

Individual Differences in Taste Perception and Bitterness Masking

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ABSTRACT

The unpleasant bitter taste found in many nutritious vegetables may deter people from consuming a healthy diet. We investigated individual differences in taste perception and whether these differences influence the effectiveness of bitterness masking. To test whether phenylthiocarbamide (PTC) ‘supertasters’ also taste salt and sugar with greater intensity, as suggested by Bartoshuk and colleagues (2004), we infused strips of paper with salt water or sugar water. The bitterness rating of the PTC strip had a significant positive linear relationship with ratings of both the intensity of sweet and salt, but the effect sizes were very low, suggesting that the PTC strip does not give a complete picture of tasting ability. Next we investigated whether various seasonings could mask the bitter taste of vegetables and whether this varied with tasting ability. We found that sugar decreased bitterness and lemon decreased liking for vegetables of varying degrees of bitterness. The results did not differ by ability to taste any of the flavors. Therefore, even though there are remarkable individual differences in taste perception, sugar can be used to improve the initial palatability of vegetables and increase their acceptance and consumption.

TABLE OF CONTENTS

	Page
LIST OF TABLES.....	iv
LIST OF FIGURES.....	v
INTRODUCTION.....	1
Quantifying the Intensity of a Taste.....	2
Supertasters and Tasting Bitterness.....	7
Supertasters and Tasting Other Flavors.....	9
Making Taster Strips.....	10
Bitterness Masking.....	11
EXPERIMENT 1.....	14
Method.....	14
Results.....	17
Discussion.....	20
EXPERIMENT 2.....	22
Method.....	22
Results.....	23
Discussion.....	26
EXPERIMENT 3.....	26
Method.....	26
Results.....	27
Discussion.....	30

	Page
GENERAL DISCUSSION.....	31
REFERENCES.....	34
APPENDIX A.....	57
APPENDIX B.....	59

LIST OF TABLES

Table	Page
1. Means and standard deviations of each category for each strip, Experiment 1.....	41
2. Mean bitterness rating of each vegetable in each seasoning condition, Experiment 2.....	42
3. Mean bitterness rating of each vegetable in each seasoning condition, Experiment 3.....	43

LIST OF FIGURES

Figure	Page
1. Frequency of salt rating of salt strip.....	44
2. Frequency of sweet rating of sweet strip.....	45
3. Frequency of bitter rating of PTC strip.....	46
4. Salt rating of the salt strip as a function of bitter rating of the PTC strip.....	47
5. Sweet rating of the sweet strip as a function of bitter rating of the PTC strip.....	48
6. Negative linear relationship of salt tasting with salt liking.....	49
7. Positive linear relationship of sweet tasting with sweet liking.....	50
8. Negative linear relationship of bitter tasting with bitter liking.....	51
9. The effect of seasoning on the bitterness of the combined vegetables depends on the seasoning, Experiment 2.....	52
10. The effect of seasoning on the hedonic rating of the combined vegetables depends on the seasoning, Experiment 2.....	53
11. Salt rating of salted broccoli as a function of salt rating of salt strip, Experiment 2.....	54
12. The effect of seasoning on the bitterness of the combined vegetables depends on the seasoning, Experiment 3.....	55
13. The effect of seasoning on the hedonic rating of the combined vegetables depends on the seasoning, Experiment 3.....	56
14. Sweet rating of sugared Brussels sprouts as a function of sweet rating of the sweet strip, Experiment 3.....	57

Consumption of vegetables is critical to maintain a healthy diet, lifestyle, and weight. Vegetables are an important source of phytonutrients and antioxidants (Steinmetz & Potter, 1996), and they protect against coronary heart disease (Ness & Powles, 1997) and many cancers (Birt, Hendrich, & Wang, 2001). Low variety and intake of vegetables is associated with high body fat percentage (McCrory et al., 1999) and interventions to increase fruit and vegetable consumption resulted in weight loss over a one-year period for parents and their children (Epstein et al., 2001).

Despite the nutritional benefits, less than 25% of children aged two to five meet recommended vegetable consumption guidelines (Lorson, Melgar-Quinonez, & Taylor, 2009). One deterrent of vegetable consumption is their bitter taste. Compounds such as isothiocyanates and giotrin, which are found in broccoli, Brussels sprouts, and kale, contribute to the bitterness of vegetables (Tepper, 1998). Newborn infants reject bitter tastes (Steiner, 1977), suggesting a genetic aversion to the flavor. Nearly all natural occurring poisons taste bitter (Brower, 1984), and thus a dislike of the bitter taste would provide an evolutionary advantage towards toxin avoidance, especially for omnivores like humans who can supplement their diet with other foods (Glendinning, 1994). Adults consider nutrition, cost, and convenience in food choices, but still require a satisfactory taste for consumption (Glanz et al., 1998; Marquis, 2005). Therefore, interventions are needed to make vegetables taste more palatable and less bitter, and thereby increase their likelihood of consumption.

However, efforts to alter the taste of food must be rooted in the fact that people differ in the intensity of their taste experiences, especially for bitterness. Variation in the ability to taste the bitter chemical phenylthiocarbamide (PTC) was first discovered by Fox (1931) when some flew into the air when he was mixing it. A colleague noted the bitterness, while Fox tasted nothing (Fox, 1931), and this was determined to be a heritable trait (Blakeslee 1932). Although the exact physiology behind the ability to taste PTC and its counterpart 6-*n*-propylthiouracil (PROP) is not fully understood, research by Hayes and colleagues (2008) suggests a complex interplay of *TAS2R38* genotype, bitter receptor expression, and number of fungiform papillae on the tongue.

Quantifying the Intensity of a Taste

Ability to taste PTC or PROP was previously measured by counting the number of fungiform papillae on the tongue using blue dye (Miller & Reedy, 1990) and is now measured by participants rating the intensity of strips of paper that have been infused with the chemicals or mixtures of the chemicals in water. Taste is by definition a subjective experience, and the way that investigators quantify the intensity of a taste has evolved immensely (for an in-depth review see Bartoshuk et al., 2002). Bartoshuk and colleagues (2002) argue that assigning verbal descriptors to the experience is insufficient because the adjectives used to describe the intensity of the taste, such as ‘weak’ or ‘strong,’ are meaningless without clearly defining to what they are referring. For example, a ‘small elephant’ is larger than a ‘large mouse,’ and ‘very strong coffee’ is objectively

weaker than ‘strong pain’ (Stevens 1958; Bartoshuk, Fast, & Snyder, 2005).

Additionally, intensity descriptors can have different meanings depending on the respondent’s experiences and the context.

Comparative taste psychology has benefited enormously from the development of numerical rating scales in the field of psychophysics. Hayes and Patterson (1921) developed the ‘graphic rating scale,’ a continuous line with descriptive phrases printed underneath. Participants made a marking on the line that corresponded with the intensity of their sensory experience. Nine-point categorical Likert scales, with the range of ‘none’ to ‘very strong,’ also began to be used around this time and continue to be employed (e.g. Kaminski, Henderson, & Drewnowski, 2000). These scales had the advantage of quantifying the sensation. However, they still relied on adjectives for assessment and were ordinal—that is, a rating of 4 was larger, but not necessarily twice as large, as a rating of 2 (Bartoshuk et al., 2002).

A nine-point categorical Likert scale was thus developed, with options to classify the taste experience ranging from ‘none’ to ‘extreme’ (Bartoshuk et al., 2005). This had the advantage of numerically quantifying the sensation. Yet the scale was ordinal (that is, a rating of 4 was larger, but not necessarily twice as large, as a rating of 2) and still relied on adjectives to make the assessment (Bartoshuk et al., 2005).

Magnitude estimation, a technique developed by S.S. Stevens (1956), asked participants to assign numbers to a sensation in a ratio way such that a

number twice as big represented an experience twice as intense. After normalizing the numbers, this method showed the rate at which the intensity of the sensations grew for each participant, but comparison of intensity across subjects was still not possible (Bartoshuk et al., 2002).

Aitken (1969) developed the Visual Analogue Scale (VAS) as a modification of the graphic rating scale meant to measure apprehension in fighter pilots. The endpoints of the scale were labeled with the minimum and maximum possible rating for the variable of interest—for Aitken (1969), ‘maximal relaxation’ to ‘maximal panic.’ Green and colleagues (1993) modified the VAS to develop the Labeled Magnitude Scale (LMS), which specifically measured oral sensations. The scale was anchored with ‘strongest imaginable sensation,’ although only referring to oral sensations due to the concern that the strongest imaginable sensation of any kind might be in another sensory modality and vary across participants (Bartoshuk et al., 2002). The ‘imaginable’ quantifier is meant to not limit the scale to the respondent’s personal experience.

Since its development, many researchers have studied the appropriate distance on the LMS to place adjective descriptors (Borg 1982; Moskowitz, 1977; Schutz & Cardello, 2001). Green and colleagues (1993) place the descriptors ‘barely detectable,’ ‘weak,’ ‘moderate,’ ‘strong,’ and ‘very strong’ in a roughly logarithmic fashion such that the final descriptor corresponds to the number 53 on a scale from 0 to 100. When used with the PTC strips, over half the participants rate the intensity of the strip as above ‘very strong’ (Bartoshuk, 2000),

demonstrating why Likert scales of intensity where the final number corresponds to that phrase might obfuscate results. However, the very notion of supertasters casts doubt that the strongest imaginable oral sensation is the same for all participants. If two people are rating based on the most intense taste they have ever experienced or could imagine, the numbers are not comparable if one person is capable of tasting more intensely than the other (Bartoshuk et al., 2004; Bartoshuk et al., 2005).

To address these concerns Bartoshuk and colleagues (2002) introduced the generalized Labeled Magnitude Scale (gLMS). The scale is anchored with ‘strongest imaginable sensation of any kind’ so that participants must think about the taste in comparison to all sensory modalities. This is done for both the hedonic rating scale, with ‘strongest imaginable liking/disliking of anything, not just food’ as the endpoints, as well as for the intensities of saltiness, sweetness, sourness, and bitterness, with ‘strongest imaginable sensation of anything, not just food’ representing the highest rating. Although it can still be argued that the strongest imaginable sensation of any kind may not be the same for everyone, what is important is that the maximum does not differ systematically with PTC tasting ability (Bartoshuk et al., 2002). Typically studies using the gLMS (such as Cruickshanks et al., 2009) still use descriptive adjectives spaced according to the recommendation of Green and colleagues (1993).

A separate but conceptually related technique pioneered by J.C. Stevens (1959) involves asking participants to compare the intensity of what they taste to

another sensory modality, usually a sound. This is termed ‘magnitude matching’ and is meant to objectively capture the oral sensation by comparing the intensity to a non-oral sensation (Marks & Stevens, 1980). It does not need to be assumed that everybody hears exactly the same, only that hearing and taste are independent (Bartoshuk et al., 2005). Supertasters compare the bitterness of dark chocolate to a brighter light than do nontasters, even though most participants describe the taste as ‘mildly bitter’ (Fast, 2004; as cited in Bartoshuk et al., 2005). This demonstrates the importance of using this technique and how easily the differentiation of taster types can be missed with improper measurement techniques such as adjective descriptors.

