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PROP Taster Status and the Rejection of Foods with Added Tastants

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Abstract Sensitivity to 6-*n*-propylthiouracil (PROP) tasting predicts sensitivity to food qualities as well as rejection of some strong tasting foods. Using consumer rejection threshold (CRT) method, this study aimed to assess whether systematic changes in the taste intensities of familiar foods would lead to earlier rejection of these products by PROP tasters than by PROP non-tasters. Subjects rated the intensity of PROP solution and were divided into tasters (Ts) and non-tasters (NTs). And Ts were further divided into medium-tasters (MTs) and super-tasters (STs). Difference thresholds and CRTs were then evaluated for caffeine in coffee, citric acid in orange juice, and for NaCl in beef soup. For each food, Ts were more sensitive to variations in tastants than NTs. Ts also rejected more bitter coffee, more sour orange juice, and less salty beef soup more readily than did NTs. Comparisons among NTs, MTs, and STs gave fewer clear differences.

Keywords: PROP taster status, food preference, difference threshold, consumer rejection threshold

Introduction

It is well known that there is considerable variation in the extent to which individuals find the compounds phenylthiocarbamide (PTC) and 6-*n*-propylthiouracil (PROP) bitter. In early studies (1-5), individuals were divided into 2 groups: tasters (Ts) and non-tasters (NTs) of PTC. Bartoshuk *et al.* (6) further subdivided Ts into medium tasters (MTs) and super-tasters (STs), based on PROP bitterness intensity ratings. They presumed that NTs had 2 recessive alleles (tt), MTs were heterozygotes with 1 dominant allele (Tt), and STs had 2 dominant alleles (TT).

Differences between PROP/PTC taster groups have also been reported for a variety of other bitter (7-11), sweet (9, 12), and salty (8), and for the binary taste mixtures (13). While PROP group differences have not always been reported for other tastes (11,14-16), such discrepancies can be attributed to different scaling methods used (13).

The relationship between PROP sensitivity and perception of other PROP taste qualities, as well as with responsiveness to somatosensory qualities such as the burning sensation of capsaicin (6,17,18), alcohol (18,19), and the tactile properties of fat (20) has been attributed to the positive correlations between PROP sensitivity and the number of fungiform papillae (FP) and taste pores/taste buds on the anterior tongue (6,21-23).

Recent research has shown that the associations between PROP and tastes in model systems are also found in food systems. Prescott *et al.* (24) reported significant differences among NTs, MTs, and STs in their sensitivity to variations in sensory properties of yoghurt, cream cheese, orange juice, and carbonated fruit drinks. Such psychophysical relationships may provide a basis for the reported differences between PROP groups in their hedonic responses to foods. Thus, Ts of PROP/PTC have more food dislikes than NTs, especially of bitter-tasting foods (25-34). Differences in preferences between Ts and NTs have also been found with foods that are sour (26), sharp (35), and sweet (36). Compared with NTs, STs report different perception and greater dislike for foods containing high fat (37,38).

Although Prescott *et al.* (24) reported decreased difference thresholds for Ts than NTs for several taste qualities, the evidence that such differences in sensitivity influence hedonic responses to foods has not been fully elucidated. Therefore, more direct research that examines the impact of such variations in sensitivity on the acceptability of changes within food systems will be useful in determining the extent to which PROP group differences are reflected in food rejections by consumers.

The present study addressed this question by assessing consumer responses to variations in taste compounds in a few common foods in Koreans in whom PROP taster status had been measured, to examine the relationship between taste sensitivity and food preference. The study used the consumer rejection threshold (CRT), a new sensory method (39) that assesses the point at which a change (increase/decrease) in a food ingredient elicits rejection of a food/beverage. By using the CRT in conjunction with measures of variations in taste sensitivity (the difference threshold; DT), it is possible to determine to what extent differences in sensitivity between PROP taster groups have an impact on food preferences. In addition, the study aimed to (1) define the distribution of PROP taster status within a young Korean population; (2) examine the correlation between PROP ratings and FP counts, and (3) to further study PROP taster group differences in ratings of taste intensity in these food systems. These studies will show the relationships between PROP taster perception and taste anatomy, and association of PROP grouping with taste perception in real food systems.

