THE PENNSYLVANIA STATE UNIVERSITY
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DEPARTMENT OF FOOD SCIENCE

ACUTE VANILLYL BUTYL ETHER DESENSITIZATION ON THE HUMAN TONGUE

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ABSTRACT

Vanillyl butyl ether (VBE) is a unique chemesthetic stimulus that is perceived as warming on the skin and tongue. While other chemesthetic compounds such as capsaicin, zingerone, and menthol have been studied extensively for their sensory properties, including desensitization, no such research has been conducted on VBE, despite its commercial relevancy. The purpose of this research is to determine whether perceptual responses to VBE decrease following acute exposure. First, a pilot dose response study was conducted to determine the appropriate concentration of VBE to use for the subsequent desensitization study. Based on this, I determined that 3200 ppm VBE would be appropriate to investigate desensitization. Intensity ratings for tingling/numbing, warming/burning, and bitter sensations were made on a general Labeled Magnitudes Scale (gLMS) following application of VBE. Data were analyzed using regression analysis, multivariate ANOVA (MANOVA), and Welch's t-test to determine statistical significance. With repeated exposure at 30 second intervals, mean tingling/numbing and warming/burning intensity ratings decreased over time in ANOVA, and had significant negative slopes in regression. The MANOVA and t-tests revealed that there was a significant drop between the intensity ratings made for the first VBE stimulus and intensity ratings made for the last VBE stimulus, which suggests acute self-desensitization for VBE.

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Chapter 1

Introduction

Vanillyl butyl ether (VBE) is a commercially relevant chemesthetic compound that is typically described as warming on the skin and tongue. It is used in personal care products such as topical pain-relief creams and oral care products, and more recently has been approved by the FDA for use in food. VBE can be added to cinnamon gum, confections, spice mixes, and beverages at levels as high as 4200 ppm (Smith et al., 2011). Other frequently-consumed chemesthetic compounds such as capsaicin, zingerone, cinnamaldehyde, and menthol have been extensively studied for their sensory properties (Green, 1989; Prescott & Swain-Campbell, 2000; Prescott & Stevenson, 1996). Capsaicin in particular is of interest to sensory scientists because of its unique response pattern. In 1989, Barry Green showed that frequent, repeated exposure to capsaicin at a rate of one exposure per minute resulted in sensitization to capsaicin; that is, the perceived intensity of capsaicin increased with each additional exposure. Interestingly, when repeated exposure is interrupted by a 15-minute break, the first intensity rating after the break is significantly lower than the ratings made before. This decrease in perceived intensity is known as desensitization (Green, 1989). In contrast, both ethanol and cinnamaldehyde have been shown to desensitize at all rates of exposure (Prescott & Swain-Campbell, 2000). No such research has been conducted on VBE, despite its commercial relevance.

Increased understanding of the perception of VBE on the human tongue could lead to improved formulations and consumer acceptability of food, beverages, and oral care products. The purpose of this project will be to determine whether the human tongue becomes more or less sensitive to VBE with acute exposure. First, a dose response study was conducted to determine the appropriate concentration of VBE to use in a desensitization series. Then, the chosen

concentration was applied to the tongue repeatedly and intensity ratings were analyzed for desensitization.

Chapter 2

Dose Response

To determine what concentration of VBE should be used in the desensitization study, a pilot dose response study was conducted to find a concentration that evokes a moderately intense sensation. Of the 18 participants that were recruited for this pilot, 15 completed visits to the Sensory Evaluation Center at Penn State. Each attended a one-on-one testing session with a researcher in a clinical type interview / examination room. An ascending series of 6 VBE solutions were swabbed onto the anterior tongue and rated for intensity of tingling/numbing, warming, hot, burning, and bitter on a general Labeled Magnitude Scale (gLMS). Data from these 15 participants were analyzed in Excel to determine mean intensity values and determine which concentration would be appropriate for future studies. This study was approved by the Penn State Institutional Review Board (STUDY00008171).

Materials and Methods

Participants of the dose response pilot received 6 concentrations of VBE in quarter log steps: 320 ppm, 560 ppm, 1000 ppm, 1800 ppm, 3200 ppm, and 5600 ppm. A 5600 ppm stock solution of VBE (Sigma-Aldrich) in pure ethanol was made and further diluted to make all 6 concentrations.

Stimuli for the study were prepared by saturating a cotton swab in VBE solution and allowing it to air dry overnight. Swabs were then rewetted in mouth-temperature (35 degrees Celsius) reverse osmosis (RO) water immediately before being swabbed onto a participant's tongue. All swabs were prepared 5 days prior to the first day of testing, and were stored in plastic

zip-top bags at room temperature until testing. All concentrations are nominal because it is impossible to know the precise amount of stimulus delivered to the tongue from the swabs.

