RETRONASAL OLFACTION AS AFFECTED BY MIRACLE FRUIT AND *GYMNEMA SYLVESTRE*

By

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To my parents

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TABLE OF CONTENTS

LIST OF TABLES

Table page

LIST OF FIGURES

Figure page

LIST OF ABBREVIATIONS

ANOVA	Analysis of variance
BMI	Body Mass Index
C	Control treatment
FSHN	Food Science and Human Nutrition
gLMS	General Labeled Magnitude Scale
GPCR	G protein-coupled receptors
GS	*Gymnema sylvestre* treatment
IRB	Institutional Review Board
LMS	Labeled magnitude scale
LSD	Least significant difference
ME	Magnitude estimation
MF	Miracle fruit treatment
PROP	6-n-propylthiouracil
PTC	Phenylthiocarbamide
VAS	Visual analog scale

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Sweet taste is believed to play an important role in flavor perception. The term flavor denotes the combination of taste and retronasal olfaction, which is the perception of odorants in the mouth. This study is the first that investigated the change in flavor intensity by altering the sweet taste of foods through taste-modifying compounds such as miracle fruit, known to add sweetness to acids and decreases sourness of acids, and *Gymnema sylvestre*, which depresses sweetness.

One hundred panelists were recruited from the Food Science and Human Nutrition department and the Sensory Laboratory. All panelists were trained to use the general Labeled Magnitude Scale (gLMS); to develop a personalized scale ranging from “no sensation” (0) to their own “strongest sensation ever experienced” (100). Panelists used the gLMS to rate the intensity of odor, sweetness, sourness, and flavor of ten food samples (in random order) before, after a miracle fruit tablet and after a brewed *G. sylvestre* tea sample. The foods were selected to represent a range of foods in which sweetness and typical flavor are usually associated or not.

The results were analyzed using SAS to perform analysis of variance (ANOVA) for Fisher’s least significant differences (LSD) between groups. Significant differences were

found at $p \leq 0.05$. The sweetness and flavor intensity of cherry tomatoes and strawberries, which are associated with sweet and sour tastes, increased after miracle fruit exposure and decreased after *G. sylvestre*. The sweetness of apple cider vinegar, lemons, pickles, and yellow mustard, which are associated with sour tastes and not sweet tastes, increased after miracle fruit, but the flavor intensity either remained the same or decreased. Sweetness and flavor intensity of dark chocolate and maple syrup, which are associated with sweet taste and not sour taste, was not affected by miracle fruit, but both decreased substantially after *G. sylvestre*. The sweetness and flavor intensity of roasted peanuts and canned Vienna chicken sausage, which served as controls since they were not associated with sweet or sour tastes, were not substantially affected by either miracle fruit or *G. sylvestre*. The odor intensity of all foods at all treatments had similar values and did not show significant differences. In addition, there were no significant differences between genders and body mass index (BMI) values. When the study was repeated in additional, separate sessions, similar results were found.

Correlation analysis was performed on selected food items. These results indicated that sweet taste can intensify retronasal olfaction (flavor), particularly in foods where sweetness and typical flavor are associated. In strawberries and maple syrup, there were strong, positive correlations between sweet taste and flavor where increasing sweetness resulted in an increase in overall flavor intensity, and likewise, by decreasing sweetness, flavor intensity was perceived at a much lower value. This relationship did not hold true in foods in which sweetness is not associated with typical flavor. In lemons, where sourness and typical flavor are associated, there was a strong, positive correlation between sour and overall flavor where an increase in sourness level resulted in an increase in overall flavor intensity.

Overall, the results showed that sweet and sour tastes, depending on the typical taste associations of the foods, can both intensify retronasal olfaction. This confirms that there is a strong interaction between enhanced or suppressed sweetness and overall flavor. Also, this shows that there is evidence that sour taste, in addition to sweet taste, can influence retronasal olfaction but more work must be done for further confirmation.

CHAPTER 1
INTRODUCTION

The overall sensory experience of eating any food is influenced by a combination of the five senses including hearing, sight, touch, taste, and smell (Lawless and Heymann 1999; Lawless and Heymann 1999). Taste, or gustation, is the perception of basic taste qualities on the tongue. Smell, or olfaction, is the perception of odor molecules by a dual process olfactory system in the nasal cavity. Orthonasal olfaction results when these volatiles are sniffed through the nostrils. When the food undergoes mastication, which breaks down the food matrix, the release of these volatiles in the back of the mouth and throat results in retronasal olfaction. These volatiles are the odors that are responsible for the overall flavor character (Bachmanov and Beauchamp 2007). The combination of taste and retronasal olfaction produce flavor. Recent literature suggests that some individuals experience more intense taste perceptions than others based on their taste genetics and number of taste buds, which may influence flavor (Bartoshuk and others 1994).