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Materials and Methods

Subjects Three-hundred-and-five Korean university students (248 female and 57 male; mean age: 23 years; range: 18-35 years) participated in the selection procedure for the PROP taster groups. Of these, 120 subjects (85 female and 35 male; mean age: 23 years; range: 18-35 years) were selected to form 3 distinct taster groups whose PROP ratings did not overlap. Table 1 shows the subject details under different grouping and their PROP bitterness rating values.

Sample preparation and presentation Solutions of 0.0032 M 6-*n*-propylthiouracil (PROP; Sigma-Aldrich, St. Louis, MO, USA) were prepared in deionized water (aquaMAX^{TM}-Ultra 350, Young-Lin Instrument Co. Ltd., Anyang, Gyeonggi, Korea), and presented to the subjects as 10 mL aliquots in 30-mL plastic cups at 20±2°C.

Evaluation of PROP taster status The subjects rated PROP intensity using a 165-mm labeled magnitude scale (LMS) (40). While they were rating PROP intensity relative to the descriptor at the top of the LMS, strongest imaginable, subjects considered not only tastes, but rather all sensations, including painful ones. The subjects rinsed their mouth 3 times with filtered tap water, placed the PROP solution in their mouth, swished it around for a few seconds, expectorated, and gave their rating. Subjects were first classified as NTs and Ts based on their rating value using the criterion of 20 mm: NTs (rating<20 mm); Ts (rating≥20 mm). Ts was further divided into MTs (rating 20-100 mm) and STs (rating>100 mm) based on the definition used in Prescott *et al.* (13). In the present study, only 48 MTs who gave narrower middle ratings (rating 35-87 mm) were used for the comparison among 3 taster groups (Table 1) in order to define the 3 taster groups more clearly.

Evaluation of FP density In addition to rating PROP intensity, FP counts were performed on the 120 subjects selected for the 3 PROP taster group comparisons. Subjects rinsed their mouths with filtered tap water. After 5 min, their tongues were dyed with blue food coloring (Queen Fine Foods Pty., Ltd., Alderley, Queensland, Australia) using a sterile cotton tip applicator (Boryung Medicine Inc., Ansan, Gyeonggi, Korea). The coloring stained the filiform papillae blue while the FP were unstained (21). A piece of filter paper (10×5 mm, Whatman's No. 1, Whatman International Ltd., Maidstone, England) was placed on the right side of tongue as a scale to calculate the magnification of the photo. Two to 3 images/subject were taken using a digital camera (5.0 mega pixels, DSC-T3; Sony, Tokyo, Japan). The images were downloaded to a computer and displayed through a liquid crystal display (LCD) monitor. The tongue image was analyzed using Adobe Photoshop 7.0. A transparent circle image (10 mm in diameter) was fitted at the scale, then placed on the left side of center line and the tip of the tongue image. The FP within the transparent circle image was counted. The counting area was selected on the basis of the study of Shahbake *et al.* (41). Analysis of variance (ANOVA) and Duncan's multiple range test were performed to compare significant difference ($p<0.05$) of means between PROP taster status groups. The relation between PROP ratings and FP counts was examined by calculating Pearson's product moment correlation coefficient across 120 subjects. All statistical analyses were conducted using SPSS software (ver. 12.0 for Windows, SPSS Inc., Chicago, IL, USA).

Determining DT of caffeine in coffee, citric acid in orange juice, and NaCl in beef soup DTs of caffeine (Sigma-Aldrich, St. Louis, MO, USA), citric acid (Sigma-Aldrich), and sodium chloride (NaCl, Ducksan Pure Chemical Co., Ltd., Ansan, Gyeonggi, Korea) were examined in coffee, orange juice, and beef soup, respectively. Coffee (50±2°C) was prepared with the modified formulation from the previous study (42). Caffeine was added at the 7 different concentrations, increasing in 0.25 log steps (Table 2).

