Taste and food preferences as predictors of dietary practices in young women

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Abstract

Objective: To investigate links between taste responses, self-reported food preferences and selected dietary outcomes in young women.
Methods: Subjects were 159 women, with a mean age of 27.0 years. Taste responses were measured using aqueous solutions of 6-*n*-propylthiouracil (PROP) and sucrose. All subjects completed a 171-item food preference checklist, using nine-point category scales. Food preference data were reduced using principal components factor analyses, with the internal consistency of factor-based subscales established using Cronbach's alpha. Dietary intakes, available for a subset of 87 women, were based on 3 days of food records. Estimated intakes of carbohydrate, fibre and β-carotene were the key dietary outcome variables.
Results: Genetically-mediated sensitivity to the bitter taste of PROP was associated with reduced preferences for Brussels sprouts, cabbage, spinach and coffee beverages. Higher preferences for sucrose in water were associated with increased preferences for sweet desserts. Food preferences, in turn, were associated with measures of current diet. Reduced acceptability of vegetables and fruits was associated with lower estimated intakes of carbohydrate, fibre and β-carotene.
Conclusions: Taste responses to sucrose and PROP were predictive of some food preferences. Food preferences, in turn, were associated with food consumption patterns. Given that taste responsiveness to PROP is an inherited trait, there may be further links between genetic taste markers, eating habits and the selection of healthful diets.

Keywords
6-*n*-propylthiouracil (PROP)
Sucrose
Taste responses
Food preferences
Dietary outcomes
Women's health

Increasing the consumption of vegetables and fruit is the stated aim of many public health nutrition education and intervention programmes[1–3]. Such programmes, for the most part, have been based on social and psychological models of behavioural change[4–6]. These include the stages of change model, theory of reasoned action, and the social learning and social support theories[4–6]. Few of these theoretical frameworks include taste and food preferences as potential predictors or antecedents of dietary change[7,8]. Leading theorists in health education believe that taste preferences are shaped by exposure, and that most people will come to like almost any food if given sufficient reinforcement and positive social context[4].

In contrast, marketing studies on the determinants of food consumption invariably show that consumer choices are largely determined by how foods taste[9]. Familiarity and sweetness tend to determine food choices in early life, whereas bitter taste is often associated with food rejection[9–11]. Bitter taste has been cited as the main reason for disliking cruciferous vegetables, citrus fruit, coffee and alcohol[7,12–15]. Low acceptance of bitter-tasting vegetables and fruit may be a barrier to the adoption of cancer-preventive diets consistent with the USDA Food Guide Pyramid[3] or the National Cancer Institute 5-A-Day for Better Health Program[6]. A better understanding of how taste factors influence vegetable and fruit consumption would aid in the design of dietary strategies for health promotion.

Far from being a learned response, sensitivity to some bitter tastes is an inherited trait[10,12,16,17]. Genetically-mediated sensitivity to the bitter taste of phenylthiocarbamide (PTC) and PROP has been associated with increased acuity for other bitter compounds[18,19] and with increased dislike of some bitter foods[20]. While classic studies in this area (see ref. 7 for review) distinguished only between PROP tasters and non-tasters, new research has identified non-tasters, regular tasters and supertasters of PROP. Those distinctions were based on PROP detection thresholds and the magnitude of bitterness ratings for more concentrated PROP solutions[18,21,22]. Supertasters, most of whom are said to be women, on average had more fungiform

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papillae and a higher density of taste buds per papilla than did either regular tasters or non-tasters of PROP[23].

