The Investigation of Food Neophobia and Bitterness Sensitivity on Food Preference in Familiar and Unfamiliar Fruits and Vegetables in California Elementary Schools

A Thesis

presented to

the Faculty of California Polytechnic State University,

San Luis Obispo

In Partial Fulfillment

of the Requirements for the Degree

Master of Agriculture in Food Science and Nutrition

by

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November 2018
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TITLE: The investigation of Food Neophobia and Bitterness Sensitivity on Food Preference in Familiar and Unfamiliar Fruits and Vegetables in California Elementary Schools.

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5 ABSTRACT

The goal of this study was to understand the relationship between food neophobia and bitterness in consumer liking. Fruit and vegetable consumption is necessary for elementary school children to build healthy habits. Free and reduced lunch programs (FRL) in schools provide nutritional opportunities to students. Bitterness sensitivity and food neophobia were examined as separate drivers of liking in acceptance testing (n=161, ages 6-12) from two local elementary schools (high and low %FRL). The food neophobia scale and the fruit and vegetable neophobia instrument (FNVI) were used to determine food neophobia. FNVI scores distinguished consumers in hierarchical cluster analysis of overall liking. FVNI scores correlated to texture liking and flavor liking in familiar and unfamiliar fruits and vegetables. Non-bitter sensitive participants unexpectedly exhibited more neophobia than bitter sensitive participants. Neophobic participants liked familiar products more than unfamiliar products. Bitter sensitive participants were less neophobic and preferred bitter vegetables.

6 INTRODUCTION

Fruit and vegetable consumption is important during childhood to establish healthy eating habits. Children do not consume enough fruits and vegetables to meet the USDA dietary guidelines ("State of the Plate ", 2015). Consuming fruits and vegetables may also reduce the risk of childhood obesity and other chronic dietary-related diseases such as coronary heart disease (CHD), some cancers, heart disease, stroke, cataracts, and hypertension (Van Duyn & Pivonka, 2000). Children from lower class economic households are at higher risk for dietary chronic diseases (Sturm & Datar, 2005). School breakfast programs are an important opportunity to provide nutritional opportunities to
young children. Increasing the nutritional quality of foods consumed throughout the
school day can mitigate this trend for at-risk populations (Datar & Nicosia, 2016). The
free and reduced lunch (FRL) program is a national American government sponsored
program to provide nutritional opportunities to low income students in schools. The
average percent of free and reduced lunch eligibility in California is 58.6% and San Luis
Obispo county is 43.1% (California Department of Education). The FRL program can
provide fruit and vegetable access to low income students (Robinson-O’Brien, Burgess-
Champoux, Haines, Hannan, & Neumark-Sztainer, 2010). Many studies have been done
in school to increase vegetable awareness, exposure, and consumption in schools
(Triador, Farmer, Maximova, Willows, & Kootenay, 2015). Nutritional studies indicate
there are appropriate nutritional and behavioral interventions to increase fruit and
vegetable components in school (Cullen et al., 2007; Hutchinson et al., 2015; M.
Laureati, Bergamaschi, & Pagliarini, 2014; Morris & Zidenberg-Cherr, 2002). Therefore,
schools are an appropriate environment to study and increase exposure and consumption
levels of fruits and vegetables in children.

Children tend to find vegetables less appealing than fruits and other food groups.
Children consider vegetables to be harder and more bitter than other food groups.
Bitterness and hardness may act as drivers for vegetable dislike in children (Poelman,
Delahunty, & de Graaf, 2017). Stokkom et al. (2016) found vegetables have lower taste
intensities than other food groups. Among all vegetables, cruciferous vegetables are one
of the lowest consumed groups (Shen, Kennedy, & Methven, 2016). Poelman et al.
(2017) found children perceive both cruciferous and non-cruciferous vegetables as more
bitter in taste and harder in texture compared to adults. This may be due to specific
bitterness compounds within these vegetables including glucosinolates. Shen et al. (2016) evaluated (n=136) liking of bitter vegetables (broccoli and white cabbage) and non-bitter vegetables (spinach and zucchini), and the results indicated that phenotype and genotype both affect bitter taste sensitivity; however, these alone cannot predict vegetable liking and intake. Differences in vegetable preference can be explained by bitterness sensitivity, especially to propylthiouracil (Dinehart, Hayes, Bartoshuk, Lanier, & Duffy, 2006).

Propylthiouracil (PROP) is a bitterness compound used to detect bitterness sensitivity in humans. Bitterness preference is described by genotype and phenotype in humans. Bitterness sensitivity to PROP is determined by the TAS2R38 gene in humans (Hayes et al., 2011). PROP sensitive participants may perceive some vegetables as more bitter than non-tasters (Dinehart et al., 2006). PROP is similar to less bitter compounds PTC and thiourea as they all contain a N-C=S moiety (Sandell & Breslin, 2006). There is evidence for consumer behavior difference by PROP sensitivity. PROP sensitive individuals rate certain stimuli higher than non-tasters (Yang, Hollowood, & Hort, 2014). For example, discriminative ability among flavor and texture attributes increased with PROP sensitivity in custards (de Wijk, Dijksterhuis, Vereijken, Prinz, & Weenen, 2007). PROP sensitive individuals may perceive flavors as more intense than non-sensitive individuals. Hayes et al.(2010) found PROP tasters prefer higher sodium foods to lower sodium foods. Similarly, non-tasters may prefer sweeter flavors as tasters put more sugar in their coffee compared to tasters (Masi, Dinnella, Monteleone, & Prescott, 2015). However, genetic sensitivity to PROP does not effectively predict sweetness ratings or hedonic responses to sucrose solutions (Drewnowski, Henderson, Shore, & Barratt-Fornell, 1997). Hayes (2013) found people with naturally high bitter thresholds can
tolerate and accept foods with higher bitterness. Therefore, it is possible PROP sensitivity may affect liking scores of attributes including flavor and texture. PROP sensitivity may affect consumer behavior by influencing perception of flavors, and potentially translate to other food behaviors such as food neophobia.

Methods for determining PROP sensitivity include using single or multiple bitterness solutions or bitterness strips ranging in concentrations from 1.0 µM-3.2 mM PROP (Kendra I. Bell & Beverly J. Tepper, 2006; Drewnowski et al., 1997; Nagai, Kubota, Morinaga, & Higashiyama, 2017; Sharafi, Hayes, & Duffy, 2013). Drewnowski et al. (1997) This method lends more insight into bitterness sensitivity experiments to detect more variability in preference. However, it is difficult to execute in an uncontrolled environment such as an elementary school. Using paper strips to determine PROP taster status and PROP thresholds has been validated to determine bitterness in adults and children (Chaithanya. E. D, 2014; Desai, Smutzer, Coldwell, & Griffith, 2011).

Food neophobia is the reluctance to eat and/or avoidance of novel foods (Pliner & Hobden, 1992). Food neophobia developed in humans to prevent selection of potentially dangerous foods (Pliner & Hobden, 1992). Food neophobia today may have nutritional detriments as it may limit selection and potentially decrease vital nutrient intakes (Grace A. Flaciglia, Sarah C. Couch, Laura Siem Gribble, Pabst, & Robet Frank, 2000). Factors that affect food neophobia include age, food exposure, interest in new foods, and concern about trying unknown foods (Hely Tuorila, 2001; Pliner & Hobden, 1992). Pliner (1994) found that exposure, parental food neophobia, and child unwillingness to try new foods have all been described as predictors of food rejection in children (Pliner, 1994). Children
who are self-reported to be neophobic have more drastic reactions to the appearance of food appearance than those who do not (Maratos & Staples, 2015). Food aversion due to food neophobia is reversible, as a study with primary aged children found that sensory interventions and sensory education decrease food neophobia (Mustonen & Tuorila, 2010). Hence, childhood is an appropriate time to study food neophobia.

While food neophobia influences eating behavior across all ages, it is especially prevalent in young children (Grace A. Flaciglia et al., 2000). Food neophobia in children can be studied through questionnaires, behavior observations, and novel and familiar food presentations in evaluated exposure levels (Pliner, 1994). Strong drivers that determine childhood neophobia include exposure and parental neophobia (Pliner, 1994). Attributes of food that may affect willingness to try new foods include appearance, food origin, and perceived flavor. Pliner (1994) determined unfamiliarity and predicted dislike had significant impact on child neophobia. This is the foundation for studying food neophobia in children, and it is therefore important to understand child willingness to try an unfamiliar products. Understanding food neophobia in children is critical to increase fruit and vegetable consumption in children.

The food neophobia scale (FNS) was developed and validated by Pliner and Hobden (1992). The FNS contains 10 questions to evaluate food neophobic behavior with responses from strongly disagree to strongly agree. Higher scores represent higher neophobia, and lower scores suggest lower neophobia on the FNS. Food neophobia has also been described as greater than or equal to average score of two (Meiselman, King, & Gillette, 2010). The FNS has been used to evaluate neophobia in young children. Rubio et al. (2008) validated a French FNS (n=603, 5-8 year olds). Laureati et al. (2015)
validated an Italian neophobia scale with children (ICFNS) (n=491, ages 6-9) with a five point questionnaire and food samples (Monica Laureati, Bergamaschi, et al., 2015). The fruit and vegetable neophobia instrument (FVNI) was developed by Hollar et al. (2013) to evaluate aversion to fruit and vegetable products in children. The FNVI differs from the FNS in that it is longer and does not contain a neutral option within 1-4 scale (definitely not to definitely). The FVNI is newer than the FNS, lends insight into fruit and vegetable neophobia in children, and it has the opportunity to be more specific than the traditional FNS.

Since food neophobia and bitterness sensitivity are often studied separately, the direct relationship between PROP bitter sensitivity and neophobia remains unclear. There is evidence that they may separately affect food choice and consumption levels. Food neophobia is often studied as food aversion and food choice while PROP sensitivity has been examined with taste preferences and vegetable consumption (Carney et al., 2018). Food neophobia may be a stronger driver in food consumption levels than PROP sensitivity in children (Tsuji et al., 2012). Food liking may be the link to further investigate this relationship between food neophobia and bitterness sensitivity. Since there are relatively few studies that examine these drivers together, there is an opportunity to study food neophobia related to bitterness in a consumer liking test.

The objective for this study is to investigate food neophobia and bitterness sensitivity on food preference of familiar and unfamiliar fruit and vegetable products in San Luis Obispo, California elementary schools.
7 LITERATURE REVIEW

7.1 Introduction

School breakfast programs are an important opportunity to provide proper nutrition to elementary school students everyday. The prevalence of dietary related chronic diseases, including obesity, is rising in children. This epidemic drastically impacts children who come from lower-class economic households (Sturm & Datar, 2005). Increasing the nutritional quality of foods consumed throughout the school day can mitigate this trend for at-risk populations (Datar & Nicosia, 2016). This literature review will discuss school breakfast and lunch requirements, fruit and vegetables in schools, nutrition, consumer acceptance, plate waste, cruciferous vegetables, bitterness sensitivity, and food neophobia.

