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Research Article

PHENYLTHIOCARBAMIDE (PTC) TASTE PERCEPTION: A STUDY CORRELATING THE SENSITIVITY TO BITTER TASTE AND THE INFLUENCE OF VARIOUS DEMOGRAPHIC AND PSYCHOGRAPHIC PARAMETERS

Sharon Rose Mathew[1], Sushama P S[2], Eram S Rao[3], Rizwana[3], Aparna Agarwal[4*]

[1]Maharshi Dayanand University, Department of Food Technology, Rohtak, India
[2]ICAR-NDRI, Department of Dairy Chemistry, Karnal, India
[3]Bhaskaracharya College of Applied Sciences, University of Delhi, Department of Food Technology, New Delhi, India
[4]Lady Irwin College, University of Delhi, Department of Food & Nutrition and Food Technology, New Delhi, India

**Corresponding Author:*
E-mail: aparna.gupta@lic.du.ac.in

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ABSTRACT. The current study sought to elucidate the relationship between taste sensitivity to phenylthiocarbamide (PTC) in a group of 157 people of both sexes (67 males and 90 females), representing a random sample of the population over the age of 18, with diverse food preferences and dietary habits. The taste sensitivity to (PTC), a bitter-tasting compound (determined to be a genetically controlled trait) was carried out with the help of PTC strips. The study also exploited the fact that the various demographic variables such as age, sex, and psychographic parameters like food choices, lifestyle, etc., significantly influenced the taste perception of phenylthiocarbamide and therein other bitter-tasting compounds. The results expressed a clear demarcation ($p<0.5$) between the taster and non-taster status between both the sexes; with the females being more sensitive to PTC (72.2% as tasters) than the males (64.2 %). A significant rise was observed in the taster status among individuals aged 18–24 years, with 75.49 % as tasters. PTC taster status and beverage consumption frequency were found to be negatively correlated; the opposite was observed for non-tasters. The study also extrapolated the finding that phenylthiocarbamide (PTC) tasters have a higher rejection of strong-tasting foods, whereas non-tasters have a higher acceptance of these foods. PTC can be used as a genetic marker to pinpoint risk factors related to and a reliable determinant of susceptibility to weight gain. Individuals who are sensitive to bitter tastes often have a fairly low orientation for bitter-tasting foods. The key findings of this study indicate a link between PTC perception and variables such as age, gender, food choices, and dietary habits.

Keywords: *Phenylthiocarbamide (PTC), bitterness, tasters, non-tasters, food preferences.*

INTRODUCTION

Taste is the sensation that occurs in the mouth when a substance reacts chemically with taste receptor cells located on taste buds or papillae [1]. Five basic tastes have been recognized so far: sweet, sour, salty, bitter, and umami. The perception of bitter taste is known to be a variable trait both within and between human populations. The bitter taste receptors (encoded by T2R genes) located on the surface of taste cells of the tongue cause the perception of bitterness [2]. Human responses to certain bitter compounds indicate a bimodal distribution that differentiates between two phenotypes, both tasters and non-tasters. However, more recent studies indicate a broader and continuous distribution. For instance, tasters are categorized as "medium tasters" and "supertasters" as per the variability in perceived bitterness [3]. Variations in the frequency of tasters in human populations range from 3 % to 98 % as per the literature review [4]. Phenylthiocarbamide (PTC) is one of the best-known compounds used to study the variation in sensitivity to bitterness. PTC belongs to the class of "thioureas" and its bitterness is characterized by N-C=S (thiocyanate) moiety [5, 6]. This compound can be found in various foods such as the Cruciferae or Brassicaceae vegetables (broccoli, cabbage, cauliflower, watercress, spinach), bitter fruits, and other foods such as pepper, green tea, and red wine which causes a bitter taste in some people [7].