However, sensitivity to PROP may not extend to other bitter tastes. Furthermore, the potential impact of PROP taster status on food selection remains unclear. PROP sensitivity was once thought to confer the evolutionary advantage of being able to detect and reject bitter poisons[24,25]. Perhaps the most frequently cited, if anecdotal, example of taste-based food rejection was the reputed avoidance by PROP tasters of bitter antithyroid compounds found in raw cruciferous vegetables, broccoli, cabbage and Brussels sprouts[24]. In later studies, based on checklists of food names[13,14], PROP tasters reported more food dislikes than did non-tasters[20,25]. PTC or PROP sensitivity was linked to a greater number of dislikes for green and cruciferous vegetables (cabbage, Brussels sprouts, spinach and kale), rhubarb, sauerkraut, beer, coffee, brown bread and various sharp cheeses[20,25,26]. More recent studies have linked PROP taste responsiveness to reduced acceptance of naringin solutions, soy products and Japanese green tea[22,27]. The latter studies are particularly relevant to the cancer prevention literature, given that many of the antioxidant phytochemicals are said to be found in green and cruciferous vegetables, soy products, citrus fruit and tea[28,29].

However, no study has managed to show that PROP sensitivity affects eating habits[14,30,31]. In past studies, PROP sensitivity had no significant impact on the consumption of cruciferous vegetables[14,32] or on the consumption of vegetables and fruit[31]. However, numerous variables mediate the links between taste responsiveness and food selection[9]. Cost, availability and convenience may modulate the relationship between taste preferences and actual food choice. We hypothesized that taste responses to PROP and sucrose would primarily affect the self-reported acceptance of selected bitter and sweet foods. Food preferences might then serve as predictors of food consumption, as indicated by selected measures of the current diet[9]. While studies with children tend to acknowledge that children's food choices are driven by taste, studies on fat- and fibre-related dietary behaviours among adults have tended to focus on the role of demographic factors, predisposing and enabling variables, skills and social norms[4]. Our hypothesis was that taste and food preferences are among the most important predictors of current diet, not only among children, but also among young adults.

This study explored associations between taste responses, food preferences and selected dietary outcomes in a sample of college-age women. PROP detection thresholds and bitterness intensity ratings for PROP solutions assessed taste responsiveness to PROP[18]. Hedonic response to sweet tastes was measured using five concentrations of sucrose in water. A 171-item food preference checklist served to measure food acceptance[33]. Dietary intakes were assessed using 3 days of food records. Intakes of carbohydrate, fibre and β-carotene, known to be associated with fruit and vegetable consumption, were the key dietary outcome variables.

Methods

Subjects

Subjects were 159 female non-smokers, with a mean age of 27.0 years (range 20–60 years), in good physical health who were recruited by advertising in the university community. The subjects were weighed and measured, and mean body mass index (BMI) values were calculated ($kg\,m^{-2}$). All subjects completed health and demographic questionnaires, the Restraint Scale[34] and the Eating Attitudes Test (EAT)[35]. Women who lived and ate all their meals in residence halls were ineligible for the study. All research protocols had been approved by the Institutional Review Board of the University of Michigan School of Public Health. Subjects were compensated for completing the two study sessions.

Stimuli

Determination of PROP taste thresholds employed a series of 15 solutions of PROP (Pfaltz & Bauer, Waterbury, CT) that ranged in concentration from $1.0 \times 10^{-6}\,mol\,l^{-1}$ to $3.2 \times 10^{-3}\,mol\,l^{-1}$, and were incremented in quarter log steps[18]. The most concentrated solution (number 15) contained $0.5446\,g\,l^{-1}$ PROP; the next concentration contained $0.3064\,g\,l^{-1}$, and so on[10,17,18]. The less concentrated solutions were prepared by diluting the four stock solutions.

Five suprathreshold concentrations of PROP in deionized water were 0.000032, 0.0001, 0.00032, 0.001 and $0.0032\,mol\,l^{-1}$ (solutions 7, 9, 11, 13 and 15). The concentrations of sucrose were 2%, 4%, 8%, 16% and 32% wt/vol, consistent with prior studies[10]. Solutions were prepared at least 1 day before testing and were stored at 4°C.