Another way to determine taster status other than the paper strips is by administering aqueous solutions of PROP or PTC of various concentrations, although both tend to yield the same results (Drewnowski et al., 1997b). Participants sip the solution and spit it out, then rinse with water before the next sample. In early work, participants tasted the solutions in ascending order and a ‘threshold’ was determined as the lowest concentration at which the subject could distinguish the mixture from plain water (Hartmann 1939; Tepper 1998). Drewnowski and colleagues (1997b) take the mean of five of these ‘reversal points.’ Other studies have participants taste and rate all concentrations (Kaminski et al., 2000; Miller & Reedy, 1990). Before it was known that salt tasting may be related to PROP tasting (Hayes, Sullivan, & Duffy, 2010; Bartoshuk et al., 2006), *suprathreshold scaling* was conducted (Drewnowski et

al., 1997b). This requires subjects to taste solutions of NaCl and rate them on a Likert scale, and the ratio of PROP intensity to NaCl intensity is one factor in coding taster status.

Bitterness ratings of PTC strips and solutions are continuous and bimodally distributed (Tepper, 1998). At first (Tepper, 1998) the population was divided into those who found PTC or PROP tasteless, named 'nontasters,' and those who could taste any amount of bitterness, named 'tasters'. Then, Bartoshuk (1991) recommended further division of the tasters into 'moderate tasters' and 'supertasters' due to the difference between people who tasted mild and extreme bitterness. Nontasters make up approximately 25% of the adult population, moderate tasters 50%, and supertasters 25% (Bartoshuk, 2000). Females are more often supertasters than are males and Caucasians have a lower percentage of supertasters than do Africans and Asians (Bartoshuk, 2000; Tepper & Nurse, 1996).

Supertasters and Tasting Bitterness

Once taster status has been determined, the question becomes what this means for tasting abilities and food preferences. Low concentrations of caffeine and urea are reported as more bitter (using suprathreshold scaling and magnitude estimation; Hall, Bartoshuk, Cain, & Stevens, 1975) and naringin is reported as less pleasant (using suprathreshold scaling and a Likert scale of hedonic rating; Drewnowski, Henderson, & Shore, 1997a) by supertasters than by nontasters.

This shows the correlation of tasting PTC with tasting other bitter compounds, so the strips can be used to assess overall intensity of bitter tasting.

A heightened ability to taste bitterness might have been an evolutionarily advantageous way to avoid poisonous plants, as most plant toxins taste bitter (Brower, 1984). PTC is also chemically related to isothiocyanates and giotrin, bitter compounds found in vegetables such as broccoli, Brussels sprouts, and kale (Tepper, 1998). When eaten in large quantities, as might have been done when food variety was scarce, these compounds dangerously restrict iodine metabolism (Tepper, 1998). Thus, a dislike of bitterness might have prevented overconsumption of certain plants.

However, in the modern world the more threatening problem is too little consumption of healthy vegetables (Lorson et al., 2009). A dislike of bitterness might be partly responsible for this phenomenon, and the fact that bitter avoidance is linked to survival makes it especially difficult to modify (Drewnowski & Gomez-Carneros, 2000). A lack of enjoyment of vegetables may lead to nutritional inadequacies because of how heavily taste is factored into consumption decisions (Glanz et al., 1998; Marquis, 2005). Taster status has been correlated with disliking and tasting more bitterness in healthy foods such as leafy vegetables (Bartoshuk, 2000; Tepper, 1998; Drewnowski, Henderson, & Barratt-Fornell, 1998; Kaminski et al., 2000). In general, supertasters tend to be pickier eaters, with more food dislikes, especially for vegetables (Kaminski et al., 2000).

There are also health benefits to being a supertaster, such as the avoidance of overly sweet and fatty foods (Bartoshuk, 1979; Tepper & Nurse, 1997). This might be one reason why cervical cancer patients were found to be predominantly nontasters and why supertasters are on average thinner than are nontasters (Bartoshuk, 2000; Duffy et al., 1999).

Supertasters and Tasting Other Flavors

The method of counting fungiform papillae and the name ‘supertaster’ imply that this population experiences overall stronger taste sensations. If this were the case, the PTC taster strip would be a simple way to not only gauge how a person tastes bitterness but would give an assessment of how strongly a person tastes the other basic flavors of salt, sweet, sour, and umami (savory).

Research on this topic usually, but not always, finds that taster status is positively associated with the ability to taste other flavors. Supertasters report more saltiness from salt solutions using the gLMS (Hayes et al., 2010), Likert scale intensity ratings (Miller & Reedy, 1990), and magnitude matching (Bartoshuk et al., 2006). When translated to food, supertasters give higher saltiness ratings to chips, pretzels, and chicken broth, and report less frequently salting their food (Hayes et al., 2010). Similarly, supertasters report more sweetness from solutions of sucrose, saccharin, and artificial sweeteners such as neohesperidin dihydrochalcone using magnitude matching (Gent & Bartoshuk, 1983) and Likert scale intensity ratings (Miller & Reedy, 1990).

However, there are also studies finding that supertaster status is unrelated to the ability to taste salt and sugar using the gLMS (Lim, Urban, & Green, 2008) and the VAS (Schifferstein & Frijters, 1991). These inconsistencies, even when validated assessment methods are used, show the need for continued research in this area.

There is very limited research on the relationship between PTC tasting and sourness, with one study finding no relationship (using fungiform papillae number and Likert scale intensity ratings; Miller & Reedy, 1990) and one finding that PROP tasting ability significantly correlated with that for citric acid (using threshold techniques and the gLMS; Hayes et al., 2008). There has been no research correlating taster status with umami tasting. There is more consistent evidence that supertasters taste fat more intensely than do nontasters, but this is confounded by the fact that they might be experiencing the texture of fat more than the taste (Bartoshuk, 2000; Tepper & Nurse, 1998). Supertaster status is also positively correlated with the degree of ‘oral burn’ reported from irritants such as capsaicin, piperine, ethanol, and alcohol (Bartoshuk, 2000; Tepper & Nurse, 1996).

Making Taster Strips

While PTC tasting is measured using taste strips, tasting of salt and sweet has previously been measured using solutions or real foods. To see if supertasters vary in tasting these flavors it is best to use the same method of delivery, which also gives more experimental control than does using foods. Taste strips provide

a quick, accurate, and reliable way to measure the strength of a taste reaction without the confounding effects of submerging it in water or combining it with other flavors in food.

Taste strips have been made before with the intention of assessing taste dysfunction. Mueller and colleagues (2003) manufactured taster strips but were only concerned with whether subjects could identify the taste, not with the intensity. Suggesting validity to the method, the results were highly correlated with correct identification of the taste from a liquid solution (Mueller et al., 2003). Cruickshanks and colleagues (2009) had participants rate the intensity of the strips using the gLMS. However, both studies focused on identifying taste impairment and did not report whether heightened tasting for one flavor correlated with another. Our aim is to see if there are ‘salt supertasters’ and ‘sugar supertasters,’ and if so whether they are independent of traditional PTC supertasters.

Bitterness Masking

Once differences in tasting ability have been established, our next question is whether these differences influence techniques to improve the taste of a food. There are many ways to increase the palatability and consumption of disliked tastes. Flavor-flavor learning occurs when an arbitrary flavor comes to be preferred based on prior exposures with a pleasant flavor. Rats that were exposed to either cinnamon or wintergreen mixed with saccharin preferred the flavor that had been sweetened when given a choice between both flavors unsweetened

(Holman, 1975); the same result was found in humans with novel flavors of tea (Zellner et al., 1983). Another technique, flavor-nutrient learning, conditions preference based on a flavor's association with calories. Rats who received an infusion of nutrients into their stomachs when they licked a flavor tube showed a preference for that flavor over another (Sclafani, 1990).

While these techniques are effective, they involve multiple presentations and a degree of experimental control that can be impractical for dietary change outside of the lab. Here we investigated the effects of presenting vegetables with various seasonings in order to determine if the bitter taste could be masked by another flavor on a single exposure. If effective, this could be used as a way to increase initial palatability to facilitate flavor-flavor and flavor-nutrient learning. We presented vegetables with salt, sugar, lemon juice, butter, or a combination of two of these flavors to determine if this affected the bitterness of the vegetables.

Hayes and colleagues (2010) found that low-sodium cheddar cheese is reported as more bitter compared to regular cheese, and hypothesized that bitterness masking from sodium could also apply to vegetables. Using aqueous solution mixtures, sodium chloride decreases the bitterness of quinine hydrochloride (QHCl) (using the gLMS; Keast & Breslin, 2002) and sodium acetate does the same for urea (using magnitude estimation; Breslin & Beauchamp, 1997). Additionally, when QHCl was mixed with NaCl and presented to the back of the tongue, reports of bitterness were two-thirds lower than for the QHCl alone (using magnitude estimation; Kroeze & Bartoshuk,

1985). While all of these studies used chemical mixtures as opposed to real foods, they suggest that salt will reduce the bitterness of vegetables.

For sugar, combining QHCl with sucrose decreased bitterness ratings by one-third (using aqueous solutions and magnitude estimation; Kroeze & Bartoshuk, 1985; Lawless, 1982). Walters (1996) and Roy (1992) suggest that combining sweetness and bitterness decreases the perceived intensity of both because of a similar transduction mechanism, such that both cannot be tasted at full intensity simultaneously, a concept known as *competitive inhibition*. Further evidence for this comes from Lawless (1982), who found that tasting a mixture of sucrose and QHCl followed by sucrose alone produced a residual taste of QHCl and vice versa. From a consumer standpoint, while sugar was once used to suppress bitterness in foods, demand for low-calorie products has caused the bitterness to become more apparent due to the decrease in sweetness (Walters, 1996; Roy, 1992).

The same demands have been made to reduce the fat content of foods, which was also used to help suppress bitterness (Roy, 1992). The proposed mechanism for this is that more viscous foods diffuse bitterness more slowly across the taste buds (Roy, 1992). These results suggest that sugar and butter will be effective in masking the bitterness of the vegetables.

Finally, we will use lemon juice. There has been little research on what the addition of sourness does to bitterness, and this area is complicated by the fact that many people confuse the tastes of sour and bitter. Robinson (1970) argues

that because few foods are strongly bitter, people tend to label the taste of strongly sour flavors as bitter. When participants taste aqueous solutions (Robinson, 1970) or strips (Cruickshanks et al., 2009), one-third label citric acid as bitter. Robinson (1970) argues that the error comes not in tasting but in naming, because almost all subjects were able to tell that the citric acid tasted different from quinine sulfate. Perhaps people will report an increase in bitterness when lemon juice is added, whether from an augmentation of bitterness or a confusion of labeling.