Participants for this study were recruited from a database of participants maintained by the Sensory Evaluation Center at Penn State. These individuals have previously opted in to be contacted about studies on taste and flavor research. Inclusion criteria included:

1. Not pregnant or nursing
2. Nonsmoker
3. 18-45 years of age
4. No history of chronic pain
5. Limited use of spicy sauces or condiments (1-3 times per month or less)
6. Limited chili pepper consumption (1-3 times per month or less)
7. Low preferred level of spice
8. Not taking prescription pain medication
9. No known smell or taste problems
10. No history of choking or difficulty swallowing
11. No tongue, cheek, or lip piercings

Criteria 5-7 were included due to unpublished data previously collected in the Hayes laboratory that suggested VBE and capsaicin may show cross-desensitization. Participants who were regularly exposed to capsaicin in their diet were therefore excluded from this study, as this might potentially decrease their response to VBE.

93 participants met the study recruitment criteria. Of these, 18 participants were scheduled for a single session in the Penn State SEC. The first 18 participants to sign up all self-

identified as women, so to reduce unnecessary variation between participants, only women were recruited for the subsequent desensitization study.

Written consent to participate in the study was obtained from each participant prior to testing. Each participant began by receiving a standardized explanation of the general Labeled Magnitude Scale (gLMS), followed by practice ratings of remembered or imagined sensations. The gLMS ranges from “no sensation”, with a tick mark at 0, to “strongest imaginable sensation of any kind”, with a tick mark at 100. Intermediate labels at “barely detectable” (1.4), “weak” (6), “moderate” (17), “strong” (35), and “very strong” (51) are also provided. The numbers are not shown on the scale.

Each participant then received all 6 concentrations of VBE in ascending concentration order. To apply the VBE to the tongue, individual swabs were saturated in mouth-temperature (35°C) reverse osmosis (RO) water and rolled four times across the anterior tongue. Participants made intensity ratings for tingling/numbing, warming, hot, burning, and bitter on a gLMS for each. To reduce confusion, a sheet of definitions and descriptors for tingling/numbing, warming, hot, and burning were provided, based on previous work (Green, 2002). These are shown in Table 1. Separate ratings were collected for tingling/numbing, warming, hot, burning, and bitter sensations.

Table 1. Attribute Definitions Provided to Participants in Dose Response Study

Attribute	Definition
Tingling/numbing	A diffuse (i.e.) fuzzy sensation like that experienced during the onset of local anesthesia (e.g.from Novocain). NOT the absence of sensation
Warming	The sensation of mild heating
Hot	The sensation that exceeds warmth, but is not yet painful
Burning	The sensation that commonly results from very high temperatures or certain chemical irritants (e.g. alcohol)

Participants were instructed to keep their tongues suspended (not touching the sides or roof of their mouth) and to minimize mouth movements while they were making their intensity ratings on the gLMS. Between stimuli, participants rinsed their mouths with mouth-temperature RO water for 30 seconds, or until any lingering sensation was gone.

All data were collected in Compusense Cloud (Guelph, ONT) software. The goal of this dose response pilot was to determine the concentration of VBE that evokes a moderate sensation, so I looked for a concentration that had a mean rating near 17.

Results

The data generated from all 15 participants who completed sessions were used in the analysis. Group means based on individual intensity ratings provided by each participant were calculated. These values are summarized in Table 2 below.

Table 2. Mean Intensity and Standard Error Values (in Parentheticals) for 5 Attributes for Each VBE Concentration

Conc.	Tingling/Numbing	Warming	Hot	Burning	Bitter
320 ppm	6.07 *(1.74)*	4.41 *(1.73)*	2.31 *(0.92)*	2.61 *(1.31)*	2.18 *(0.79)*
560 ppm	10.23 *(2.32)*	4.09 *(1.40)*	2.66 *(1.01)*	5.05 *(1.42)*	4.11 *(1.25)*
1000 ppm	12.21 *(2.20)*	9.93 *(2.61)*	9.32 *(3.11)*	13.23 *(3.27)*	4.85 *(1.34)*
1800 ppm	16.92 *(3.23)*	15.55 *(3.61)*	13.57 *(3.97)*	19.04 *(4.78)*	6.21 *(2.44)*
3200 ppm	23.13 *(5.05)*	18.04 *(5.08)*	22.00 *(5.23)*	25.41 *(5.63)*	7.85 *(5.35)*
5600 ppm	27.36 *(5.73)*	22.43 *(6.84)*	32.82 *(6.47)*	33.63 *(7.01)*	8.95 *(5.22)*

In general, the intensity of all attributes increased with increasing concentration, although not at the same rate (i.e., bitterness was much lower than the other qualities). I was interested in concentrations where the mean intensity rating was around 17 (‘moderate’ on the gLMS). For tingling/numbing and burning attributes, the mean intensity rating was closest to 17 at 1800 ppm (the mean ratings at 1800 ppm were 16.92 and 19.04, respectively). For warming and hot attributes, the mean intensity rating was closest to 17 at 3200 ppm, with ratings of 18.04 and 22.00, respectively. The intensity of bitterness did not reach a moderate level at any of the concentrations of VBE presented.

