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The Effect of Umami Stimulation on Salivary Secretion Rate and Duration

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Abstract

Purpose: Umami reportedly promotes salivation. We aimed to investigate the effects of taste stimuli on slow and fast salivary secretion in humans using umami, sweet, and sour stimuli. **Methods:** Eight healthy women participated between 14:00 and 15:00, taking the circadian rhythm of salivary secretion into account. The types and concentrations of the taste solutions were glutamic acid (1.7×10^{-3} M), inosinic acid (9.8×10^{-3} M), and guanylic acid (9.8×10^{-3} M) for umami stimulation, citric acid (6.5×10^{-3} M) for acidity stimulation, and sucrose (1.6×10^{-2} M) for sweetness stimulation. First, the unstimulated salivary flow rate was measured. Then, 3 ml of a flavor solution was dropped under the tongue using a syringe. The saliva was expelled into an aluminum cup every minute and weighed. The first minute's value minus 3 ml flavor solution was the stimulated salivary secretion rate produced by each flavor. The time-to-return to the initial unstimulated salivary flow rate was the duration of the stimulated saliva secretion rate. **Results:** The mean unstimulated salivary flow rate across participants was 0.64 ± 0.25 ml/min (range: 0.23 - 1.03 ml/min). The highest amount of saliva was induced by citric acid. There were significant differences between citric acid and the other flavor solutions ($p < 0.05$ for glutamic acid, inosinic acid, and sucrose; $p < 0.01$ for guanylic acid). There were no significant differences in duration of salivation between the flavor solutions. When the participants were divided into slow (0.45 ± 0.16 ml/min) and fast groups (0.83 ± 0.15 ml/min) based on their median resting salivary secretion rate, there were no significant differences between the two groups in the amount of saliva secreted at 1 minute after stimulation and the duration of the salivary secretion rate. **Conclusion:** Umami stimulation was effective in slowing salivary secretion and sustaining salivary secretion after stimulation.

Keywords

Salivary Secretion, Umami Flavor, Oral Health, Stimulated Salivary Secretion

1. Introduction

During the resting state, the oral cavity secretes saliva at an average rate of 0.3 - 0.4 mL/min [1], which moves through the oral cavity as a thin film with an average thickness of 0.1 mm [1]. During this process, saliva absorbs the microorganisms and acids from the tooth surfaces and mucous membranes before being swallowed and thus, purifies the oral cavity [2]. Because the saliva secretion rate is positively correlated with the frequency and volume of saliva swallowed per swallow, the secretion rate of saliva directly influences the efficiency of oral clearance and maintains oral health [3].

With the increase in the elderly population, measures to combat dry mouth and aspiration pneumonia are urgently required. Various methods have been reported for promoting salivary secretion. It has been reported that approximately 80% of the saliva volume secreted during food chewing (average of approximately 4.0 mL/min) is due to taste stimuli [4], and of the four tastes of sour, sweet, salty, and bitter, sour taste promotes salivation the most [5].

Recently, the salivary-stimulating effect of umami [6] has also been reported and used in patients with dry mouth. Although stimulation of salivation by umami taste is considered a desirable drug-independent method, few studies have compared the effects of umami taste stimulation on the slow resting salivary secretion rate in humans with those of other tastes. Therefore, this study aimed to investigate the effects of umami, sweet, and sour taste stimuli on slow and fast salivary secretions.

2. Methods

Participants

This study was approved by the Ethics Committee of the Meikai University School of Dentistry (A2204).

Eight healthy women participants (mean age, 23 ± 3.4 years) who had no disease affecting salivary secretion and were not receiving any medication were included in the study.

Experimental conditions

Considering the circadian rhythm of salivary secretion [7] the measurement time was set between 14:00 and 15:00 h, and the room temperature was kept constant at 26˚C. Eating, drinking, and brushing of teeth were prohibited for 1 h before the measurements.

Taste solutions used

Umami stimuli were generated with glutamic acid (L-glutamic acid, Wako Pure Chemical Industries, Osaka, Japan), inosinic acid (inosine 5'-sodium phosphate, Wako Pure Chemical Industries, Osaka, Japan), guanylic acid Guanosine 5'diphosphate (Wako Pure Chemical Industries, Ltd., Osaka, Japan), and guanylic acid (Guanosine 5'-diphosphate, disodium salt abcam Co.,). Citric acid (Wako Pure Chemical Industries, Ltd., Osaka, Japan) and sucrose (Sigma-Aldrich Japan K.K., Tokyo, Japan) were used to generate acidic and sweet stimuli, respectively.