PTC test strips are used to discover genetic variations depending on whether a bitter taste is experienced, i.e., individuals who perceive PTC as bitter tasting are "tasters," whereas those who taste blind to this are "non-tasters" [8]. According to Mendelian law, the inability to taste PTC is a simple recessive trait. Subjects with two recessive alleles (tt) are 'non-tasters' and those with one dominant allele (Tt) or two dominant alleles (TT) are 'tasters'. The TAS2R38 bitter taste receptor gene located on chromosome 7 mediates the ability to taste PTC. Polymorphism in this gene has been linked to more than 70% of the population's phenotypic variance in PTC sensitivity. Amino acid substitution at position 49 (alanine or proline), 262 (valine or alanine), and 296 (isoleucine or valine) explain most of this variance. Different haplotypes namely (AAI, AAV)-with frequency < 5 %, (PVI, PAI)-with frequency <1 %, AVI, and PAV of the TAS23R38 gene coding for operatively distinct receptors have been identified [9]. In order of the three polymorphisms (A49P, V262A, I296V), the "non-taster" AVI and the "taster" PAV are the two most prominent haplotypes. The frequency of both PTC non-tasters and tasters worldwide is reflected by the frequency of these two haplotypes in a population. Individuals who are most sensitive and least sensitive to the taste of PTC are the ones who are homozygous for PAV and AVI haplotypes respectively. Intermediate sensitivity is shown by those who carry a copy of each of the haplotypes. (PAV/AVI) [3].

Several studies have suggested the modifiers of the PTC phenotype-genotype relationship as certain individual characteristics, gender, smoking, alcoholism, aging, ethnicity, demographic factors, environmental influences, illness, diseases, chemosensory disturbances, etc. [10-19]. PTC is widely used as an important tool to study the genetic diversity in the human population; as sensitivity to PTC helps in tracing out family lineages and migration patterns [14]. Genetic differences in bitter taste sensitivity may also explain gender differences in food choices. Other parameters, such as age, gender, and ethnicity, can also influence the sensitivity to bitter-tasting chemicals [19]. The taste insensitivity to PTC can be associated with a wide array of non-communicable diseases (obesity, hypertension, diabetes, etc.); which is known to influence an individual's food preferences and dietary patterns which in turn contribute to increased susceptibility to weight gain. Studies have shown a strong correlation between non-tasters and obesity [7].

Obesity itself leads to a multitude of non-communicable diseases such as diabetes, cardiovascular diseases (heart attack and stroke), musculoskeletal disorders, and certain cancers (including ovarian, prostate, liver, gallbladder, kidney, and colon). The taste blindness to bitter compound- PTC could be attributed to the fact that there is an increased prevalence of non-tasters allele associated in the case of obese individuals and thus the phenotypic variation in sensitivity is genetic in origin [15]. PTC can be used as a genetic marker to identify risk factors associated with and a reliable indicator of weight gain susceptibility.

A study has revealed that the impairment of taste perception in type 2 diabetic individuals, prompted by increased serum glucose levels is due to the adaptation of the sensory cells to elevated circulating concentrations of glucose [20]. A significant correlation between serum glucose and BMI (Body Mass Index) was observed exclusively in non-tasters which is indicative of the fact that taste perception is strongly associated with circulating metabolic hormones besides dietary habits [21]. Recently, a study was undertaken to assess the relationship between phenylthiocarbamide perception and anthropometric factors, as well as consumption and preference for bitter vegetables. The study revealed no significant differences between the PTC phenotypic groups in terms of intake and perception of Brassicaceae vegetables, oral and nasal conditions, family history of illnesses associated with metabolic syndrome, smoking behaviors, or other factors. Furthermore, as compared to non-tasters, the average BMI of super-tasters (both men and women) was considerably lower [22].

This study intends to gain insights into diversity in taste sensitivity to PTC when subjected to individuals differing in their food preferences and dietary habits.