PROP taste thresholds

Establishing detection thresholds for PROP was a two-step procedure. First, each subject was presented with the least concentrated solution of PROP (solution 1), and then with increasingly more concentrated solutions, until she reported detecting a taste distinct from that of water. Then, two identical cups were presented, one containing the detected concentration of PROP and the other containing deionized water. The subject was asked to judge which of the two samples had the bitter taste[10]. Wrong answers led to the presentation of the next higher concentration of PROP (again paired with deionized water), while correct answers led to a second presentation of the same concentration of PROP. Two consecutive correct answers at the same concentration were followed by the next lower concentration of PROP. Reversal points were defined as the concentration at which a string of correct responses turned to an incorrect response or vice versa. After discarding the first reversal, the calculated PROP threshold was the arithmetic mean of the subsequent five reversal points. On the average, each threshold determination took 25 min.

Suprathreshold scaling

Subjects also tasted and rated five aqueous solutions of PROP and five solutions of sucrose (average volume 5 ml), presented in 10 ml plastic cups at room temperature and in a random order. PROP solutions were always presented last. Subjects rated intensity of bitterness or sweetness of each stimulus using nine-point category scales, where 1 was 'not at all bitter' and 9 was 'extremely bitter'. Hedonic ratings for each stimulus were assessed using the nine-point hedonic preference scale[36]. This fully anchored nine-point category scale ranges from 1 ('dislike extremely') to 9 ('like extremely'), with a neutral point at 5 ('neither like nor dislike'). The subjects used whole mouth tasting and the standard sip-and-spit technique[10], waiting a minimum of 3 min and rinsing with deionized water between samples. Mean PROP intensity ratings were calculated for the five PROP solutions. Mean hedonic ratings for sweetness were calculated by averaging over the five sucrose solutions.

Food preference measures

The food preference checklist was based on 171 foods selected from all food categories. Subjects were asked to indicate how much they liked or disliked each food item using the nine-point hedonic preference scale[36]. This method was adapted from food preference checklist studies conducted with Army personnel[33]. An option for 'never tried' was also included.

Factor analysis was used to reduce preference data for individual foods[33,37] into factor-based category subscales. Only foods consumed by >75% of the sample were used in factor analysis, which resulted in the elimination of such foods as kale, collards, mustard greens, etc. Separate factor analyses were conducted for green vegetables (13 items), other vegetables (16 items), fruits (12 items) and desserts (12 items). Principal components factor analysis with varimax rotation generally yielded solutions of between one and three factors per food group that accounted for between 47% and 66% of the variance. For example, the vegetable group yielded three factor-based subgroups that might be described as carotene-rich vegetables (including winter squash, beets, carrots and sweet potatoes), potatoes (boiled, baked, fried and mashed) and salad greens (cucumber, celery, raw tomatoes and raw onions). The internal consistency of factor-based subscales was established using Cronbach's alpha.

Food consumption measures

Dietary intake assessment, performed for 87 out of the 159 subjects, was based on 3 days of food records, including at least one weekend day. Subjects were instructed on the keeping of diet records by a registered dietitian and were debriefed, if needed, on their next visit to resolve any ambiguities in the reporting of foods and estimating portion sizes. Diet records were analysed using the Nutritionist IV computer program (version 4.1, 1997, First DataBank, The Hearst Corporation, San Bruno, CA). Per cent dietary carbohydrate (as % energy) and intakes of fibre (g/1000 kcal) and β-carotene (μg/1000 kcal) were the key dietary outcome variables.

Statistical analyses

Statistical analyses used SPSS for Windows, version 6.0 (SPSS Inc., Chicago, IL). Pearson correlations were used to test links between PROP sensitivity, sweetness preferences and food preference data. Pearson correlations were also used to test links between food preferences and dietary outcome variables.

Results

Subjects

Subject characteristics are summarized in Table 1. Mean weight was 62.7 kg and mean BMI was 23.2 kg m^{-2}. The subject sample was free from eating disorders, as indicated by low scores on the EAT scale.