To unsweetened orange juice (Sunkist Fresh 100 Juicy Orange, Haitai Beverage Co., Ltd., Ansung, Gyeonggi, Korea) (10±2°C), 7 different concentrations of citric acid increasing in 0.12 log steps were added (Table 2). Beef soup was prepared according to the formulation used in Kim (43) with beef brisket, green onion, smashed garlic, and black pepper whole but without radish. All the batches

Table 1. Demographic information of subjects for each PROP taster group (NTs, Ts, MTs, and STs)[1)]

(a) 305 subjects who participated in PROP rating

	NTs	Ts	MTs	STs
Mean PROP rating±SD in mm (range; max=165 mm)	6.65±6.56 (0-1.9)	76.35±34.09 (20-165)	61.39±20.60 (20-100)	126.72±18.67 (101-165)
No. of subjects (F/M)	43 (34/9)	262 (214/48)	202 (160/42)	60(54/6)
Mean age (range), year	22 (19-32)	23 (18-35)	23 (18-33)	23 (18-35)

(b) 120 subjects who were selected for the other experiments

	NTs	Ts	MTs	STs
Mean PROP rating±SD in mm (range; max=165 mm)	6.93±6.27 (0-19)	89.30±36.47 (35-163)	59.04±12.61 (35-87)	125.60±17.22 (101-163)
No. of subjects (F/M)	32 (24/8)	88 (61/27)	48 (24/24)	40 (37/3)
Mean age (range), year	22 (19-29)	23 (18-35)	23 (19-29)	23(18-35)

[1)]NTs, non-tasters; Ts, tasters; MTs, medium-tasters; and STs, super-tasters.

Table 2. Concentrations of added caffeine, citric acid, and NaCl used in difference threshold (DT) test

Sample Identification[1)]	Caffeine in coffee (M)	Citric acid in orange juice (M)	NaCl in beef soup (M)
REF	0	0	0.0857
D1	0.0005	0.0025	0.0800
D2	0.0010	0.0033	0.0746
D3	0.0017	0.0043	0.0696
D4	0.0031	0.0057	0.0650
D5	0.0054	0.0075	0.0607
D6	0.0097	0.0100	0.0566
D7	0.0172	0.0131	0.0528

[1)]REF, reference sample; D1-7, the sample paired with REF in DT.

Table 3. Concentrations of added caffeine, citric acid, and NaCl used in consumer rejection threshold (CRT) test

Sample Identification[1)]	Caffeine in coffee (M)	Citric acid in orange juice (M)	NaCl in beef soup (M)
REF	0	0	0.0857
C1	0.0007	0.0025	0.0713
C2	0.0012	0.0035	0.0593
C3	0.0021	0.0050	0.0493
C4	0.0037	0.0070	0.0410
C5	0.0066	0.0100	0.0341
C6	0.0118	0.0141	0.0284
C7	0.0209	0.0199	0.0236

[1)]REF, reference sample; C1-7, the sample paired with REF in CRT.

were mixed, cooled, and kept frozen (−15°C). Frozen beef soup was thawed and heated, and then kept in a 1-L thermos (AHGB-10, Zojirushi Corp., Osaka, Japan) to maintain the temperature (55±2°C). NaCl was added to beef soups at the concentrations decreasing from 0.0857 M of reference (REF) beef soup in 0.03 log steps (Table 2). The concentration of REF beef soup was the result of a previous study, which determined preferred NaCl concentrations in such soups (43).

Stimulus aliquots (15 mL) were presented in 40-mL glass cups, coded with 3-digit random numbers. The presentation order of 7 concentrations was randomized to minimize the effect of presentation order (44). At each concentration, subjects were presented with the REF plus the comparison stimulus, with the order within the pair randomized. Subjects rinsed their mouth 3 times before each sample pair and once between samples within a pair. Subjects placed the whole sample in their mouth, swished it around for a few seconds, and then expectorated it. They were required to identify the stronger tasting stimulus of the pair. There was a 1.5 min interval between pairs. DT of caffeine, citric acid, and NaCl were determined at the significantly different level from the reference using the binomial test.

