Taste Perception and Food Choices

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ABSTRACT

Objectives: The extent to which variation in taste perception influences food preferences is, to date, controversial. Bitterness in food triggers an innate aversion that is responsible for dietary restriction in children. We investigated the association among genetic variations in bitter receptor TAS2R38 and food choices in healthy children in the Mediterranean area, to develop appropriate tools to evaluate the relation among genetic predisposition, dietary habits, and feeding disorders. The aims of the study were to get a first baseline picture of taste sensitivity in healthy adults and their children and to explore taste sensitivity in a preliminary sample of obese children and in samples affected by functional gastrointestinal diseases.

Methods: Individuals (98 children, 87 parents, 120 adults) were recruited from the general population in southern Italy. Bitterness sensitivity was assessed by means of a suprathreshold method with 6-propyl-2-thiouracil. Genomic DNA from saliva was used to genotype individuals for 3 polymorphisms of TAS2R38 receptor, A49P, A262 V, and V296I. Food intake was assessed by a food frequency questionnaire.

Results: Children's taste sensation differed from that of adults: we observed a higher frequency of supertasters among children even in the mother–child dyads with the same diplotypes. Among adults, supertaster status was related with proline-alanine-valine (taster allele) homozygous haplotype, whereas supertaster children were mainly heterozygous. Regarding the food choices, we found that a higher percentage of taster children avoided bitter vegetables or greens altogether compared with taster adults. Taster status was also associated with body mass index in boys.

Conclusions: Greater sensitivity to 6-propyl-2-thiouracil predicts lower preferences for vegetables in children, showing an appreciable effect of the genetic predisposition on food choices. None of the obese boys was a supertaster.

Key Words: bitter taste, food choices, 6-propyl-2-thiouracil, TAS2R38

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Sense of taste evolved to discriminate beneficial foods from environmental poisons as a critical system to ensure human survival. This goal was achieved driving innate feeding behavior to accept nutritive food or refuse potential toxic substances. Good (pleasant) tastes, as sweet and umami (the savory taste of some L-amino acids), elicited by energetic compounds as carbohydrates and proteins, trigger attraction towards nutritive food. Bad (unpleasant) tastes, as bitter and sour, evolved to detect potentially lethal compounds as plant secondary metabolites or microbial toxins. Salty taste, developed to ensure ions and water homeostasis when life moved from sea to land, can be good or bad depending on the concentration of sodium and on the physiological context.

Ancestral feeding behavior was retained by contemporary humans, although food choices do not pertain to life or death. Nevertheless, taste is still a critical determinant of food selection, especially in children. As a legacy of the prehistoric age, neophobia, the refuse of new unknown food, restrains the dietary habits of infant babies and is related to feeding behavioral disorders.

The taste sensors are specific receptors located in the taste buds of the gustatory papillae on the tongue and soft palate. Sweet, umami, and bitter tastants are recognized by G-coupled protein receptors encoded by the TAS1R and TAS2R taste receptors gene families, whereas salty and sour compounds are detected by ion channels. The T1R receptors are closely related and consist of the heterodimers TAS1R2/TAS1R3, which are able to recognize a wide range of sweet-tasting compounds, and TAS1R1/TAS1R3, responsible for the perception of the umami taste of L-glutamate.

The pivotal role of bitter perception to avoid accidental ingestion of potentially harmful substances is outlined by the presence in the human genome of 25 members of the *T2R* gene family, mapping as clusters on chromosomes 7q and 5p. Human *T2R* genes display a high degree of polymorphism potentially involved in the variance of individual bitterness sensitivity; however, the functional consequences of the most of the receptor variants on taste sensitivity is not yet known.

Allelic variations affecting the perception of some bitter compounds, such as salicine, quinine, and aloin, have been reported in the *TAS2R16*, *TAS2R19*, and *TAS2R43/44* genes, respectively, but the linkage between the genotype and the trait variance is poor (1). TAS2R38, a receptor for the thiourea compounds phenyltiocarbamide (PTC) and 6-n-propylthiouracil (PROP), is the only bitter receptor able to explain most of the variance in human bitter taste. On the basis of sensitivity to thiourea, the human population can be phenotypically classified into 3 categories: insensitive, sensitive, and hypersensitive to bitterness. The variance of this distribution is explained by the haplotypes generated by 3 polymorphisms in the *TAS2R38* gene accounting for 55% to 85% of the variance in PTC sensitivity (2).