7.2 School Breakfast Needs and Requirements

Free and reduced school meal programs are necessary to provide substantial nutrition to children from low-income households. In school cafeterias, students are presented with separate whole grain and fruit products. Students qualifying for free-reduced breakfast programs must purchase two servings of whole grain and two servings of fruit for breakfast. Whole grain breakfast items must contain at least 50% formula weight of whole grain wheat. Fruit serving must be ¼ cup per food item to qualify as a fruit serving. Students must select all of these items to purchase these items; however, consumption is not required.
7.3 Free and Reduced Lunch Program

The Free and Reduced Lunch Program is a national government sponsored program to help students have nutritional opportunity in schools. Free and reduced breakfast and lunch (FRL) programs have strict guidelines on the amount of fruit and vegetable servings in meals to provide nutritional opportunities for underprivileged children. Children qualify for free reduced lunch (FRL) if their guardians make less than a certain amount of money per year with a certain number of dependents outlined in Appendix 1. The average of free and reduced lunch eligibility in California is 58.6% and in San Luis Obispo County is 43.1% (Appendix 2).

For many children, school is a potentially valuable source of fruit and vegetables as part of their daily meals. Schools do not necessarily have a larger impact on nutrition than household and other eating opportunities. However, school breakfast and lunch programs should not be discredited and should still be recognized as valuable eating opportunities for kids. For children who have low access to fruits and vegetables, schools can be a place to access these products. This is not necessarily the case for children of privilege who have the potential access to fruits and vegetables via other opportunities.

7.4 Fruit, Grain, and Vegetable Products in Schools

There are many individual grain and fruit products that exist in school breakfast programs. Typical grain products include muffins, breads, doughnuts, bars, etc. Fruit products exist as whole fruit, canned fruit, pre-cut fruit, and juice options. Vegetable products are presented as fresh through a salad bar or mixed in cooked food dishes such as peas in spaghetti (Marlette, Templeton, & Panemangalore, 2005). Products with both
fruit and grain components that meet federal requirements do not currently exist in schools. Novel fruit and grain products have been used before in other applications successfully for children outside of school settings (Potter et al., 2013). Dried fruit such as raisins has been combined with grain products to produce consumer acceptable products (Marlette et al., 2005). Nicklaus (2015) found that the addition of fruit increases food product acceptability to children.

Current fruit and vegetable products in California elementary schools include a variety of California grown fruits and vegetables. This is dependent on the school lunch program availability and budget. Fruits such as apples, bananas, and strawberries can be easily found on the menu. Vegetables such as broccoli, carrots, and celery can easily be found in salad bars in the school cafeteria. These nutritional opportunities are important to increase fruit and vegetable consumption.

### 7.5 Consumption in Schools

Eating occasions in school are an important opportunity for fruit and vegetable consumption for children. This is especially true as fruit and vegetable consumption is lower in children than the recommended dietary allowance (Mary Story, 2017). School breakfast and lunch programs have fruit and vegetables requirements that are dictated by law. In California schools, fruits and vegetables are served through a salad bar in the cafeteria. The products on the salad bar consist of multiple raw fruits and vegetables depending on the availability. Many studies have been done in school to increase vegetable awareness, exposure, and consumption to increase fruit and vegetable exposure in schools (Triador et al., 2015). Nutritional studies indicate there are appropriate
nutritional and behavioral interventions to increase fruit and vegetable components in school (Cullen et al., 2007; Hutchinson et al., 2015; M. Laureati et al., 2014; Morris & Zidenberg-Cherr, 2002). Gardening interventions can also be used in this age group to increase fruit and vegetable preference in children (Hutchinson et al., 2015).

7.6 Plate Waste

Understanding consumption of unfamiliar, novel products may help increase consumption. One method to study consumption in school environments is plate waste. Plate waste testing measures the amount of food uneaten by a consumer through various methods including recall, weighing, and visual-digital. Recall plate waste is easy for researchers to conduct, but it may not visual-digital methods plate waste are effective and efficient method to monitor school cafeterias (Parent, Niezgoda, Keller, Chambers, & Daly, 2012). This method includes using photography after purchase of a school lunch tray and before disposal to estimate the amount of portions consumed and unconsumed by a consumer. Visual plate waste methods are effective in determining the amount consumed by children in cafeteria setting (Connors & Rozell, 2004). Plate waste could be an appropriate method to test consumer acceptability and indication of liking in school environments due to its adaptability to different cafeterias (Marlette et al., 2005).
Table 1: Acceptance and plate waste of offered school lunch items by sixth-grade students in three separate schools in Kentucky over 2 academic years, fruit (N=743) Source: (Marlette et al., 2005).

<table>
<thead>
<tr>
<th>Food group</th>
<th>No. Students offered to</th>
<th>% Students Accepted by</th>
<th>% Average Plate Waste</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Fruit</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Apple, fresh</td>
<td>656</td>
<td>23</td>
<td>62</td>
</tr>
<tr>
<td>Applesauce</td>
<td>105</td>
<td>37</td>
<td>23</td>
</tr>
<tr>
<td>Orange</td>
<td>481</td>
<td>8</td>
<td>54</td>
</tr>
<tr>
<td>Pears, sliced,</td>
<td>152</td>
<td>30</td>
<td>16</td>
</tr>
<tr>
<td>canned Frozen</td>
<td>144</td>
<td>42</td>
<td>35</td>
</tr>
<tr>
<td>fruit juice bar</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 1 shows that fruit has extremely high levels of plate waste in all product forms. Plate was can be reduced by introducing prepared food instead of whole fruit products. The highest percent of plate waste comes from fresh fruits. On the contrary, more processed fruit was consumed at higher rates than the raw items. Combining these food groups into a fruit and grain bar may result in lowering food waste in cafeteria settings. Measuring plate waste by using fruit and grain products is critical to assessing consumer acceptance in schools (Marlette et al., 2005). Plate waste is relevant information for researchers; however, it will not be investigated in this thesis.

7.7 Nutrition

Inclusion of fruit and whole grain in diets reduces the risk of chronic diseases such as obesity, diabetes, and cardiovascular disease (Williamson and Carughii 2010). Whole grain includes dietary fiber that increases satiety and lowers blood sugar (Clark & Slavin, 2013). Fruit and whole grain bars contained important nutritional components including fiber, vitamins, and minerals. Food form, including dried and processed fruit,
may not necessarily destroy valuable nutrients including fiber when compared to fresh fruit (Chang, Alasalvar, & Shahidi, 2016). Potter (2013) demonstrated different fiber levels in fruit and grain products in Figure 1.

![Figure 1. Insoluble, soluble, and total dietary fiber content of the non-extruded (NE) and extruded samples (Potter et al., 2013).](image)

Potter et al (2013) used carbohydrate analysis including C-cell analysis, soluble fiber and insoluble fiber analysis to measure fiber amount. The results showed addition of strawberry and banana added the most fiber to the products. Adding fruit has been shown to increase the nutritional value of the food product and overall liking. Novel food products in the form of fruit and grain products may increase fruit consumption and product liking in children.

7.7.1 Sensory Testing

Sensory testing is the scientific discipline used to evoke, measure, analyze, and interpret reactions to those characteristics of foods and materials as they are perceived by the senses of sight, smell, taste, touch, and hearing (Stone, Bleibaum, & Thomas, 2012)
A brief review of acceptance testing and sensory application with children will be covered.

### 7.7.2 Consumer Acceptance Testing

Acceptability testing is the most common method used to determine consumer liking of a product. It is also denoted as preference testing and consumer liking testing. An acceptance test evaluates how much the product is liked by consumers. Consumer acceptance testing is often measured with a hedonic likert scale. Hedonic testing is effective for predicting product success by measuring the consumer liking of the product. The hedonic scale can be presented in five, seven, or nine points and use verbal or facial scales (Nicklaus, 2015).

### 7.7.3 Consumer Acceptance Testing with Children

Children have different needs than adults in sensory testing, as children are more at risk to cognitive fatigue due to shorter attention spans. Facial hedonic scales are used to accommodate for cognitive fatigue as it is easier to focus on the faces, and not the written number (Meilgaard, Civille, & Carr, 2007). Hedonic testing with five and seven-point facial scales has been effective for evaluating liking in children for novel products. The five-point and the seven-point hedonic scale are popular methods to evaluate children because it has low consumer fatigue during testing (Guinard, 2001). Figure 2 shows an example of a seven-point hedonic face-measuring liking with a likert scale.
Potter et al (2013) used a seven-point hedonic scale to determine that tangerine fruit added improved the acceptability of whole grain and fruit products when compared to a control among participants (n=48, ages 8-9). Product attributes including color and appearance affected the liking of fruit products. Testing students in this age range produces effective results for novel food product development.

### 7.8 Vegetable Preference Among Children

Children tend to find vegetables less appealing than fruits and other food groups. Children consider vegetables to be harder, more bitter, and less tasty compared to other food groups. Bitterness is also a driver of dislike in vegetables in children (Poelman et al., 2017). Stokkom et al (2016) examined the taste intensities of sweetness, sourness, bitterness and umami, saltiness, and fattiness for cauliflower, broccoli, leek, carrot, onion, and red bell pepper with a trained panel, and researchers verified vegetables have lower
taste intensities. Hardness can be a driver to dislike because it is harder to chew. Cooked vegetables are more liked than raw vegetables (Stokkom et al., 2016). To make vegetables more acceptable, it can be beneficial to cook them or change the texture to make vegetables more appealing.

7.9 U.S. Fruit and Vegetable Consumption

Many Americans eat much less fruit and vegetables than recommended, especially dark green vegetables (Guenther, Dodd, Reedy, & Krebs-Smith, 2006). As a whole population, the U.S. population eats slightly less vegetables now than five years ago. According to the State of the Plate vegetable consumption log, total fruit and vegetable consumption in the US is down by 6%-7% from 2010 ("State of the Plate ", 2015). This decrease does not apply to California, as fresh fruit products within California have increased over the last five years. However, children in California still do not consume enough fruits and vegetables. There is an trend for increasing fresh products consumption in the USA ("State of the Plate ", 2015). The increase in fresh fruit trends in California will translate to a market demand from California agriculture not only within California, but potentially nation wide. Fruits and vegetables have protective qualities on human health (Block, Patterson, & Subar, 1992). It is important to consume fruits and vegetables to establish healthy eating habits. Vegetable consumption is important for a healthy lifestyle. There is evidence that vegetables reduce the risk of chronic disease in a population. Hung et al. (2004) found a positive association between consumption of green vegetables and reduction of chronic disease among adults. Therefore, increasing cruciferous vegetable consumption could be important for long-term human health.
7.10 U.S. Children Fruit and Vegetable Consumption

Children in the United States do not consume enough fruits and vegetables to meet the USDA Dietary guidelines ("State of the Plate", 2015). It is important for children to consume fruits and vegetables to build healthy habits for adulthood. Consuming fruits and vegetables also may reduce the risk of childhood obesity and other dietary chronic related diseases such as coronary heart disease (CHD), some cancers, heart disease, stroke, cataracts, and hypertension (Van Duyn & Pivonka, 2000). Dietary related chronic disease is a major concern as it affects a large population of the US. Chronic disease affects one out of five Americans, and many have multiple conditions (CDC, 2018). These conditions contribute to major healthcare costs in the United States. Preventive measures such as diet can be used to mitigate the risk of chronic disease in the U.S. population. There is a need for higher fruit and vegetable consumption in children as it is important to build healthy habits at a young age to contribute to the reduction of risk to these dietary related chronic diseases.