Lastly, we will investigate whether the variation in tasting ability shown using the taster strips affects the degree of bitterness masking by any of the seasonings. Hayes and colleagues (2010) found that the difference in bitterness between regular and low-sodium cheeses was especially elevated for supertasters, suggesting that in our study adding salt to the vegetables will decrease bitterness more for supertasters than for nontasters.

Experiment 1

The purpose of Experiment 1 was to determine whether taster strips could show natural variability in the ability to taste salt and sugar analogous to that for bitter. Additionally, we were looking at whether tasting ability for the three flavors are correlated.

Method

Subjects. Participants were 379 Arizona State University undergraduates enrolled in an introductory psychology course. There were 222 males, 155

females, and 2 subjects who did not report gender. The age range of participants was 18 to 25, with an average age of 19.3.

Materials. Whatman No. 1 filter papers were briefly submerged into salt or sugar water and dried on paper overnight. The concentrations were 0.46 M salt ($\frac{1}{2}$ teaspoon in $\frac{1}{2}$ cup water) and 0.62 M sugar (6 teaspoons in $\frac{1}{2}$ cup water). These concentrations represented an average of those used in previous studies (Cruickshanks et al., 2009; Lim et al., 2008). We also wanted to make strips for the tastes of sour and fat, but were unable to find a chemical or product that could consistently represent the taste. Citric acid was attempted for sour but some subjects reported it as tasting salty, which is consistent with previous work (Mueller et al., 2003). While this is interesting on its own, it does not help us identify sour tasters. The PTC strips were manufactured by Neo/Sci Corporation.

The scale used by participants to rate the strips was a combination of the gLMS and magnitude matching (see Appendix A). A hedonic rating of each strip was given that ranged from 100 (strongest imaginable liking of anything, not just food) to 0 (neutral) to -100 (strongest imaginable disliking of anything, not just food). Participants also gave each strip a rating on saltiness, sweetness, sourness, and bitterness, from 0 to 100 (strongest imaginable sensation of any kind). There were no descriptive adjectives anywhere on the scale. Lastly, participants circled one of eight sounds, from ‘silence’ to ‘loudest imaginable sound,’ that corresponded to the intensity of the taste.

Procedure. Participants tasted the strips one at a time and sipped water in between. Verbal instructions were given with the scale to emphasize the endpoints. No information was given about the flavor of the strips. Subjects gave informed written consent prior to participation and were debriefed after completion (see Appendix B).

The order of presentation of the strips was not random but instead proceeded from the weakest on average to the strongest: sugar, then salt, then PTC. This is recommended by Bartoshuk (2000; and colleagues, 2002) and Lim and colleagues (2008) to avoid contrast effects whereby participants who tasted intense bitterness on the PTC strip may report subsequent stimuli as overly strong or weak by comparison. Either way, contrast effects would vary systematically with the variable of interest—that is, they would only affect supertasters and would bias our results. Therefore, the order of presentation of the strips was the same for all subjects.

Statistical analysis. Taster status was coded for each strip and the cutoff points were adjusted based on the average rating of the strips. Sweet nontasters were defined as giving a sweet rating of under 20, moderate tasters as between 21 and 60, and supertasters as between 61 and 100. Salt nontasters were defined as giving a salt rating of under 30, moderate tasters as between 31 and 65, and supertasters as between 66 and 100. PTC nontasters were defined as giving a bitter rating under 30, moderate tasters as between 31 and 80, and supertasters as between 81 and 100.

A chi-square test was used to determine the relationship between the category rating (saltiness of the salt strip, sweetness of the sweet strip, and bitterness rating of the PTC strip) of each strip and its sound intensity. This test was also used to test the relationship between the category ratings and sound intensities of the strips with each other.

An ANOVA was used to see if PTC taster status could predict the category ratings of the other two strips. The bitterness rating of the PTC strip was also used as the independent variable in a regression analysis to see the same. A regression analysis was employed to determine whether tasting a flavor on the strip related to its hedonic rating.

Results

The average rating of each strip on each category is shown in Table 1. For the sweet strip there were 181 (48%) nontasters, 113 (30%) moderate tasters, and 85 (22%) supertasters. For the salt strip there were 126 (33%) nontasters, 105 (28%) moderate tasters, and 148 (39%) supertasters. For the PTC strip there were 74 (20%) nontasters, 155 (41%) moderate tasters, and 150 (40%) supertasters. There were 22 (6%) participants who were nontasters on all three strips, 19 (5%) who were moderate tasters on all three strips, and 39 (10%) who were supertasters on all three strips.

Gender and taster status are correlated, with women rating the PTC strip as bitterer and as less pleasant than did men. For men, there were 53 (24%) nontasters, 94 (42%) moderate tasters, and 75 (34%) supertasters; for women,

there were 21 (14%) nontasters, 60 (39%) moderate tasters, and 74 (48%) supertasters. Of the participants who were nontasters on all three strips, 82% were men; moderate tasters on all three, 53% men; and supertasters on all three, 34% men.

Figures 1-3 show the distribution of category ratings. It can be seen that the responses cover the entire range of options from 0 to 100 on all strips, showing variability. Results of the salt strip show a fairly even number of participants who selected each number with a mean rating of 50, data for the sweet strip were slightly bimodal with peaks at 0 and 70 and a mean of 34, and data for the PTC strip were extremely bimodal with most participants selecting either 0 or 100 and a mean of 59.

Within each flavor, the category rating and sound intensity were significantly correlated with each other at the $p < .001$ level, the highest $\chi^2 = .57$ for the sweet strip. Between flavors, all category ratings were significantly correlated with each other one at the $p < .001$ level, the highest $\chi^2 = .52$ for the sweet and salty strips. All of the sound intensities were also significantly correlated with each other.

PTC taster status had significant predictive ability in an ANOVA for the sweet rating of the sweet strip, $F(2, 378) = 14.73, p < .001$, and the salty rating of the salt strip, $F(2, 378) = 18.98, p < .001$. Post-hoc tests for both revealed that supertasters tasted significantly more flavor than did nontasters and moderate tasters, who did not significantly differ from each other. When the sound

intensity was used as the dependent variable, taster status bordered on significant predictive ability for the sweet strip, $F(2, 372) = 2.80, p = .062$, and was significant for the salt strip, $F(2, 371) = 6.44, p = .002$. For the salt strip, post-hoc tests revealed that supertasters reported the flavor as ‘louder’ than did nontasters and moderate tasters.

This analysis was repeated as a regression model with bitter rating of the PTC strip as the independent variable. With sweet rating of the sweet strip as a dependent variable, a linear model was significant, $F(1, 369) = 15.17, p < .001$ level and $R^2 = .04$; with salty rating of salt strip as a dependent variable, a linear model was significant, $F(1, 369) = 27.48, p < .001$ level and $R^2 = .07$. Both of these R^2 are below 0.10, a standard ‘small’ effect size. Graphs of these trends can be seen in Figure 4-5. The sound rating of the PTC strip was also able to predict the sound ratings of the salt and sweet strips.

Next we looked at whether the tasting of a flavor could predict its liking. Sweet tasting had a strong positive linear relationship with liking, $F(1, 376) = 219.87, p < .001, R^2 = .37$. Salt tasting had a small negative linear relationship with liking, $F(1, 377) = 14.10, p < .001, R^2 = .04$. Bitter tasting had a very strong negative linear relationship with liking, $F(1, 357) = 929.99, p < .001, R^2 = .80$. Graphs of these trends are shown in Figures 6-8. A quadratic model did not add significant predictive ability for any of the trends.

Although the majority of subjects did not taste any sourness on the PTC strip, 20% of subjects gave the strip a sour rating of 20 or greater. The bitter

rating of the PTC strip predicted the sour rating in an exponential growth model including all subjects who gave a non-zero sourness rating, $F(1, 136) = 19.93$, $p < .001$, $R^2 = .13$.

Gender predicted all three category ratings, with females rating each as higher than did males, the lowest $F(1, 376) = 4.01$, $p = .045$ for the sweet strip. However, the only sound intensity that gender predicted was for the PTC strip, $F(1, 365) = 11.54$, $p = .001$, where the females rated the strip as 'louder' than did the males. Additionally, the only liking score that gender predicted was for the PTC strip, $F(1, 369) = 10.49$, $p = .001$, with females liking the strip less than males did.

Discussion

This study showed that there is natural variability in the ability to taste salt and sugar when they are infused into filter paper and administered in a similar way to the PTC taster strips. The category ratings of the strips and their sound intensities were highly correlated, consistent with Bartoshuk and colleagues (2004) who found a significant correlation between the gLMS and magnitude matching for PROP aqueous solutions. Note that the participants who did not taste anything on the strips are only 'nontasters' at these specific concentrations.

Intensity ratings of all three tastes were correlated with each other, but the effect sizes were low for a model attempting to predict the salty or sweet ratings from the PTC bitterness rating. A closer examination of the scatterplots shows that it was not unusual for a person to rate one strip as very intense and another as

tasteless. Indeed, it was very rare for a participant to be a nontaster or supertaster on all three strips. In Figures 1-3 it can be seen that there are people who rated the salty or sweet strips as close to the strongest sensation they could imagine, and could therefore be labeled ‘salt supertasters’ and ‘sweet supertasters.’ In Figures 4-5 it can be seen that these people are spread between being traditional nontasters, moderate tasters, and supertasters. While supertaster status as defined by the PTC taste strip is informative, it cannot definitively tell us how strongly a person tastes other tastes.

We found that women are more likely to taste the PTC strip stronger and ‘louder’ than men are, which is consistent with other studies from our laboratory and previous literature (Bartoshuk, 2000). Additionally, almost half of the women who participated were supertasters, as opposed to about one-third of men.

We found a slight negative linear relationship between salt tasting and salt liking. Even though salt is typically an enjoyed and sought-after flavor, it only serves to enhance other tastes and so is not pleasant when tasted strongly by itself—beginning at three years of age people prefer salted to unsalted soup but reject salt water (Sullivan & Birch, 1990). We found a positive linear relationship between tasting and liking of the sweet strip, in contrast to other studies finding a quadratic relationship (Hayes & Duffy, 2008; Drewnowski & Greenwood, 1982). These studies used increasing sucrose concentrations within participants, whereas we kept the concentration constant and let our subjects’ tasting variability show us this relationship, which explains this difference. We also found a very strong

negative linear relationship between bitter tasting and bitter liking, which was expected as bitterness is an unpleasant flavor (Drewnowski & Gomez-Carneros, 2000).

Experiment 2

In Experiment 2 we investigated whether the addition of salt, sugar, lemon juice, or butter would decrease the bitterness of vegetables. In addition to tasting and rating the unseasoned and seasoned vegetables, participants were given the three taster strips to see if their tasting ability influenced the effectiveness of the masking. We expected that subjects who have a heightened ability to taste salt, sugar, or bitterness on the strips would also taste them stronger on the seasoned vegetables. This will serve as validation that the strips can be extrapolated to real foods. Whether strength of tasting saltiness, sweetness, or bitterness influences masking by any of the seasonings was also explored.