Three nonsynonymous substitutions in the *TAS2R38* gene give rise to amino acid changes to the protein at residues A49P, A262V, and V296I, putatively involved in G-protein interaction and receptor activation. The combination of the 3 single nucleotide polymorphisms results in 5 observed haplotypes with different worldwide distribution. In Europeans the taster haplotype proline-alanine-valine (PAV) and the nontaster haplotype alanine-valine-isoleucine (AVI) make up the vast majority of haplotypes present; 3 additional variants

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as the less common alanine-alanine-valine (AAV) and the rare haplotypes proline-valine-isoleucine (PVI) and alanine-alanine-isoleucine (AAI) can be observed (2).

In vivo and in vitro studies reported PAV as the major determinant of taster status and AVI as the major nontaster haplotype, so individuals with 2 copies of the AVI allele are basically nontasters, whereas individuals with 1 or 2 copies of the PAV allele are medium tasters or supertasters. PROP sensitivity of heterozygous common haplotypes PAV or AVI in combination with less of a common or a rare variant appears to lie in between (3,4).

The genotype-phenotype relation is not stringent; this is partly the result of the subjective methods of identification of the phenotype but also of the likely complexity of the genetic factors controlling taste. More genes were suggested to cooperate in the control of the phenotype (1,5,6). Several reports showed that the perception of bitter taste is related not only to the specific taste of bitter compounds but also to the wide behavior spectrum of the individual in relation to food choices (7). Hypersensitive individuals have a more restricted diet, compared with sensitive or insensitive individuals (8).

These issues are of paramount importance in children after weaning: this is the time when many children gradually develop erratic food acceptance, often generating anxiety in mothers. Maternal expectations may not coincide with the transmission of only 50% of the genetic predisposition to food choices, because the other partner is responsible for the other 50%. The genetic predisposition of the child is naïve, because transformations brought by experience, social behavior, and traditions have no time to modify genetic predisposition. There is indeed scope to explore mother–child dyads to verify the concordance between them and the conditioning of the genetic predisposition.

There are few studies (9) analyzing the relation among food choices, sensitivity to bitter taste, and genetics in the Mediterranean population. Such studies may help us to understand the preference for bitter vegetables and other greens in this population.

The specific research question at the base of the present study is to explore the phenotype-genotype correlation in bitter taste sensitivity in either normal adults or mother–child dyads. A further task is to explore bitter taste sensitivity in obese children and those affected by a variety of food-related symptoms or diseases.

METHODS

Population

1. A total of 120 healthy adult volunteers (medical students) + 44 healthy children
2. A total of 54 children affected by a variety of functional disturbances
3. A total of 92 mother–child dyads, including 41 of the 44 healthy and 51 of the 54 affected children

Inside the second group, there were children affected by:

1. Feeding disturbances (6)
2. Functional gastrointestinal disturbances (10)
3. Celiac disease (18)
4. Organic diseases (familial hypercholesterolemia, diabetes, obesity, metabolic dysfunctions) (10)
5. Food allergy (10)

Forty-four unselected healthy children, with their mothers, were recruited consecutively at a well baby clinic in the field; 54 children affected by a variety of disturbances were recruited from outpatients in the Department of Pediatrics.

Their age (45F/53M) ranged from 3 to 19 years. One hundred twenty healthy young adults (medical or nursing students) were recruited on a voluntary base, after dissemination seminars at the university. Overall, the study sample mirrored the genetic and cultural environment of the local urban setting. Subjects were considered eligible for the study if they were not on dietary restrictions, with the exception of people with celiac disease, who were on a gluten-free diet. The study was scrutinized and approved by the ethics committee of the University ''Federico II'' of Naples. Informed consent was obtained from individuals or guardians.