7.11 California Fruit and Vegetable Production

California is the leading fruit and vegetable producer in the United States. The most common fruits and vegetables produced in California can be seen in Table 2. Highlighted products are studied in this thesis.
Table 2: List of Top Selling Fruits and Vegetables from California Agriculture Review (Jr., 2016).

<table>
<thead>
<tr>
<th>Fruits</th>
<th>Vegetables</th>
</tr>
</thead>
<tbody>
<tr>
<td>Apricots</td>
<td>Olives</td>
</tr>
<tr>
<td>Blueberries</td>
<td>Oranges</td>
</tr>
<tr>
<td>Cantaloupe Peaches</td>
<td>Broccoli</td>
</tr>
<tr>
<td>Dates</td>
<td>Peaches, Freestone</td>
</tr>
<tr>
<td>Dried Plums</td>
<td>Peaches, Clingstone</td>
</tr>
<tr>
<td>Figs</td>
<td>Plums</td>
</tr>
<tr>
<td>Grapes</td>
<td>Plums, Dried</td>
</tr>
<tr>
<td>Honeydew</td>
<td>Pomegranates</td>
</tr>
<tr>
<td>Kiwifruit</td>
<td>Raspberries</td>
</tr>
<tr>
<td>Kumquats</td>
<td>Strawberries</td>
</tr>
<tr>
<td>Lemons</td>
<td>Tangerines</td>
</tr>
<tr>
<td>Limes</td>
<td>Tomatoes</td>
</tr>
<tr>
<td>Nectarines</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Vegetable</th>
<th>Fruits</th>
</tr>
</thead>
<tbody>
<tr>
<td>Artichokes</td>
<td>Lettuce, all</td>
</tr>
<tr>
<td>Asparagus</td>
<td>Mushroom, Agaricus</td>
</tr>
<tr>
<td>Broccoli</td>
<td>Onions</td>
</tr>
<tr>
<td>Cabbage</td>
<td>Peppers, Bell</td>
</tr>
<tr>
<td>Carrots</td>
<td>Peppers, Chili</td>
</tr>
<tr>
<td>Celery</td>
<td>Pumpkins</td>
</tr>
<tr>
<td>Corn, Sweet</td>
<td>Romaine lettuce</td>
</tr>
<tr>
<td>Cucumbers</td>
<td>Spinach</td>
</tr>
<tr>
<td>Garlic</td>
<td>Squash</td>
</tr>
<tr>
<td>Lettuce, Head</td>
<td>Tomatoes</td>
</tr>
<tr>
<td>Lettuce, Leaf</td>
<td></td>
</tr>
<tr>
<td>Tomatoes</td>
<td></td>
</tr>
</tbody>
</table>

The main cruciferous vegetables grown in California are broccoli, cabbage, and cauliflower. These are critical vegetables to serve in California schools to increase cruciferous vegetable consumption. Table 3 depicts the production value of studied products, and the bitter vegetables are highlighted.

Table 3: California vegetable production measured in $ with cruciferous vegetables highlighted from USDA database (USDA) (Database, 2018).

<table>
<thead>
<tr>
<th>Product</th>
<th>Production Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Strawberries</td>
<td>$3,100,215,000</td>
</tr>
<tr>
<td>Broccoli</td>
<td>$850,183,000</td>
</tr>
<tr>
<td>Celery</td>
<td>$302,067,000</td>
</tr>
<tr>
<td>Cauliflower</td>
<td>$295,882,000</td>
</tr>
</tbody>
</table>
7.11.1 Cruciferous Vegetables

The brassicaceae vegetable (BV) family, also known as cruciferous vegetables, is an important vegetable group to consume. Products include cabbages, or mustard plants such as bok choy, broccoli, Brussels sprouts, cauliflower, cabbage, choy sum, garden cress, red cabbage, mustard greens, rutabaga, and turnips. BVs contain important nutrients including: vitamins, minerals, fiber, non-starch polysaccharides and protective phytochemicals such as the following: flavonoids, aglycones, lutenins, and retinoids, carotenoids, glucosinolates, and indoles (Cartea, Francisco, Soengas, & Velasco, 2010) & (Van Duyn & Pivonka, 2000) & (Jahangir, Kim, Choi, & Verpoorte, 2009). These compounds have antioxidant, anti-carcinogenic, anti-mutagenic activity and cardiovascular protective activities (Beecher, 1994; Cartea et al., 2010). Murillo and Mehta (2001) published a review to outline compounds in BV exhibiting anti-mutagenic effects that may potentially reduce the risk of dietary related chronic diseases when added to the diet. However, these mechanisms are not fully established (Murillo & Mehta, 2001).

7.11.2 Glucosinolates

Cruciferous vegetables contain bitterness compounds similar to phenylthiocarbamide (PTC) called glucosinolates (Fahey, Zalcman, & Talalay, 2001). The chemical structure of glucosinolates are similar to PROP and PTC as they contain a thiourea moiety (N-C=S) (Sandell & Breslin, 2006). Glucosinolates may be responsible for the chemo-protective properties of cruciferous vegetables; however, these are also linked to lower consumer acceptance due to their bitter flavor. At high levels, these bitter
tasting compounds can have mutagenic properties and have potentially toxic effects (Jahangir et al., 2009). Aversion to bitter foods has evolved in humans to avoid products with potentially toxic or poisonous compounds. Therefore, it is important to investigate the effect of these bitter compounds on vegetable liking and consumption.

### 7.12 Consumption of Cruciferous Vegetables

Consumption rates of cruciferous vegetables are lower than other vegetable groups (Shen et al., 2016). Bitterness compounds in cruciferous vegetables may affect liking and consumption. Shen, Kennedy and Methven (2016) evaluated (n=136) liking of bitter vegetables (broccoli and white cabbage) and non-bitter vegetables (spinach and zucchini). Results indicated that phenotype and genotype both affect bitter taste sensitivity; however, these alone cannot predict vegetable liking and intake. Vegetable consumption of liking can also be driven by demographics such as age and gender (Shen et al., 2016). Differences in vegetable preference can be explained by bitterness sensitivity, especially to propylthiouracil (Dinehart et al., 2006).

### 7.13 Children and Consumption Preferences

Children have different food preferences and perceptions than adults in regards to flavor and texture of products. Poelman, Delahunty, and de Graff (2017) found children perceive vegetables as more bitter in taste and harder in texture compared to adults. The researchers tested cruciferous vegetables and non-cruciferous vegetables in different attributes. Children also score vegetables low in flavor compared to other food groups, which increases the need to understand vegetable acceptability in children. Children’s
food consumption is commonly believed to be appearance and flavor driven; however, there is evidence texture may play a role in acceptability. Werthermann et al (2015) conducted a study of texture preference among 32 children (3-4 years old) and their parents and determined texture significantly altered preference of yogurts. Children acceptance of food products may be driven by both flavor and texture. Parental perspectives can also provide valuable information and insight into child food preference and behavior. This use of both children and parental preferences successfully assesses children consumption and preference of foods.

7.13.1 Opportunity for Research

There is an opportunity to understand how dietary related disease, vegetable consumption, food preference, and California agriculture all contribute to reducing the risk of dietary chronic disease and increasing vegetable consumption. It would be wise to understand how consumer acceptance of California agriculture products could potentially be used to reduce the risk of dietary related chronic disease. It is also important to understand food preference to increase variety of California fruits and vegetables in the population. Overall, better understanding of this relationship and market demand can increase sales in California agriculture products and reduce health care costs in the US. This opportunity may be addressed by sensory evaluation of cruciferous vegetables through genotypic attributes such as bitterness sensitivity, and behavioral aspects such as food neophobia affect consumption of cruciferous vegetables.
7.13.2 **Cruciferous Vegetables and Bitterness**

Common flavors associated with cruciferous vegetables include bitter, acidic, or astringent taste (Jahangir et al., 2009). Cruciferous vegetables contain bitter compounds called glucosinolates in the consumed part of the plants including: leaves, terminal leaf buds, loose heads, vegetative buds, and inflorescences, and stems (Sandell & Breslin, 2006). Bitterness compounds are found in cooked and uncooked cruciferous vegetables.

To what extent are bitterness compounds present in cooked and uncooked cruciferous vegetables? Erwan and Engal (2002) examined the correlation between glucosinolates and bitterness intensity in cooked and uncooked cauliflower. Odor active compounds are linked as deterrents to cauliflower liking, and bitterness compounds were still evident even in cooked cauliflower. This may explain some bitterness testing aversion in cooked and uncooked cauliflower. Processing vegetables with heating and other cooking steps may reduce the bitterness compounds and increase acceptability; however, lower amounts of bitterness compounds may still remain in cooked vegetables.

Stokkom et al (2016) used cluster analysis was used to establish patterns in discrimination in sensory attributes between vegetables, including raw and cooked broccoli and cauliflower. Cooked broccoli was significantly less bitter than raw broccoli, and comparable to cooked cauliflower; however, there was no significant difference between raw and cooked cauliflower bitterness scores. Since raw and cooked broccoli and cauliflower both contain glucosinolates, it is possible for supertasters to be sensitive to tastes of both raw and cooked products. Hence, both raw and cooked vegetables have the bitterness compounds hypothesized to have potential health benefits. Testing the
uncooked cruciferous vegetables in this study will show the differences between bitter and non-bitter taster and reflect products in the school environment.

7.13.3 Bitterness Masking

To what extent can scientists mitigate bitterness to increase acceptability? Bitterness in foods can be masked or mitigated to increase acceptability and consumption. For future work, it may be important to understand how to increase consumption in vegetables for bitter sensitive individuals. Sharafi et al (2013) conducted a study (n=37 adults) tested the use of sodium salts to improve acceptability of dark green vegetables in adults. High intensity sweeteners can also be used to mask bitter compounds in medical settings (Wu et al., 2016). There is potential to increase cruciferous vegetable acceptability and consumption with these bitterness-masking techniques. This thesis would like to recognize the development in this field; however, it will not investigate bitterness masking.

7.14 Bitterness and Propylthiouracil

Propylthiouracil (PROP) is a bitterness compound used to detect bitterness sensitivity in humans. Bitterness preference is described by genotype and phenotype in humans. Bitterness sensitivity to PROP is determined by the TAS2R38 gene in humans (Hayes et al., 2011). Prop tasters have dominant alleles that code for bitterness receptors on the tongue, and non-tasters have non-dominant alleles. PROP sensitive participants may perceive some vegetables as more bitter than non tasters (Dinehart et al., 2006). PROP is similar to less bitter compounds PTC and thiourea. This review will discuss the
relationship between bitterness and demographics, methods of determining bitterness sensitivity, the role of genetics in determining bitter sensitivity, and super taster status.

