The relationship between phenylthiocarbamide (PTC) and 6-n-propylthiouracil (PROP) taster status and taste thresholds for sucrose and quinine

Won-Ic Chang, Jin-Woo Chung, Young-Ku Kim, Sung-Chang Chung, Hong-Seop Kho*

Department of Oral Medicine and Oral Diagnosis, School of Dentistry & Dental Research Institute, Seoul National University, Yunkeun-Dong 28, Chongro-Ku, Seoul 110-749, Korea

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Summary

Objective: The aim of this study was to investigate the relationship of taster status with taste detection and recognition thresholds for sucrose and quinine.

Design: Sixty-nine subjects (35 men and 34 women; mean age, 23.9 ± 1.2 years) were included. Stimulus fluids were prepared, one each for phenylthiocarbamide (PTC), 6-n-propylthiouracil (PROP), sucrose and quinine HCl. In each series, successive solutions, which comprised a total of 15 grades, differed by 0.25 log units of the molar concentration. Two concentrations of NaCl (0.32 and 1.0 M) were prepared. The subjects were classified as nontasters and tasters using their PTC and PROP perceptions. Tasters were classified as medium-tasters and supertasters by the ratio of perceived bitterness of above-threshold PROP relative to the perceived saltiness of NaCl (PROP ratio). Taste detection and recognition thresholds for sucrose and quinine were determined by standard two-alternative forced choice trials. A Student’s t-test, a Pearson’s correlation analysis and linear contrasts in one-way analysis of variance (ANOVA) were used.

Results: The percentages of nontaster, medium-taster and supertaster were 13, 70 and 17%, respectively. There were no significant gender differences in the taste detection and recognition thresholds for sucrose and quinine. The threshold for PTC and PROP showed significant correlations with taste threshold for quinine. Linear contrast in one-way ANOVA showed that the greater the value of PROP ratio, the more sensitive to sweet and bitter tastes (p < 0.001).

* Corresponding author. Tel.: +82 2 2072 3989; fax: +82 2 744 9135.
E-mail address: hkho@plaza.snu.ac.kr (H.-S. Kho).

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Introduction
Phenylthiocarbamide (PTC) and its chemically related compound, 6-n-propylthiouracil (PROP), provide an extremely bitter taste to some subjects (tasters) but are tasteless or only slightly bitter to others (nontasters).1—4 Although approximately 15—30% of people are known to be nontasters genetically,5,6 the taster/nontaster frequency differs among ethnic groups.7—10 Noting that the taster group showed much variability in taste threshold, it was proposed that sub-populations of ‘supertasters’ and ‘medium-tasters’ might exist. Supertasters were distinguished from medium-tasters by their elevated ratio of perceived bitterness of above-threshold PROP solutions relative to the perceived saltiness of NaCl solutions.11 Tasters, especially supertasters, may have a reduced dietary exposure to bitter but beneficial phytonutrients found in vegetables and fruits.12,13 Therefore, screening for PTC and/or PROP (PTC/PROP) taster status may have a public health importance.14,15

The PTC/PROP perception has been known to correlate with the taste perception of various primary taste qualities,16,17 especially bitter and sweet tastes.18—21 However, these previous results on the relationship of PTC/PROP perception with perception of taste quality were based on food aversions and taste intensities, not on threshold tests, which are the most widely used quantitative taste tests. Of the available quantitative threshold tests, a taste detection threshold test establishes the lowest concentration at which a substance can be distinguished from water. In contrast, a taste recognition threshold test determines the lowest concentration at which the taste quality of a substance can be identified.22

The aim of this study was to investigate whether or not the PTC/PROP taster status is related to the taste detection and recognition thresholds for sucrose and quinine.

Materials and methods
Participants
Sixty-nine subjects (35 men and 34 women; mean age, 23.9 ± 1.2 years), who were students of the School of Dentistry at Seoul National University, were enrolled in the study. All of them were non-smokers. A questionnaire, which included questions regarding chronic sinusitis, chronic obstructive pulmonary disease, diabetes, psychological disorders, loss of olfactory sense, history of ear surgery or tonsillectomy and dry mouth, was used to select the subjects. The subjects did not show any positive responses to the conditions included in the questionnaire. Participants had no history of medication use in the previous three months and no history of serious illness. None of the subjects wore dentures. They were instructed to refrain from eating or drinking anything but water for at least 1 h prior to being tested.23—25

Procedures
The experiment was performed in the following order: on the first day, taste detection and recognition thresholds for sucrose and quinine HCl were determined. During the second day, taster/nontaster status was determined using PTC and PROP testing. Medium-taster/supertaster status was determined on the third day. All experiments were completed within 1 h of each day.