Genotyping

Genomic DNA was obtained from saliva with the phenol-chloroform extraction method following a protocol developed in our laboratory. The allelic variations of the *TAS2R38* gene C145G (rs713598), C785T (rs1726866), and G886A (rs10246939) were genotyped by means of real-time polymerase chain reaction with 7900HT fast (Applied Biosystems, Carlsbad, CA) using allele-specific probes and primers (Applied Biosystems).

To estimate the population prevalence of the different haplotypes, we excluded from the analysis the children of the mother–child dyads because their data are not independent of those of the mothers and would overrepresent maternal haplotypes. The expected error of genotyping was estimated to be $<1\%$ by previous work in our laboratory.

PROP Tasting

A 2-step approach was adopted to estimate the tasting phenotype of the subjects. All of the subjects underwent a suprathreshold test to assess the sensitivity of perception at suprathreshold concentrations. For a random sample of the subjects, after the first suprathreshold test, we applied the threshold method, which assesses the individual's ability to discriminate low concentrations of the stimulus. Suprathreshold intensity ratings are often used to correctly separate medium tasters from supertasters because their distribution overlaps substantially at threshold. The detection threshold, based on the lowest concentration at which a person detects the presence of a sensation, was instead described as the best method to classify individuals as tasters or nontasters.

The test was offered to children and adults, who fasted for at least 1 hour. The children were instructed not to swallow the solutions and, if required, underwent brief training in the ''sip and spit'' method. Subjects tasted in ascending order 2 solutions of 280 and 560 μmol/L PROP (6-propyl-2-thiouracil; Aldrich Chemical, Milwaukee, WI) in distilled water, rinsing with water before and after each solution. The reported feeling or, in extremely young children, the facial expression was recorded. The sensitivity evaluation was performed by constructing a 4-point scale in which the labels ''no taste,'' ''weakly unpleasant'' (bitter, barely perceptible), ''unpleasant'' (bitter), and ''very unpleasant or terrible'' (extremely bitter) corresponded to values between 0 and 3. Facial reactions were referred to a 4-point hedonic scale corresponding to ''no taste/neutral,'' ''weakly unpleasant/depression of mouth corners,'' ''unpleasant/frown and depression of mouth corners,'' and ''very unpleasant/frown and grimace.'' According to the score achieved, subjects were classified as nontasters (NT, score 0–2), medium tasters (MT, score 3–4), and supertasters (ST, score 5–6).

For quality control, to estimate the intraindividual variability of the suprathreshold test, we repeated the same test in 48 of the 144 healthy individuals. The intraindividual concordance between the first and the second suprathreshold tests was 78.7%. In addition, we

applied the detection threshold method to a random sample of 10% (n = 30) of the study population. PROP threshold was determined using a ''forced choice'' procedure, in which individuals tasted 2 samples, 1 of water and 1 of PROP solution, and were asked to identify the sample with the stronger taste. Six PROP solutions, from 0.032 to 3.2 mmol/L in distilled water, were used. Threshold values were identified as the first concentration correctly selected in 2 subsequent presentations. Subjects were classified as nontasters if the threshold was $\geq$0.15 mmol/L and tasters if $\leq$0.1 mmol/L.

Through the classification of individuals by the 2 methods a good agreement was obtained in separating insensitive from sensitive subjects, because the threshold of the subjects classified as nontasters by the suprathreshold test was $\geq$0.56 mmol/L and that of the medium tasters or supertasters ranged from 0.032 to 0.1 mmol/L.

Food Preferences

The data on dietary habits were collected using a food frequency questionnaire by the 3-day recall method. The questionnaire enquired about the consumption of vegetables, legumes, fruits, and sweet and savory snacks. Consumption of vegetables was detailed to bitter vegetables such as cabbage, broccoli, asparagus, and spinach and nonbitter vegetables such as artichoke, eggplant, zucchini, and legumes. Mothers filled out the questionnaire on their own eating habits and those of their children.