Discussion

Based on the pilot data summarized in Table 1, 3200 ppm VBE was the concentration selected for use in the desensitization study. 3200 ppm VBE was rated as stronger than moderate for tingling/numbing and burning attributes, but there were some attributes (warming and hot) that did not reach moderate intensity until 3200 ppm. Using a higher concentration also leaves more room to find desensitization that might be missed at lower concentrations, due to a floor effect on the gLMS.

Also, given the apparent redundancy of the chemesthetic qualities, the number of attributes being rated will be reduced in the subsequent study. Making ratings for four very similar or confusable attributes (tingling/numbing, warming, hot, burning) was difficult for some participants, and despite providing the definitions for each, participants used the attributes differently. Several participants had their highest rating for warming in the middle of the concentration series, and then had increased ratings for hot after that point. This indicates that they considered warming a less intense version of hot. Other participants had increased ratings for both warming and hot as the concentration of VBE increased, which indicates that they either thought they were the same thing, or they thought their sensations were different but correlated. Because little to no research on the subtle difference between warming and hot exists, nor how these descriptors are used by participants, I decided to combine them with other attributes to form categories. Thus, in the subsequent desensitization study, the attributes to be rated were reduced to three: tingling/numbing, warming/burning, and bitter.

Chapter 3

Desensitization

The objective of the desensitization study was to observe how the perceptual response to VBE changes during and after repeated exposure. Participants (n=41) completed one on one testing in the Sensory Evaluation Center in a clinical type interview / examination room. Each participant had 3200 ppm VBE swabbed onto the anterior tongue every 30 seconds for five minutes. After a ten-minute break, one final probe stimulus of 3200 ppm VBE was applied. Immediately following each application, participants used a gLMS to rate the intensity of tingling/numbing, warming/burning, and bitter. Data were analyzed using regression analysis, multivariate ANOVA (MANOVA), and Welch's t-tests, comparing the last intensity rating made with the first intensity ratings made during the session. If desensitization was achieved, the last intensity rating would be statistically significantly lower than the first rating. This study was approved by the Penn State Institutional Review Board (STUDY00008171).

Materials and Methods

Based on Chapter 2, I decided to use 3200 ppm VBE for the desensitization study, as it evokes a moderately intense sensation. The same solution of 3200 ppm VBE in ethanol that was prepared for the dose response study was used to make the stimuli for the current study.

As before, cotton swabs were saturated in 3200 ppm VBE solution and allowed to dry overnight, before being stored in plastic zip-top bags at room temperature. Swabs were saturated in mouth-temperature (35 degrees Celsius) reverse osmosis (RO) water immediately before

being swabbed onto the participant's anterior tongue. VBE swabs were made 5 days prior to the first day of testing.

Participants for this study were recruited from a database of participants maintained by the Sensory Evaluation Center at Penn State. These individuals have previously opted in to be contacted about studies on taste and flavor research. Inclusion criteria included:

1. Female
2. Not pregnant or nursing
3. Nonsmoker
4. 18-45 years of age
5. No history of chronic pain
6. Limited use of spicy sauces or condiments (1-3 times per month or less)
7. Limited chili pepper consumption (1-3 times per month or less)
8. Low preferred level of spice
9. Not taking prescription pain medication
10. No known smell or taste problems
11. No history of choking or difficulty swallowing
12. No tongue, cheek, or lip piercings

As before, criteria 6-8 were included due to findings from a preliminary study in the Hayes lab that was suggestive of cross-desensitization between VBE and capsaicin. Participants that were regularly exposed to capsaicin were excluded from the study due to their potential for decreased responses to VBE. Participation was restricted to women because only women had participated in the pilot study. Individuals who participated in the pilot dose response study were eligible to participate in the desensitization study. 96 participants fit the criteria for this study. Of

them, 41 participants completed a session in the SEC; eight of them had participated in the pilot study.

Written consent to participate in the study was obtained for each participant prior to testing. Each participant began by receiving a standardized explanation of the general Labeled Magnitude Scale (gLMS), followed by practice ratings of remembered or imagined sensations. The gLMS ranges from “no sensation”, with a tick mark at 0, to “strongest imaginable sensation of any kind”, with a tick mark at 100. Intermediate labels at “barely detectable” (1.4), “weak” (6), “moderate” (17), “strong” (35), and “very strong” (51) are also provided. The numbers are not shown on the scale.

Each participant then received VBE impregnated swabs every 30 seconds for five minutes (nominal concentration of 3200 ppm). After a ten-minute break, one final VBE stimulus was applied. To apply the VBE to the tongue, swabs were saturated in mouth-temperature reverse osmosis (RO) water and rolled 4 times across the anterior tongue. Participants made intensity ratings for tingling/numbing, warming/burning, and bitter on a gLMS following each application. Throughout the session, participants were instructed to keep their tongues suspended (not touching the sides or roof of their mouth), minimize mouth movements, and avoid rinsing with water.