Method

Subjects. Data were gathered from 220 Arizona State University undergraduates participating for course credit. There were 130 (59%) males and 90 (41%) females, with an average age of 18.6. Participants were instructed not to eat for two hours before the study began.

Materials. The vegetables were Steamfresh brand frozen broccoli and cauliflower which were cooked in the microwave according to package directions and served at room temperature. The seasonings added were $\frac{1}{4}$ teaspoon salt, $\frac{1}{2}$ teaspoon lemon juice, $\frac{1}{4}$ teaspoon sugar, or $\frac{1}{2}$ teaspoon unsalted butter per piece

of vegetable. The broccoli and cauliflower were served in 11g pieces. Due to the low average response to the sugar strip in Experiment 1, the concentration was increased to 0.83 M (8 teaspoons in ½ cup water). The rating scale for the taster strips was identical to that of Experiment 1. The vegetable rating scale had an additional line to rate liking of texture and no sound comparison.

Procedure. Participants were run in the afternoon in groups of one to eight. They were served one piece of each vegetable unseasoned. The rating scale was explained to them and they ate the vegetables and filled out the scale, sipping water in between the vegetables. Next they tasted and rated the salty, sweet, and bitter taster strips, sipping water in between each one. They were then given one more piece of each vegetable, seasoned according to randomized condition. Subjects gave informed written consent prior to participation and were debriefed after completion (see Appendix B).

Statistical analysis. Taster status for each strip was coded according to the same cutoffs as Experiment 1. A repeated-measures ANOVA was employed to determine the effect of the seasonings on the bitterness rating and liking of the vegetables. Taster status was for each of the three strips was added as a second independent variable.

Results

For the sweet strip there were 69 (44%) nontasters, 50 (32%) moderate tasters, and 37 (24%) supertasters. For the salt strip there were 70 (32%) nontasters, 60 (28%) moderate tasters, and 90 (41%) supertasters. For the PTC

strip there were 47 (21%) nontasters, 77 (35%) moderate tasters, and 97 (44%) supertasters.

We chose broccoli and cauliflower in order to see how different seasonings would change the bitterness rating of a bitter vegetable and a non-bitter vegetable. However, the two unseasoned vegetables did not differ in bitterness, with the broccoli receiving an average bitterness rating of 14 and cauliflower receiving 13. The mean bitterness ratings for each condition can be seen in Table 2.

A repeated-measures ANOVA showed no significant three-way interaction between the time point (before or after seasoning), seasoning condition, and vegetable (broccoli or cauliflower) for the bitterness ratings. There was a two-way interaction for time by condition when collapsed across vegetables, $F(3, 413) = 10.72, p < .001$, see Figure 9. Post-hoc tests of simple effects revealed that the addition of sugar significantly reduced the reported bitterness, $F(1, 100) = 14.26, p < .001$, and the addition of lemon significantly increased the reported bitterness, $F(1, 133) = 16.78, p < .001$. When taster status for each strip was separately added as another independent variable, individually or all together, there were no significant higher-level interactions.

The broccoli was given an average hedonic rating of 24 and the cauliflower 11. A repeated-measures ANOVA showed no significant three-way interaction between the time point, seasoning condition, and vegetable for the hedonic ratings. There was a two-way interaction for time by condition when

collapsed across vegetables, $F(3, 418) = 17.58, p < .001$, see Figure 10. Post-hoc tests of simple effects revealed that the addition of sugar significantly increased reported liking, $F(1, 101) = 5.91, p = .017$, and the addition of lemon significantly decreased reported liking, $F(1, 135) = 48.45, p < .001$.

The responses to the salt and sweet strips produced similar distributions to Experiment 1, with the salt strip receiving an average saltiness rating of 51 and the sweet strip receiving an average sweetness rating of 36 (even though the concentration of sugar was increased). When the salt rating of the salt strip was used as the independent variable in a regression model, it predicted the salt rating of the salted broccoli, $F(1, 84) = 19.41, p < .001, R^2 = .19$, see Figure 11. The average bitterness rating of the PTC strip was 58. When this was used as an independent variable in a regression analysis it predicted the sweet rating of the sugared broccoli, $F(1, 50) = 5.5, p = .023, R^2 = .09$.

Gender and taster status are related, with women rating the PTC strip as bitterer and as less pleasant than men did, $F(1, 219) = 5.851, p = .016$. Gender was not related to bitterness rating for either the unseasoned broccoli or cauliflower but women liked the taste and texture of both vegetables significantly more than men did, the highest $F(1, 219) = 10.59, p = .001$ for the taste of broccoli. Females showed a greater average increase in the sweet rating when sugar was added to both vegetables.

Discussion

Sugar decreased perceived bitterness and increased reported liking, and lemon did the opposite. The fact that bitterness and liking appear to have a negative relationship with each other is consistent with the literature that bitterness is an unpleasant taste (Drewnowski & Gomez-Carneros, 2000) and that heightened perceived bitterness is associated with lower palatability (Kaminski et al., 2000). Individual differences in taste perception as shown by the strips did not affect the degree of bitterness masking or augmentation by any seasoning, but these results are limited because of the low bitterness rating for both vegetables.

Experiment 3

The broccoli and cauliflower in Experiment 2 were both rated low on bitterness, so we did not obtain any results on how the seasonings might have affected a highly bitter vegetable. In Experiment 3 we used Brussels sprouts instead of broccoli, as they are very bitter (Tepper, 1998), especially to supertasters (Kaminski et al., 2000). Cauliflower was still used as a control less-bitter vegetable. In this experiment the food was served fresh, not frozen. We also added the seasonings of lemon with olive oil (sour and fat), sweetened cream cheese (sweet and fat), and salted butter (salt and fat), to imitate a more natural cooking environment.

Method

Subjects. Data were gathered from 270 subjects. There were 143 (53%) males and 127 (47%) females, with an average age of 19.5.

Materials. The fresh Brussels sprouts and cauliflower were separately submerged in water and placed in the microwave for four minutes until cooked. The cauliflower was then cut into 11g servings and the Brussels sprouts were cut into 6g servings. The salt, sugar, lemon juice, and both butter conditions were given the same amounts as in Experiment 1. For lemon with olive oil we used ¼ teaspoon lemon juice and ¼ teaspoon olive oil. For sweetened cream cheese 12g plain sugar was mixed in 100g of Philadelphia cream cheese, and ½ teaspoon was spread on the vegetables.

Procedure. The procedure for this study was otherwise identical to that of Experiment 2.

Statistical analysis. The analyses employed for these data were identical to that of Experiment 2.

Results

The vegetables were significantly different in their bitterness, with unseasoned Brussels sprouts receiving an average rating of 22 and unseasoned cauliflower receiving an average rating of 13, $t(267) = 14.77, p < .001$. The mean bitterness ratings in each condition can be seen in Table 3.

Taster status of the participants was coded as in Experiment 2. For the sweet strip there were 157 (58%) nontasters, 79 (29%) moderate tasters, and 34 (13%) supertasters. For the salt strip there were 95 (36%) nontasters, 86 (33%) moderate tasters, and 81 (31%) supertasters. For the PTC strip there were 20 (8%) nontasters, 139 (52%) moderate tasters, and 111 (41%) supertasters.

A repeated-measures ANOVA showed no significant three-way interaction between the time point (before and after seasoning), seasoning condition, and vegetable (Brussels sprouts or cauliflower) for the bitterness ratings. There was a two-way interaction for time by condition when collapsed across vegetables, $F(7, 519) = 2.74, p = .017$, see Figure 12. Post-hoc tests of simple effects revealed that sugar, $F(1, 68) = 17.73, p < .001$; salted butter, $F(1, 68) = 7.92, p = .006$; and sweetened cream cheese, $F(1, 64) = 14.56, p < .001$, significantly reduced bitterness. When taster status for each strip was separately added as another independent variable, there were no significant higher-level interactions.

The average hedonic rating was 18 for Brussels sprouts and 20 for cauliflower. A repeated-measures ANOVA showed no significant three-way interaction between the time point, seasoning condition, and vegetable for the hedonic ratings. There was a two-way interaction for time by condition when collapsed across vegetables, $F(6, 523) = 4.92, p < .001$, see Figure 13. Post-hoc tests of simple effects revealed that lemon juice, $F(1, 100) = 26.59, p < .001$; unsalted butter, $F(1, 99) = 12.33, p = .001$; and lemon with olive oil, $F(1, 65) = 13.25, p = .001$, significantly reduced reported liking. When taster status for each strip was separately added as another independent variable, individually or all three together, there were no significant higher-level interactions.

The average bitterness rating of the PTC strip was 64, higher than that of Experiments 1 and 2. The bitterness rating of the PTC strip predicted the

bitterness rating of plain Brussels sprouts, $F(1, 267) = 12.12, p = .001, R^2 = .05$. The average saltiness rating of the salty strip was 46. When the salt rating of the salt strip was used as the independent variable in a regression model, it predicted the salty rating of the Brussels sprouts with salt, $F(1, 29) = 12.44, p = .001, R^2 = .30$, and cauliflower with salt, $F(1, 33) = 6.83, p = .013, R^2 = .17$, and salted butter, $F(1, 33) = 8.29, p = .007, R^2 = .19$. The average sweet rating of the sugar strip was 24, which is lower than that of Experiment 1 even with the increased concentration of sugar. The sweet rating of the sweet strip predicted the sweet rating of the Brussels sprouts with sugar, $F(1, 33) = 5.34, p = .027, R^2 = .14$, see Figure 14, and sweetened cream cheese, $F(1, 33) = 9.22, p = .005, R^2 = .21$. For all three strips, there were also numerous instances in which the participants' ratings could predict a response that is outside the flavor of the strip—for example, sweet rating of the sugar strip can predict the salty rating of the Brussels sprouts with lemon and olive oil. All of the predictions are in the direction of more saltiness tasted on the strip meaning more of the flavor tasted on the vegetables.

Females rated the PTC strip as more bitter, $F(1, 269) = 6.67, p = .010$ and the salt strip as saltier, $F(1, 261) = 6.69, p = .010$, than males did. Males rated both vegetables as more bitter than the females did, and females liked the taste and texture of the Brussels sprouts more than the males did.

Discussion

Even though the Brussels sprouts were significantly more bitter than the cauliflower, the seasonings affected the two vegetables in the same way for both bitterness and liking. This suggests that the effect of the seasonings is unrelated to the bitterness of the vegetable. Sugar, salted butter, and sweetened cream reduced reported bitterness. Lemon, unsalted butter, and lemon with olive oil reduced reported liking. In combination with the results from Experiment 2, this is strong evidence that sweet seasonings are effective bitterness maskers and that sour seasonings decrease the palatability of vegetables. The effect of butter is unclear and warrants further investigation before conclusions can be drawn, but whether it is salted or unsalted appears influential. In future studies we will use a three to one ratio of olive oil to lemon juice, as this is what is commonly used in cooking (Alfaro, 2012).