It is widely accepted that the levels of sugars and acids affect the perception of the taste attributes sweetness and sourness. There is a belief that intensifying taste can also intensify the overall flavor perception. Adding sugars and artificial sweeteners to foods can enhance the overall flavor, especially in foods where sweetness is associated with the characteristic flavor. In contrast, a lack of sweetness can cause a food to “taste” bland, which translates to having low overall flavor perception. Adding odors can cause changes to perceived sweetness (Stevenson and others 1999). It is not known whether tastes interact directly with retronasal olfaction for flavor perception or if taster status influences olfaction. In this study, the intensities of the odor, sweet and sour tastes, and flavor attributes of various foods will be measured using the general Labeled Magnitude Scale (gLMS) for valid group comparisons across individuals (Bartoshuk and others 2004).

It was hypothesized that altering sweet taste by using taste-modifying miracle fruit, which adds sweetness, and *Gymnema sylvestre*, which decreases sweetness, influences retronasal olfaction of certain foods based on their association with sweetness and sourness. More specifically, miracle fruit should increase flavor intensity and *G. sylvestre* should decrease flavor intensity. We also believe that the taste and flavor intensities will vary between supertaster and nontaster individuals, although they will show similar correlations. There is no anticipated change to the odor intensity for any foods.

The main objective of this study is to investigate the effects of increasing and decreasing sweetness on the perception of taste attributes and how this contributes to retronasal olfaction, or flavor perception, when panelists consume foods. This study represents the first to evaluate whether such a relationship exists between sweet taste and retronasal olfaction by using miracle fruit and *G. sylvestre* to modify sweet taste. If this study supports a positive relationship between the increase or decrease of sweetness and typical flavor perception, it would provide further understanding of retronasal olfaction in supertasters and nontasters.

It is hoped that sensory scientists and taste psychophysicists will be able to use the information from this study as new insights to the understanding of the relationship of sweet taste and retronasal olfaction. Sweetness is commonly associated with pleasure and has been shown to be a driving force for likeability in many foods (Zellner and others 1983). More specifically, it is known that increasing sweetness can lead to improved flavor and can be expected to enhance retronasal olfaction (Bartoshuk and others 2004). The role of retronasal olfaction influences food enjoyment and the overall quality of life (Bartoshuk and others 2004). Furthermore, this process plays a role in food preferences and may influence consumer acceptability and thus, purchase intent. In addition, the food industry can benefit from the use of novel taste stimuli and taste-modifying substances to increase sweetness without additional caloric intake.

CHAPTER 2
LITERATURE REVIEW

Flavor Perception

Flavor is a complex sensation used to describe foods and beverages. Until relatively recently, the understanding of the mechanism behind flavor perception has been poorly understood. The term flavor is defined as the integration of tastes and retronasal olfaction, which is the perception of odorants in the mouth (Rozin 1982). Additional influences are from orthonasal olfaction (perception of sniffing odorants through the nose), the trigeminal system, tactile sensations, as well as by appearance (Rozin 1982; Auvray and Spence 2008). These attributes suggest that flavor perception is derived from multiple sensory systems, primarily the gustatory and olfactory systems that are dually responsible for the taste-odor integration (Dalton and others 2000; Small and Prescott 2005).

During mastication, the food matrix breaks down in the mouth and on the tongue. This change in texture releases additional odorants in the mouth, which are perceived retronasally. The perception of the maximal flavor intensity was found to occur close to the moment of swallowing near the border of the back of the tongue and soft palate (Buettner and others 2002).

The flavor of a food can be altered (usually enhanced) by the addition of natural or artificial odor/flavor chemicals, as well as taste stimuli. Usually, harsh tastes (bitter and sour) tend to suppress while pleasant tastes (sweet and salty) generally enhance the flavor (Lawless and Heymann 1999). The interactions change depending on the various taste and odorant combinations. One particular study showed that human perception of the intensity of a menthol flavor was driven by the release of sugars in their mouths, which is detected by the tongue and gustatory system (Davidson and others 1999).

There is belief that sweet taste, and perhaps other tastes and trigeminal senses, plays an important role in retronasal odor perception. Therefore, it is beneficial to understand the anatomical and physiological processes of odor and taste systems, as well as their interactions. Not only can research in this area benefit the food industry's assessment of acceptability and flavor of new products, but also help to understand the biological function of accurate flavor identification of foods prior to ingestion.

Odor Perception

The human olfactory system is a dual sensory system used to perceive odor and aroma molecules in the external, outside world and in the mouth (Rozin 1982). There are two major pathways termed orthonasal and retronasal olfaction. The initial mode of olfactory delivery is engaged through orthonasal olfaction, which is perceived through the nasal passage by the process of sniffing through the nostrils (Lawless and Heymann 1999). This moves odorants from the external air through the nasal passage to the olfactory epithelium. When a food enters the mouth and is broken down by mastication, the release of higher concentrations of odor molecules in the back of the throat is perceived as retronasal olfaction (Lawless and Heymann 1999; Buettner and others 2002). More than 7,100 volatile compounds which may contribute to odor perception have been identified in foods (Reineccius 2006). There is a strong association between odor and flavor, and this is the key process responsible for flavor perception (Bachmanov and Beauchamp 2007).