The data resulting from this study were analyzed in several ways. First, regression analysis was performed on the plots of the mean intensity ratings (Figures 1, 2, and 3) to determine whether the overall decrease in intensity was significant. Next, a multivariate ANOVA was conducted to determine whether there are significant differences between any intensity ratings for each attribute. Finally, Welch’s t-tests were conducted to determine whether I observed evidence of desensitization. T-tests were selected *a priori* in favor of Tukey’s LSD as a

means of conserving statistical power. Because not all intensity ratings need to be compared to every other to estimate desensitization, only changes between three key time points (t=0, 300, and 900) were compared. All statistical analysis was performed in R.

Results

Group means for each stimulus application for tingling/numbing, warming/burning, and bitter were plotted against time and analyzed via regression analysis, multivariate ANOVA, and Welch's t-tests.

Figure 1 shows the plot of mean tingling/numbing intensity ratings over time. Regression analysis, the results of which can be seen in Appendix A and Table 2, indicates that there is a significant downward slope to the data ($p=0.013$). This indicates that perceived intensity drops across the entire testing period. The MANOVA indicated significant differences between at least two mean tingling/numbing ratings ($p<0.001$). Welch's t-tests (Appendix C) confirm that desensitization took place between the 0 and 900 seconds ($p=0.007$). However, significant desensitization did not occur during the break in stimuli, between 300 and 900 seconds ($p=0.15$).

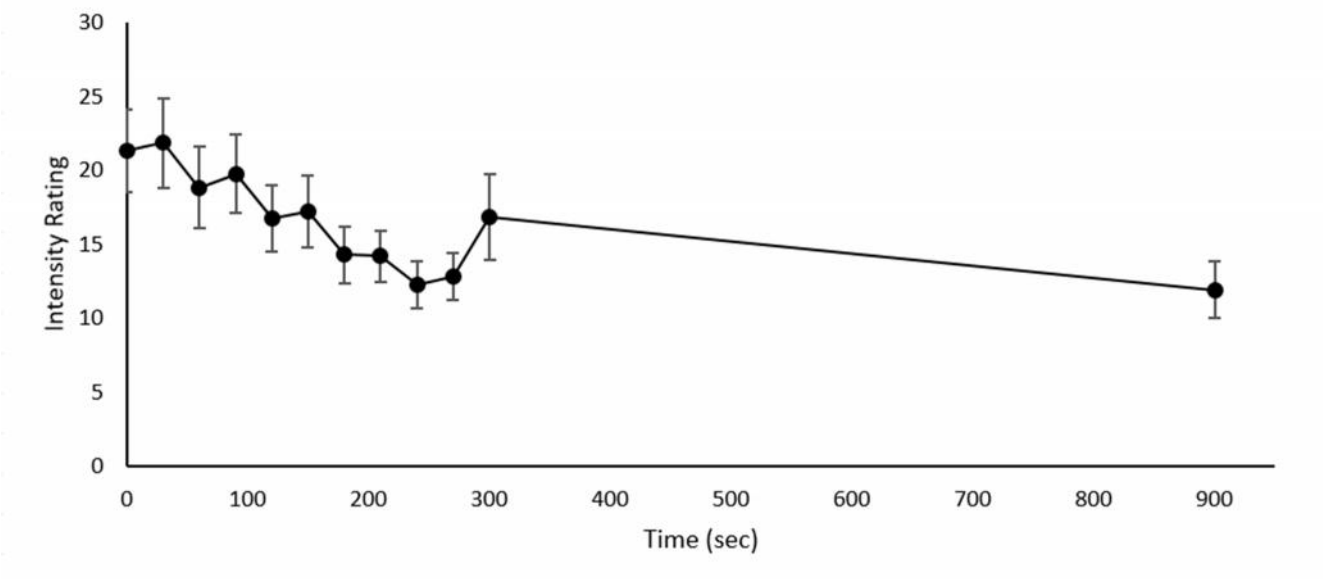

Figure 1. Average Intensity Ratings of Tingling/Numbing for 3200 ppm VBE Over Time. Error bars represent standard error values.

Figure 2 shows the plot of mean warming/burning ratings over time. As with tingling/numbing, the regression analysis indicates that there is a significant downward slope to the data and therefore, significant desensitization across the entire session ($p<0.0001$). The MANOVA also indicated that there was a significant difference between at least two mean warming/burning ratings ($p<0.001$). Welch's t-tests revealed that there was a significant difference in intensity of warming/burning at 0 seconds and 900 seconds ($p= 0.0011$). Additionally, there was a significant decrease in intensity between the rating made right before the break (at 300 seconds) and the rating made after (at 900 seconds) ($p = 0.032$).