Participants' strength of tasting salt, sugar, or PTC did not influence the effectiveness of bitterness masking or the change in hedonic rating for any seasoning. This suggests that while there are wide individual differences in bitterness tasting, the seasonings that change bitterness and palatability do so in a similar degree for each taster type.

Category ratings of the three taster strips were able to predict the strength of tasting the seasoning in many cases. This was always in the direction of a higher rating on the strip meaning a higher rating of the seasoning. This indicates that the strips are an accurate way of assessing taste intensity of real foods.

However, the high number of predictions is also a disadvantage of using the strips because of their lack of specialization.

Females rated the PTC strip as stronger and liked the taste of the vegetables more than men did, which is consistent with previous findings (Einstein & Hornstein, 1970). It is well-known that women eat more vegetables than men do, but this is often believed to be a result of health concerns and social expectations (Mooney & Walbourn, 2001). The present study suggests that even without these factors, women taste—or at least report—less bitterness from vegetables and enjoy their taste more.

General Discussion

Interventions to increase the palatability of vegetables must take into account individual differences in taste perception. We found widespread natural variability in the ability to taste salt and sugar that were infused into taster strips. While we did find that bitterness rating of the PTC strip could predict salty and sweet ratings in a linear regression model, the effect sizes were low and the variability of responses within supertasters was wide. This leads us to suggest that being a PTC ‘supertaster’ with heightened sensitivity to bitterness is only somewhat related to the ability to taste sweet and salt. Therefore, the label of ‘supertaster’ is too simplistic and perhaps there are salt supertasters, sweet supertasters, and bitter supertasters independently.

Future studies using the taster strips should include multiple concentrations for each flavor to obtain a more detailed taster profile for each

participant. We will also be exploring more chemicals in order to have strips that assess tasting ability for sour and fat/umami. As an additional test of the gLMS, we will ask participants to identify what they are using as their ‘strongest imaginable sensation’ to which they compare their taste experiences when making their ratings. Finally, we will use a technique developed by Cruickshanks and colleagues (2009) to familiarize subjects with the gLMS: asking them to rate several sounds of clearly differing intensity and re-instructing participants who do not rate them in the correct rank order.

In both masking experiments, sugar decreased reported bitterness and lemon juice decreased liking. This was true regardless of the bitterness of the vegetable and persisted even when the sugar or lemon juice was combined with fat. Our results did not show that salt masks bitterness in real foods, in contrast with studies suggesting that it does so for bitter chemicals (Kroeze & Bartoshuk, 1985), although salted butter did decrease bitterness in Experiment 3.

Subjects’ variability in the ability to taste salt, sugar, and PTC did not have any influence on the degree to which any of the seasonings changed bitterness or hedonic ratings. This suggests that even though there are wide individual differences in baseline bitterness perception, the seasonings change bitterness in approximately the same degree. There were several instances in which the salt and sugar strips could predict how much of that flavor was tasted on the seasoned vegetables, suggesting that tasting ability from the strips can be extrapolated to real foods.

For our next studies measuring bitterness masking we will try to find a vegetable even more bitter than Brussels sprouts. We will also use a more unfamiliar vegetable to see if the seasonings can help with neophobia and measure subject familiarity with the vegetables to control for prior exposure. Additionally, we will explore whether low-calorie artificial sweeteners have the same effect as sugar.

The bitter taste of vegetables can hinder their acceptance, but this is not an insurmountable problem. Individual differences in taste perception, which are present for saltiness and sweetness in addition to bitterness, must be taken into account when designing interventions to change taste. Sugar is recommended improve the initial palatability of vegetables and allow for the multiple exposures necessary for flavor-flavor and flavor-calorie learning to take place. Once this has occurred, the sugar or other flavorings can be removed and the flavor of the vegetable will be enjoyed, leading to greater consumption and health benefits.

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Table 1.

Means and standard deviations of each category for each strip, Experiment 1.

	Sweet strip	Salty strip	Bitter strip
Liking	14.4 (27.7)	-22.2 (38.2)	-55.6 (39.6)
Salty rating	5.9 (14.9)	50.9 (31.3)	7.1 (16.7)
Sweet rating	34.6 (29.8)	2.6 (8.4)	0.7 (3.9)
Sour rating	4.8 (14.1)	13.1 (21.1)	12.9 (24.3)
Bitter rating	6.5 (15.3)	25.9 (28.1)	59.6 (38.6)
Sound intensity	2.4 (1.1)	4.1 (1.6)	4.7 (2.5)

Table 2.

Mean bitterness rating of each vegetable in each seasoning condition, Experiment

2.

	Broccoli		Cauliflower	
	Plain	Seasoned	Plain	Seasoned
Salt	13.6	12.9	14.7	9.8
Lemon	10.8	19.1	13.3	27.3
Sugar	15.6	9.5	9.9	4.2
Unsalted butter	23.8	20.4	15.1	10.6

Table 3.

Mean bitterness rating of each vegetable in each seasoning condition, Experiment

3.

	Brussels sprouts		Cauliflower	
	Plain	Seasoned	Plain	Seasoned
Salt	19.6	14.9	13.3	9.3
Lemon	24.6	22.1	12.1	15.1
Sugar	25.7	17.6	15.3	2.9
Unsalted butter	14.7	15.1	15.1	14.5
Salted butter	25.2	10.8	12.6	11.1
Lemon with olive oil	20.9	17.7	12.3	15.7
Sweetened cream cheese	23.8	15.1	13.7	6.9

Figure 1.

Frequency of salt rating of salt strip.

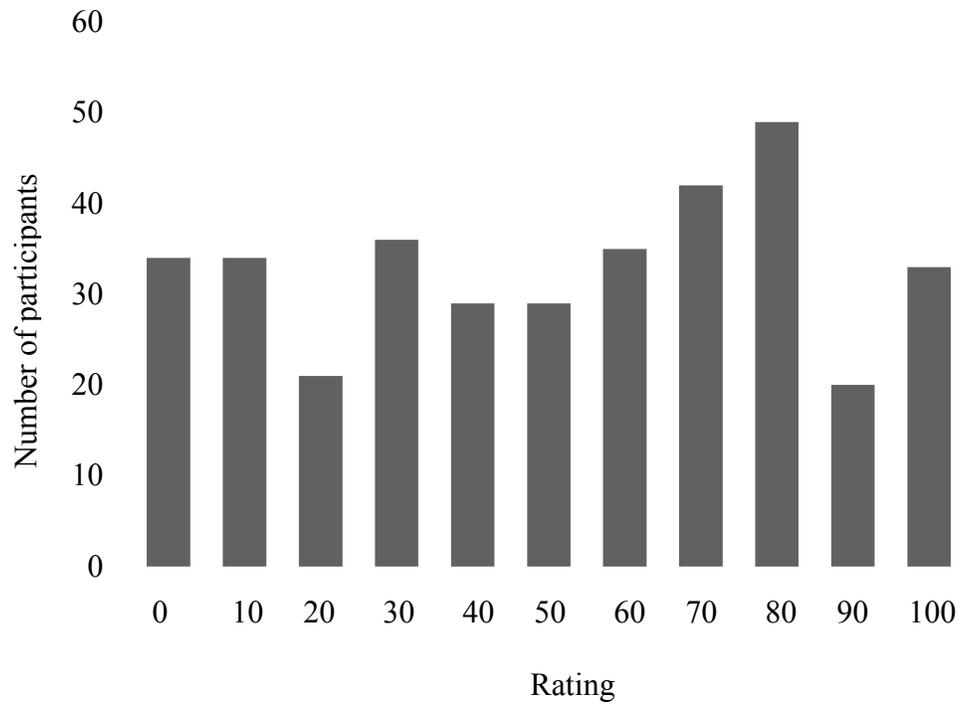


Figure 2.

Frequency of sweet rating of sweet strip.

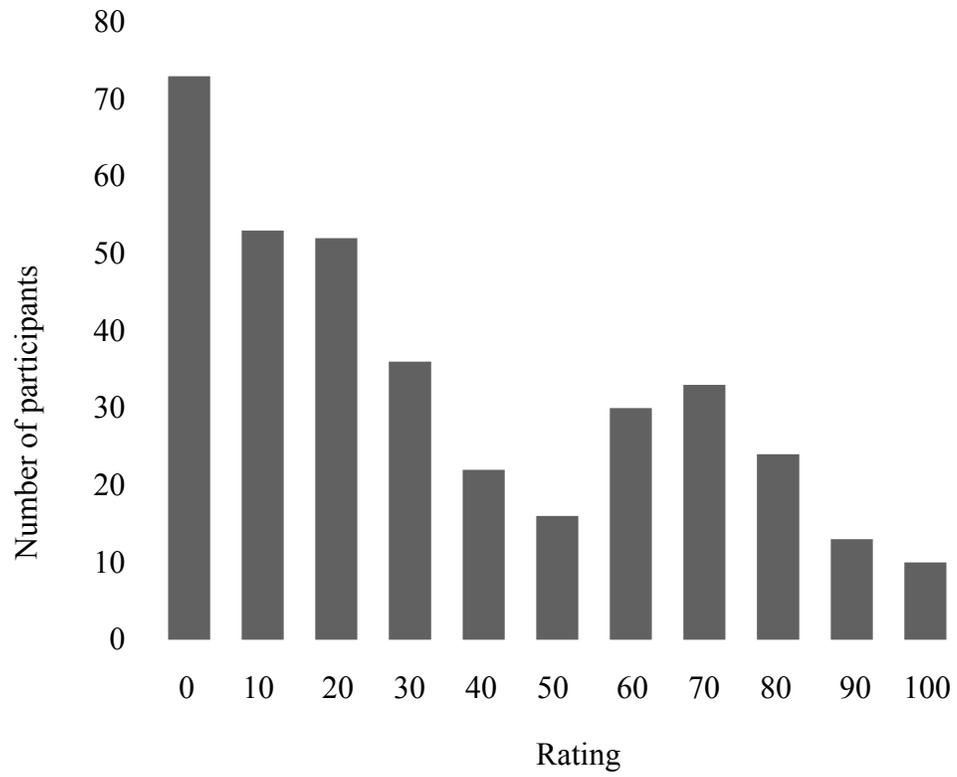


Figure 3.

Frequency of bitter rating of PTC strip.