PROP sensitivity

As in past studies[10,18], a bimodal distribution of PROP detection thresholds served to classify subjects as either tasters or non-tasters of PROP (Fig. 1). PROP tasters were defined as having thresholds of less than 1.0×10^{-4} mol l^{-1} (equivalent to solution 9) and non-tasters as having thresholds in excess of 2.0×10^{-4} mol l^{-1}, equivalent to solution 10.

A scatterplot of detection thresholds by mean

Table 1 Characteristics of the 159 female subjects; data are given as means and SEMs

	Mean	SEM
Age (years)	27.0	0.7
Height (cm)	164.3	0.6
Weight (kg)	62.7	1.0
BMI (kg m^{-2})	23.2	0.4
Restraint score	13.9	0.4
EAT score	10.8	0.5

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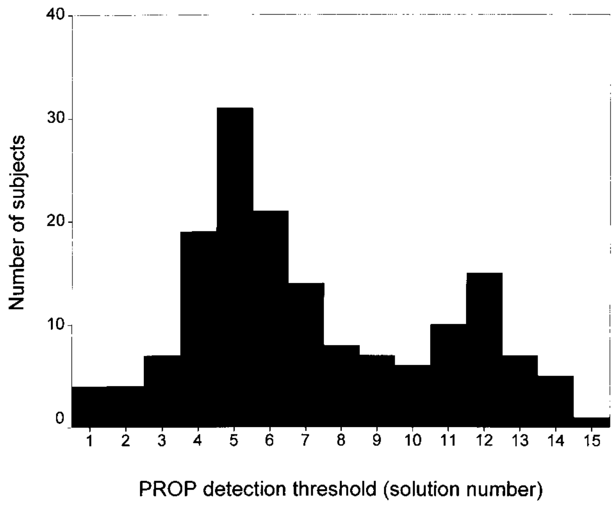

Fig. 1 Distribution of taste detection thresholds for 6-*n*-propyl-thiouracil (PROP)

bitterness ratings for the five PROP solutions is shown in Fig. 2. The two measures of PROP sensitivity were associated with each other, and subjects with lower PROP thresholds rated PROP solutions as more bitter ($r=-0.67$; $P<0.01$).

Taste responsiveness and food acceptance

As shown in Table 2, greater responsiveness to PROP was significantly correlated with reduced acceptance of cruciferous and some green leafy vegetables, including Brussels sprouts, cabbage and spinach. Reported preferences for espresso and regular coffee were also lower among PROP-sensitive subjects. PROP responsiveness was unrelated to reported preferences for sweet desserts. In contrast, higher hedonic ratings for sucrose solutions were correlated with higher

Table 2 Pearson correlations between measures of sensory response to bitter tastes (PROP) and sweet tastes (sucrose) and self-reported preferences for selected vegetables, beverages and sweet desserts

	PROP sensitivity		Sucrose hedonic rating
	Intensity	Threshold	
Vegetables			
Brussels sprouts	–0.18*	0.20*	0.11
Cabbage (raw)	–0.14	0.20*	0.02
Cabbage (cooked)	–0.16†	0.12	0.12
Coleslaw	–0.17*	0.09	0.16*
Radishes	–0.14†	0.11	0.11
Spinach (raw)	–0.11	0.18*	0.03
Sweets and desserts			
Brownies	–0.10	0.02	0.31*
Chocolate candy	0.03	–0.13	0.21*
Chocolate cake	0.13	–0.21*	0.21*
Hot fudge sundae	0.00	–0.09	0.27*
Ice-cream	–0.06	0.01	0.25*
Strawberry shortcake	0.07	–0.00	0.18*
Sweet potato pie	–0.05	0.01	0.33*
Beverages			
Coffee (regular)	–0.24*	0.27*	0.01
Espresso coffee	–0.26*	0.21*	–0.05
Tea (with sugar)	–0.04	–0.05	0.20*

$^*P<0.05$.
$^\dagger P<0.05$ (one tailed).

ratings for most sweet desserts and for sugar in tea. Within this limited context, taste responses to aqueous solutions of sucrose and PROP do predict self-reported preferences for some sweet and bitter foods, even though correlation coefficients and coefficients of determination were rather low.