Determining CRT of caffeine in coffee, citric acid in orange juice, and NaCl in beef soup To determine the CRT of caffeine and citric acid in the coffee and orange juice systems, 7 different concentrations of caffeine and citric acid were used in 0.25 log steps from 0.0007 to 0.0209 M and in 0.15 log steps from 0.0025 to 0.0199 M, respectively. For the CRT test of NaCl in the beef soup system, concentrations of NaCl were decreased in 0.08 log steps from 0.713 to 0.0236 M (Table 3). The levels of the log steps for increasing and decreasing concentration differed between DT and CRT, since DT was performed to determine taste sensitivity of tasters, whereas, CRT to examine the thresholds rejected. Sample preparation and presentation procedures were as above. The major difference between the 2 procedures was the question asked. To determine the CRT, subjects were asked to indicate which sample of the pair they preferred. CRTs of caffeine, citric acid, and NaCl were determined at the significantly different level in preference from the reference using the binomial test.

Taste intensity ratings for bitterness of coffee, sourness of orange juice, and saltiness of beef soup Samples of coffee, orange juice, and beef soup containing the highest concentrations of caffeine, citric acid, and NaCl, respectively, used in the CRT test were presented as 15 mL aliquots in 40-mL glass cups. Samples were evaluated in a fixed order, as follows: coffee, orange juice, and beef soup, with a 5 min break between samples. Prior to tasting each sample, subjects rinsed their mouth 3 times with filtered water. Subjects placed the whole sample in their mouth, swished it around for a few seconds, and then expectorated. They then rated bitterness, sourness, and saltiness intensity of coffee, orange juice, and beef soup, respectively, using the LMS. Analysis of variance (ANOVA) and Duncan's multiple range tests were performed to examine significant difference ($p<0.05$) between PROP taster status groups using SPSS software (ver. 12.0 for Windows, SPSS Inc., Chicago, IL, USA).

Results and Discussion

Distribution of PROP taster status of Korean Figure 1 shows the frequency distribution of PROP ratings of the subjects in the present study. The proportions of NTs and Ts were 14.1 and 85.9%, respectively. Ts were further divided into MTs and STs and the ratios were 66.2 and 19.7%, respectively.

The proportion of NTs (14.1%) within the Korean population was lower than estimates from Western population, which are typically in the range of 25-30% (2,6,45,46). Meanwhile, the proportion of NTs (13.7%) among Korean females was higher than those of NTs among other Asian female groups from Hong Kong (8.3%) (47) and Indonesia (1.2%) (48). These data add therefore to previous indications that PROP sensitivity differences exist not only between Asian and Western populations, but also among different populations within Asia. Whether such differences reflect genetic/anatomical differences or difference in scale usage across populations (46,49) remains to be determined.

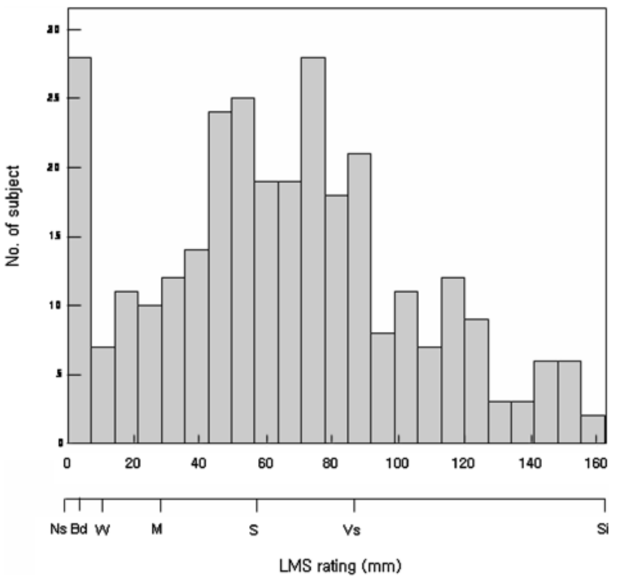

Fig. 1. The frequency distribution of PROP rating (n=305) with the labeled magnitude scale (LMS). Si, strongest imaginable; Vs, very strong; S, strong; M, moderate; W, week; Bd, barely detectable; Ns, no sensation.