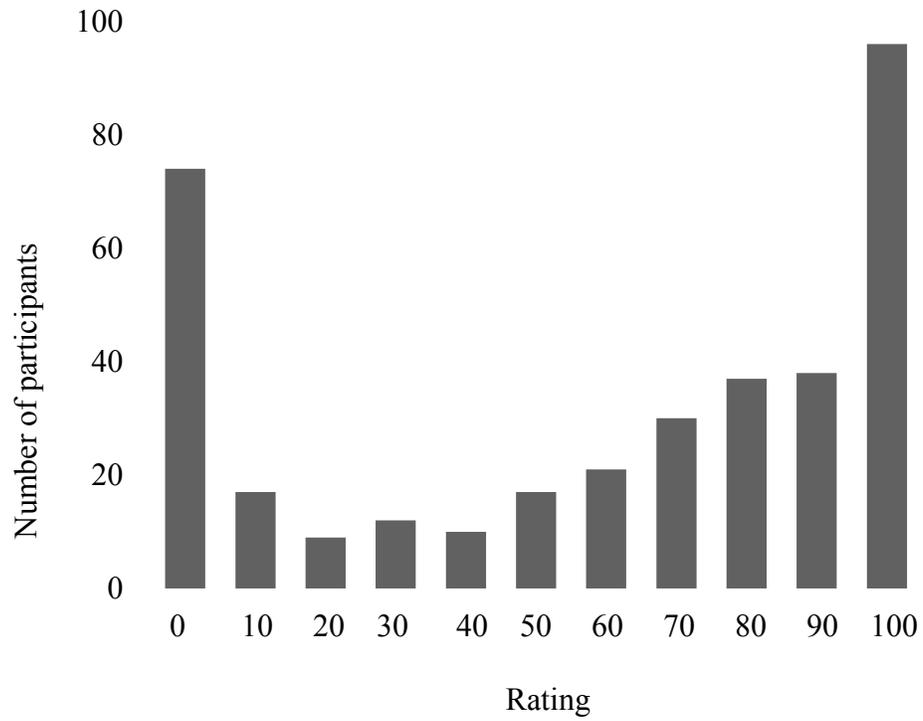


Figure 4.

Salty rating of the salty strip as a function of bitter rating of the PTC strip.

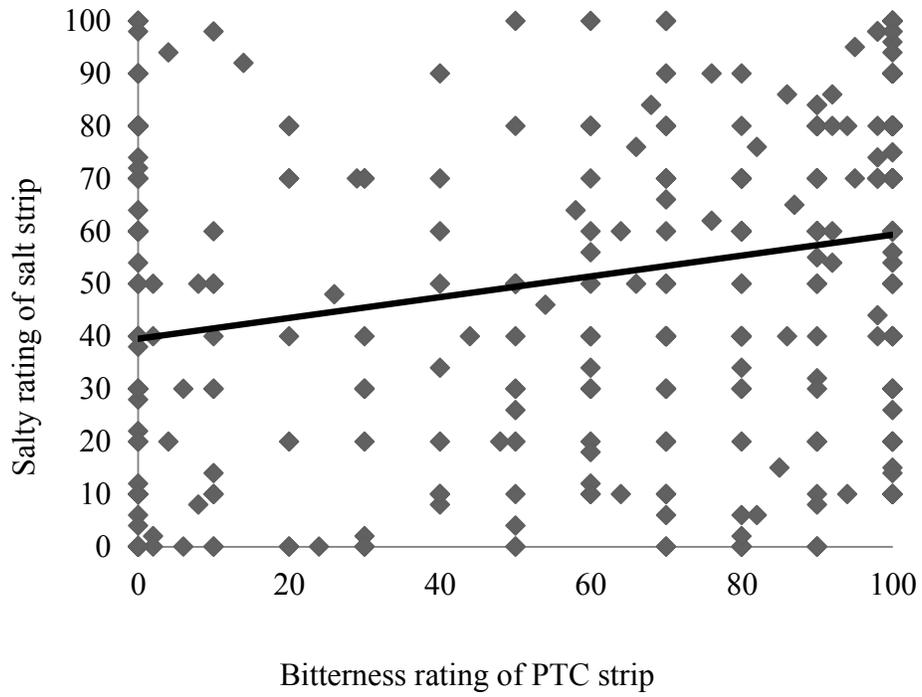


Figure 5.

Sweet rating of the sweet strip as a function of bitter rating of the PTC strip.

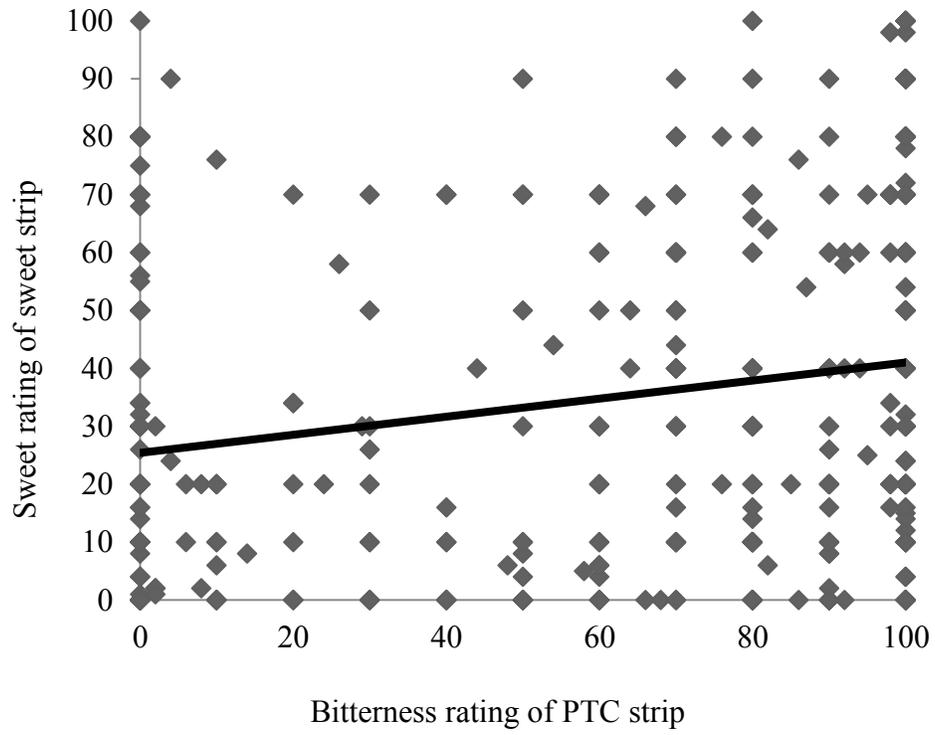


Figure 6.

Negative linear relationship of salt tasting with salt liking.

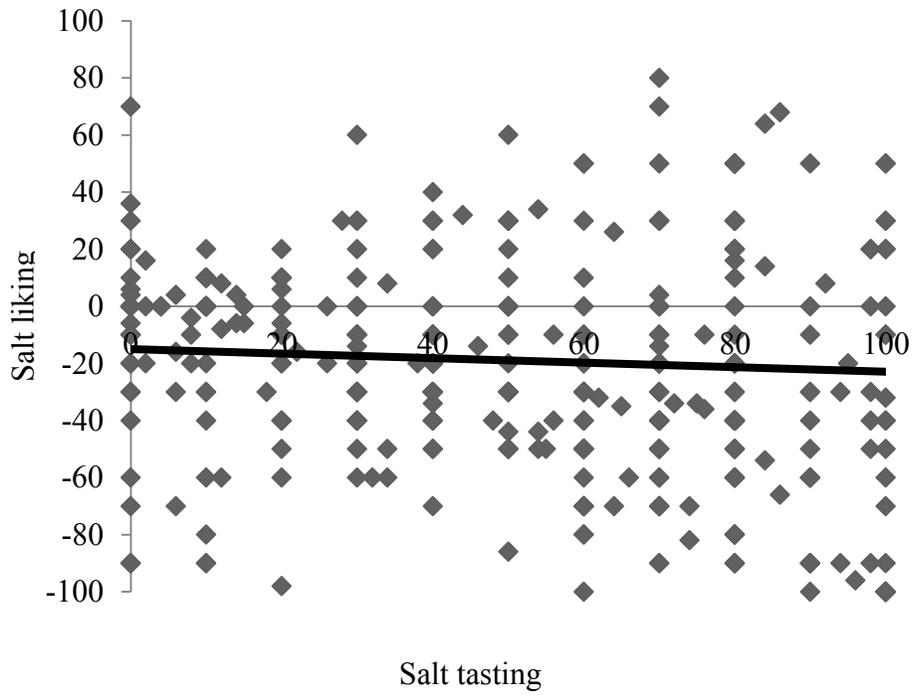


Figure 7.

Positive linear relationship of sweet tasting with sweet liking.

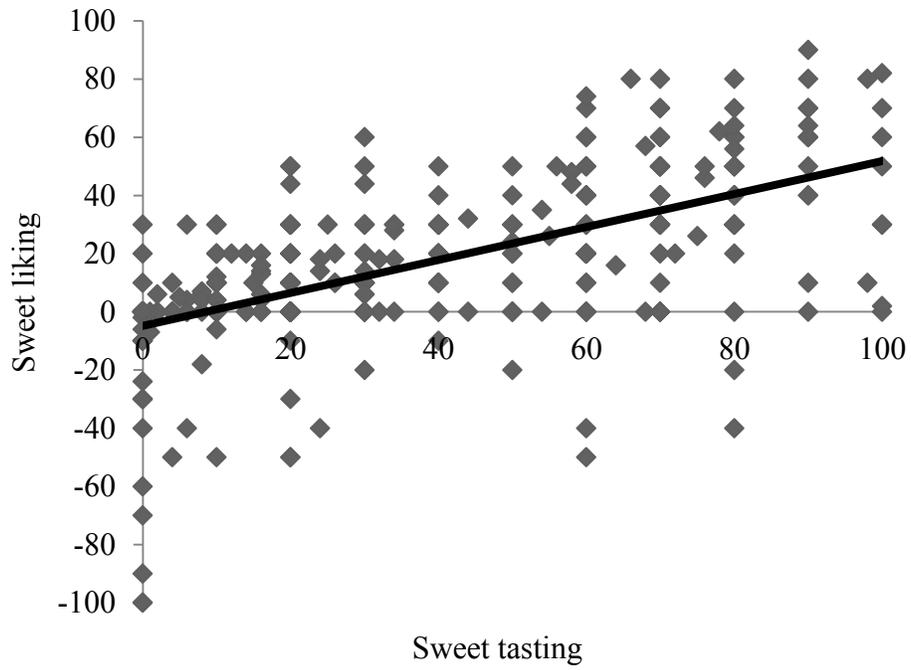


Figure 8.

Negative linear relationship of bitter tasting with bitter liking.