Further analyses were conducted using factor-based food preference subscales. Figure 3 shows the relationship between PROP detection thresholds and ratings on the cruciferous vegetable subscale, representing Brussels sprouts, cauliflower, cabbage (raw and

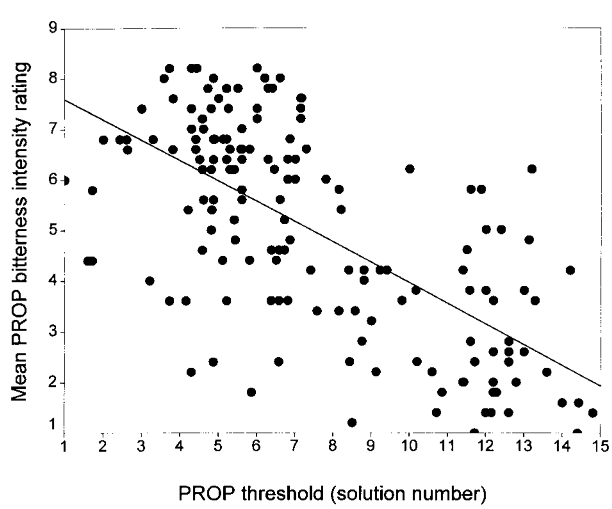

Fig. 2 Scatterplot of PROP detection thresholds against mean PROP bitterness intensity ratings. PROP-sensitive subjects are characterized by low thresholds and high intensity ratings

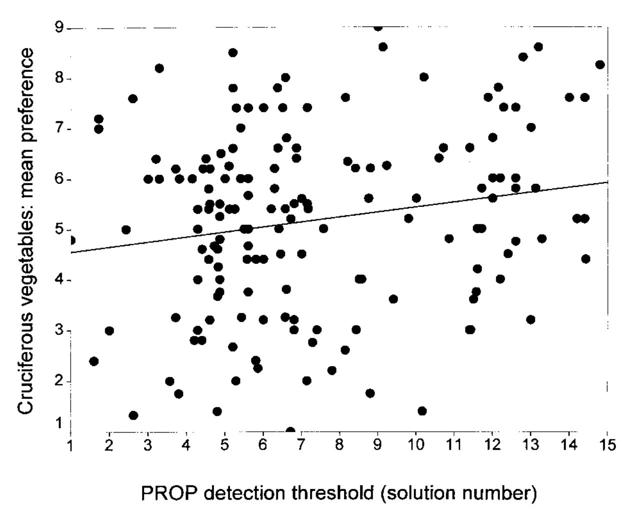

Fig. 3 Scatterplot of mean acceptance ratings for cruciferous vegetables against PROP detection thresholds (solution number). Cruciferous vegetables were Brussels sprouts, cauliflower, cabbage (raw and cooked) and radishes

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Table 3 Pearson correlations between mean preference scores on factor-based subscales for vegetables, fruit and desserts and selected dietary outcomes