Counts of FP on anterior tongue Mean FP counts of NTs and Ts were 43.34 and 55.76, respectively. In the Ts group, those of MTs and STs were 55.15 and 56.50, respectively. ANOVA showed significant differences in these counts according to the taster group (NTs, MTs, and STs) ($p<0.05$). Mean FP counts of NTs were significantly lower than those of Ts ($p<0.05$) as well as of MTs and STs, while there was no significant difference between those of MTs and STs. Ratings of PROP intensity were significantly correlated with FP counts ($p<0.05$), although the magnitude of the association was relatively modest (r=0.233) and lower than seen in other studies (6,21,22). Studying American subjects, Miller and Reedy (21) reported that taster FP counts were 1.8 times higher than those of NTs. In contrast, the present Koreans data gave FP counts of Ts that were only 1.3 times of those of NTs. Whether this reflects consistent anatomical differences between ethnic populations is unknown.

DT of caffeine in coffee, citric acid in orange juice, and NaCl in beef soup The number (and percentage) of subjects choosing the stronger taste sample of coffee, orange juice, and beef soup in DT tests is shown in Table 4, 5, and 6, respectively. Significance values for each concentration of tastant in each system were determined according to the taster group based on critical number of correct responses using a one-sided binomial test. Ts discriminated the differences of bitter and sour taste intensity at lower concentration of caffeine and citric acid added in coffee (0.001 M, $p<0.05$) and orange juice (0.0025 M, $p<0.01$) than NTs, respectively. In the beef soup system, Ts selected saltier beef soup with less NaCl reduction from the reference sample (0.0800 M, $p<0.001$) than NTs.

MTs and STs discriminated the difference of bitter taste intensity in coffee at lower concentrations of caffeine

Table 4. The number of subjects who selected the coffee sample with added caffeine for stronger bitter taste[1)]

Concentration of caffeine (M)	NTs		Ts		MTs		STs	
	No.	(%)	No.	(%)	No.	(%)	No.	(%)
0.0005	15	(47)	51	(58)	26	(54)	25	(63)
0.0010	16	(50)	58**	(66)	31*	(65)	27*	(68)
0.0017	24**	(75)	59***	(67)	30	(63)	29**	(73)
0.0031	24**	(75)	61***	(69)	34**	(71)	27*	(68)
0.0054	27***	(84)	71***	(81)	39***	(81)	32***	(80)
0.0097	25**	(78)	80***	(91)	42***	(88)	38***	(95)
0.0172	30***	(94)	84***	(96)	45***	(94)	39***	(98)

1)The number of participants, NTs=32; Ts=MTs+STs=88; MTs=48; STs=40. NTs, non-tasters; Ts, tasters; MTs, medium-tasters; and STs, super-tasters. *, **, ***$p<0.05$, 0.01, and 0.001, respectively (one-tailed).

Table 5. The number of subjects who selected the orange juice sample with added citric acid for stronger sour taste[1)]

Concentration of citric acid (M)	NTs		Ts		MTs		STs	
	No.	(%)	No.	(%)	No.	(%)	No.	(%)
0.0025	19	(59)	58**	(66)	29	(60)	29**	(73)
0.0033	17	(53)	53*	(60)	30	(63)	23	(58)
0.0043	22*	(69)	56**	(64)	29	(60)	27*	(68)
0.0057	24**	(75)	67***	(76)	38***	(81)	29**	(73)
0.0075	25**	(78)	66***	(75)	40***	(83)	26*	(65)
0.0100	24**	(75)	70***	(80)	37***	(77)	33***	(83)
0.0131	27***	(84)	83***	(94)	40***	(83)	33***	(83)

1)The number of participants, NTs=32; Ts=MTs+STs=88; MTs=48; STs=40. NTs, non-tasters; Ts, tasters; MTs, medium-tasters; and STs, super-tasters. *, **, ***$p<0.05$, 0.01, and 0.001, respectively (one-tailed).