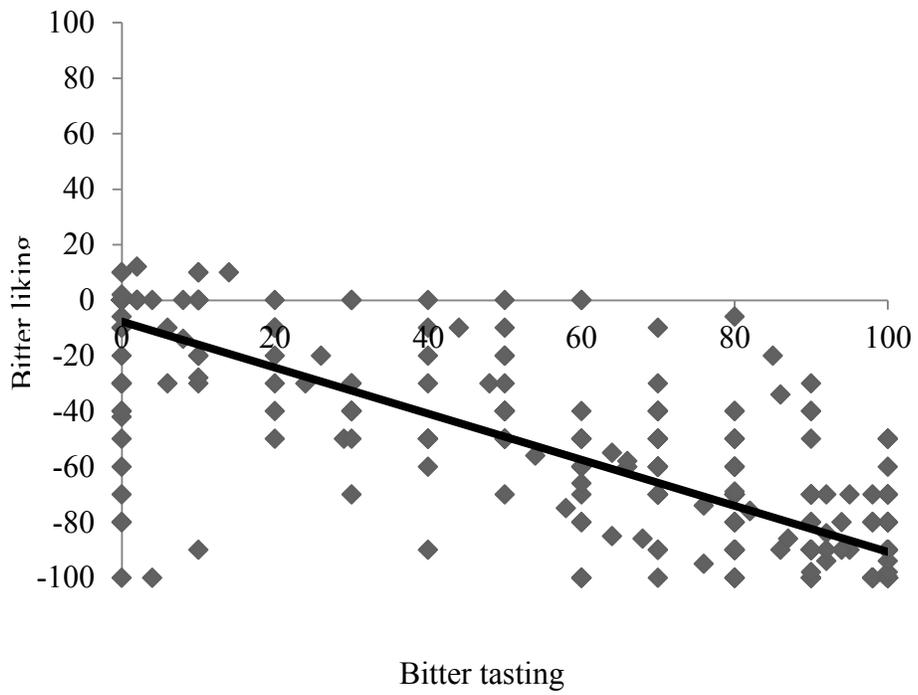


Figure 9.

The effect of seasoning on the bitterness of the combined vegetables depends on the seasoning, Experiment 2.

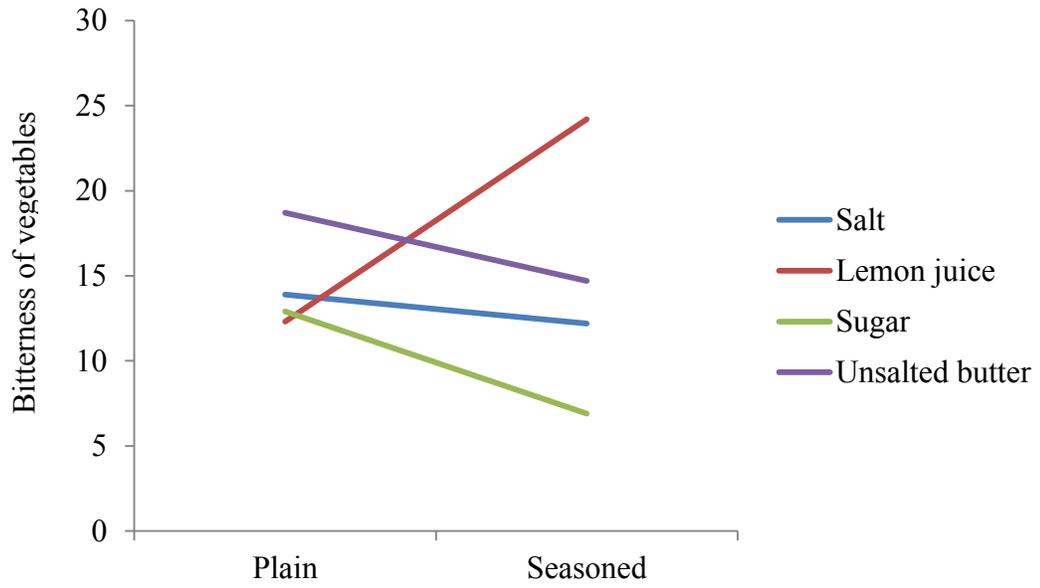


Figure 10.

The effect of seasoning on the hedonic rating of the combined vegetables depends on the seasoning, Experiment 2.

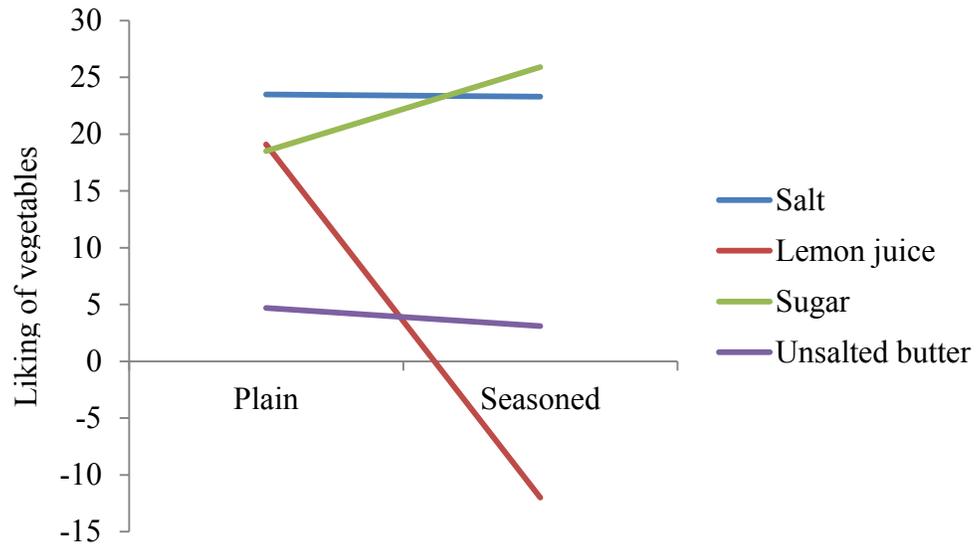


Figure 11.

Salty rating of salted broccoli as a function of salt rating of salt strip, Experiment 2.

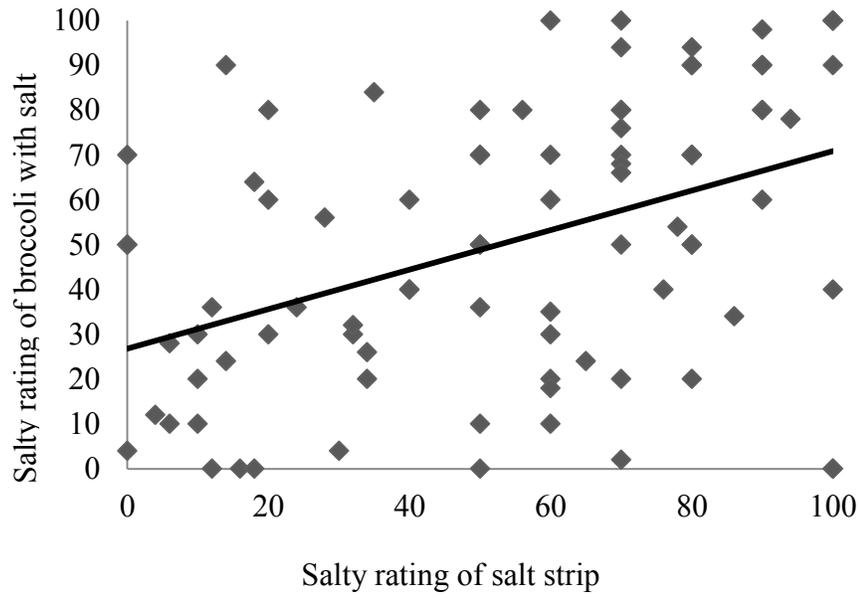


Figure 12.

The effect of seasoning on the bitterness of the combined vegetables depends on the seasoning, Experiment 3.

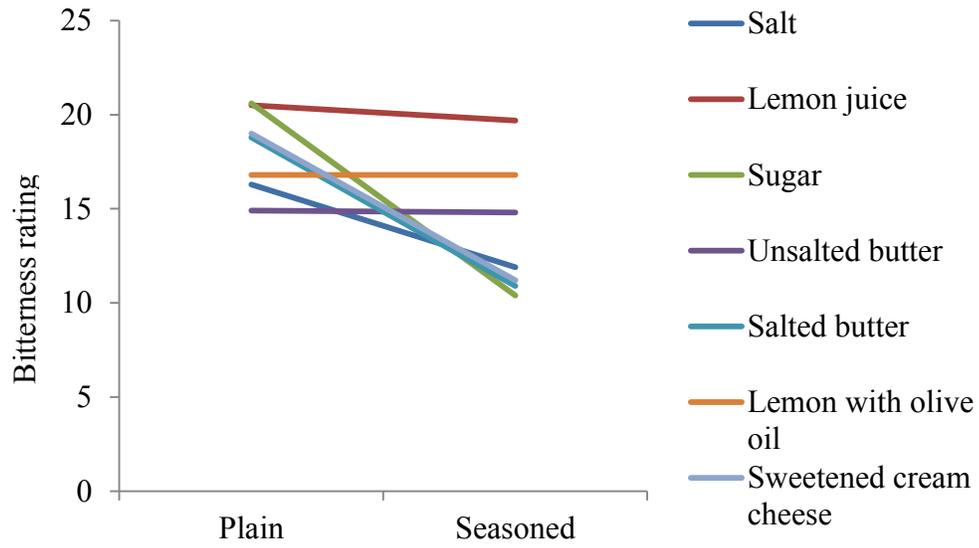


Figure 13.

The effect of seasoning on the hedonic rating of the combined vegetables depends on the seasoning, Experiment 3.