### 7.14.1 Bitterness Sensitivity, Demographics, and Fungiform Papillae

Studies have examined bitter and non-bitter vegetables with relationship to PROP sensitivity and demographics. Demographics including gender, age, ethnicity, and socioeconomic factors have been found to have more influence on food choice than PROP sensitivity (Shen et al., 2016). The size, shape, and density of certain taste buds (fungiform papillae) can affect liking of different food products when examined with demographics and PROP sensitivity (Hayes, Bartoshuk, Kidd, & Duffy, 2008). There is potential for fungiform papillae to have a more direct relationship with PROP (Shen et al., 2016) & (Bakke & Vickers, 2011). Demographics, fungiform papillae density, thermal tasters can also affect taster status and liking (Hayes & Keast, 2011). There is little research done with children on fungiform papillae and thermal taster status in regards to bitterness sensitivity. This may be an opportunity for future work.

### 7.14.2 Bitterness and Genotype

Multiple chemosensory genes are responsible for genetic variation and food preferences in humans. (Hayes, Feeney, & Allen, 2013) There is evidence that there are 25 unique genes are used to detect bitter flavors in humans, although the TAS2R38 is the most studied gene in humans (Hayes et al., 2013). Genotype and phenotype can explain preference outside of bitterness, such as preferences for high fat and sugar foods (Hayes & Duffy, 2008). While genetic variation have a significant determinant of PROP taster
status, there are more variables that may potentially affect PROP taster status (Hayes et al., 2008). This work builds the foundation to study between PROP sensitivity status, food preference, and dietary choices (Hayes & Keast, 2011).

7.14.3 Bitterness Sensitivity and Body Mass Index

It is important to acknowledge the potential nutritional affects PROP sensitivity may potentially have on some health parameters. PROP sensitivity has been hypothesized to relate to body mass index (BMI) and body fat percent (BF%). However, this relationship is not conclusive. Bajec and Pickering (2010) did not find a significant relationship between PROP responsiveness compared to BMI nor BF%. Nagai et al (2017) examined BMI and PROP sensitivity in Japanese college age women, and non-tasters had higher body weight and type than tasters. The taster groups ate significantly less green vegetables than tasters. This study is difficult to compare to the American population as the BMI range in Japanese and Asian cultures are not necessarily representative of Western cultures. Deshaware and Singhal (2017) examined PROP sensitivity and taster status in an Indian population with 393 participants from four different geographical areas across India. PROP taster status did not correlate to BMI or food preference. PROP sensitivity may have an indirect role on BMI, but this will not be addressed in this thesis.

7.14.4 Methods of Determining Bitter Sensitivity

Methods for determining PROP sensitivity include with the bitterness compound or solutions with different levels of bitterness. Drewnowski et al (1997) established taster status taster using solutions method to determine the status of individuals as non-taster,
medium-taster and super-tasters. PROP tasters were determined by completing a magnitude test consisting of a series of 15 PROP solutions that ranged in concentration from 1.0 µM to 3.2 mM PROP. Sharafi et al (2013) used aqueous magnitude scaling with less increments of PROP solutions (3.2, 1, 0.32, 0.1, and 0.032 mM). Nagai (2017) examined Japanese college aged women using one 0.32 mM PROP solution to determine sensitivity status. Bell and Tepper (2006) determined children’s PROP sensitivity (n=65) using 0.56 mM PROP solution They classified children as tasters or non-tasters to examine patterns in consumer acceptability and vegetable consumption. This method lends more insight into bitterness sensitivity experiments to detect more variability in preference. However, it is difficult to execute in an uncontrolled environment such as an elementary school.

Using paper strips to determine PROP taster status and PROP thresholds has been validated to determine bitterness in adults (n=81) ages 18-64 (Desai et al., 2011). Paper strips with different levels of PROP were added to determine thresholds within tasters. Chaithanya et al (2014) also used bitterness strips to study the relationship between bitterness sensitivity and teeth cavity presence in 200 children ages 6-12. Bitterness strips were 2x2 cm Whatman filter paper with approximately 1.6mg of PROP. Researchers found non-tasters had more cavities in their teeth than tasters. Bitterness sensitivity may be used as a potential predictor for cavities and food choice behavior in children.

For this study, it is acceptable to categorize children as sensitive or not sensitive to bitterness compounds, and bitterness strips may be appropriate to test with a larger population of children outside of a laboratory environment.
7.14.5 Super Tasting and Bitterness

Prop sensitive individuals can be categorized by non-tasters, tasters, and super –
tasters in relation to bitterness sensitivity. Super tasters are categorized by perceived
intensity, as they perceive bitterness more intensely than regular tasters (Hayes & Keast,
2011). Taster status is mostly determined by genetics such as the presence of the
TAS2R38 gene and other TAS2R genes (Hayes et al., 2011). Conversely, the presence of
PROP sensitivity TAS2R38 gene does not necessarily associate with heightened taste
sensations including super tasting (Hayes & Duffy, 2008). Super taster status may be
affected by other factors than just the presence of a dominant TAS2R38 gene. These
factors may include fungiform papillae and other bitterness detection genes. There is
potential for super tasters to have different preferences normal tasters as super tasters
may rate attributes such as sweetness, sourness, saltiness and bitterness higher than less
sensitive participants (Hayes & Keast, 2011). Super tasting is important to acknowledge
because it may affect liking scores and perceptions of food products.

7.14.6 Bitterness Sensitivity and Consumer Behavior

PROP sensitivity may affect consumer behavior by influencing perception of
flavors, and potentially translate to other food behaviors such as food neophobia. PROP
sensitive individuals may perceive food attributes differently than non-sensitive
individuals. Overall, PROP super and medium tasters rate stimuli higher than non-tasters
(Yang et al., 2014). For example, discriminative ability among flavor and texture
attributes increased with PROP sensitivity in custards (de Wijk et al., 2007).
PROP sensitive individuals may perceive flavors as more intense. Hayes et al (2010) found PROP tasters prefer higher sodium foods to lower sodium foods. Similarly, non-tasters may prefer sweeter flavors as tasters put more sugar in their coffee compared to tasters (Masi et al., 2015). However, genetic sensitivity to PROP does not effectively predict sweetness ratings or hedonic responses to sucrose solutions (Drewnowski et al., 1997). Hayes (2013) found people with naturally high bitter thresholds can tolerate and accept foods with higher bitterness. Therefore, it is possible PROP sensitivity may affect liking scores of attributes including flavor and texture.

PROP tasters could have discriminative abilities that are linked to traits beyond bitterness sensitivity including flavor intensity; PROP taster status does not necessarily dictate food preference or food behavior including food adventurousness and consumption. For instance, adventurous eaters may behave like PROP tasters; however, being an adventurous food eater is not subjected to PROP taster status (Ullrich, Touger-Decker, O'Sullivan-Maillet, & Tepper, 2004). Bell and Tepper (2006) determined non-tasters consumed more vegetables than taster children, and non-taster children liked raw broccoli and consumed more vegetables more than taster children. Turnbull and Matisoo-Smith (2002) found taster children disliked spinach more than non-taster children. Hence, PROP sensitivity may explain some increase in acceptability in higher stimulus and lower consumption of bitter foods among children.

7.14.7 Bitterness Sensitivity and Food Questionnaires

Food questionnaires and other behavioral assessments are useful to study in relation to PROP sensitivity to gain more insight on consumer behavior. Nagai (2017) used a food frequency questionnaire to report consumption and preference of foods
Ulrich (2004) found other food behaviors such as food adventurousness significantly impacts liking and food choice in PROP tasters. Food adventurous participants enjoy seeking out new foods. Bitterness sensitivity is best measured in conjunction with other qualities to understand eating behavior such as consumption, food adventurous, and food neophobia.

7.15 Food Neophobia

Neophobia is the reluctance to eat and/or avoidance of novel foods (Pliner & Hobden, 1992). Food neophobia developed in humans to prevent selection of potentially dangerous foods (Pliner & Hobden, 1992). Food neophobia is a behavior derived from the “omnivores dilemma” as omnivores should eat new foods to increase variety of foods; however, novel foods may contain toxins and might be poisonous (Pliner & Hobden, 1992). Food neophobia today may have nutritional detriments as it may limit selection and potentially decrease vital nutrient intakes (Grace A. Flaciglia et al., 2000). Food neophobia is important study in children to understand food aversion in early ages.

7.16 Food Neophobia Factors

Factors that affect food neophobia are demographics, food exposure interest in new foods, new foods are interest in new foods and concern about trying unknown foods (Hely Tuorila, 2001; Pliner & Hobden, 1992). A study done by Pliner (1994) suggests exposure, parental food neophobia, child willingness to try new foods have all been described as predictors of food rejection in children (Pliner, 1994).
In the US population, food neophobia is present among many different demographics regarding gender, age, education, and income. Meiselman et al (2010) used a five point scale to measure food neophobia on two large commercial samples of US consumers in a population study (n =1567, n= 6843). Neophobia was defined as ≥ 20 on the FNS. High and low neophobia were defined as FNS > 35 and < 25. This study found neophobia in adults increased with age and decrease with exposure, education and income (Meiselman et al., 2010). Tuorila et al (2001) found neophobia in the Finnish population can be explained by exposure, income, education, and urbanization. This may be due to the fact that exposure levels are different in rural and urban environments. The FNS was also highly predictive of participant’s willingness to try new foods (Hely Tuorila, 2001).

7.16.1 Food Neophobia in Children

While food neophobia influences eating behavior across all ages, it is especially prevalent in young children. Food neophobia is usually the highest in childhood (Grace A. Flaciglia et al., 2000). Food neophobia in children can be studied through questionnaires, behavior observations, and novel and familiar food presentations in evaluated exposure levels (Pliner, 1994). Main factors that determine childhood neophobia include exposure and parental neophobia (Pliner, 1994). Attributes of food that may affect willingness to try new foods include appearance, food origin, and perceived flavor. Pliner (1994) determined unfamiliarity and predicted dislike had significant impact on child neophobia. This is the foundation for studying food neophobia in children, and it is therefore important to understand child willingness to try an
unfamiliar products. Understanding food neophobia in children is critical to increase fruit and vegetable consumption in children.

7.16.2 Child Food Neophobia and Parental Influence

Parental food neophobia is a may be used as an indicator of child neophobia, as parental FNS scores may predict child’s neophobia and willingness to try new products (Pliner, 1994). Child neophobia can be related to parental neophobia in infancy and it is possible that rejection in infancy is related to neophobia in early childhood (Moding & Stifter, 2016). Parent’s scores on the FNS can predict the willingness of children to try new food (Pliner, 1994). Hely and Tuorila (2001) found children tend to exhibit similar neophobia levels as their parents. This study will not examine parental neophobia in terms of child neophobia.