Data Analyses

Differences between groups were estimated by the χ^2 test for k-independent samples, with first-degree error at 0.05. The mother–child concordance was evaluated by kappa statistics stratifying by taster phenotype and *TAS2R38* diplotype. The relation between food choices and bitter sensitivity was estimated crossing subjects by PROP status, diplotypes, sex, or age. Differences in mother–child dyads were also evaluated. Data were analyzed using SPSS 15.0 (SPSS Inc, Chicago, IL).

RESULTS

PROP Taster Status

Three hundred five subjects underwent the phenotypic classification of bitter sensation by the suprathreshold method: 69 (22.6%) were nontasters, 173 (56.7%) were medium tasters, and 130 (20.7%) were supertasters (Table 1).

Children's bitter sensation differed from that of adults, as expected. Although the frequency of nontasters was similar in the 2 age groups, the frequency of supertasters was nearly 2-fold in children (16.3% vs 30.2%, $\chi^2 = 8.59$; $P < 0.014$). There was no sex difference in the distribution of the taste phenotypes either in adults or children.

TAS2R38 Genotype

Two hundred fifty-three individuals were genotyped for the variant loci *TAS2R38* P49A, A262V, and V296I. To avoid bias caused by the presence of blood relatives in the sample, the children of the mother–child dyads were excluded. Haplotype analysis performed in 188 nonrelated individuals revealed that the common variants PAV and AVI made up the vast majority of alleles present in our population, accounting for 51% and 44%, respectively, thus composing 95% of the sample. The less common AAV haplotype and the rare variants AAI and AVV made up the remaining 5%.

From the combination of the 5 haplotypes, 8 diplotypes were observed: the most frequent was PAV/AVI, which represented half of the total diplotypes, followed by the homozygous PAV/PAV and AVI/AVI, accounting for 24.5% and 16.5%, respectively. Combinations of a common (PAV or AVI) and less of a common or rare variant represented 9%. Children were evaluated separately: the distribution of their haplotypes was not different from that of adults (Table 2).

TABLE 1. Phenotypic classification of the sample by PROP status

		Frequency	%
Adults	Nontasters	47	22.5
	Medium tasters	128	61.2
	Supertasters	34	16.3
	Total	209	100.0
Children	Nontasters	22	22.9
	Medium tasters	45	46.9
	Supertasters	29	30.2
	Total	96	100.0
Total		305	

PROP = 6-propyl-2-thiouracil.

Genotype-Phenotype Association

To assess how genetics influences the variance of bitterness perception, we evaluated the association between the *TAS2R38* diplotypes and the intensity rating of PROP suprathreshold solutions. A few cases with rare haplotypes were not considered because of the small sample size. Table 3 shows the relation between phenotype and genotype. It may be noted that 85% of the individuals who carry the AVI haplotype are nontasters, whereas the PAV haplotype was more frequent in medium tasters and supertasters.

The agreement between haplotype and taster phenotypes is 94.8% overall; only in 13 of 250 (5.2%) individuals the phenotype did not overlap with the genotype.

The PROP concentration-intensity rating does not segregate by diplotype because the medium tasters or supertasters may be PAV homozygous as well as heterozygous. Among the individuals carrying the PAV haplotype, the presence of 2 copies was associated with the supertaster status in a similar proportion for adults and children (27.3 vs 36.4), but PAV heterozygosity was associated with a double percentage of supertasters in children (39.5%) versus

TABLE 2. Distribution of *TAS2R38* diplotypes in unrelated individuals

Diplotype	Frequency	%
AVI/AVI	31	16.5
PAV/AVI	94	50.0
PAV/PAV	46	24.5
PAV/AAV	6	3.2
AVI/AAV	8	4.3
Others	3	1.5
Total	188	100.0

AAV = alanine-alanine-valine; AVI = alanine-valine-isoleucine; PAV = proline-alanine-valine.