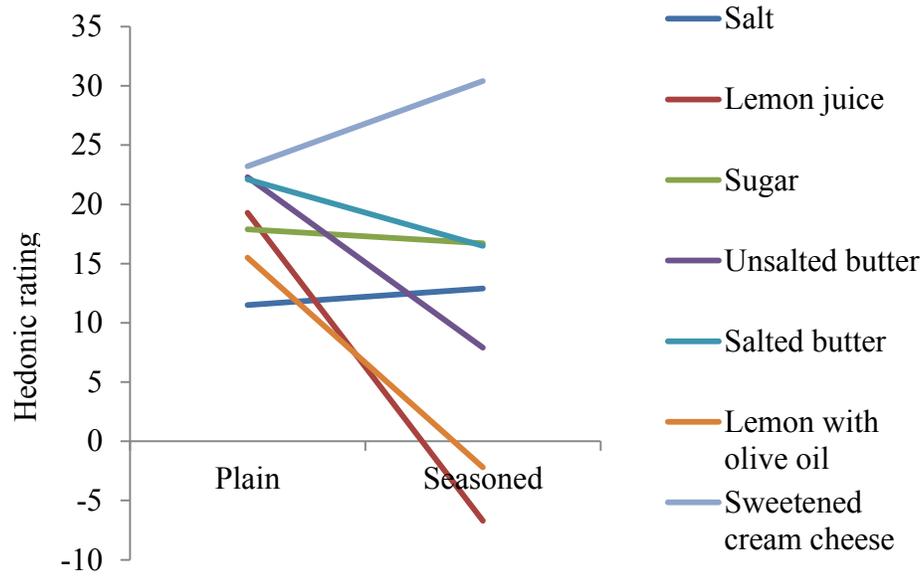
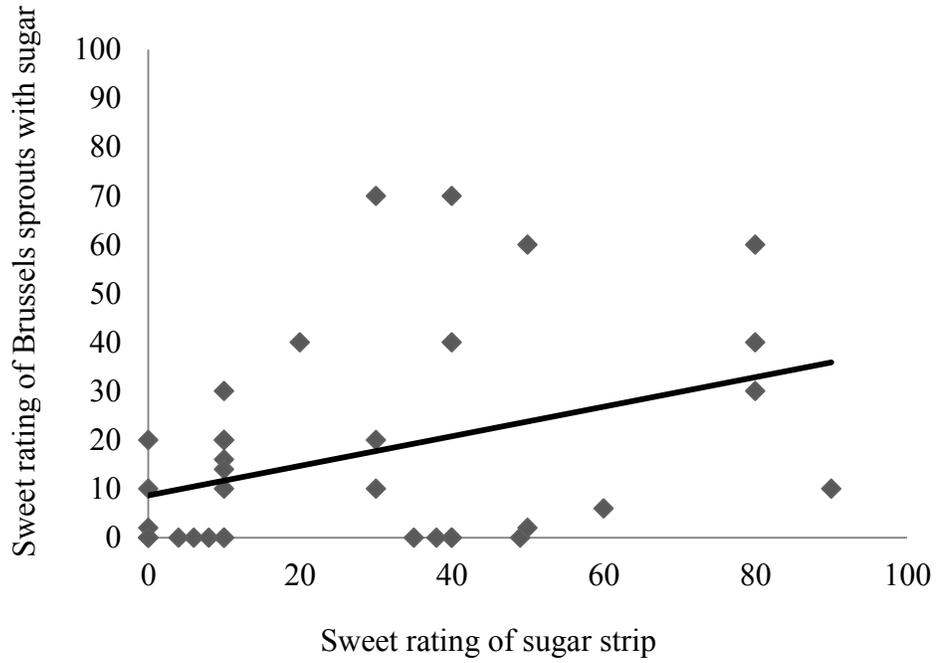
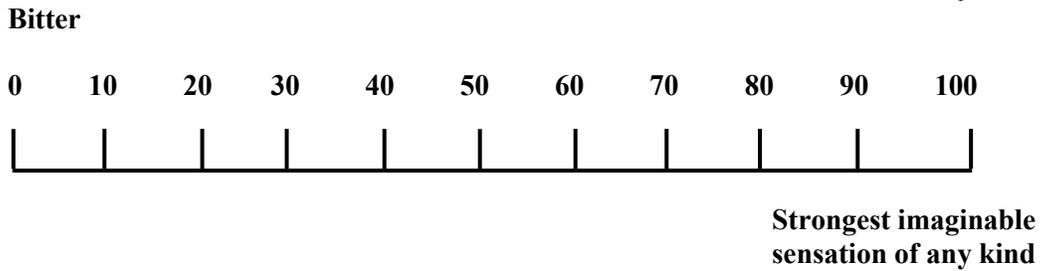
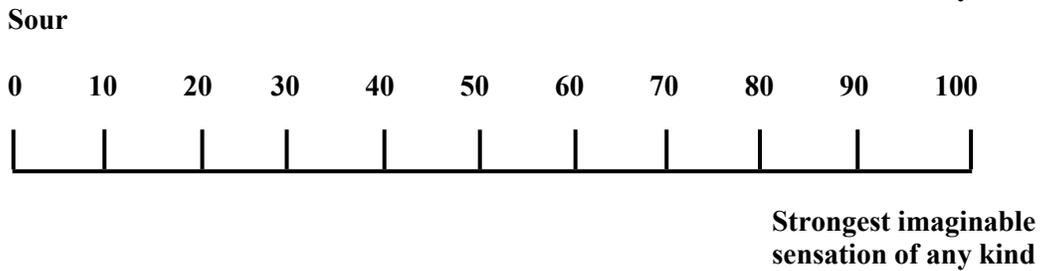
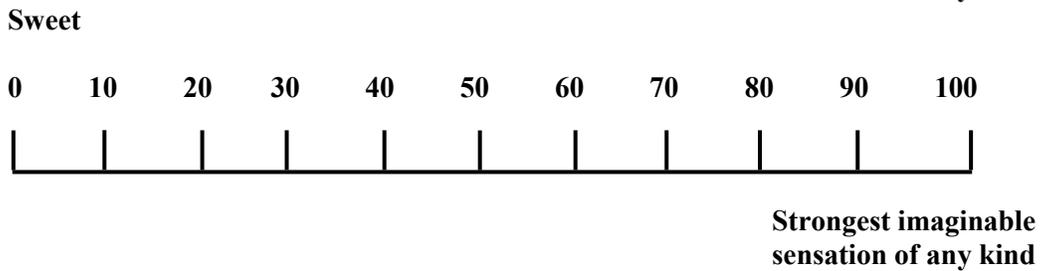
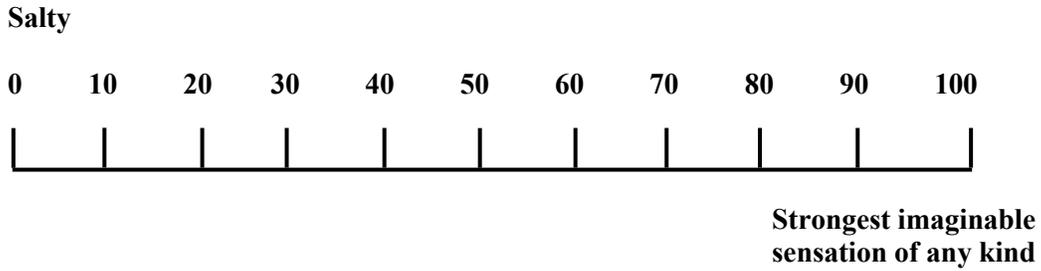
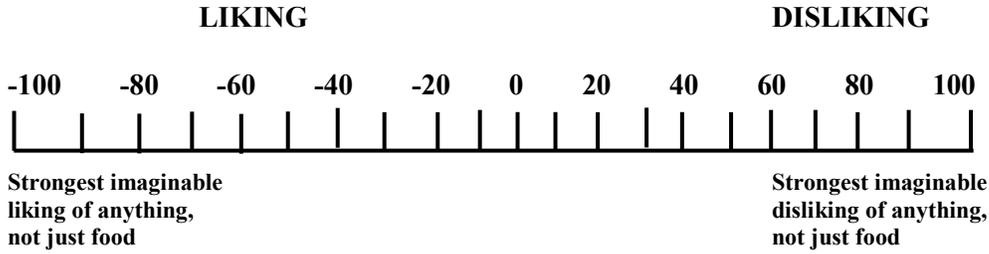


Figure 14.

Sweet rating of sugared Brussels sprouts as a function of sweet rating of the sweet strip, Experiment 3.



APPENDIX A
RATING SCALE FOR TASTER STRIPS



Please circle the sound that corresponds to the intensity of the taste you experienced

Silence – Whisper – Conversation – Playing piano – Train whistle –
Rock concert – Jet engine – Loudest sound imaginable

APPENDIX B
INFORMED CONSENT DOCUMENT FOR ALL STUDIES

Informed Consent Document for Research Participation in Food Study 4

INTRODUCTION

This form provides you information that may affect your decision about participating in this research and to record the consent of those who agree to be involved in the study.

RESEARCHERS

Dr. Elizabeth D. Capaldi and her research assistants Lynn Wilkie and Devina Bajaj in the Department of Psychology at Arizona State University have invited your participation.

STUDY PURPOSE

The purpose of this study is to examine food intake and your participation in this study will be used to bolster current conceptions of human eating patterns.

DESCRIPTION OF RESEARCH STUDY

If you decide to participate, then as a study participant you will join a study involving research on food intake. You will taste and rate several items during this experiment. Your participation will last for approximately 30 minutes in Schwada 330C at Arizona State University. Approximately 500 subjects from the PGS 101 pool will be participating in this study from ASU.

RISKS AND BENEFITS

There are no known risks to participating in this study. All experimental foods are known to be safe and FDA approved, and you will not be forced to eat any foods you don't want to eat. There is likely no direct benefit to you for participating in this study, but your participation will help us better understand food intake. If the researchers find new information during the study that would reasonably change your decision about participating, then they will provide this information to you.

CONFIDENTIALITY

All information obtained in this study is strictly confidential unless disclosure is required by law. The results of this research study may be used in reports, presentations, and publications, but the researchers will not identify you. In order to maintain confidentiality of your records, Lynn Wilkie will code and organize all data by a group number that does not allow anyone to personally identify you. The data will be kept in a locked cabinet in a locked room where it will remain for at least three years following the completion of this study. Only Elizabeth D. Capaldi, Lynn Wilkie, and Devina Bajaj will have access to the confidential information. Under no circumstance will any personally identifiable information be released to any other persons than those mentioned in this section.

WITHDRAWAL PRIVILEGE

If you agree to be in the study you are still free to withdraw at any time without any consequences to your compensation. Your participation in this study is completely voluntary, and you can refuse to answer specific questions or eat specific foods. However, your participation for the duration of this study is greatly appreciated.

COSTS AND PAYMENTS

You will receive .5 research credits for participation. There are no costs to you.

COMPENSATION FOR ILLNESS AND INJURY

If you agree to participate in the study your consent does not waive any of your legal rights. However, no funds have been set aside to compensate you in the event of injury.

VOLUNTARY CONSENT

Any questions you have concerning the research study or your participation in the study, will be answered by Lynn Wilkie, 480-727-6518, or preferably by email at lynn.wilkie@asu.edu. While Dr. Elizabeth D. Capaldi is the Principal Investigator of this research project her responsibilities as Provost and Executive Vice President of Arizona State University prevent her from being available to address your concerns.

If you have questions about your rights as a participant in this research, or if you feel you have been placed at risk; you can contact the Chair of the Human Subjects Institutional Review Board, through the ASU Research Compliance Office, at 480-965-6788.

This form explains the nature, demands, benefits, and risks of your participation. By signing this form you agree knowingly to assume any risks involved. Your participation is voluntary. You may choose not to participate or to withdraw your consent and discontinue participation at any time without penalty. In signing this consent form, you are not waiving any legal claims, rights, or remedies. A copy of this consent form will be offered to you.

FOOD CONSUMPTION STUDY FALL 2011

Your signature below indicates that you consent to participate in the above study.

Subject's Signature

Printed Name

Date

INVESTIGATOR'S STATEMENT

"I certify that I have explained to the above individual the nature and purpose, the potential benefits and possible risks associated with participation in this research study, have answered any questions that have been raised, and have witnessed the above signature. These elements of Informed Consent conform to the Assurance given by Arizona State University to the Office for Human Research Protections to protect the rights of human subjects. I have provided (offered) the subject/participant a copy of this signed consent document."

Signature of Investigator

Date _____