7.17 Food Neophobia and Eating Behavior

Food neophobia affects child food preference and eating behavior (Dovey, Staples, Gibson, & Halford, 2008; Galloway, Lee, & Birch, 2003; Grace A. Flaciglia et al., 2000). Food neophobic children have been documented to have different dietary patterns than non-neophobic children. However, this dietary pattern may not necessarily be nutritionally detrimental as food neophobic children do not have a significant decrease of essential macronutrients compared to non-neophobic children; however, vitamin E is the only essential nutrient lacking in the diets of neophobia children in a study done with children (n=651) in forth and fifth grade (Grace A. Flaciglia et al., 2000).
Food neophobia is related to food liking in children’s food acceptance (Howard, Mallan, Byrne, Magarey, & Daniels, 2012). Visual aspects of food, such as appearance, have a significant impact on childhood neophobia (Maratos & Staples, 2015). Children who are self-reported neophobic have more drastic reactions to the appearance of food appearance than those who do not (Maratos & Staples, 2015). Aversion due to food neophobia is reversible, as sensory interventions and sensory education decrease food neophobia scores in a study conducted with primary aged children (Mustonen & Tuorila, 2010). Hence, this is an ideal age range to examine food neophobia with a sensory consumer evaluation study.

7.17.1 Methods to Measure Food Neophobia

There are many validated questionnaires used to measure food neophobia and food behavior in humans outlined by M. Damsbo (Damsbo-Svendsen, Frost, & Olsen, 2017).

- Children’s Eating Behavior Questionnaire (CEBQ)
- Food Neophobia Scale (FNS) (Pliner & Hobden, 1992)
- Food Neophobia Questionnaire (FNQ) + Changing Neophobic Behavior + Food Presentation Situations (Rubio et al., 2008)
- Food Neophobia Scale From Children (FNSC) (Pliner, 1994)
- WilTry Instrument – Children’s willingness to try vegetables and fruits (Thomson et al., 2010)
- The Fruit and Vegetable Neophobia Instrument (Hollar et al., 2013)

The most appropriate scale is the food neophobia scale (FNS) as it is the most commonly used scale to measure neophobia in a variety of populations including children.
and adults. The FNS has been validated in studies with both adults and children. The FNSC was developed for young children below age five, and parental participation is necessary. The other scales such as FNQ, CEBQ, and Willtry, are important for understanding child eating behavior; however, these are not necessary to incorporate in this study. The study found that food preferences are strongly linked to food neophobia in pre-school children. This emphasizes the need to examine food neophobia in influencing children’s food preferences (Russell & Worsley, 2008).

7.17.2 Food Neophobia Scale

The food neophobia scale (FNS) was developed and validated by Pliner and Hobden (1992) to build the foundation of testing food neophobia in humans. The following questionnaires are presented on a 1-5 scale (agree strongly – disagree strongly), and reversed items are denoted as (R) (Figure 3).
Higher scores represent neophobia, and lower scores suggest lower neophobia on the FNS. Neophobia ranges in the United States are from 1.8-2.5 (Meiselman et al., 2010). Participants can be described via two classification methods. Pliner and Hobden (1992) classified participants as neophobic, neither neophobic nor non-neophobic, and non-neophobic participants based upon the mean score of the participants. Participants can be classified as neophobic or non-neophobic as an average response of 2.5 to 3.5 or summed to a total score of 25 to 35 (Olabi, Najm, Baghdadi, & Morton, 2009). Food neophobia has also been described as greater than or equal to average score of two (Meiselman et al., 2010). The FNS has been used to evaluate neophobia in adults and children, and it has been successfully translated to other languages such as Spanish, Italian, and French (Monica Laureati, Bergamaschi, et al., 2015; V. Fernández-Ruiz, 2013).
7.17.3 **Measuring food neophobia in children**

The FNS has been successfully used to determine food neophobia in children. Rubio et al (2008) validated a French FNS (n=603, 5-8 year olds). Researchers divided the children into five neophobia types consisting of the following: “no neophobia”, “flexible neophobia” “rigid neophobia” “strong neophobia” and “food hyper selective syndrome”. Children within different neophobic groups may have different levels and expressions of food neophobia. Placing participants in multiple groups may be advantageous to examine food neophobia behavior in detail. While this study may not investigate different levels of neophobia, it is important to acknowledge the different levels of neophobia that may exist within subjects.

Laureati et al (2015) validated an Italian neophobia scale with children (ICFNS) (n=491, ages 6-9) with a five point questionnaire shown in Figure 4 and food samples (Monica Laureati, Bergamaschi, et al., 2015). The ICFNS was found to be most effective in validating children as young as seven with a five point hedonic scale.

1. **Mangio quasi tutti i giorni cibi nuovi e diversi dal solito (R)**
   
   *I eat almost every day new and unusual foods (R)*

   ![Figure 4: Italian use of primary scale with 5 scales. Source: Assessing childhood food neophobia: Validation of a scale in Italian primary school children (Monica Laureati, Bergamaschi, et al., 2015).](image-url)
7.17.4 **Fruit and vegetable neophobia instrument**

The fruit and vegetable neophobia instrument (FVNI) was developed by Hollar et al. (Hollar et al., 2013) to evaluate aversion to fruit and vegetable products in children (Figure 5). The FVNI is different from the FNS as it is longer and does not contain a neutral option with 1-4 scale (definitely not – definitely). The first two questions in the figure were demographic questions, and not necessarily part of the FNVI (Hollar et al., 2013). The FVNI is newer than the FNS, and it lends insight into fruit and vegetable neophobia, and it has the opportunity to be more specific than the traditional FNS. It is not as well established or used in the literature as the FNS. For this experiment, using the FNS is the best to evaluate overall food neophobia and the FVNI is a new scale best to evaluate fruit and vegetable preference.

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FAV3    How much do you like fruit?
FAV4    How much do you like fruits that you have never tried?
FAV5    How much do you like tasting new fruits?
FAV6    Will you taste a fruit if you do not know what it is?
FAV7    Will you taste a fruit if it looks strange?
FAV8    Will you taste a fruit if you have never tasted it before?
FAV9    When you are at a friend’s house, will you try a new fruit?
FAV10   When you are at school, will you try a new fruit?
FAV11   When you are at home, will you try a new fruit?
FAV13   How much do you like vegetables?
FAV14   How much do you like vegetables that you have never tried?
FAV15   How much do you like tasting new vegetables?
FAV16   Will you taste a vegetable if you do not know what it is?
FAV17   Will you taste a vegetable if it looks strange?
FAV18   Will you taste a vegetable if you have never tasted it before?
FAV19   When you are at a friend’s house, will you try a new vegetable?
FAV20   When you are at school, will you try a new vegetable?
FAV21   When you are at home, will you try a new vegetable?
7.17.5 Neophobia and Food Exposure

Assessing food exposure is critical to understand food neophobia, as food exposure is a proposed driver for food neophobia. Increase food exposure seems to decrease food neophobia and increase willingness to try novel foods (Pliner, 1994; Pliner & Hobden, 1992). Birch and Marlin (1982) found preference in novel fruits and cheeses increases with exposure frequency in children (n=6 and n=13). Mustonen and Tuorila (2010) also found sensory education and exposure is also associated with decreased food neophobia in children (n=164, ages 8-11 years old at two schools). Sensory education can improve variety of diets potentially due to overcoming food neophobia (Mustonen & Tuorila, 2010). Galloway et al. (2003) determined food exposure in 192 7-year old girls and their parents decreases food neophobia. Dovey et al (2008) proposed theoretical representation of the decrease in food neophobia with increase food exposure (Figure 6).
Figure 6: Likelihood for acceptance of fruits and vegetables in food neophobic and “picky/fussy” eating children. Source: “Food neophobia and picky/fussy eating in children: A review” (Dovey et al., 2008)

Food neophobia decreases with food exposure instances. This is consistent with a study conducted by de Wild et al. (2017) that showed increased food exposure increased vegetable consumption in non-neophobic children higher than neophobic children. Food neophobic children may require other methods to increase vegetable consumption (de Wild et al., 2017). Food exposure is a critical driver of food neophobia; however, there may be other factors that affect food neophobia behavior.

7.17.6 Picky Eaters and Food Neophobia

Pickiness is an eating aversion similar to food neophobia. Picky eaters avoid foods regardless of familiarity while food neophobia is aversion due to familiarity (Figure 6). Picky eaters similar dietary impacts such as consuming a lesser variety of vegetables (Galloway et al., 2003). Galloway et al. (2003) determined pickiness is primarily predicted by environment and experiential factors that can change while neophobia is predicted by enduring and dispositional factors; therefore, neophobia can be reversed through exposure interventions as seen in Figure 6. Multiple exposures can decrease food neophobia in neophobic children, but does not change picky children. There is also no scale to examine picky eating behavior. Therefore, food neophobia has the potential to be reversible by increasing food exposure and other dietary behavior habits while picky eating is not necessarily reversible by these measures (Dovey et al., 2008). Hence, it is beneficial in this thesis to examine food neophobia rather than picky eating.
7.17.7 Food Neophobia Demographics and Personality

Food neophobia is highest in early childhood, as younger children tend to be more neophobic than adolescents and adults (Figure 7). There is little evidence to support a relationship between gender and food neophobia (Meiselman et al., 2010). Other food behaviors may be related to gender that may affect food neophobia. For example, anxious eating is associated with females (Galloway et al., 2003). Galloway examined the predictors for food neophobia in girls (n=192 participants, ages 7). Girls with neophobia consumed fewer vegetables than non-neophobic participants. Girls with neophobia were self reported as more anxious and had mothers with food neophobia (Galloway et al., 2003). Food neophobia may be related to personality traits such as anxiety. While neophobia may relate to personality traits such as anxiety, analyzing these personality factors is beyond the scope of this study. Age and gender will be monitored in this study as it is an easily collectable demographic.
7.17.8 Social and Economic Status on Food Neophobia

Social and environmental factors and cognitive factors both can contribute to food neophobia. (Lafraire, Rioux, Giboreau, & Picard, 2016). There are potential links to social economic factors and food neophobia. Children growing up in higher socio-economic status may have higher exposure and a more varied diet, and their neophobia may be tolerated. Children of lower socio-economic status may not have exposure to a variety of novel foods, and they may not have a choice on what they eat, as they simply cannot afford to be food neophobic. The literature is not conclusive in this area, but these factors may be important to recognize.

7.17.9 Food Neophobia, Obesity and Body Mass Index

There may be a relationship between food neophobia and health parameters such as BMI and obesity. Laureati et al (2015) found there was no difference in BMI and food neophobia and liking of fruit and vegetables in Italian children. While food neophobia has a potentially detrimental affect on diet, the effect of food neophobia on BMI is not
fully understood. It is important to acknowledge the potential relationship between food neophobia and obesity and BMI; however, BMI is beyond the scope of this thesis.

7.17.10 Food Neophobia And Bitterness

Since food neophobia and bitterness sensitivity are often studied separately, the direct relationship between PROP bitter sensitivity and neophobia remains unclear. There is evidence that they may separately affect food choice and consumption levels. Food neophobia is often studied as food aversion and food choice while PROP sensitivity has been examined with taste preferences and vegetable consumption (Carney et al., 2018). Food neophobia may be stronger driver in food consumption levels than PROP sensitivity in children (Tsuji et al., 2012). Food liking may be the link to further investigate this relationship between food neophobia and bitterness sensitivity. Since there are many factors that drive food neophobia, it would be beneficial to examine some of the qualities that may impact all of the factors. Since there are relatively few studies that examine these drivers together, there is an opportunity to study food neophobia related to bitterness in a consumer liking test.