MATERIALS AND METHODS

Data collection and analysis

The PTC strips were procured from Precision Laboratories, U.K. (Thiourea Test Paper). A digital questionnaire was prepared to collect insights about the individual's demographic characteristics, health status, medical history, family history of chronic diseases, dietary habits, regular exercise habits, and food preferences. The data was statistically analyzed using the Chi-Square test. All analyses were made using SAS® OnDemand for Academics software and the differences were considered statistically significant at $p<0.5$.

Inclusion and Exclusion criteria

The subjects were divided into tasters and non-tasters based on their ability to taste the PTC strips. They refrained from eating or drinking anything other than water for at least 1 hour before tasting the PTC strips. The inclusion criteria involved people aged between 18 and 60. The study excluded individuals below the age of 18 since the gustatory papillae reach their full development during puberty [23]. Individuals above the age of 60 were excluded from this study, which is in line with the age ranges used in other related studies [24, 25], as these studies have consistently reported gustatory and olfactory functions decreasing with age, potentially linked to central nervous system and endocrine system disorders.

RESULTS AND DISCUSSION

In the PTC test conducted, out of 157 participants, 90 were females (57.32 %) and 67 were males, (42.67 %) (Table 1). The study included participants above 18 years of age as gustatory papillae reach full development at puberty [23].

The percentage of tasters was observed more within the age group of 18-24 years (Table 2) and the percentage of non-tasters was more among individuals above the age group of 45 years. Table 3 demonstrates the statistical analysis of the association between the age group and the ability to taste the PTC. Studies have supported the fact that the gustatory papillae reach full development at puberty. Taste intensities deteriorate rapidly with age (45+) since the number of taste buds in the foliate papillae decreases and the remaining tend to shrink [23].

Table 1. *Association between gender and ability to taste PTC*

Participants	Female	Male
Total no. of participants (in numeric terms)	90	67
Total no. of participants (in words)	Ninety	Sixtyseven
Percentage (%)	57.32	42.67

Table 2. *Association between age group and ability to taste PTC*

Age group	Ability to taste the PTC		
	Perceived bitter taste	Tasteless	Total
18-24 years: Frequency	77	25	102
Percent	49.04	15.92	64.97
Row Pct	75.49	24.51	
Col Pct	71.30	51.02	
25-34 years: Frequency	10	6	16
Percent	6.37	3.82	10.19
Row Pct	62.50	37.50	
Col Pct	9.26	12.24	
34-45 years: Frequency	12	4	16
Percent	7.64	2.55	10.19
Row Pct	75.00	25.00	
Col Pct	11.11	8.16	
>45 years: Frequency	9	14	23
Percent	5.73	8.92	14.65
Row Pct	39.13	60.87	
Col Pct	8.33	28.57	
Total	108	49	157
	68.79	31.21	100.0

Table 3. *Statistical analysis of the association between age group and ability to taste the PTC*

Statistics	DF	Value	Prob
Chi-Square	3	12.1391	0.0069
Likelihood Ratio Chi-Square	3	11.3640	0.0099
Mantel-Haenszel Chi-Square	1	8.7932	0.0030
Phi Coefficient		0.2781	
Contingency Coefficient		0.2679	
Cramer's V		0.2781	

Differences were considered statistically significant at p<0.5.Where, DF–Degrees of freedom, Prob-Probability

The influence of sensory attributes in orienting food choices & preferences and the ability to taste PTC are given in Table 4. The statistical analysis of the data is demonstrated in Table 5. Sensory attributes of the food like texture, appearance, color, and taste influence food choices and preferences in the majority of the participants (78.98 %). Out of them, 76.61 % were found to be tasters, and 23.39% as non-tasters. Out of the 17 individuals who do not perceive sensory attributes in orienting food choices and preferences, 82.35 % of individuals were found to be non-tasters. This might highlight that PTC tasters could have a higher rejection of strong-tasting foods whereas non-tasters have a higher acceptance of these foods. Further studies need to be conducted based on individuals' preferences for food belonging to this category.