TABLE 3. Association between *TAS2R38* diplotypes and PROP sensitivity phenotypes

	Nontaster	Medium taster	Supertaster	Total
AVI/AVI or AAV (%)	39 (84.8)	5 (10.9)	2 (4.3)	46 (100)
PAV/PAV or AVI or AAV (%)	6 (2.9)	147 (72.1)	51 (25.0)	204 (100)
Total (%)	45 (18)	152 (60.8)	53 (21.2)	250 (100)

$\chi^2 = 171.0$, $P < 0.00$. PROP = 6-propyl-2-thiouracil.

adults (17.1%) with the same genotype ($\chi^2 = 8.83$, $P < 0.002$) (Table 4). Individuals who were AVI homozygous were, as expected, more often nontasters in adults (26/31 = 84%) and in children (6/7 = 86%).

Concerning the subjects with an AAV haplotype, the heterozygous AAV/AVI were similar to nontaster AVI homozygous, rating the PROP solutions as ''weak'' or ''barely detectable'' (8 of 9 individuals), whereas 6 of 10 individuals who carried the AAV/PAV diplotype were medium tasters and the remaining 3 were supertasters, as observed for the PAV/AVI heterozygous.

The genotype-phenotype analysis in the mother–child dyads showed that there is a high degree of concordance between mother and child genotype (55/62 = 88.7%) (Table 5). Similarly, the correlation of phenotypes between mother and child was strong (65/81 = 80.3%) (Table 5).

Bitter Sensitivity and Food Choices

We studied the relation between the sensitivity to bitter stimuli and food acceptance in the context of the dietary habits of the Mediterranean culture. Although with uncertain concordance among studies, greater sensitivity to PROP predicts lower preferences for cruciferous and other green vegetables.

In our sample the overall consumption of vegetables was low; however, we observed a meaningful difference in the frequency of bitter vegetable consumption between taster groups (Table 6) and between adults and children. The status of taster or supertaster limited the consumption of bitter vegetables more often in children than in adults. Of the 74 children taster or supertaster, only 19 (25.6%) ate vegetables versus 57 of 119 (47.9%) taster or supertaster adults ($\chi^2 = 6.61$; $P < 0.01$).

Moreover, whereas among the adult males the intake of bitter vegetables appeared loosely associated with PROP status (10/17 = 58% supertasters ate no vegetables), among adult females it was significantly related to the supertaster status, because 32 of the 41 supertasters (78.0%) took no servings of bitter vegetables in 3 days ($\chi^2 = 5.755$; $P < 0.016$).

No differences were observed in the children regarding the intake of legumes among tasters or nontasters, whereas in the adult sample, supertasters eating legumes were, unexpectedly, nearly 2-fold the percentage of nontasters ($\chi^2 = 3.63$; $P < 0.07$). In addition, among the nontaster adults a sex difference was observed: 22 of 31 (71%) female nontasters ate no legumes compared with only 3 of 15 (20%) male nontasters ($\chi^2 = 10.584$; $P < 0.001$).

The evaluation of bitter vegetable intakes by genotype revealed that there were no differences between AVI/AVI or AVI/AAV individuals and PAV homozygous or heterozygous among adults, whereas 48 of the 63 children with the PAV allele (76.2%) consumed no bitter vegetables compared with 4 of 7 children with nontaster genotype. Finally, the PROP status did not influence the overall intake of fruits or salty snacks.

With regard to the relation between the bitter sensitivity phenotype and body mass index, in our sample of children we had 42 normal weight, 35 overweight, and 11 obese children; nevertheless, we observed that none of the obese boys or girls was a supertaster, as compared with 32% of children of normal weight ($\chi^2 = 4.88$; $P = 0.027$).

Bitterness Perception in Children Affected by Symptoms or Disease

Although the study design had no power to explore taste sensation in several groups of children affected by a variety of complaints, we observed that the 6 children with feeding disorders showed a PROP sensitivity identical to that of normal children, whereas among children affected by functional gastrointestinal disorders, 33.3% were supertasters, compared with 19.2% of normal children. Interestingly, celiac children also had a higher (31.6%) frequency of supertasters. Unfortunately, because of the small sample size we could not reach statistical significance (by simulation we observed that the difference could have been significant with a larger sample size).