Preparation of taste solutions
Stimulus fluids were prepared, one each for sucrose (‘sweet’, $3.2 \times 10^{-4} – 1.0$ M) and quinine HCl (‘bitter’, $1.0 \times 10^{-7} – 3.2 \times 10^{-4}$ M). PTC ($3.2 \times 10^{-6} – 1.0 \times 10^{-2}$ M) and PROP solutions ($1.0 \times 10^{-6} – 0.32 \times 10^{-2}$ M) were also prepared. In each series, successive solutions comprised a total of 15 grades that differed by 0.25 log units of the molar concentration. Two concentrations of sodium chloride solution (0.32 and 1.0 M) were prepared. All solutions were prepared from reagent grade chemicals using distilled, deionized water. All fluids were stored at 4 °C and brought to room temperature before use.

Determination of taste detection threshold
The taste thresholds were obtained by standard two-alternative forced choice trials.24,26 The taste solution and distilled water were dispensed to the subject as 10 ml samples in 15 ml test tubes. On each trial the subject was presented with one tube containing taste solution and another containing distilled water. One tube was labeled A and the other B according to random schedule. The subject

Conclusion: The PTC and PROP taster status is closely related with taste detection and recognition thresholds for sucrose and quinine.

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rinsed his or her mouth with distilled water prior to tasting each sample. The subject then indicated which tube contained the taste solution which could be distinguished from water, even though the subject could not determine taste quality. The subject was always required to choose one tube or the other but was reassured that guessing was appropriate when the taste solution was weak enough to be indistinguishable from water.

The concentration of an individual’s first exposure to each taste solution was determined by the detection threshold of the previous subject for that taste. Subsequent increases and decreases in concentration depended on the individual’s own responses. Any incorrect response caused an increase in the stimulus concentration on the next trial. The stimulus concentration was decreased after two consecutive correct responses. The stimulus at which the concentration sequence changed from decreasing to increasing or vice versa was designated as a reversal. The procedure was repeated five times. The first reversal was disregarded, and the taste detection threshold was found by taking the mean of the last four reversal concentrations.

**Determination of taste recognition threshold**
The taste recognition threshold was determined according to the same method used for determining the taste detection threshold. However, the subjects had to indicate which tube contained the taste solution, and also had to identify what kind of taste was contained in the taste solution. The concentration of the first exposure to each taste solution was determined by the subject’s detection threshold of that taste. The subject was always required to choose one tube from a choice of two. The procedure was also repeated five times and the taste recognition threshold was determined using the mean of the last four reversal concentrations.

**Determination of taster status**
The experiment was commenced with the weakest PTC and PROP solutions and progressed in the order of increasing concentration. The method was the same as that of the taste recognition threshold. The tasters were classified as those individuals able to recognize the bitterness of PTC and PROP solutions with a concentration less than $1.80 \times 10^{-4}$ M. Subjects who could not recognize the bitterness of solutions stronger than $1.80 \times 10^{-4}$ M were classified as nontasters.

To separate supertasters from medium-tasters, a PROP ratio was used. Two concentrations of sodium chloride solution (0.32 and 1.0 M) and PROP solution (1.0 and 3.2 mM) were dispensed to the subject as 10 ml samples in 15 ml test tubes. The subject then marked the labeled magnitude scale. The procedure was performed twice, and the mean value was obtained. The PROP ratio was determined by the following formula:

$$\text{PROP ratio} = \frac{0.001P/0.32N + 0.0032P/1N}{2}$$

where P is the PROP, N the NaCl (supertaster: $\geq 1.2$; medium-taster: $>0.4$, $<1.2$; nontaster: $\leq 0.4$).

**Statistics**
A Student’s t-test was used to analyze differences in the taste detection and recognition thresholds between genders. A Pearson’s correlation analysis was used to examine the relationships between PTC/PROP taste perception and taste thresholds for sucrose and quinine. Then, linear contrasts in one-way analysis of variance (ANOVA) were tested for statistical significance to investigate whether or not the taster status determined by the PTC/PROP taste perception, is related to the taste detection and recognition thresholds for sucrose and quinine. The contrasts represented the increasing value of PROP ratio in the three types of taste status.