7.17.11 Food Adventurousness

Food adventurousness is a food behavior similar to food neophobia. Food adventurousness examines how much participants try unfamiliar foods while food neophobia examines how willing participants are to try unfamiliar foods. Ulrich et al (2004) measured food adventurousness by the question “How much do you try new and unfamiliar foods” to determine frequency. They found PROP tasters might still behave similar to non-tasters if they are food adventurous. Adventurous PROP tasters liked
more variety of foods including bitter and strong tasting foods. Tasters who were not
food adventurous showed a dislike of bitter substances and behaved like food neophobic
participants (Ullrich et al., 2004). Food adventurousness may be important to examine in
future studies pertaining to food neophobia, bitterness sensitivity, and food neophobia.

7.18 Conclusion

Understanding food neophobia and bitterness sensitivity as drivers for acceptance
in elementary school settings may increase fruit and vegetable consumption. The need for
consuming fruits, vegetables, and cruciferous is well understood. Vegetable and fruit
consumption is critical for children as it potentially reduces the risk of dietary related
chronic disease. The literature is unclear about this relationship between PROP, food
neophobia, and acceptance of vegetables. There is also little research investigating the
food impacts of food neophobia and bitterness sensitivity in a school environment.
Conducting research on food neophobia and bitterness sensitivity in elementary schools
may give insight to improve school breakfast and lunch program. In conclusion,
understanding vegetable consumption from a sensory perspective is critical to improving
the diets of elementary school students.
8 OBJECTIVES

The overall objective is to investigate the role of food neophobia and bitterness sensitivity in food preference of familiar and unfamiliar fruits and vegetables in California elementary schools. Below are specific objectives:

1. Food Preference
   a. To determine exposure and willingness to try familiar and unfamiliar fruit and vegetable products
   b. To determine overall preference (all attributes) for familiar and unfamiliar fruit and vegetable
   c. To determine the overall preference between demographics (gender, age, and race)
   d. To determine overall preference (all attributes) in a high %FRL and low %FRL school

2. Food Neophobia
   a. To assess food neophobia levels in school children with the FNS and the FVNI
   b. To examine the relationship between demographics (gender, age, and race) on food neophobia levels in elementary schools
   c. To examine the relationship between school %FRL status and presence of food neophobia
   d. To determine overall preference (all attributes) for fruit and vegetable between neophobic and non-neophobic participants
3. Bitterness
   a. To assess the presence of bitterness sensitivity in local California elementary school children
   b. To examine the relationship between demographics (gender, age, and race) on bitterness sensitivity in elementary schools
   c. To examine the relationship between school %FRL status and presence of bitterness sensitivity
   d. To determine the overall liking preference of familiar and unfamiliar fruit and vegetable products of in bitter sensitive and non-bitter sensitive participants
   e. To determine the overall liking preference of in bitter sensitive and non-bitter sensitive participants by school %FRL status

4. Food neophobia and bitterness sensitivity
   a. To assess presence of food neophobia in bitter and non-bitter sensitive participants overall
   b. To assess presence of food neophobia in bitter and non-bitter sensitive participants by school %FRL status
   c. To assess the bitter sensitivity in neophobic and non-neophobic participants overall
   d. To assess the bitter sensitivity in neophobic and non-neophobic participants by school %FRL status

To identify patterns in consumer groups based on overall liking using hierarchical cluster analysis (HCA) and principle component analysis (PCA).
9 MATERIALS AND METHODS

9.1 Study Design and Participants

Elementary school children 6-12 years of age were recruited for a consumer acceptance test, food neophobia and bitterness sensitivity assessment. This project has received human subjects’ approval through the Institutional Review Board (IRB) at California Polytechnic State University. Participants (n=161, ages 6-12) were recruited from a low %FRL (22.5% eligible for FRL) and a high %FRL (58% eligible for FRL) in San Luis Obispo, California. The two schools were classified as Low %FRL and High %FRL based on their relative %FRL in the district. FRL statuses of the participants were predetermined based on income level and number of dependents within the family unit. Participants were selected on a volunteer basis with an incentive of $25. Students were not directly asked FRL status to comply with Cal Poly IRB guidelines. The participants completed five unique activities via questionnaire, where they were given a unique code to ensure anonymity.

9.2 Products

Six products, two fruit and four vegetables were chosen based on their presence or absence in local elementary school cafeterias. One familiar and unfamiliar fruit, non-bitter vegetable, and bitter vegetable were selected for the study. Familiar foods selected were strawberry, celery, and broccoli. Unfamiliar foods products were dragon fruit (red-fleshed), jicama, and cauliflower.

Products were purchased at a local grocery store, and stored at refrigerator temperature (37°F). Products were washed and dried on paper towels the morning of testing and prepared to fit into 4-oz plastic soufflé cups (First Street brand) with
randomized four-digit codes. Products were then placed into ridged plastic containers, and stored coolers under refrigeration (37°F) until transported to testing site. Products were brought to testing sites one hour before test. Upon arrival, products remained in thermal containers to remain in coolers. Test products were served raw to mimic the salad bar conditions in an elementary school cafeteria.

9.3 Measures

Food neophobia was evaluated by the FNS and the FVNI (Figure 3 and Figure 5). The FNS was presented first to broadly evaluate neophobia, and then the FVNI was presented to specially evaluate fruit and vegetable neophobia. Participants who scored higher on average than two on the FNS were categorized as neophobic in accordance with Meisleman et al. (2010). In this study, researchers used a five-point scale (strongly agree – strongly disagree) to measure food neophobia on two large commercial samples of US consumers in a population study (n =1567, n= 6843). Neophobia was defined as a total score ≥ 20 on the FNS or an average of “2”. This scale is appropriate for larger groups of study. Participants who scored above an average of “2” in the FVNI developed by Hollar et al. (2013) were considered non-neophobic. Hollar et al. (2013) did not specify a category for neophobic versus non-neophobic in fruit and vegetable scale; hence, those who scored responded positively to “definitely” or “probably” were classified as non-neophobic versus participants who responded to “definitely not” or “probably not”.

Bitterness strips were obtained from Bartovation (Westchester, NY) Bitterness compounds tested included PROP, PTC, thiourea, and a control with no chemicals. Individual strips weighed about two grams. The chemical present on the strip for PROP and PTC are less than 0.1% by weight, and thiourea is less than 1% by weight; therefore,
PROP and PTC contained less than 20µg, and thiourea contained less than 200µg. There is about 20-30% of the transfer on the tongue, so the exposure to PTC and PROP is approximately 4-6µg and the exposure to thiourea is about 40-60µg per strip (S. Bartman personal communication, August 30, 2018). Individual strips were placed in plastic one-ounce soufflé cups (First Street brand) with randomized four-digit codes. Bitterness strips were used instead of solutions due off-site testing. During testing, participants were asked if they could taste anything when presented with a bitterness strip. Participants who selected “Yes” were denoted as sensitive to compound, and participants who selected “No” were marked as bitter non-sensitive. Participants were also asked to describe what they tasted to verify responses.

Data collection was conducted in elementary schools with child sized tables and chairs. Individual booths were set up with cardboard dividers on the tables. Children were individually escorted in the room, and up to 21 students could test at time. Surveyors were present to ensure silence and order. Samples were kept in insulated portable storage bags with cool packs until 30 minutes before testing. Testing was conducted after lunch or after school to ensure participants hunger status was minimal. Testing took approximately 30 minutes per participant. The questionnaire was completed using Red Jade© sensory software.

9.4 Statistical Analysis

Exposure, willingness, and all attribute testing were analyzed with Red Jade© software. Exposure was determined counted the number of participants who responded, “yes” to the recognition question. Willingness was also measured by counting the number of participants who responded “yes” to the willing to try this. Preference means and
standard deviations were calculated from those who were willing to try the food products. Post-hoc comparison using Duncan’s analysis was completed through Red Jade© to if differences between products were significant at $\alpha=0.05$ in terms of exposure, willingness, and all attribute acceptance test among groups of equal variance. Preference between two groups such as school, gender, age, food neophobia status, and bitter sensitivity was conducted through two-sided t-test with unequal variance using JMP© software. Specific products will have different n-values because participants were given the option to skip products they did not want to taste.

For additional comparisons beyond acceptance testing, overall liking was chosen as the primary attribute to conduct comparisons among food neophobia, bitterness sensitivity comparisons, and to complete HCA and PCA. Participants were excluded if they did not complete the questionnaire, or showed no internal discrimination. For example, if a participant selected “3” for all products in overall liking, they were excluded because they did not show any internal ranking system.

Food neophobia was assessed by comparing averages of the FNS and FVNI. The statistical analysis of food neophobia was conducted by comparing neophobic participants (FNS average > 2) to non-neophobic participants (FNS average ≤ 2) using independent two-sided t-test with unequal variance was used to determine preference differences between different demographics and between neophobic versus non-neophobic participants. Pearson’s chi-square test was used to assess the relationship between food neophobia as a categorical variable to categorical demographics such as school, gender, age, race, and taster status. All races except White or Caucasian and Hispanic or Latino were grouped into ‘other’ category, which consists of African
American or Black, Asian, and Native American participants. Pearson’s chi-square was used to evaluate the relationship between demographics and neophobia on bitterness sensitivity. Independent t-tests of were used to determine significance among preference in sensitive and non-sensitive participants considering school %FRL status using JMP©.

Advanced methods including hierarchical cluster analysis (HCA) and principal component analysis (PCA) were used to examine more advanced relationship between preference in terms of overall liking, food neophobia, bitterness, and demographics. HCA was used to determine similarities between subgroups in the study with bitterness sensitivity and food neophobia. Linear regression was used to investigate potential correlations with food neophobia and fruit and vegetable neophobia. All analysis was performed using JMP© and XLSTAT© Sensory, and SASS© software.
10 RESULTS AND DISCUSSION

10.1 Acceptance testing

Participants recognized the predetermined familiar products more than the unfamiliar products. No significant difference was found between exposure levels of the familiar products. However, dragon fruit was significantly ($p=0.0001$) the most unfamiliar product (Table 4). Cauliflower was the most recognized unfamiliar product. Overall, participants were willing to try most of products, regardless of familiarity. Of those unwilling to try products, the unfamiliar products were significantly more rejected than familiar products ($p=0.0001$). There was a significant difference in rejection of fruit and non-bitter vegetables, but no significant difference in rejection with bitter vegetables ($p=0.0001$). Strawberry was the most accepted product, and cauliflower was the most rejected product (Table 5).

Table 4: Exposure to novel foods assessment by California elementary school children, 1=yes, 2=no.