Table 4. *Influence of sensory attributes in orienting food choices & preferences and the ability to taste PTC*

Feel sensory attributes	**Ability to taste the PTC**		
	Perceived bitter taste	**Tasteless**	**Total**
Maybe: Frequency	10	6	16
Percent	6.37	3.82	10.19
Row Pct	62.50	37.50	
Col Pct	9.26	12.24	
No: Frequency	3	14	17
Percent	1.91	8.92	10.83
Row Pct	17.65	82.35	
Col Pct	2.78	28.57	
Yes: Frequency	95	29	124
Percent	60.51	18.47	78.98
Row Pct	76.61	23.39	
Col Pct	87.96	59.18	
Total	108	49	157
	68.79	31.21	100.00

Pct: *Percentage*

Table 5. *Statistical analysis showing the influence of sensory attributes in orienting food choices & preferences and the ability to taste PTC*

Statistics	**DF**	**Value**	**Prob**
Chi-Square	2	24.5404	<.0001
Likelihood Ratio Chi-Square	2	23.0184	<.0001
Mantel-Haenszel Chi-Square	1	8.0747	0.0045
Phi Coefficient		0.3954	
Contingency Coefficient		0.3677	
Cramer's V		0.3954	

Differences were considered statistically significant at p<0.5. Where, DF: Degrees of freedom; Prob: Probability.

On grouping the individuals based on their daily intake of free sugars and ability to perceive PTC; it was observed that the PTC taster frequencies are close to each other in individuals who include 5-10 tsp of free sugars/day (68.08 %), less than 5 tsp/day (72.82 %), whereas 5 out of 6 individuals (83.33 %) whose daily diet included 10-15 tsp or more than 10 tsp of free sugars/day (100 %), perceived it as tasteless (Table 6). Individuals consuming more free sugars in their daily diet have been identified as non-tasters due to the masking effect exhibited by sugars on bitter perception [26]. Table 7 demonstrates the results of the statistical analysis of the association between daily intake of free sugars and the ability to taste PTC.

Table 6. *Association between daily intake of free sugars and the ability to taste PTC*

Daily free sugars	**Ability to taste the PTC**		
	Perceived bitter taste	**Tasteless**	**Total**
10-15 tsp/day: Frequency	1	5	6
Percent	0.64	3.18	3.82
Row Pct	16.67	83.33	
Col Pct	0.93	10.20	
5-10 tsp/day: Frequency	32	15	47
Percent	20.38	9.55	29.94
Row Pct	68.09	31.91	
Col Pct	29.63	30.61	
Less than 5 tsp/day: Frequency	75	28	103
Percent	47.77	17.83	65.61
Row Pct	72.82	27.18	
Col Pct	69.44	57.14	
More than 10 tsp/day: Frequency	0	1	1
Percent	0.00	0.64	0.64
Row Pct	0.00	100.00	
Col Pct	0.00	2.04	
Total	108	49	157
	68.79	31.21	100.00

Pct: Percentage

Table 7. *Statistical analysis of the association between daily intake of free sugars and the ability to taste PTC*

Statistics	**DF**	**Value**	**Prob**
Chi-Square	3	10.5851	0.0142
Likelihood Ratio Chi-Square	3	10.1229	0.0175
Mantel-Haenszel Chi-Square	1	3.1835	0.0744
Phi Coefficient		0.2597	
Contingency Coefficient		0.2513	
Cramer's V		0.2597	

Differences were considered statistically significant at $p < 0.5$. Where, DF: Degrees of freedom; Prob: Probability.

PTC taster status and the frequency of intake of beverages were found to be inversely related to each other; converse results were observed for non-tasters. It is due to the genetic diversity among tasters; that might result in more aversion for bitter taste associated with tea/coffee due to their higher sensitivity to it. It follows the study with a similar compound 6-n-propylthiouracil (PROP) that indicates amongst tasters, there is lower coffee intake and hence there is a lower risk for them to be heavy drinkers [27], but opposite findings were reported in the case of tea. The frequency of intake was not studied individually for tea and coffee in this study, so it limits the ability to provide an unbiased correlation. Coffee is a popular drink among the masses due to the stimulant effect of caffeine which is bitter in taste. Most participants prefer to drink coffee (66.24 %) (Table 8). A combination of several compounds like catechins, saponins, caffeine, and amino acids is attributed to the bitterness of the tea. The percentage of tea drinkers was found to be 45.22 %. (Table 8).