**Results**
As shown in Table 1 and Fig. 1, the percentages of nontasters, medium-tasters and supertasters were 13, 70 and 17%, respectively. Taster/nontaster status determined using the PTC was exactly in accordance with that found using the PROP (data not shown).

The detection and recognition thresholds for sucrose and quinine HCl in all subjects are shown in Table 2. Although each detection and recognition threshold was higher in men than in women, there was no significant difference.

As shown in Table 3, the PTC threshold showed highly significant correlations with the PROP threshold ($r = 0.953$, $p < 0.01$). The PTC and PROP thresholds showed significant correlations with the detection and recognition thresholds for sucrose and quinine.

<table>
<thead>
<tr>
<th>Table 1</th>
<th>The proportion of nontasters, medium-tasters and supertasters.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Men</td>
</tr>
<tr>
<td>Nontaster</td>
<td>5</td>
</tr>
<tr>
<td>Medium-taster</td>
<td>26</td>
</tr>
<tr>
<td>Supertaster</td>
<td>4</td>
</tr>
<tr>
<td>Total</td>
<td>35</td>
</tr>
</tbody>
</table>
HCl. The PROP threshold showed a significant correlation with the sucrose detection threshold ($r = 0.317$, $p < 0.01$). The detection threshold had a significant correlation with the recognition threshold in the case of sucrose ($r = 0.292$, $p < 0.05$) and quinine HCl ($r = 0.304$, $p < 0.05$).

The test of linear contrast in a one-way ANOVA showed that the greater the value of the PROP ratio, the less the values of taste detection and recognition thresholds for sweet and bitter, and thus the more sensitive to detection and recognition of sweet and bitter tastes (Table 4). In other words, supertasters showed lower thresholds for sweet and bitter than medium-tasters and medium-tasters showed lower thresholds than nontasters.

### Discussion

The percentage of nontasters among Korean young adults was found to be 13% in this investigation and 20% in a previous study.10 These numbers are higher

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**Figure 1** Scatterplot of log 6-n-propylthiouracil (PROP) threshold vs. log PROP ratio for 69 subjects. Subjects classified as nontasters (NT), medium-tasters (MT), or supertasters (ST) are indicated in the unshaded areas. An open diamond denotes that the PROP ratios of two subjects were overlapped in the same position. PROP ratio = $(0.001P/0.32N + 0.0032P/1N)/2$, where $P$ is the PROP, $N$ the NaCl (supertaster: $\geq 1.2$; medium-taster: $> 0.4, < 1.2$; nontaster: $\leq 0.4$).

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**Table 2** Sucrose and quinine detection and recognition thresholds (mean ± S.D.).

<table>
<thead>
<tr>
<th></th>
<th>Sucrose detection ($\times 10^{-2}$)</th>
<th>Sucrose recognition ($\times 10^{-2}$)</th>
<th>Quinine HCl detection ($\times 10^{-6}$)</th>
<th>Quinine HCl recognition ($\times 10^{-6}$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Men</td>
<td>$0.22 \pm 0.27$</td>
<td>$1.79 \pm 1.51$</td>
<td>$1.51 \pm 4.17$</td>
<td>$21.51 \pm 43.98$</td>
</tr>
<tr>
<td>Women</td>
<td>$0.18 \pm 0.23$</td>
<td>$1.35 \pm 0.78$</td>
<td>$0.35 \pm 0.23$</td>
<td>$6.88 \pm 6.76$</td>
</tr>
<tr>
<td>$P$</td>
<td>$0.555$</td>
<td>$0.131$</td>
<td>$0.108$</td>
<td>$0.060$</td>
</tr>
<tr>
<td>Total</td>
<td>$0.20 \pm 0.25$</td>
<td>$1.57 \pm 1.22$</td>
<td>$0.94 \pm 3.01$</td>
<td>$14.30 \pm 32.31$</td>
</tr>
</tbody>
</table>

**Table 3** Correlations between taste perception of PTC and PROP and taste thresholds for sucrose and quinine. ($n = 69$)