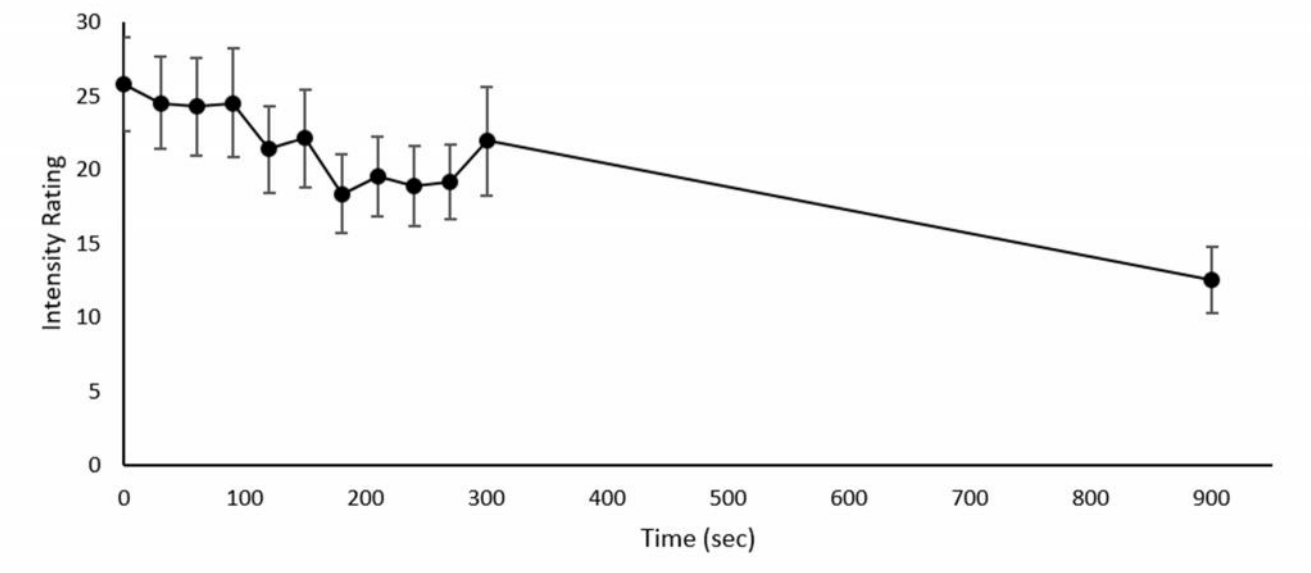

Figure 2. Average Intensity Ratings of Warming/Burning for 3200 ppm VBE Over Time

Bars represent standard error values.

Finally, Figure 3 is the plot of mean bitterness ratings over time. Unlike the previous attributes, there was no evidence of a change in bitterness ratings over time ($p=0.25$), as seen in Table 3. The MANOVA revealed that there is no significant difference between any two bitterness ratings, which Welch's t-tests confirmed (see Appendix C). Higher mean ratings at 150 seconds and 300 seconds appear to be the result of two participant's high intensity ratings; however, their practice gLMS ratings were all appropriate, so we assume that their higher ratings were due to individual variation. Therefore, we can conclude that there is no significant self-adaptation of the bitterness evoked by VBE.

