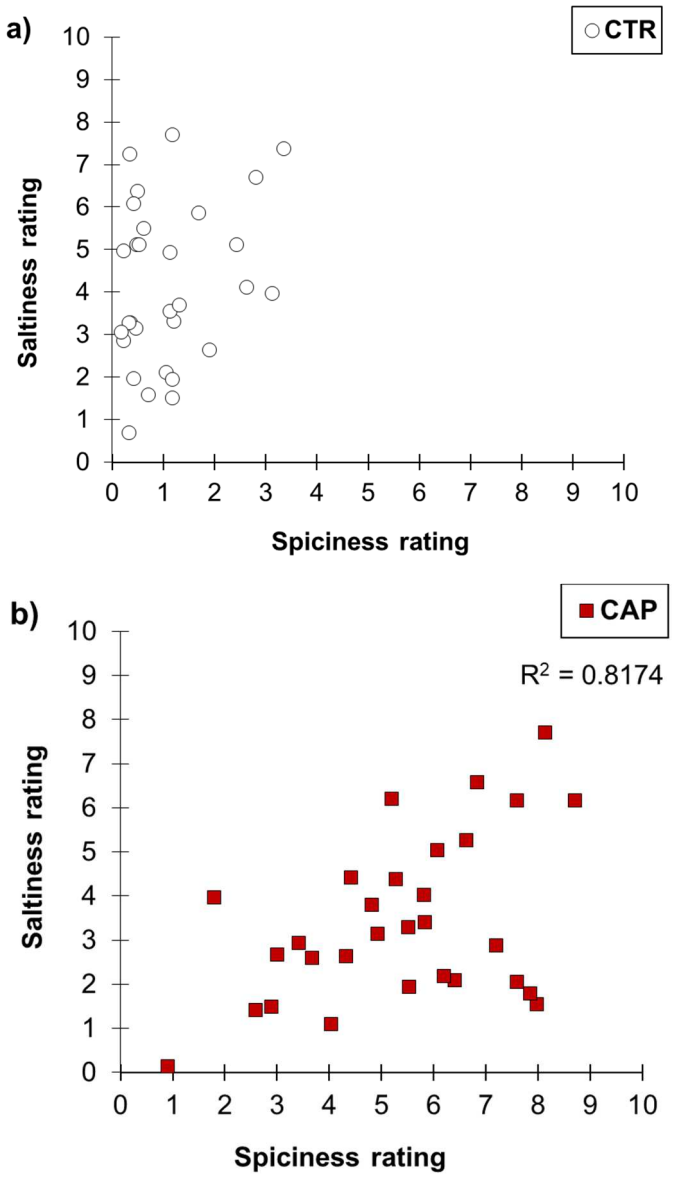

Figure 3*: Scatter plot of maximum spiciness rating against maximum aroma perception for CTR (white dot) and CAP (red square). R^2 value is the coefficient of determination based on Pearson's correlation ($p < 0.05$).*

Conclusion

This study first demonstrated that capsaicin caused a significant reduction in saltiness perception by 13%, and this could be due to the dilution effect by extra saliva with capsaicin stimulation. The individual variations were observed on the saltiness and spiciness ratings, but saltiness ratings were found to be positively correlated with spiciness ratings, so there might be a multimodal interaction between trigeminal and taste sensation. The swab analysis and sensory methods established in the simple salt solution can be further applied into other matrices,

such as more complicated dry food systems, which would allow capsaicin-stimulated saliva to penetrate the matrix and release the embedded salt to the tongue more effectively and lead to a more significant impact on its release and perception.

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