Table 6. The number of subjects who selected reference beef soup sample for stronger salty taste1)

Concentration of NaCl (M)	NTs		Ts		MTs		STs	
	No.	(%)	No.	(%)	No.	(%)	No.	(%)
0.0800	17	(53)	59***	(67)	31*	(65)	28**	(70)
0.0746	24**	(75)	60***	(68)	34**	(71)	26*	(65)
0.0696	27**	(84)	61***	(69)	32*	(67)	29**	(73)
0.0650	24**	(75)	69***	(78)	36***	(75)	33***	(83)
0.0607	28***	(88)	80***	(91)	41***	(85)	39***	(98)
0.0566	30***	(94)	82***	(93)	43***	(90)	39***	(98)
0.0528	32***	(100)	84***	(96)	46***	(96)	38***	(95)

1)The number of participants, NTs=32; Ts=MTs+STs=88; MTs=48; STs=40. NTs, non-tasters; Ts, tasters; MTs, medium-tasters; and STs, super-tasters. *, **, *** $p<0.05$, 0.01, and 0.001, respectively (one-tailed).

added (0.001 M, $p<0.05$) than NTs (0.0017 M, $p<0.01$) while there was no difference between MTs and STs. STs identified the more sour orange juice at the lowest concentration of citric acid (0.0025 M, $p<0.01$) added. The DT level of MTs (0.0057 M, $p<0.001$) was not lower than NTs. For beef soup, MTs and STs (≥0.08 M) both discriminated the smaller difference of saltiness of beef soup than did NTs (0.0746 M, $p<0.01$). There were no difference between MTs and STs in DT level.

Prescott *et al.* (24) reported that Ts were able to discriminate smaller variation of tastants than NTs in food systems (yoghurt, cream cheese, orange juice, and carbonated fruit drinks). Consistent with this, in the present study, determination of DTs indicated that Ts overall showed higher sensitivity to variations in caffeine, citric acid than did NTs, recognizing differences between samples even at the smallest different concentration pairs in coffee and orange juice, while NTs did not. The present study also showed PROP group differences in sensitivity to NaCl variations. Considering that 70% of Ts discriminated more salty stimuli when the control was paired with the sample prepared with the least reduction in NaCl, it is possible that Ts might have discriminated the difference of salty taste intensity even at a lower concentration.

When we considered the PROP taster status in terms of 3 distinct groups (NTs, MTs, STs), STs were more sensitive to the bitterness of caffeine in coffee, the sourness of citric acid in orange juice, and the saltiness of NaCl in beef soup than NTs, but the sensitivity differences between STs and MTs, and between MTs and NTs were not always evident. One possible reason for this is the fact that, while FP densities are correlated with PROP ratings, the relationship between PROP responses and responses to other tastes may be largely determined by FP density (23). In the present sample, the correlation was only 0.233, indicating that there may be significant overlap between NTs and MTs, and between MTs and STs, in numbers of FP.

CRT of caffeine in coffee, citric acid in orange juice, and NaCl in beef soup The number (and percentage) of subjects who rejected more bitter coffee, more sour orange juice, and less salty beef soup is shown in Table 7, 8, and 9, respectively. Significance values for each concentration of tastant in each system were determined according to the taster group based on critical number of responses preferred the reference sample using one-sided binomial test. For coffee, the obtained rejection threshold of caffeine was 0.0066 M for NTs ($p<0.001$) and 0.0012 M for Ts ($p<0.001$). This means that NT showed difference in their preference when higher than 0.0066 M of caffeine was added to the coffee sample while Ts showed preference difference when higher than 0.0012 M of caffeine was added. For orange juice, the obtained rejection threshold of citric acid was 0.0100 M for NTs ($p<0.001$) and 0.0025 M for Ts ($p<0.001$), mining NTs were starting to show difference in their preference when 0.0100 M of citric acid was added to the orange juice, while Ts were when only 0.0025 M of citric acid was added. For beef soup, there was also a difference in the resulted rejection threshold of NaCl between NTs (0.0341 M, $p<0.05$) and Ts (0.0593 M,

Table 7. The number of subjects who preferred reference coffee sample1)

Concentration of caffeine (M)	NTs		Ts		MTs		STs	
	No.	(%)	No.	(%)	No.	(%)	No.	(%)
0.0007	13	(41)	49	(56)	24	(50)	25	(63)
0.0012	13	(41)	59***	(67)	33**	(69)	26*	(65)
0.0021	18	(56)	42	(48)	24	(50)	18	(45)
0.0037	20	(63)	57**	(65)	33**	(69)	24	(60)
0.0066	24**	(75)	64***	(73)	34**	(71)	30**	(75)
0.0118	21	(66)	67***	(76)	34**	(71)	33***	(83)
0.0209	26***	(81)	79***	(90)	42***	(88)	37***	(93)

1)The number of participants, NTs=32; Ts=MTs+STs=88; MTs=48; STs=40. NTs, non-tasters; Ts, tasters; MTs, medium-tasters; and STs, super-tasters. *, **, *** $p<0.05$, 0.01, and 0.001, respectively (one-tailed).