Concentrations were set to those used for cooking in daily life: glutamic acid 1.7 $\times 10^{-3}$ M, inosinic acid 9.8 $\times 10^{-3}$ M, guanylic acid 9.8 $\times 10^{-3}$ M, citric acid 6.5 $\times$ 10^{-3} M, and sucrose 1.6 $\times 10^{-2}$ M.

Measurement of salivary secretion rate

First, the unstimulated salivary flow rate was measured according to the common method (Dawes, 1987) for 3 min, and the average value for 1 min was calculated as the participant' unstimulated salivary flow rate. The participants were divided into slow (0.45 ± 0.16 ml/min) and fast groups (0.83 ± 0.15 ml/min) groups based on their median unstimulated salivary flow rate.

The flavor solution (3 mL) was dropped under the tongue using a syringe and the participant was asked to spit the saliva into an aluminum cup every minute and weighed. The first 1 min value minus 3 mL of the flavor solution used for stimulation was taken as the stimulated salivary flow rate secreted by each flavor. Saliva was then collected every minute until it returned to each participant's initial unstimulated salivary flow rate, and the time it returned was defined as the duration of stimulated saliva secretion.

After each taste solution, the participants were allowed to rinse their mouths for 10 seconds with 10 mL of distilled water, and 5 min was allowed before the next taste stimulus.

Statistical analysis

The data were analyzed using one-way analysis of variance following which multiple comparisons were made using the student's t-test.

3. Results

Stimulated salivary flow rate and duration by each taste solution.

The mean unstimulated salivary flow rate of each participant was 0.64 ± 0.25 mL/min (range: 0.23 - 1.03 mL/min).

The amount of saliva secreted during the first minute after stimulation with each solution is shown in **Figure 1**. The results showed that citric acid produced the most abundant saliva, with significant differences between it and the other flavor solutions (glutamic acid, inosinic acid, and sucrose: $p < 0.05$; guanylic acid: $p < 0.01$).

The results of the salivation duration stimulated by each flavor solution are shown in **Figure 2**. The duration of salivation was 10.3 ± 6.4 min with citric acid, but there was no significant difference between the solutions. The duration of salivation with the three umami and sucrose solutions was approximately 7 - 8 min.

Salivation rate and duration of low and high unstimulated salivary flow rate groups

There was no significant difference in the amount of saliva between the two groups 1 minute after stimulation for all flavor solutions. The mean values for the inosinic and citric acids tended to be higher in the group with a lower flow rate (**Figure 3**).

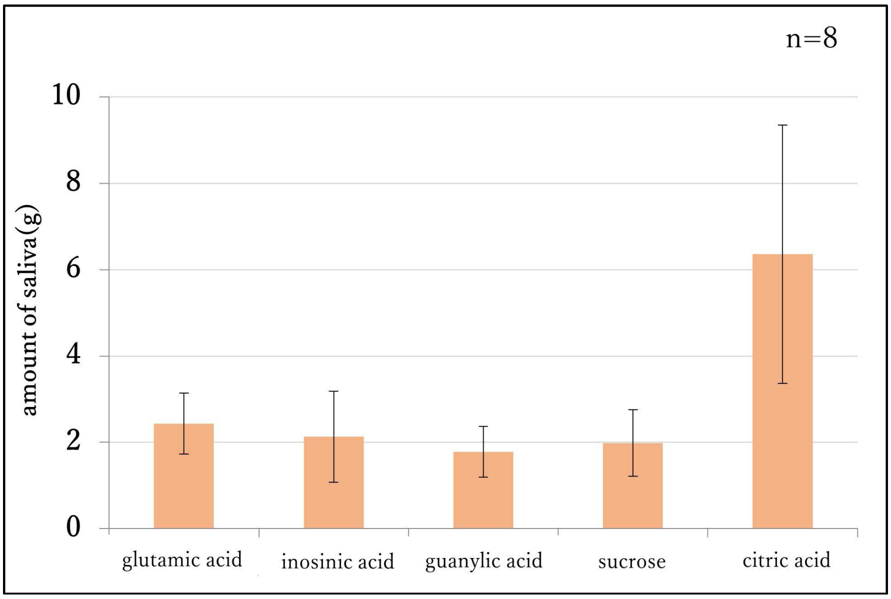

Figure 1. Amount of saliva secreted 1 min after stimulation with each solution. Significant differences were found between citric acid (glutamic acid, inosinic acid, sucrose: $p < 0.05$; guanylic acid $p < 0.01$).