<table>
<thead>
<tr>
<th>Exposure</th>
<th>Strawberry n=158</th>
<th>Broccoli n=159</th>
<th>Celer y n=160</th>
<th>Cauliflower n=159</th>
<th>Jicama n=159</th>
<th>Dragon fruit n=159</th>
</tr>
</thead>
<tbody>
<tr>
<td>No</td>
<td>2%</td>
<td>2%</td>
<td>6%</td>
<td>11%</td>
<td>47%</td>
<td>77%</td>
</tr>
<tr>
<td>Yes</td>
<td>98%</td>
<td>98%</td>
<td>94%</td>
<td>89%</td>
<td>53%</td>
<td>23%</td>
</tr>
<tr>
<td>Mean Score ±Stdev</td>
<td>$1.02^d ±0.14$</td>
<td>$1.02^d ±0.14$</td>
<td>$1.06^c ±0.23$</td>
<td>$1.11^c ±0.31$</td>
<td>$1.47^b ±0.5$</td>
<td>$1.77^a ±0.42$</td>
</tr>
</tbody>
</table>
Table 5: Willingness to try novel foods in California elementary school children, n=161, ages 6-12, yes=1, no=2.

<table>
<thead>
<tr>
<th>Willingness</th>
<th>Strawberry n=158</th>
<th>Celery n=160</th>
<th>Broccoli n=159</th>
<th>Jicama n=159</th>
<th>Dragon fruit n=159</th>
<th>Cauliflower n=159</th>
</tr>
</thead>
<tbody>
<tr>
<td>No</td>
<td>1%</td>
<td>4%</td>
<td>7%</td>
<td>8%</td>
<td>9%</td>
<td>12%</td>
</tr>
<tr>
<td>Yes</td>
<td>99%</td>
<td>96%</td>
<td>93%</td>
<td>92%</td>
<td>91%</td>
<td>88%</td>
</tr>
<tr>
<td>Mean±Stde</td>
<td>1.01±0.19</td>
<td>1.04±0.25</td>
<td>1.07±0.27</td>
<td>1.08±0.27</td>
<td>1.09±0.28</td>
<td>1.12±0.32</td>
</tr>
</tbody>
</table>

Participants’ exposure scores confirmed researcher’s determination of familiar and unfamiliar food products. The difference in exposure levels among the unfamiliar fruit and vegetable product could potentially be explained by exposure outside of school systems. For instance, cauliflower might be recognized more than dragon fruit and jicama due to recent market trends and abundance in other eating opportunities. Cauliflower was also the least tried, and this may be due to its bitter flavor and it was noted that elementary schools in the area had fruit and vegetable posters in cafeterias to expose children to more fruits and vegetables, which may help explain the high level of exposure and willingness to eat. Along with exposure to food, Pliner (1994) noted that parental influence is a driver for child neophobia. Parental neophobia from parents of these participants corresponded to the neophobia in children (Ayoughi et al., 2019).

Familiar products scored higher than their unfamiliar counterparts of all attributes tested (Table 6). Non-bitter vegetables scored higher than bitter vegetables in flavor, texture, and aftertaste. Strawberry was scored significantly higher than the other products,
and cauliflower and dragon fruit scored among the lowest across attributes \((p=0.0001)\). None of the products were particularly disliked as they all scored above three out of five in appearance, overall liking, flavor, texture, and aftertaste. Strawberry was noticeably the sweetest product, which may explain the high acceptability for flavor. This supports exposure and willingness are important factors in assessing food neophobia and food preference, as documented by Mcfarlane and Pliner (Mcfarlane & Pliner, 1997). Product scored well in attributes in which they were expected. It is understandable that dragon fruit (unfamiliar fruit) scores higher than the vegetables because fruits tend to score better for appearance than vegetables.
Table 6: Acceptance Scores of Familiar and Unfamiliar Fruit and Vegetable Products by Elementary School children.

<table>
<thead>
<tr>
<th></th>
<th>Strawberry n=157</th>
<th>Dragon fruit n=145</th>
<th>Celery n=154</th>
<th>Jicama n=154</th>
<th>Broccoli n=148</th>
<th>Cauliflower n=140</th>
</tr>
</thead>
<tbody>
<tr>
<td>Appearance</td>
<td>Mean±Stdev</td>
<td>Top 2 Box</td>
<td>Mean±Stdev</td>
<td>Top 2 Box</td>
<td>Mean±Stdev</td>
<td>Top 2 Box</td>
</tr>
<tr>
<td></td>
<td>4.71±0.54</td>
<td>97%</td>
<td>4.03±0.93</td>
<td>73%</td>
<td>3.64±1.05</td>
<td>55%</td>
</tr>
<tr>
<td></td>
<td>4.03±0.79</td>
<td>71%</td>
<td>3.70±0.97</td>
<td>60%</td>
<td>3.52±0.95</td>
<td>60%</td>
</tr>
<tr>
<td>Aroma</td>
<td>3.85±0.79</td>
<td>71%</td>
<td>3.04±0.93</td>
<td>51%</td>
<td>3.15±1.16</td>
<td>.13</td>
</tr>
<tr>
<td></td>
<td>4.03±1.06</td>
<td>63%</td>
<td>3.16±1.05</td>
<td>39%</td>
<td>2.84±1</td>
<td></td>
</tr>
<tr>
<td>Overall Liking</td>
<td>Mean±Stdev</td>
<td>Top 2 Box</td>
<td>Mean±Stdev</td>
<td>Top 2 Box</td>
<td>Mean±Stdev</td>
<td>Top 2 Box</td>
</tr>
<tr>
<td></td>
<td>4.76±0.48</td>
<td>97%</td>
<td>3.56±0.96</td>
<td>48%</td>
<td>3.67±1.02</td>
<td>56%</td>
</tr>
<tr>
<td></td>
<td>3.89±0.96</td>
<td>67%</td>
<td>3.73±1.02</td>
<td>61%</td>
<td>3.73±0.94</td>
<td>61%</td>
</tr>
<tr>
<td>Flavor</td>
<td>Mean±Stdev</td>
<td>Top 2 Box</td>
<td>Mean±Stdev</td>
<td>Top 2 Box</td>
<td>Mean±Stdev</td>
<td>Top 2 Box</td>
</tr>
<tr>
<td></td>
<td>4.87±0.41</td>
<td>99%</td>
<td>3.41±0.33</td>
<td>52%</td>
<td>3.70±1.31</td>
<td>62%</td>
</tr>
<tr>
<td></td>
<td>3.90±1.12</td>
<td>72%</td>
<td>3.61±1.14</td>
<td>62%</td>
<td>3.42±0.2</td>
<td>51%</td>
</tr>
<tr>
<td>Texture</td>
<td>Mean±Stdev</td>
<td>Top 2 Box</td>
<td>Mean±Stdev</td>
<td>Top 2 Box</td>
<td>Mean±Stdev</td>
<td>Top 2 Box</td>
</tr>
<tr>
<td></td>
<td>4.50±0.59</td>
<td>95%</td>
<td>3.41±0.25</td>
<td>64%</td>
<td>3.63±1.23</td>
<td>58%</td>
</tr>
<tr>
<td></td>
<td>3.66±1.09</td>
<td>64%</td>
<td>3.51±1.09</td>
<td>50%</td>
<td>3.45±1.14</td>
<td>54%</td>
</tr>
<tr>
<td>Aftertaste</td>
<td>Mean±Stdev</td>
<td>Top 2 Box</td>
<td>Mean±Stdev</td>
<td>Top 2 Box</td>
<td>Mean±Stdev</td>
<td>Top 2 Box</td>
</tr>
<tr>
<td></td>
<td>4.56±0.68</td>
<td>90%</td>
<td>3.41±1.21</td>
<td>60%</td>
<td>3.46±1.31</td>
<td>56%</td>
</tr>
<tr>
<td></td>
<td>3.68±1.01</td>
<td>60%</td>
<td>3.32±1.31</td>
<td>46%</td>
<td>3.21±1</td>
<td>44%</td>
</tr>
</tbody>
</table>

Female participants significantly liked strawberries more than male participants \((p=0.0290)\). This supports previous research that girls tend to eat more fruits than boys (Bere, Brug, & Klepp, 2008). Hispanic or Latino populations tended to be more familiar with dragon fruit than the other groups. Dragon fruit is more prevalent in Hispanic cultures as it originates from Central America, and is more common in Mexican food culture than that of the United States (Zee, Yen, & Nishina, 2004). There was no significant difference found between the high and Low %FRL schools. While there were no significant differences found between schools, there is an opportunity for schools to
increase familiarity of fruits and vegetables by incorporating unfamiliar fruits and vegetables into their cafeterias, especially if they could be liked by prominent demographics such as Hispanic or Latino students.

There are many possible reasons for why unrecognized foods were highly accepted. Participants were recruited from a privileged area on the central coast of California. Children are exposed to fresh fruits and vegetables through farmers markets and local agriculture. The area’s culture encourages behavior such as hiking and outdoor activities. Children could have been encouraged to try more foods and vegetables due to these other types of cultural exposures. Future work should be conducted in another site within California or area of the U.S. with different demographics and less access to fresh fruits and vegetables.

10.2 Food Neophobia

A majority of the participants from the Low %FRL School scored non-food neophobic (NFN) through the FNS (73%) and the FVNI (98%). Similarly, more participants scored NFN in the High %FRL school via the FNS (69%) and the FVNI (100%). There were enough neophobic participants to compare neophobic and non-neophobic participants via the FNS. There were not enough neophobic participants to compare to non-neophobic participants via the FVNI as only one participant scored as neophobic on the FVNI. Participant neophobia corresponded with their parental neophobia (Ayoughi et al., 2019).

Through the FNS, more participants at the High %FRL school scored neophobic than the Low %FRL school. More males scored neophobic than females, and more participants ages 8, 9, and 11 were more neophobic than the other ages. More Hispanic or
Latino scored neophobic than other or White or Caucasian; however, these differences are not significant. Differences between groups via the FNVI could not be investigated as only one participant scored neophobic on FVNI. Non-neophobic participants (n=79) liked cauliflower and jicama significantly more than neophobic participants (n=33) ($p=0.257$ and $p=0.043$). Overall, neophobic participants scored familiar products higher than unfamiliar products, and non-neophobic participants scored unfamiliar products higher than familiar products; however, these relationships are not significant.

Results suggest food neophobia levels are comparable between the two schools. The High %FRL school scored on average more neophobic than the Low %FRL school; however, this relationship is not significant. The acceptance scores between neophobic and non-neophobic participants behaved as predicted. Neophobic participants scored familiar products higher than unfamiliar products, and non-neophobic participants scored unfamiliar products higher than familiar products. These findings are consistent with other neophobia studies as Coulthard et al. (2016) found children rated a familiar vegetable product higher than an unfamiliar vegetable product, and Galloway et al. (2003) who found girls with neophobia consume less vegetables than non-neophobic girls.

The results suggest students at both the low and High %FRL schools are relatively non-neophobic via the FNS or FVNI. The relationship between neophobic and non-neophobic participants may not be fully represented in these results. There were not enough fruit and vegetable neophobic participants to analyze non-neophobic versus neophobic by the FVNI, as there was only one participant who scored neophobic. This
obviously creates biased data, so this data may be used to view trends amongst groups but more research needs to be done to support conclusions.