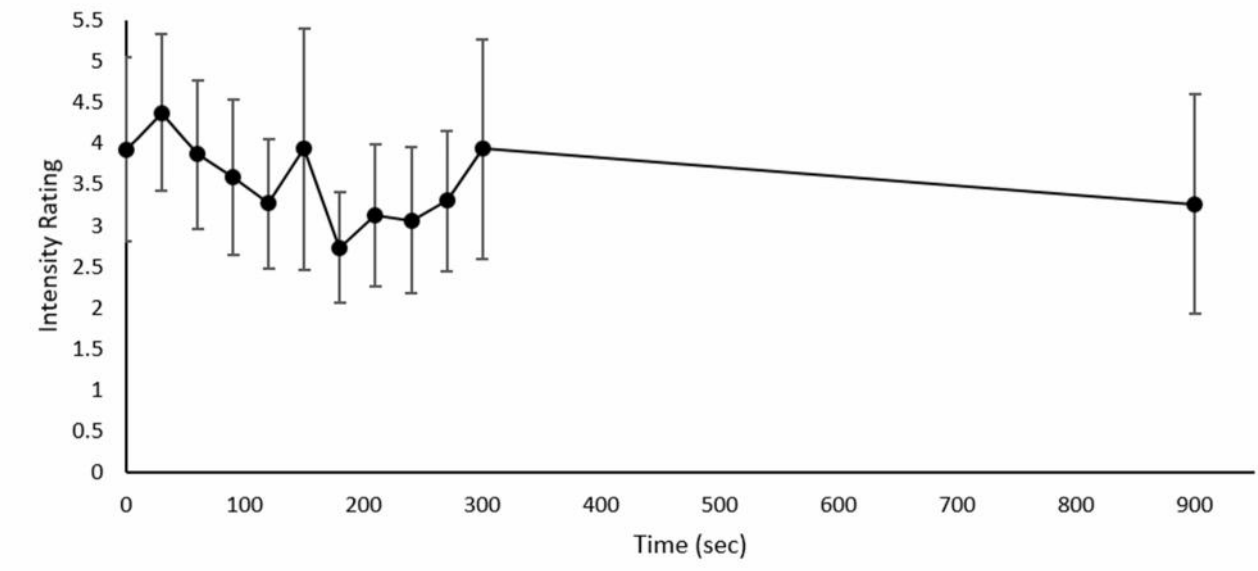

Figure 3. Average Intensity Ratings of Bitter for 3200 ppm VBE Over Time

Bars represent standard error values.

Table 3. Regression Analysis for Average Attribute Ratings Over Time

Attribute	p-value
Tingling/Numbing	0.01331
Warming/Burning	0.0001094
Bitter	0.2546

Discussion

Overall, I found that the tingling/numbing and warming/burning sensations evoked by VBE desensitize over the entire course of the treatment, both during a period of rapid, consistent application and after a ten-minute break. This pattern of desensitization is similar to that of the irritation of cinnamaldehyde (Figure 4), a chemesthetic compound with many of the same

commercial food applications as VBE (Prescott & Swain-Campbell, 2000). This is in contrast to what we observe for capsaicin, which increases in perceived intensity over the period of rapid applications, and then significantly decreases in intensity after a longer break (Green, 1989).

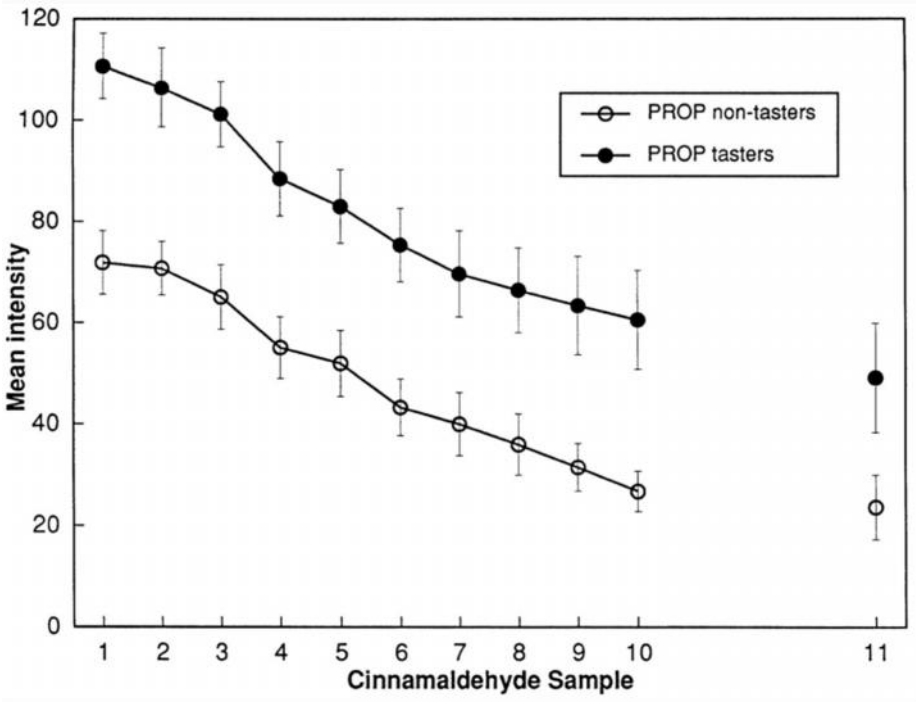

Figure 4. Cinnamaldehyde Desensitization as Shown in PROP Non-tasters and Tasters.

Adapted from "Responses to Repeated Oral Irritation by Capsaicin, Cinnamaldehyde and Ethanol in PROP Tasters and Non-tasters" by J. Prescott and N. Swain-Campbell, 2000, Chem Senses 25: 239-246.

One difference between cinnamaldehyde's desensitization pattern and VBE's is that the intensity ratings made for both tingling/numbing and warming/burning just before the ten-minute break (at t=300 seconds) were higher than the previous four ratings. This increase appears to be the result of high intensity ratings made by a few participants. However, as before, their gLMS practice ratings were all appropriate, so we assume that these ratings are genuine and the result

of individual variation. The degree of individual variation in responses to VBE could be something to investigate in future studies.