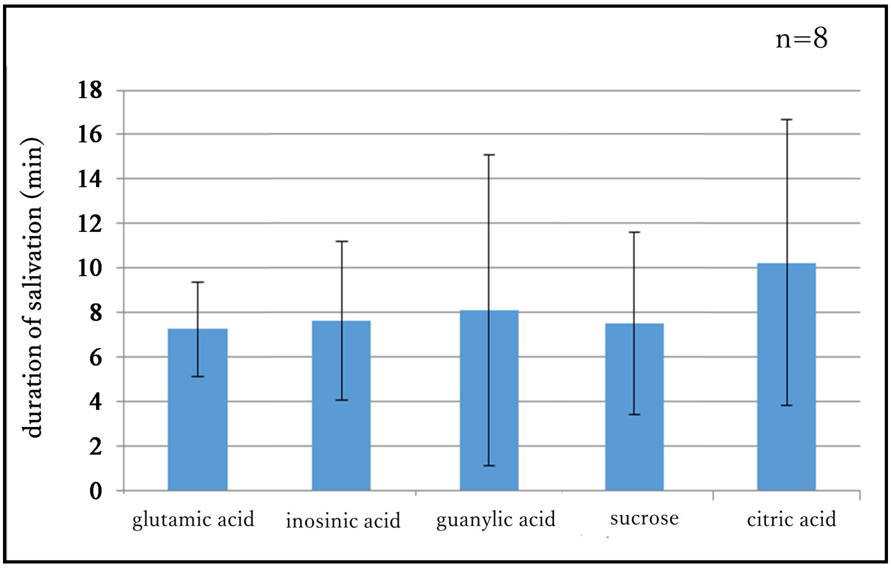

Figure 2. Time required to return to original unstimulated salivary flow rate (no significant difference was found for each value).

The duration of the salivary flow (**Figure 4**) was not significantly different between the two groups for all flavor solutions.

The mean duration of secretion for sucrose, inosinate, guanylate, and citric acid was longer in the slower flow-rate group.

4. Discussion

Citric acid was the best in inducing salivation as a taste stimulation. However, there was no significant difference in the time taken to return to the initial