### 10.3 Bitterness Sensitivity

A majority of the participants tested as sensitive to PROP (84%), thiourea (79%), and PTC (69%) White or Caucasian participants were less bitter sensitive than Hispanic or Latino or other ethnicities. This is consistent with research (Williams, Bartoshuk, Fillingim, & Dotson, 2016). More females were sensitive to PROP and PTC, but equal to males in thiourea sensitivity. Many bitter sensitive participants described the bitterness strips as “bitter” or “chemical.” There was no significant difference found among school %FRL status and bitterness sensitivity; however, there were more bitter sensitive participants at the High %FRL school compared to the Low %FRL school. This might be because the High %FRL had more Hispanic and Latino participants than the Low %FRL school. This could potentially change if future research is conducted at different schools with different demographics.

PROP sensitive participants (n=96) liked bitter vegetables more than non-bitter vegetables; however, there were no significant differences in preference levels between PROP sensitive and non-sensitive participants (n=16) in this study. PTC and thiourea sensitive (n=82, n=91) and non-sensitive participants (n=30, n=21) liked familiar products more than unfamiliar products. PTC sensitive participants liked dragon fruit significantly more than non-sensitive participants (p=0.034). PTC non-sensitive participants liked unfamiliar fruit and vegetable products less than sensitive participants (p=0.034, p=0.062, p=0.100). Thiourea sensitive participants liked bitter vegetables significantly more than non-sensitive participants (p=0.038, p=0.006). Thiourea non-
sensitive participants liked non-bitter vegetables more than bitter vegetables; however, this was significant. There were no significant differences found between high and Low %FRL schools. This highlights a potential trend for unfamiliar foods being liked less by non-tasters, and should be further investigated with larger sample sizes.

The preference of vegetables by non-tasters contradicts other works that show sensitive participants may prefer bitter vegetables less than non-bitter vegetables (Keller, Steinmann, Nurse, & Tepper, 2002). However, it is possible in this study that bitter sensitive participants may be more flavor sensitive than non-sensitive participants. Previous research done by Hayes et al. (2010) show PROP tasters are more sensitive to salty flavor changes than non-tasters. This sensitivity to flavor changes may relate to other flavors. There may be potential for other liking drivers such as texture that affect overall liking scores including food adventurousness, where participants seek out new, unknown foods, previous exposures, and home life.

While the results are unexpected, PROP tasters could have discriminative abilities that are linked to traits beyond bitterness sensitivity including flavor intensity; PROP taster status does not necessarily dictate food preference or food behavior including food adventurousness and consumption levels. For instance, adventurous eaters may behave like PROP tasters if they are not PROP sensitive; however, being an adventurous food eater is not linked to PROP taster status (Ullrich et al., 2004). Turnbull and Matisoo-Smith (2002) found taster children disliked spinach more than non-taster children.

Non-food neophobic participants were more bitter sensitive than food neophobic participants; however, this relationship was not significant. PROP non-sensitive participants were not significant more neophobic than PROP sensitive participants in
both the low and High %FRL schools. PTC non-sensitive participants were significantly more neophobic than non-sensitive participants in the Low %FRL school ($p=0.0038$). Inversely, more PTC sensitive participants at the High %FRL were neophobic than PTC non-sensitive participants. In the Low %FRL school, more thiourea non-sensitive participants were almost significantly ($p=0.0585$) more neophobic than thiourea sensitive participants. In the Low %FRL school, the reverse was observed; there were more neophobic thiourea sensitive participants; however, this relationship is not significant. It was expected that bitter participants would exhibit more food neophobia due to their non-bitter sensitive counter parts. This relationship should be further investigated to include more participants to balance unequal groups. Preference level differences by bitterness sensitivity and school %FRL status could potentially be further explained by food neophobia.

Overall, bitter sensitive participants liked products more than non-sensitive participants. However, it is possible in this study that bitter sensitive participants may be more flavor sensitive than non-sensitive participants. While there is evidence to support liking of products, this does not necessarily relate to consumption levels. Children may be rate bitter vegetable higher in product attributes, but this may not translate to consumption levels. Bell and Tepper (2006) determined non-tasters consumed more vegetables than taster children, and non-taster children liked raw broccoli and consumed more vegetables more than taster children. Hence it is strange that PROP sensitivity may explain some acceptability in higher stimulus in this study; yet also be responsible for lower consumption of bitter foods in other studies. There may be due to variations in the
study including unequal groups and low non-sensitive groups. There also may be potential for other liking drivers such as texture that affect overall liking scores.

### 10.4 Hierarchical Cluster Analysis and Principal Component Analysis

To examine the relationship between food neophobia, bitter sensitivity, and other demographics including %FRL school status, HCA and PCA were used to determine trends and potential drivers based on overall liking scores. HCA determined fruit and vegetable neophobia scores as a continuous variable and fruit and vegetable liking could describe different groups of clusters. The differences are small and can be used to describe trends but not make any claims. PCA findings support HCA in that there are some neophobic and bitter sensitive trends to explain product liking. The correlation circle (95.39%) demonstrates neophobia and non-bitter sensitivity to all tested compounds are potential drivers for familiar products (Figure 8).
Figure 8: Correlation circle of PCA analysis of Overall Liking of Fruit and Vegetable Products.
Fruit and vegetable neophobia and sensitivity are potential drivers for non-familiar products. Conversely, White or Caucasian ethnicity and PTC non-sensitivity were potential drivers for bitter vegetable liking, and sensitivity to PTC was a potential driver for non-bitter vegetable liking. This would support other works that show sensitive participants are more sensitive to certain taste sensations higher than non-sensitive participants (Hayes et al., 2008; Yang et al., 2014). While Hayes et al. (2008) demonstrated this was true of sodium perception; it could be possible that this trend carries beyond taste. There may be an unstudied phenomenon in the participant groups including food adventurousness, as food adventurous participants may behave like PROP tasters and rate bitter vegetables higher than non-bitter vegetables (Ullrich et al., 2004). However, studies from Turnbull and Matisoo-Smith (2002) and Bell and Tepper (2006) found taster children disliked and consumed less bitter vegetables than non-bitter vegetables. The liking for unfamiliar products could also be attributed to previous exposure due to the cultural nature of the location of the study in California. While this data analysis may be limited by unequal group as only one participant who is fruit and vegetable neophobic is included in this analysis, these results shows potential areas for opportunities to further the understanding of the complicated relationship between bitterness sensitivity, food neophobia, and product liking.

From this study, food neophobia and bitterness sensitivity seem to have the inverse of the relationship expected. Participants who are bitter sensitive are the least neophobic and score higher in flavor sensitive. This suggests the relationship between bitter sensitivity and preference may include other drivers. Potential sensory drivers for
future research include texture profiling and mouth behavior. This study would also
benefit by comparing liking scores to consumption levels through plate waste, frequency
questionnaire, or free choice test in future work. Further research should investigate other
sensory aspects such as texture consumer profiling such as mouth behavior. Other
behavioral aspects to explore include food adventurousness and picky eating, and
consumption frequencies.

10.5 Linear Regression

The associations with food neophobia (FNS) were also explored in a multiple linear regression setting. The objective is to identify the most important predictors of FNS based on self-reported sensitivities and other demographic factors. The reduced-form model is specified as

\[
FNSScore_i = \beta_1 + \beta_2 \text{PropSensitive}_i + \beta_3 \text{PTCSensitive}_i + \beta_4 \text{ThioureaSensitive}_i + \beta_5 \text{ControlSensitive}_i + \beta_6 \text{FoodAllergies}_i + \beta_7 \text{Female}_i + \beta_8 \text{School}_i + \beta_9 \text{Age} + \beta_{10} \text{Ethnicity}_i + u_i.
\]

The dependent variable, \(FNSScore\), is the average food neophobia score per participant (1-5). The model include four dummy variables representing sensitivity (Prop, PTC, Thiourea, and Control, respectively). \textit{FoodAllergies} is a dummy equal to 1 for respondents indicating that they have food allergies, \textit{Female} is a dummy equal to one for female respondents, and \textit{School} is a dummy equal to 1 for respondents at the Bishop’s Peak Elementary School in San Luis Obispo, CA (the other school being Hawthorne Elementary). \textit{Age} is a continuous measure of respondent age, in years, ranging from 7 to
12. Finally *Ethnicity* is a vector of dummy variables representing the self-reported race of respondents. The model includes White or Caucasian, Hispanic or Latino, and Native American. The reference category, other, includes Asian, African American, and “other race,” all of which represented very small proportions respondents. FNS score can be predicted by Thiourea sensitivity ($p = 0.0257$) and Native American Race status ($p = 0.0176$). FNVI scores can almost be potentially associated with Thiourea sensitivity ($0.0593$).

### 10.6 Limitations

While participants in this study are representative of San Luis Obispo, they are not demographically representative of elementary schools across California or the US. Participant groups by neophobia and bitter sensitivity are relatively unequal, which provides statistical limitations from this study. There is potential bias within schools as all of the participants from the Low %FRL school were able to stay after school to participate in this study. Participants from the High %FRL school were able to test during school and after school. It is also that participants who did not like fruit and vegetables chose not to participate in this study, so the majority of participants probably already liked vegetables by agreeing to be part of this study. There may have been missed opportunities to study fruit and vegetable neophobic children, as children who did not have any interest in the study probably did not participate. There also may be privileged bias within the community with the relatively high economic area, farmers markets, and previous exposure to fruits and vegetables. This study should include a broader demographic of children who may not have the same opportunities as the tested participants.
11 CONCLUSION

This study examined hedonic liking scores of six familiar and unfamiliar fruit and vegetable products, food neophobia, and bitterness sensitivity in a High %FRL and Low %FRL elementary schools. Familiar products were liked more than unfamiliar products. Neophobic participants liked familiar products more than unfamiliar products. Unexpectedly, bitter sensitive participants liked fruit and vegetable products more than non-sensitive participants. %FRL school status of the participant did not seem to influence neophobia status, bitterness sensitivity or liking scores. Both food neophobia and bitterness sensitivity may have an impact on fruit and vegetable preference as independent drivers of food liking in children. Hierarchical cluster analysis and principal component analysis demonstrated fruit and vegetable neophobia, bitterness sensitivity, and other demographics might explain fruit and vegetable preference in children. Food neophobia and bitter sensitivity may describe food preference in elementary school students, but this relationship is still unclear. There is an opportunity for schools to increase familiarity of fruits and vegetables by incorporating unfamiliar fruits and vegetables into their cafeteria menus.
12 ACKNOWLEDGEMENTS

The California State University Agricultural Research Institute (ARI) has made partial funding for this project available. Thank you to the administration and staff at Bishop’s Peak and Hawthorne Elementary School, Dan Block, James McMillen, Kama Beaton, and Josie Graydon. We would like to thank all the parents and children who participated in this study and completed our surveys in the San Luis Obispo Coastal Unified School District as well as all of the faculty and staff who supported this research.
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