This was a pilot exploratory phase, aimed to give a preliminary look at those patients who will participate in a specifically tailored study.

DISCUSSION

Taste sensitivity is significantly different in different populations because it is related to cultural attitudes and traditions. The present work is the first study of bitter sensitivity in a pediatric population in the Mediterranean area, namely in southern Italy. Our

TABLE 4. Genotype-phenotype correlation in PAV homozygous or heterozygous individuals

		Medium taster	Supertaster	Total
PAV/PAV (%)	Adults	32 (72.7)	12 (27.3)	44 (100)
	Children	14 (63.6)	8 (36.4)	22 (100)
PAV/AVI or /AAV (%)	Adults	78 (82.9)	16 (17.1)	94 (100)
	Children	23 (60.5)	15 (39.5)	38 (100)
Total		147	51	198

$\chi^2 = 8.83$, $P < 0.002$.

TABLE 5. Analysis of concordance between genotypes and phenotypes in the mother–child dyads

	Child		
Mother	AVI*	PAV†	Total
Genotype			
AVI*	7	5	12
PAV†	2	48	50
Total‡	9	53	62
	Nontaster	Taster	Total
Phenotype			
Nontaster	5	9	14
Taster	7	60	67
Total§	12	69	81

* AVI: AVI/AVI, AVI/AAV.
† PAV: PAV/PAV, PAV/AVI, PAV/AAV.
‡ k = 0.6, 95% confidence interval $0.35 < 0.6 > 0.84$.
§ k = 0.268, 95% confidence interval $0.05 < 0.268 > 0.45$.

aim was to observe the relation between taste sensitivity and food choices and to evaluate the weight of genetic predisposition by comparing phenotypes and genotypes in the population, as well as in mother–child dyads.

Increased sensitivity to bitterness is associated with child neophobia, responsible for children's rejection of new, unfamiliar foods, which results in a diet particularly poor in food variety (10). The data obtained in this observational study provide a solid basis to explore feeding disorders and food-related diseases in children.

Taste receptors and effectors that mediate gustatory signals in the oral cavity have been found in gastrointestinal mucosa, suggesting a role in chemosensing that triggers the physiological responses to luminal content, such as absorption of beneficial or rejection of toxic foods. In this regard it is likely that genetic variations in taste receptors could modify food intake, leading to aberrant conditions such as feeding disorders up to obesity and related metabolic dysfunctions.

The distribution of PROP phenotypic groups in our population was suggestive of a model of Mendelian inheritance of bitterness sensitivity, the nontaster individuals being almost one-quarter of all (22.6%), and the supertasters (20.7%) and the medium tasters roughly 50% (56.7%).

The mode of inheritance of PROP/PTC sensitivity remains uncertain, showing features between a simple and a complex trait (11). Phenotypic variation in taste perception depends on various factors controlling a more general taste ability, such as sex and ethnicity.

TABLE 6. Bitter vegetables intake by taster groups estimated by a 3-day dietary recall

	Consumption		
Status	Yes	No	Total
Nontaster (%)	18 (31.6)	39 (68.4)	57 (100)
Medium taster (%)	60 (44.4)	75 (55.6)	135 (100)
Supertaster (%)	16 (27.6)	42 (72.4)	58 (100)
Total (%)	94 (37.6)	156 (62.4)	250 (100)

$\chi^2 = 8.779$; $P < 0.067$.

Nevertheless, the distribution of the taster groups in our sample was in agreement with the frequencies estimated in the European population (2). In addition, we observed more supertasters among children than in adults, suggesting that innate bitter sensitivity may be modified during life, in agreement with other reports about the decline of PROP/PTC sensitivity in adult life, with increasing age (12).

Sex differences in taste sensitivity were reported among adults by several authors seemingly resulting from anatomical differences, in that women have more fungiform papillae and more taste buds than men (13). Sex and age also can influence the expression of phenotype in children: it has been shown that the percentage of nontasters does not differ by sex in young children (14,15), but at puberty more nontaster individuals are boys and more taster individuals are girls (16). We did not find sex diversity between taster groups, neither among preschool children nor among adolescents.