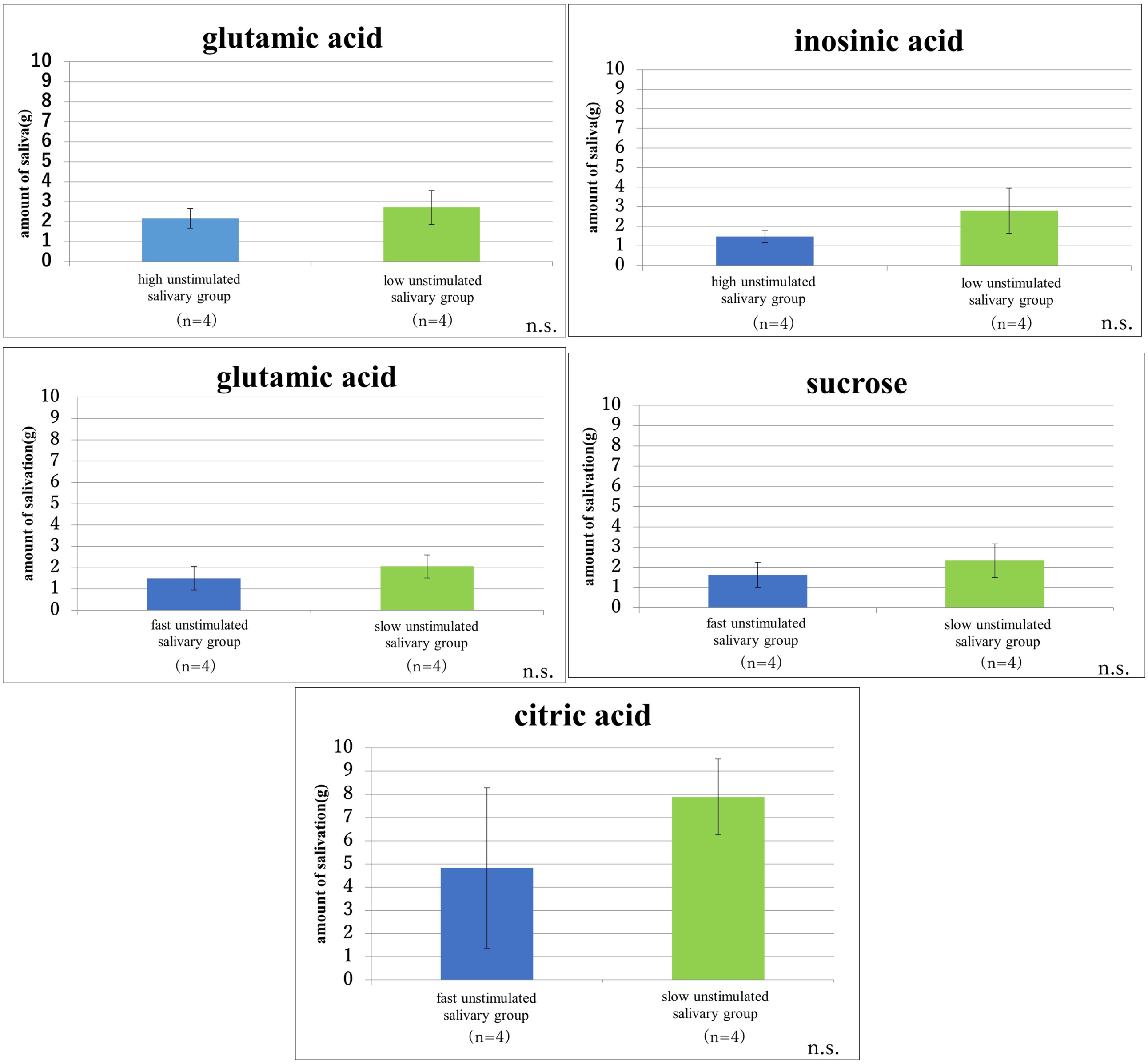

Figure 3. Saliva volume at 1 min after stimulation in the high and low unstimulated salivary flow rate groups (no significant difference was found between the two groups).

unstimulated salivary flow rate between citric acid, umami, and sucrose. This indicated that taste quality had no significant effect on the duration of stimulated salivary secretion.

A comparison of the slow and fast unstimulated salivary flow rate groups showed no significant difference in either the amount or duration of saliva production. In terms of salivary volume, the mean values of inosinic and citric acids tended to be higher in the slow group. The mean duration of salivary secretion for sucrose, inosinate, guanylate, and citrate was longer in the slower secretion group. These results indicate that even if the unstimulated saliva flow rate is slow, the stimulated salivary secretion rate and duration are not different from those of the fast-secreting group.