Food category	Cronbach's alpha	CHO (%)	Fibre (g/1000 kcal)	β-carotene (μg/1000 kcal)
Green vegetables				
1 Brussels sprouts, cauliflower, cooked cabbage, radish, raw cabbage	0.81	0.23*	0.08	0.26*
2 Broccoli, green beans, peas, string beans	0.71	0.11	0.11	0.29*
3 Artichoke, asparagus, cooked spinach, raw spinach	0.74	0.30*	0.23*	0.26*
Vegetables, potatoes and salad				
1 Acorn squash, beets, baked yellow squash, buttersquash, cooked carrots, sweet potatoes	0.86	0.21*	0.20	0.35*
2 Baked potatoes, boiled potatoes, corn on the cob, French fries, mashed potatoes	0.67	−0.01	−0.22*	0.03
Sweets and desserts				
1 Brownies, chocolate cake, chocolate pudding, doughnuts, hot fudge sundae, ice-cream, pastry	0.84	0.00	−0.12	0.02
2 Banana split, strawberry shortcake	0.59	0.08	0.03	0.17
3 Apple pie, pumpkin pie, sweet potato pie	0.64	0.24*	0.10	0.07
Fruit				
1 Apricots, cherries, nectarines, pears, raspberries, strawberries	0.80	0.15	0.08	0.19
2 Apples, grapes, oranges, orange juice	0.74	0.11	−0.10	0.01
3 Grapefruit, grapefruit juice, lemons, rhubarb	0.71	0.05	0.13	0.23*

*$P < 0.05$.

cooked) and radishes. Internal consistency of the subscale was established using Cronbach's alpha (α = 0.81). PROP-sensitive individuals were more likely to dislike cruciferous vegetables.

While many factors contribute to food preference, sensitivity to bitter taste tends to be associated with food rejection. As shown above, liking for vegetables (ratings >5 on a nine-point scale) was not linked to PROP taster status. In contrast, subjects who rejected cruciferous vegetables (ratings <4 on a nine-point scale) were for the most part PROP sensitive. Pearson correlation between PROP thresholds and food preferences was significant ($P < 0.05$).

Food preferences and measures of current diet

Associations between food preferences and nutrient intakes are shown in Table 3. Correlation analyses were performed for the 87 subjects for whom both sets of data were available. Food preferences were based on mean scores along factor-based subscales. As might be expected, preferences for green vegetables were associated with a higher proportion of energy from carbohydrate and higher intakes of β-carotene. Preferences for high-fibre vegetables (artichoke, asparagus, raw and cooked spinach) were associated with higher intakes of dietary fibre. Preferences for carotene-rich vegetables (winter squashes, beets, carrots, sweet potatoes) were associated with higher intakes of β-carotene and fibre. Preferences for potatoes (including French fried potatoes) were negatively associated with fibre intakes.

Preferences for sweet desserts were not linked to any dietary outcome variables of interest. Only preferences for pies (apple, pumpkin, sweet potato) were associated with a higher proportion of carbohydrate in the diet. Sugar consumption was not measured.

Discussion

Genetically-mediated sensitivity to PROP was associated with lower reported preferences for cruciferous and some green leafy vegetables, including Brussels sprouts, cabbage and spinach. These vegetables are among the main sources of phytochemicals, including a non-provitamin A carotenoid, lutein, that have been implicated in lowering cancer risk[38,39]. Reported preferences for vegetables were, in turn, associated with selected measures of the current diet. Higher preferences for vegetables were associated with higher estimated intakes of carbohydrate, dietary fibre and β-carotene, chief dietary indices of vegetable consumption. Given an adequate number of subjects and a sufficient power of analysis, we should be able to demonstrate a direct influence of genetic taste factors on dietary outcomes.

In the meantime, the present data provide a useful, if limited, indication of a link between taste responses and food preferences. The usefulness of taste studies in predicting food preferences and food consumption has been the subject of some controversy[40,41]. The obese 'sweet tooth', as revealed by hedonic responses to sucrose solutions, was once thought to be the major contributing factor to human obesity[42–44]. Though sip-and-spit taste tests have been criticized for their lack of ecological validity and unclear relevance to eating habits[40,41], hedonic response to sweet taste is still viewed as a measure of individual tendency to overeat sweets and desserts[42]. The present data show that increased sensory preferences for sweet sucrose solutions were indeed associated with greater self-reported preferences for sweet desserts and for sugar in tea. However, there was no evidence that self-reported preferences for sweet desserts in this study sample were linked to actual consumption of energy, carbohydrate or fat.