<table>
<thead>
<tr>
<th></th>
<th>Sucrose recognition</th>
<th>Quinine HCl detection</th>
<th>Quinine HCl recognition</th>
<th>PTC</th>
<th>PROP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sucrose detection</td>
<td>$0.292^a$</td>
<td>$0.539^b$</td>
<td>$0.284^a$</td>
<td>$0.226$</td>
<td>$0.317^b$</td>
</tr>
<tr>
<td>Sucrose recognition</td>
<td>$0.274^a$</td>
<td>$0.198$</td>
<td>$0.304^a$</td>
<td>$-0.006$</td>
<td>$0.006$</td>
</tr>
<tr>
<td>Quinine HCl detection</td>
<td>$0.682^b$</td>
<td>$0.564^b$</td>
<td>$0.953^b$</td>
<td>$0.299^a$</td>
<td>$0.415^b$</td>
</tr>
<tr>
<td>Quinine HCl recognition</td>
<td>$0.342^a$</td>
<td>$0.342^a$</td>
<td>$0.342^a$</td>
<td>$0.682^b$</td>
<td>$0.564^b$</td>
</tr>
</tbody>
</table>

PTC: phenylthiocarbamide; PROP: 6-n-propylthiouracil.

$^a p < 0.05$ (two-tailed).

**Table 4** Sucrose and quinine detection and recognition thresholds in nontasters, medium-tasters and supertasters (mean ± S.D.).

<table>
<thead>
<tr>
<th></th>
<th>Sucrose detection ($\times 10^{-2}$)</th>
<th>Sucrose recognition ($\times 10^{-2}$)</th>
<th>Quinine HCl detection ($\times 10^{-6}$)</th>
<th>Quinine HCl recognition ($\times 10^{-6}$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nontaster ($n = 9$)</td>
<td>$0.37 \pm 0.48$</td>
<td>$1.86 \pm 1.30$</td>
<td>$4.41 \pm 7.71$</td>
<td>$64.11 \pm 73.03$</td>
</tr>
<tr>
<td>Medium-taster ($n = 48$)</td>
<td>$0.18 \pm 0.20$</td>
<td>$1.55 \pm 1.27$</td>
<td>$0.40 \pm 0.39$</td>
<td>$7.34 \pm 7.19$</td>
</tr>
<tr>
<td>Supertaster ($n = 12$)</td>
<td>$0.15 \pm 0.14$</td>
<td>$1.43 \pm 0.96$</td>
<td>$0.51 \pm 0.86$</td>
<td>$4.76 \pm 3.51$</td>
</tr>
<tr>
<td>Significance of linear contrast ($p$)</td>
<td>$&lt;0.001$</td>
<td>$&lt;0.001$</td>
<td>$&lt;0.001$</td>
<td>$&lt;0.001$</td>
</tr>
</tbody>
</table>
than those found in American Indians, and lower than those observed in European and American Caucasians. The percentage of supertasters was 17% in this study, which was lower than the results of previous studies reporting 21–30% of supertasters. This is likely explained by a combination of factors, such as ethnic differences, variations in the experimental procedures and criteria used for determining taster status. The major group of subjects was Caucasian in most previous studies. Different levels of PROP ratio were used to differentiate supertaster, medium-taster and nontaster. Only perceived intensity of PROP or PTC bitterness rather than the PROP ratio was used in some studies. PTC-treated filter paper instead of taste solution was used as a stimulant.

Gender differences in taste sensitivity have been reported by several authors, whereas other authors failed to find gender differences as we observed in the present study. The presence or absence of gender difference may depend on age and/or characteristic of subjects. It was reported that both genders showed similar sensitivity up to the age of 16–20 years, but from this age onward men declined at a faster rate than women. Anatomical data seemingly support the gender difference, in that women have more fungiform papillae and more taste buds than men. The reason for this anatomical difference is not clear, however, since it could reflect differing dietary habits, smoking behaviors and alcohol consumption, as well as possible hormonal factors.

Previous studies also showed that PTC/PROP perception has been associated with enhanced perception and increased acuity for sweet and bitter compounds. However, the reported differences in perception of sweet taste between tasters and nontasters were not consistently observed. Responses of nontasters, medium-tasters and super-tasters to sweet compounds were not different. Links between taster status and response to sweet compounds may depend on the population sample. Interestingly, studies suggest the association of PROP perception with response to sweet compounds used both men and women subjects. The studies not suggesting the association used only female subjects. Women are more likely to be either medium-tasters or supertasters than are their male counterparts.

A novel aspect of the present study was that the experiments were based on the taste threshold rather than supra-threshold taste intensity scaling, hedonic rating and food preferences that have been used in previous studies. Our results based on the taste threshold supported the positive relationship between PTC/PROP taster status and taste sensitivity to sweet and bitter compounds. Further studies using both threshold method and intensity or preference ratings in the same subjects can provide a definitive conclusion.

References