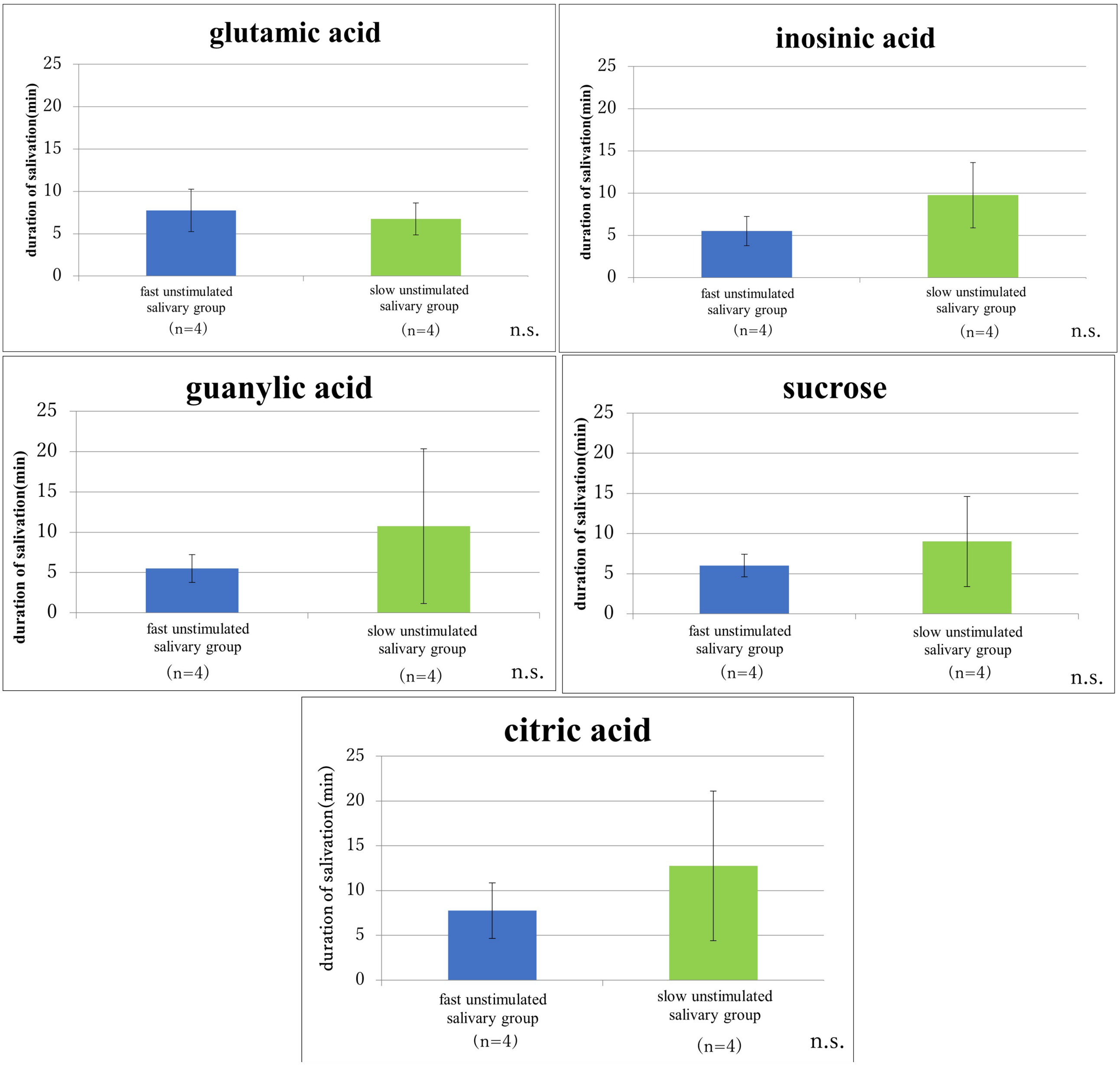

Figure 4. Duration of salivation after stimulation for the high and low unstimulated salivary flow rate groups (no significant difference was found between the two for either group).

It has been reported that stimulated salivary secretion rate is directly related to salivary gland size, while unstimulated salivary flow rate is independent of gland size [8]. On the other hand, it has been reported that the salivary flow rate induced by taste stimuli is affected by the type and intensity of the stimuli and the sensitivity of the gustatory cells that perceive them [9]. In a report [9] that investigated the relationship between taste adaptation and salivation, it was shown that when the protruding tongue is fixed and the same area on the tongue is stimulated, the parotid salivary flow rate reaches its maximum secretion rate 7 s immediately after stimulation, and is reduced by half approximately 11 s later. This indicates that saliva is secreted in response to the type and intensity of taste sensation and decreases rapidly when the intensity of taste sensation changes due to adaptation.

In the oral cavity, this is less likely to occur because of tongue and lip movements. However, even when the same taste type and intensity are provided, the sensation differs from one individual to the other, suggesting that the duration of secretion differs. The duration of secretion is strongly influenced by taste and is independent of the rate of salivary secretion at rest. Even if unstimulated saliva is significantly decreased in patients with xerostomia, active and continuous stimulation of saliva secretion may be an effective treatment if the rate and duration of secretion by taste stimulation are comparable to those in normal individuals.

The long-term use of drugs, acidity, and sweetness as salivary stimulants is complicated; however, the umami flavors used in this experiment can be easily used in daily meals. The three umami solutions used in this experiment were inferior to citric acid in terms of stimulated saliva volume but showed good results in terms of secretion duration. There have been reports [10] that umami promotes secretion from the minor salivary glands and is expected to have a secretion-promoting effect, especially in patients with dry mouth. Umami is a common taste in daily meals in Japan, such as bonito, kelp, and shiitake mushrooms and they may be particularly effective in people with low salivary secretion.

5. Conclusion

We found that the umami stimulation was effective in patients with slow salivatory rates. In addition, umami is highly effective in sustaining salivation after stimulation. In the future, umami flavor could be used to promote salivary secretion.

Acknowledgements

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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