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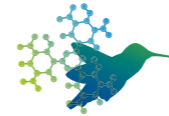
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Alpro Foundation VZW
Kortrijksesteenweg 1093C
9051 Sint-Denijs-Westrem
Belgium

T +32 (0)9 260 22 11
F +32 (0)9 260 22 99

www.alprofoundation.org



GENETIC VARIATION IN BITTER TASTE AND FOOD SELECTION

Ahmed El-Soheemy, PhD
Department of Nutritional Sciences, University of Toronto, Canada

Introduction

Individuals make food choices based on a number of physiological, nutritional, environmental and socio-cultural factors, yet the sensory qualities of foods are critical to dietary preferences. Taste in particular may be the most important determinant of whether a food is liked or disliked. Humans detect at least five distinct taste modalities: **bitter, sweet, salty, sour and umami**¹, and common variants in the genes coding for several taste receptors may account for some of the differences in food preferences and dietary habits that have been observed within and between populations².

Taste perception helps individuals evaluate the nutrient content of foods and discriminate between safe and harmful foods³⁻⁵. Bitter taste is thought to warn against the ingestion of potentially toxic chemi-

cals, which are primarily found in various plants^{3,4} and produced by plants as a natural defense mechanism⁶. As such, bitter taste perception is a double edge sword since many plant foods that impart a bitter taste are also very nutritious¹, yet humans have an innate tendency to reject bitter tasting substances⁵. The tendency to consume or reject bitter tasting substances varies between individuals⁷⁻¹³, which is largely due to genetic differences in bitter taste receptors.

The best known examples of **variation in bitter taste perception** are those of the synthetic compounds phenylthiocarbamide (PTC) and 6-n-propylthiouracil (PROP). These compounds both contain a thiourea group that imparts a bitter taste¹⁴. Approximately 25% of the world's population are unable to taste PTC and PROP, although the prevalence of "nontasters" varies between ethnocultural groups¹⁵

from as little as 3% of West Africans to as much as 40% of Indians^{16,17}. PTC and PROP "tasters" can be further categorized as "medium tasters" and "supertasters" based on their perceived sensitivity to the bitter taste of these compounds².

The ability to taste bitter compounds such as PTC and PROP is mediated by approximately 25 different genes, which are collectively named the T2R bitter taste receptor family³. These genes, expressed in taste receptor cells embedded predominantly on the tongue⁴, produce receptors that bind bitter substances. Based on the number of genes that comprise the T2R bitter taste receptor family and the potential for inter-individual variations within each gene, it is not surprising that differences exist in bitter taste perception, such as that seen with PTC and PROP. Several single nucleotide polymorphisms (SNPs) (common genetic variations found in at

least 1% of the population) are known to exist in numerous genes within the T2R bitter taste receptor family. These SNPs may alter the functioning of the bitter taste receptor in which they reside, resulting in variations in bitter taste perception amongst individuals.

Genetic variability of the PTC- and PROP-sensing TAS2R38 receptor

Substantial research has been conducted on the role of the TAS2R38 gene in bitter taste perception, and evidence suggests that three SNPs in this gene can explain up to 85% of the inter-individual variability in PTC, and to a lesser extent PROP, sensitivity^{18,19}. These three SNPs can combine to form 8 different haplotypes of the TAS2R38 gene. Two of these haplotypes, named AVI and PAV, have a frequency of 47% and 49%, respectively, among Europeans¹⁸. The remaining 6 haplotypes are considered rare and exist in only 4% of this population¹⁸. Each individual has two copies of these variations (mainly the AVI and PAV haplotypes), therefore, the majority of the population are PAV homozygotes (two copies of PAV), heterozygotes (one copy of each AVI and PAV) or AVI homozygotes (two copies of AVI). With respect to PTC and PROP sensitivity, **PAV homozygotes are considered “supertasters”, while AVI homozygotes are “nontasters”**. PAV/AVI heterozygotes tend to be “medium tasters” of PTC and PROP^{18,20}. A simple taste test utilizing PTC-containing filter paper has been shown to be a reliable predictor of the TAS2R38 genotype in young adults from various ethnocultural groups²¹.

Relationship between bitter taste perception and vegetable consumption

PTC and PROP sensitivity has been associated with increased bitter taste perception resulting in reduced preference for bitter-tasting foods such as cruciferous and certain green vegetables²²⁻²⁷. This association is seen mostly in children and young adults^{22,24,25,27}, likely because bitter taste perception declines with increasing age^{28,29} and because adults have a greater

tendency to try novel foods due to diet-related attitudes and beliefs formulated over the years³⁰. Although many studies have examined the relationship between PTC/PROP sensitivity and food preferences, relatively few have examined the association between PTC/PROP sensitivity and food intake.

Studies in young children suggest that those able to taste PROP have lower preferences for bitter tasting foods than do non-tasters^{22,25,27}, and that vegetable consumption by children can be classified according to PROP sensitivity¹³. When 65 preschool children with a mean age of 4-5 years (24 PROP tasters and 41 non-tasters) were given a choice of 5 types of vegetables (black olives, cucumbers, carrots, red pepper and raw broccoli) to consume as a snack, those who were non-tasters consumed more bitter-tasting vegetables (olives, cucumber and broccoli), and more vegetables in general, than those who were PROP tasters. Furthermore, non-taster children liked the taste of raw broccoli more than tasters¹³. This study demonstrated that in children, PROP sensitivity is associated with food preferences, and is predictive of vegetable consumption.