Table 8. *Preference for tea or coffee amongst tasters and non-tasters*

Preference	**Ability to taste the PTC**		
	Perceived bitter taste	**Tasteless**	**Total**
Tea: Frequency	55	16	71
Percent	77.46 %	22.53 %	45.22 %
Coffee: Frequency	73	31	104
Percent	70.19 %	29.81 %	66.24 %

Differences were considered statistically significant at $p<0.5$.

Tasters were observed to prefer tea more than non-tasters. Among tasters, the majority of them preferred black tea (88.57 %) over regular tea with milk (68.42 %) followed by green tea (61.63 %). Non-tasters prefer to drink green tea (35.29 %) over regular tea with milk (31.5 %) followed by black tea (11.43 %) (Table 9). The statistical analysis of the data showing the association between the type of tea and the ability to taste PTC is given in Table 10. The preference trend was found to be inconsistent, as taste is only one of the factors that determine food preference. Green tea consists of epigallocatechin gallate as the typical polyphenolic compound which is reported to be more bitter than catechin. The concentration of catechin and epicatechin is also higher in green tea than in fermented black tea [28]. This might be one of the reasons for the tasters' preference for black tea over green tea. The health benefits of green tea may be one of the other factors influencing its popularity among participants, despite its bitter taste.

Although the results of certain parameters studied in this research are consistent with other related studies conducted so far, the study in this area is inconclusive due to the small sample size, and the contradictory results highlight the need to conduct further studies, especially those concerned with various chronic diseases and individual food preferences along with their intake frequency.

Table 9. *Association between the type of tea and ability to taste PTC*

Type of tea	Ability to taste the PTC		
	Perceived bitter taste	**Tasteless**	**Total**
Regular tea with milk: Frequency	13	6	19
Percent	8.28	3.82	12.10
Row Pct	68.42	31.58	
Col Pct	12.04	12.24	
Black tea: Frequency	31	4	35
Percent	19.75	2.55	22.29
Row Pct	88.57	11.43	
Col Pct	28.70	8.16	
Green tea: Frequency	11	6	17
Percent	7.01	3.82	10.83
Row Pct	64.71	35.29	
Col Pct	10.19	12.24	
None of the above: Frequency	53	33	86
Percent	33.76	21.02	54.78
Row Pct	61.63	38.37	
Col Pct	49.07	67.35	
Total	108	49	157
	68.79	31.21	100.00

Table 10. *Statistical analysis of the association between type of the tea and the ability to taste PTC*

Statistics	DF	Value	Prob
Chi-Square	3	8.5672	0.0356
Likelihood Ratio Chi-Square	3	9.7450	0.0209
Mantel-Haenszel Chi-Square	1	5.5218	0.0188
Phi Coefficient		0.2336	
Contingency Coefficient		0.2275	
Cramer's V		0.2336	

Differences were considered statistically significant at $p<0.5$. Where, DF: Degrees of freedom; Prob: Probability

CONCLUSION

Our main findings suggest that there exists an association between PTC perception and certain parameters like age, gender, food choices, and dietary habits. There was no significant relationship found between cruciferous vegetable preference and the other food preferences studied. Food preferences are influenced by various attributes other than taste like economic, social, and psychological parameters. This study highlights the need to study the dynamic Indian population for PTC perception and its correlation to various chronic diseases to substantiate the outcomes conclusively.

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Conflict of Interest. The authors declared that there is no conflict of interest.

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Abbreviations. PTC, phenylthiocarbamide; **Freq**, frequency and **Pct**, percentage.

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