Table 8. The number of subjects who preferred reference orange juice sample[1)]

Concentration of citric acid (M)	NTs		Ts		MTs		STs	
	No.	(%)	No.	(%)	No.	(%)	No.	(%)
0.0025	15	(47)	57**	(65)	33**	(69)	24	(60)
0.0035	16	(50)	48	(55)	29	(60)	19	(48)
0.0050	21	(66)	57**	(65)	34**	(71)	23	(58)
0.0070	21	(66)	55*	(63)	30	(63)	25	(63)
0.0100	27***	(84)	66***	(75)	36***	(75)	30**	(75)
0.0141	25**	(78)	64***	(73)	32*	(67)	32***	(80)
0.0199	27***	(84)	71***	(81)	37***	(77)	34***	(85)

[1)]The number of participants, NTs=32; Ts=MTs+STs=88; MTs=48; STs=40. NTs, non-tasters; Ts, tasters; MTs, medium-tasters; and STs, super-tasters. *, **, ***$p<0.05$, 0.01, and 0.001, respectively (one-tailed).

Table 9. The number of subjects who preferred reference beef soup sample[1)]

Concentration of NaCl (M)	NTs		Ts		MTs		STs	
	No.	(%)	No.	(%)	No.	(%)	No.	(%)
0.0713	17	(53)	43	(49)	20	(42)	23	(58)
0.0593	17	(53)	53*	(60)	32*	(67)	21	(53)
0.0493	23*	(72)	65***	(74)	39***	(81)	26*	(65)
0.0410	21	(66)	64***	(73)	36***	(75)	28**	(70)
0.0341	22*	(69)	65***	(74)	37***	(77)	28**	(70)
0.0284	25**	(78)	71***	(81)	40***	(83)	31***	(78)
0.0236	25**	(78)	70***	(80)	39***	(81)	31***	(78)

[1)]The number of participants, NTs=32; Ts=MTs+STs=88; MTs=48; STs=40. NTs, non-tasters; Ts, tasters; MTs, medium-tasters; and STs, super-tasters. *, **, ***$p<0.05$, 0.01, and 0.001, respectively (one-tailed).

$p<0.05$) showing NTs rejected less salty beef soup with a greater NaCl concentration difference from the reference sample than Ts.

In the present study, PROP taster status was related to preference for the caffeine added coffee, citric acid added orange juice, and beef soup with reduced NaCl. When subjects were divided into NTs and Ts, NTs showed different CRTs at different levels to Ts. Specifically, for all 3 foods, Ts rejected samples with less change to the reference samples than did NTs, suggesting that PROP taster status may be associated with actual food rejections, in line with the results of previous studies (25,26,28-30,32-35,49,50), which indicated that food selection is driven in part by sensitivity to tastes, in particular bitterness and sourness. Similarly, there is agreement between the greater preference for Ts for the less sour orange juice found here, and earlier studies (26,35) that found Ts preferred lower sourness than NTs in lemon juice, vinegar and sauerkraut, and cheese. Again, differences in the CRT to variations of NaCl in beef soup between Ts and NTs show a similar pattern to that observed by Pasquet *et al.* (50), who found an inverse relationship between PROP taster status and hedonic ratings of NaCl solutions.

Comparing between subgroups of Ts, for coffee the rejection threshold did not differ between MTs and STs, but for orange juice MTs showed lower rejection threshold (0.0025 M, $p<0.01$) than STs (0.0100 M, $p<0.01$). For beef soup, MTs also showed a lower rejection threshold; less reduction from the reference level (0.0593 M, $p<0.05$) than STs (0.0493 M, $p<0.05$) indicating MTs preferred the saltier beef soup (reference) when the NaCl concentration added to the test soup sample was equal to, or lower than 0.0593 M while STs showed preference of the saltier soup when the NaCl concentration added to the test soup sample was equal to, or lower than 0.0493 M.