Because polymorphisms at the *TAS2R38* locus explain the majority of the phenotypic variation in PROP sensitivity (17), we assessed how heritable variability in bitter taste perception predicts the phenotypic groups in our population. Haplotype analysis of the 3 *TAS2R38* polymorphisms allowed us to identify 2 major forms, the taster allele PAV and nontaster allele AVI, accounting for the 95% of the sample analyzed, and the rare variants AAV, AAI, and AVV. The occurrence of the *TAS2R38* genotypes was similar to that of the sample (representative of the population) of Italian ancestry, genotyped by Sacerdote et al (18).

The agreement between haplotype and phenotype was extremely high; nevertheless, the genotype-phenotype association among supertasters was different in adults compared with children. Whereas the hypersensitive children were homozygous as well as heterozygous, the hypersensitive adults were mainly homozygous. It may be argued that the prevalent association between strongest sensitivity to PROP and the PAV homozygous diplotype in the adults may be related to a decrease in PROP sensitivity across adult life (12).

A genetic factor able to influence the sensitivity to PROP has been identified in the gustin gene, the salivary isoform of carbonic anhydrase, with a suggested role in taste bud development (19). Individuals homozygous for the gustin polymorphism associated with a fully functional protein were more frequent supertasters, whether they were PAV homozygous or heterozygous, whereas

individuals with 2 copies of the nonfunctional allele were more frequently nontasters (6). These findings suggest that variation in PROP sensitivity and ultimately in chemosensory ability of supertasters may be influenced by taste bud density mediated by a functional gustin gene.

Anatomical differences in the density of fungiform papillae, in the taste buds or in receptor cells within taste buds, or ultimately in the amount of receptor expressed between sensitive subjects may determine the need for 2 copies of the active receptor form to express higher sensitivity. Moreover, the observation that heterozygous subjects expressed extremely different ratios of PAV and AVI alleles (3) may explain the variability in heterozygous responses to PROP.

When the basic taster/supertaster haplotype PAV was associated with AAV, the phenotype was of the taster kind, whereas when AAV was linked with AVI, the nontaster haplotype was 88%. It appears that the AAV haplotype is not associated with a single sensation, but it reinforces the basic taster/nontaster phenotypes.

A number of studies suggest that PROP/PTC tasters are more sensitive to a variety of bitter substances found in food and perceive more intense oral sensations, including sweetness or astringency than nontasters (20). From taste studies investigating the role of PROP sensitivity in eating behavior, food selection appears linked to these differences. Food preference studies showed that supertasters dislike bitter vegetables and generally strong-tasting foods and express lower preference for sweet foods, sweet drinks, and salad dressings (21). PROP tasters are also more sensitive to food texture: Investigations of reported food intake have shown that tasters consume fewer vegetables and added fats than do nontasters (22).

In the present study vegetable consumption was overall less; nevertheless, children consumed fewer bitter vegetables and vegetables at all than adults, irrespective of age or health status. We speculated that in a food culture in which the overall acceptance of vegetables is low, the influence of PROP status on vegetable liking may be weak; however, sex differences were observed between PROP sensitivity and vegetable intake among the adults and the children.

Tepper et al (23) showed that although PROP status influences the perception of chemically diverse bitter substances, there were no differences in liking the foods containing the same bitter compounds that were tested. This finding suggests that the relation between the ability to taste PROP and the perception and liking of bitter and other strong-tasting foods is complex and until now not completely understood.

None of the obese children was a supertaster: It is clear that obese individuals have a diminished sensitivity to bitter substances. Children affected by functional gastrointestinal disorders and children affected by gluten intolerance showed a higher proportion of supertasters than unaffected children, but these findings need confirmation through properly designed cross-sectional studies.

CONCLUSIONS

We obtained a first complex picture of bitter taste sensitivity in a population, with a strong relation between phenotype and genotype. Food preferences were also linked to the sensitivity status, although not by a simple linear model. Our preliminary data support the opportunity to explore taste status in children affected by functional gastrointestinal disorders or food-induced diseases.

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