The present data showing that PROP sensitivity was associated with reduced preferences for cruciferous vegetables and coffee are consistent with some earlier studies. Glanville and Kaplan[13] showed that PROP-sensitive adults had more food aversions and preferred mild- over sharp-tasting foods. PROP tasters preferred coffee with milk or sugar as opposed to black coffee, and tended to dislike lemon and grapefruit juices, sauerkraut, vinegar and horse-radish[13]. In a study of Hungarian twins, PTC tasters reported lower preferences for salami, anchovy paste, brown bread, beer and kale[26]. The rejection of raw cruciferous vegetables by PTC/PROP tasters has been noted previously. Goitrin (1,5 vinyl-2-thiooxazolidone) and isothiocyanates are bitter PTC-related compounds caused by hydrolysis of glucosinates naturally present in raw cabbage[45]. On the other hand, several studies have found no relationship between PTC/PROP responsiveness and responses to other bitter tastes[31,46] or the rejection of bitter-tasting foods.

In particular, no study has demonstrated a convincing link between PTC/PROP sensitivity and actual food consumption. Krondl *et al.*[32,46] reported no effects of PTC taster status on the consumption of cruciferous vegetables. One study[32], conducted with 32 women aged 53–76 years, showed that PTC tasters found cooked cabbage to be more intensely flavoured than did non-tasters. However, taste preferences and reported vegetable use were unaffected by PTC taster status[32]. Subjects in the second study[46] were 18 female tasters and 18 non-tasters. Vegetable consumption was determined using a modified food frequency questionnaire that included 11 cruciferous vegetables—namely broccoli, Brussels sprouts, red cabbage, white cabbage, cauliflower, collards, kale, kohlrabi, radishes, white turnips and watercress. Also included were two non-cruciferous but bitter vegetables: spinach and endive. However, since few subjects consumed any of the vegetables, frequency of consumption was reduced to a dichotomous variable: use versus non-use. No significant differences between tasters and non-tasters were found[46]. Another study[31] also failed to link PTC sensitivity with eating habits. In that study, 282 subjects were separated into 146 tasters and 113 non-tasters on the basis of their responses to PTC-impregnated filter paper. Dietary behaviours were assessed using a list of 25 foods, including raw cabbage, carrots and celery, as well as strawberries, spinach, oysters, peaches and pears. Frequency of consumption was rated along a nine-point scale, ranging from 'tried once or twice' to 'eaten more than once per day'. The study found no link between PTC taster status and a consistent pattern of food avoidance[31].

Self-reported food preferences were consistently, if weakly, correlated with selected dietary outcomes. In particular, preferences for vegetables were correlated with chief dietary indices of vegetable consumption, that is intakes of carbohydrate, fibre and β-carotene. While the magnitude of the correlations did not exceed 0.30, food preferences ought to be ranked among other psychosocial factors as potential predictors of food choice and food consumption.

The influence of taste and food preferences on vegetable consumption is particularly interesting[27]. Many phytochemicals with potential chemopreventive activity are either bitter-tasting or are found in bitter vegetables and fruits[7,38]. Bitter isothiocyanates derived from cruciferous vegetables may have a chemopreventive action in cancer control[38,39]. Flavonoids such as naringin, the bitter component of grapefruit juice, are also thought to be biologically active[22]. Isoflavones in soy, polyphenols in tea and wine, glucosinates in cruciferous vegetables, and other phytochemicals in 'functional foods' all share a bitter taste. While bitter taste is the commonly cited reason for low acceptance of cruciferous vegetables[47], some consumers may be more sensitive to it than others. Inherited sensitivity to the bitter taste of PROP has been shown to be associated with greater responsiveness to some, but by no means all, bitter tastes[7,10]. It remains to be seen whether PROP sensitivity limits exposure to useful dietary constituents, or interferes with the success of nutrition education and intervention programmes.

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