Group differences in the CRT hedonic responses were less than those seen with the DT. For orange juice and beef soup, STs' rejection thresholds were not significantly different from those of NTs. These data suggest, therefore, that although individuals have different sensitivities to PROP bitterness, and they differ in perception of bitterness of caffeine, sourness of citric acid, and saltiness of NaCl, PROP sensitivity does not clearly discriminate individuals in their hedonic responses to variations of taste intensities in coffee, orange juice, and beef soup. This dissociation of sensory sensitivity and hedonic response may reflect the additional influence, over and above taste genetics, of learning as a determination of food hedonics (51). Moreover, Drewnowski (52) pointed out that taste, food selection, and eating habits are influenced by factors such as food energy density, cost, convenience, health, and variety. The extent to which tolerance to product variations reflects non-sensory factors is not known.

One question was whether differences in the perception of tastes between PROP taster groups can be shown at any concentration range. Some studies have found taster group differences at only lower concentrations using saccharin (9), urea, and caffeine (7). Prescott *et al.* (13) demonstrated PROP taster group differences principally at the higher tastant concentrations in binary taste mixtures. It is assumed that differences of PROP taster groups can be found in taste intensity ratings and food preference tests

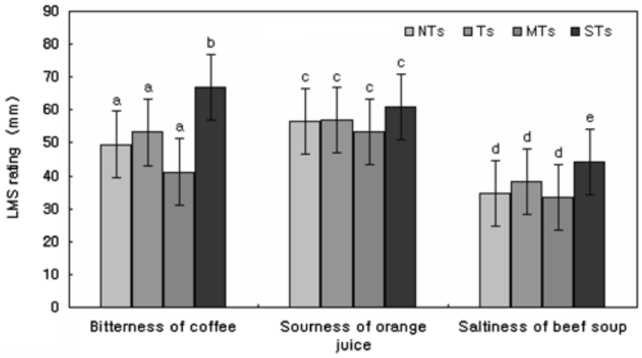

Fig. 2. Mean ratings of PROP taster groups for bitterness in coffee, sourness in orange juice, and saltiness in beef soup with the labeled magnitude scale (LMS). [a-e]Means within a food system not sharing a letter are significantly different (p<0.05).

even at common food level concentrations, since PROP sensitivity has an effect not only at the subthreshold level (7,9), but also at the suprathreshold level (6,13). The results of the present study further indicate close relationships between PROP taster status and preferences in food systems, particularly with respect to optimal taste intensities.

Taste intensity rating of bitterness in coffee, sourness in orange juice, and saltiness in beef soup There was no significant difference between NTs and Ts in ratings of bitterness in coffee, sourness in orange juice, and saltiness in beef soup (p>0.05) as indicated in Fig. 2. Analyzing the ratings among PROP taster groups, STs gave significantly higher ratings of the bitterness of coffee (p<0.001) and saltiness of beef soup (p<0.05) than did MTs or NTs, but there were no differences between NTs and MTs. For orange juice, there were no significant group differences (p>0.05) in sourness intensity ratings, even though STs tended to give higher rating than NTs and MTs. It is presumed that there was no difference between NTs and Ts, since the samples' concentration of tastant was even higher enough to be perceived by NTs. However, the result of the present study is also suggested that STs were seemed to be more expressive than other taster groups using the top of the descriptor on the LMS.

The present study directly tested taste sensitivity and food preference in real food systems characterized with optimal taste level. The results indicate that there are differences between Ts and NTs in sensitivity to the tastants in food systems and that these sensitivity differences have an impact on preferences for foods that varied in their taste qualities. The study thus adds to the literature showing an impact of taste genetics on food selection; for example, the demonstration by Sandell and Breslin (53) of the importance of individual taste gene alleles for the perception of foods. Understanding the underlying mechanisms of how variations in food components such as tastes determine acceptance or rejection of foods and beverages should allow a more exact specification of the impact of formulation changes in relation to specific consumer segments.

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