A similar relationship between PROP sensitivity, bitter food preferences and cruciferous vegetable consumption was found in a study conducted with 159 young women with a mean age of 27 years. This study examined whether or not taste responses to an aqueous solution containing PROP were predictive of food preferences and whether food preferences, in turn, were associated with food consumption patterns³¹. The study found that **PROP tasters**, compared to non-tasters, were **more likely to dislike, and consequently reject, cruciferous vegetables**.

Although the two previously described studies demonstrate an association between PROP sensitivity and vegetable consumption, **other studies have found inconsistent or null associations between these two factors**. One study conducted on a relatively homogenous population of 36 Caucasian women (18 of each tasters and non-tasters), with a mean age of 24 years, demonstrated that some PTC sensitivity was associated with the consumption of some, but not all, cruciferous vegetables. On average, PTC tasters

consumed less cooked turnips and raw watercress, but did not differ from PTC non-tasters in the consumption of other cooked and raw cruciferous vegetables such as broccoli, Brussels sprouts, red and white cabbage, cauliflower, collards, kale and kohlrabi¹². However, this study involved a small sample size, so it may not have been sufficiently powered to detect differences between PTC sensitivity and the consumption of some of these other cruciferous vegetables.

Another study examined the relationship between PROP taster status and food consumption in men and women who were classified as either non-tasters (n=49), medium tasters (n=89) or supertasters (n=45). The study found that PROP supertasters did not differ from tasters and non-tasters in intake of bitter vegetables, but they did consume less green salad in general³².

The relationships between PROP sensitivity, self-reported food preferences and dietary patterns were examined in a nested case-control study involving 179 breast cancer patients and 179 cancer-free controls with a mean age of 49 years³³. Results demonstrated that there was no evidence to support the theory that genetic taste responsiveness to PROP has a major influence on dietary choices and can predict significant health outcomes such as cancers³³. Furthermore, PROP responses were not significantly associated with food preferences or consumption patterns of any foods, including vegetables³³.

Although there is no conclusive data as of yet on the association between PTC/PROP sensitivity and vegetable consumption, the evidence demonstrating a **stronger association between PROP sensitivity and food preferences in children versus adults**^{22,24,25,27} combined with data demonstrating that **PROP tasting children consume fewer vegetables than non-tasters**, it appears that age may modify the association between PTC/PROP sensitivity and food consumption. In support of this notion, there is evidence demonstrating that PAV/AVI heterozygous children are more PROP sensitive than adults of the same genotype, and that PAV/PAV or AVI/AVI homozygous children do not differ in PROP sensitivity from adults of the same genotypes³⁴. A follow up study confirmed this observation and further explored

the relationship between age and PROP sensitivity. The study found that PAV/AVI heterozygous children, followed by heterozygous adolescents, could perceive a bitter taste at lower PROP concentrations than could heterozygous adults. No age effects were observed in either PAV/PAV or AVI/AVI homozygotes, which may be due to less variation in taste perception among homozygotes³⁵.

There are several limitations of these studies, which may account for the variability in the association between bitter taste perception and vegetable consumption. Although **bitter taste perception is asso-**

ciated with food preferences, other environmental and lifestyle factors likely affect actual vegetable consumption in children and adults. Another factor that may explain some of the inconsistent findings is that the varieties of vegetables examined are not uniform across studies. PTC/PROP testing only detects compounds that contain thiourea groups, which are not present in all types of bitter vegetables. There are many T2R receptors that recognize other bitter compounds found in foods, and there are several known genetic variations of these receptors, which likely affect vegetable consumption.

Relationship between TAS2R38 genotype, PROP sensitivity and vegetable consumption

Only one study has directly examined the association between TAS2R38 genotypes and vegetable consumption. The first study examined the relationship between the TAS2R38 genotype and cruciferous vegetable intake in 634 healthy men and women randomly sampled from the Italian European Prospective Investigation into Cancer and Nutrition (EPIC) cohort³⁶. The authors did not describe the mean age of the cohort, but participants of the original EPIC study ranged in age from 35 to 70 years³⁷. Findings from the random sample of healthy men and women revealed that **AVI homozygotes consumed more cruciferous vegetables than individuals with at least one copy of the PAV variant**. AVI homozygotes consumed a mean of 13.6 grams, while carriers the PAV variant consumed a mean of 10.2 grams, of cruciferous vegetables per day³⁶.

Conclusions

Studies to date, using PTC/PROP sensitivity as a measure of bitter taste sensitivity, suggest an **inverse association between bitter taste perception and vegetable consumption**, which may be **stronger in children than in adults**. Genetic studies indicate that the PAV haplotype of the TAS2R38 gene elicits a higher sensitivity to bitter taste than the AVI haplotype, which corresponds to a reduction in vegetable consumption in PAV carriers than non carriers. Bitter taste sensitivity is regulated by many taste receptors, each with the possibility for genetic variation. Therefore, further research is needed to determine whether or not variability in bitter taste receptors modify vegetable consumption.

References

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