Chapter 4

Limitations

The primary limitation to this study is that our data for both the dose response study and desensitization study are analyzed based on mean responses. However, there is substantial variation in how individuals perceive oral stimulants, including VBE. For example, as discussed in reference to the dose response study, not all participants reported perceiving VBE the same way. Some thought the sensation evoked was strictly tingling/numbing, some thought that the lower concentrations were warming and the higher concentrations were burning, and others felt that all the available attributes were evoked by VBE. While this inconsistency may be due to confusion surrounding the attribute definitions, it is also possible that individuals genuinely experienced different sensations.

While most participants rated the 3200 ppm swab as moderately to strongly intense during the desensitization study, there were several participants who rated all stimuli as ‘weak’ or lower on the gLMS. The gLMS warm-up scales from those participants are approximately what we would expect, which indicates that they understood how to use the scale properly, and their ratings were genuine. However, it is unclear why these participants would experience so much less irritation than the others. It may be genetic variation, or they may be regularly exposed to compounds (other than capsaicin, which was screened against) such as ethanol that may have cross-interactions with VBE. This may be an area of future study.

Chapter 5

Further Directions

This study was conducted to improve understanding of the perception of VBE on the human tongue, as this might lead to improved formulations and consumer acceptability of food, beverages, and oral care products. My data provide new insight into VBE's desensitization pattern. However, this study was conducted in an extremely controlled environment and does not mimic the way consumers actually eat. Temporal sensory methods could be used in future studies to understand how the intensity of VBE varies over time when consuming a real product containing VBE.

Future research could also address the questions that arose during this study. Perceived intensity of tingling/numbing and warming/burning spiked up at t=300 seconds, despite the overall downward trend of intensity ratings. Future studies could verify that this phenomenon is replicable, and look to understand why it occurs. A cross-desensitization study could shed some insight as to why some of our participants rated the intensity of 3200 ppm VBE swabs as 'weak' or lower on the gLMS. Deeper insight into the receptors involved in the perception of VBE may also lead to an understanding of genetic differences that may cause some participants to feel much weaker sensation.

To better understand the sensory profile of VBE, future studies could more thoroughly investigate the attributes used to describe the sensation (i.e., hot, warming, burning, tingling/numbing, etc).

Chapter 6

Conclusion

Prior to these experiments, vanillyl butyl ether had not been researched for its sensory properties, despite its commercial use in personal care products, food, and beverages. I successful showed that the tingling/numbing and warming/burning sensations evoked by VBE desensitize following acute exposure on the human tongue, in a pattern similar to cinnamaldehyde. In the future, these findings may lead to more acceptable formulations of products containing VBE. However, there is much more research to be done to obtain a deeper understanding of the sensory properties of VBE and its variation between people.

Appendix A

Regression Analysis for Average Intensity Ratings

Regression analysis for Tingling/Numbing intensity ratings:

```
Call:
lm(formula = Time ~ Tingling_Numbing, data = avg.tingle)

Residuals:
    Min      1Q  Median      3Q     Max
-172.98 -113.20  -35.93   40.25  471.96

Coefficients:
                Estimate Std. Error t value Pr(>|t|)
(Intercept)       989.62     264.07   3.748   0.0038 **
Tingling_Numbing  -47.11      15.70  -3.001   0.0133 *
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 179.8 on 10 degrees of freedom
Multiple R-squared:  0.4739,   Adjusted R-squared:  0.4213
F-statistic: 9.009 on 1 and 10 DF,  p-value: 0.01331
```

Regression analysis for Warming/Burning intensity ratings:

```
Call:
lm(formula = Time ~ Warming_Burning, data = avg.burn)

Residuals:
     Min       1Q   Median       3Q      Max
-188.011  -78.042    4.742   59.507  199.035

Coefficients:
                Estimate Std. Error t value Pr(>|t|)
(Intercept)     1416.308    198.705   7.128 3.19e-05 ***
Warming_Burning  -57.094      9.295  -6.142 0.000109 ***
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 113.5 on 10 degrees of freedom
Multiple R-squared:  0.7905,   Adjusted R-squared:  0.7695
F-statistic: 37.73 on 1 and 10 DF,  p-value: 0.0001094
```

Regression analysis for Bitter intensity ratings:

```
Call:
lm(formula = Time ~ Bitter, data = avg.bitter)

Residuals:
    Min      1Q  Median      3Q     Max
-173.55 -118.95  -64.31   10.32  640.44

Coefficients:
            Estimate Std. Error t value Pr(>|t|)
(Intercept)    836.8      520.9   1.606    0.139
Bitter        -176.8      146.3  -1.209    0.255
```

```
Residual standard error: 231.6 on 10 degrees of freedom
Multiple R-squared:  0.1274,   Adjusted R-squared:  0.04019
F-statistic: 1.461 on 1 and 10 DF,  p-value: 0.2546
```

Appendix B

Multivariate ANOVA

Tests for the random effects:

	Panelist
Tingling_Numbing	243.52 ***
Warming_Burning	426.59 ***
Bitter	324.16 ***

*** p < 0.001, ** p < 0.01, * p < 0.05

Tests for the fixed effects:

	Sample
Tingling_Numbing	4.48 ***
Warming_Burning	4.72 ***
Bitter	0.53

*** p < 0.001, ** p < 0.01, * p < 0.05

Appendix C

Welch's T-Tests

```
Welch's Two Sample t-test

data:  tingle.0 and tingle.900
t = 2.7715, df = 69.857, p-value = 0.007146
alternative hypothesis: true difference in means is not equal to 0
95 percent confidence interval:
  2.623608 16.093465
sample estimates:
mean of x mean of y
 21.27805  11.91951


Welch's Two Sample t-test

data:  tingle.300 and tingle.900
t = 1.4373, df = 68.912, p-value = 0.1551
alternative hypothesis: true difference in means is not equal to 0
95 percent confidence interval:
 -1.914375 11.782668
sample estimates:
mean of x mean of y
 16.85366  11.91951



Welch's Two Sample t-test

data:  warm.0 and warm.900
t = 3.3986, df = 72.244, p-value = 0.001105
alternative hypothesis: true difference in means is not equal to 0
95 percent confidence interval:
  5.476141 21.011664
sample estimates:
mean of x mean of y
 25.77317  12.52927


Welch's Two Sample t-test

data:  warm.300 and warm.900
t = 2.1863, df = 66.6, p-value = 0.03231
alternative hypothesis: true difference in means is not equal to 0
95 percent confidence interval:
  0.8177176 17.9969166
sample estimates:
mean of x mean of y
 21.93659  12.52927
```

```
Welch's Two Sample t-test

data:  bit.0 and bit.900
t = 0.37793, df = 77.566, p-value = 0.7065
alternative hypothesis: true difference in means is not equal to 0
95 percent confidence interval:
 -2.821174  4.143125
sample estimates:
mean of x mean of y
 3.926829  3.265854


Welch's Two Sample t-test

data:  bit.300 and bit.900
t = 0.3509, df = 80, p-value = 0.7266
alternative hypothesis: true difference in means is not equal to 0
95 percent confidence interval:
 -3.110455  4.442162
sample estimates:
mean of x mean of y
 3.931707  3.265854
```

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Academic Vita for Lisa Keim

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Education

The Pennsylvania State University, Schreyer Honors College, University Park, PA
College of Agricultural Sciences; Bachelor of Science in Food Science May 2018
Smeal College Business Fundamentals Certificate

Honors Thesis Topic: Acute vanillyl butyl ether desensitization on the human tongue

Honors/Awards: Dean's List (6 semesters); Schreyer Academic Excellence Scholarship; NMSC Special Scholarship; Theola F. Thevaos Honors Scholarship in the College of Agricultural Sciences; Beliasov Family Scholarship in Food Science; Oswald Scholarship; Dean and Harriet Girton Scholarship in Food Science; NASA Pennsylvania Space Grant Consortium WISER/STARTUP

Experience

Quality Assurance Intern, Martin's Famous Pastry Shoppe, Inc., Chambersburg, PA *Summer 2017*

- Created process flow diagrams with quality control points to assist in SQF Quality Code implementation and compliance
- Developed and documented standardized packaging procedures to reduce waste and prevent mislabeling recalls
- Developed product with natural mold inhibitors to improve shelf life and consumer acceptability
- Compared texture attributes of fresh, frozen, and aged product to confirm international product quality after storage and shipping
- Created process control charts for product weights from 250,000 data points collected across 6 months and 5 production lines

Sensory Technician, Sensory Evaluation Center, Penn State *May 2015 to present*

- Conducted descriptive, discrimination, and hedonic tests for companies, government agencies, and university students
- Compiled data into reports for clients

Summer Scholar Intern, Cornell University, Geneva, New York *Summer 2016*

- Applied organic chemistry and food chemistry principles to quantify carotenoid levels in kale using high-performance liquid chromatography and ChemStation software
- Presented findings to professors, peers, and the public at poster session

Research Assistant, Food Science Sensory Department, Penn State *January 2015 to May 2016*

- Administered weekly one-on-one evaluations with participants to quantify capsaicin desensitization
- Contributed to experimental design; prepared treatment and control solutions
- Worked effectively and coordinated with graduate and undergraduate team members

Intern, Chester County Food Bank, Exton, PA *May 2014*

- Processed and repacked foods for distribution; worked on local farms; distributed food at food pantries

Activities and Memberships

Gamma Sigma Delta Honor Society *February 2018 to present*

Sensory Evaluation of Foods Teaching Assistant *August 2017 to present*

Food Science Club, Penn State *August 2014 to present*

- Secretary *August 2017 to present*
- Ag Student Council Representative *August 2015 to May 2017*

IFTSA Product Development Teams, Penn State *September 2014 to present*

Institute of Food Technologists *September 2014 to present*

Penn State IFC/Panhellenic Dance Marathon OPPerations Committee *September 2016 to present*