Olfactory receptors are true nerve cells that are located in the nasal cavity on the olfactory epithelium (Lawless and Heymann 1999; Lawless and Heymann 1999). They are highly ciliated, which allows for increased surface area, exposing maximum receptors to chemical stimuli. Thousands of receptors send nerve fibers into glomerular structures in the olfactory bulb. There are many areas of branching and synaptic contact onto the next neurons, which undergo transduction to the brain to transmit smells, emotions, and experiences (Lawless and Heymann 1999).

Primarily, olfactory sensations are linked when substances are sensed in the mouth via retronasal olfaction. Due to this association, the olfactory system is often confused with the sense of taste. This is a good explanation when an individual experiences a head cold; the loss of retronasal olfactory inputs causes the perception of foods to change to little or no flavor. Odors also have the ability to modify taste sensations. Although odor molecules are typically tasteless when experienced alone in a solution, the addition of food odors that are typically associated with sweet taste such as vanilla, caramel, strawberry, and mint to solutions can enhance the sweetness of foods (Dalton and others 2000; Small and Prescott 2005; Auvray and Spence 2008).

Taste Perception

Gustation, or the perception of taste, refers to the sensations arising from the oral cavity including on the tongue and in the mouth in the chemosensory gustation system. There are four known and widely accepted basic taste qualities called sweet, salty, sour, and bitter, and there is a fifth debated taste termed umami (Bellisle 1999; Beauchamp 2009). There is a tendency to use the term taste to refer to all mouth sensations, but it should be used only for the taste qualities and substances that produce those sensations. Taste can also evoke other sensations such as odor, touch, temperature, and irritation although non-gustatory components are sensed by different systems (Lawless and Heymann 1999).

The epithelial surface of the tongue contains numerous papillae. There are different types of taste papillae located on the tongue and in the mouth, which are primarily classified as fungiform, foliate, and vallate (Lawless and Heymann 1999). Also, there is also some evidence that there are taste buds in the palate, oropharynx, larynx, epiglottis, and upper esophagus (Bachmanov and Beauchamp 2007). Taste papillae contain clusters of epithelial cells, or taste buds, within them that have a lifespan of approximately one week and are continuously regenerated. These taste buds contain taste receptor cells. Some of these cells terminate in slender microvilli (the sites of interaction between stimulus and receptor). Taste stimuli reach the taste bud through a taste pore and make contact with the receptor sites. After processing within the taste bud, messages are generated and carried by the cranial nerves – VII (facial), IX (glossopharyngeal), and X (vagus) (Lawless and Heymann 1999).

Further processing in the brain results in the generation of behavioral responses to the taste stimuli. These responses result in the perception of the different aspects of taste: quality, intensity, hedonics, location, and persistence. There are numerous differences in taste perception in various individuals, especially as an individual ages. For example, women who are experiencing menopause experience a diminished bitter sensation that leads to increased preference and intake for bitter foods and beverages (Bartoshuk and others 2007).

Determining Taste Status

Recent literature suggests that there are substantial taste sensitivity differences among individuals– especially with regard to bitter compounds. The first discovery in the differences in bitter taste perceptions were by accidental tasting of phenylthiocarbamide (PTC) in 1931 by A.L. Fox (Fox 1932). Some individuals thought it was tasteless while others thought it was strongly bitter, which led to the understanding that the ability to taste was inherited. We now know that there are 25 bitter genes in humans including TAS2R38 (Duffy and others 2004). This gene expresses receptors that bind PTC which contain a N-C=S group. Testing PTC can be used to determine taste sensitivity. Since it emits a sulfurous odor and is potentially toxic, it was replaced by 6-n-propylthiouracil (PROP) which also contains a N-C=S group (Barnicot and others 1951; Lawless 1980). This is used as an anti-thyroid agent and used to treat hyperthyroidism. PROP can present problems for some susceptible individuals. One can test genetic variation with quinine, which does not contain the N-C=S group but also exhibits bitter qualities. Commonly found in tonic water, it is also useful as an anti-malaria agent. A quinine-water solution is applied to the tongue and mouth to be used as an indirect method for assessing taste status.

Early taste status research used category scales to assess taste sensitivity. The major problem with these types of scales is that a particular attribute described as “weak” by one individual may be actually “strong” to another (Bartoshuk and others 2004). This is not a useful scale to measure actual intensities since individuals can be classified into one of the following taster status groups: supertasters, medium tasters, and nontasters. Supertasters perceive the most intense sensations while nontasters perceive the least.

Taster status also influences the perceived intensity of other taste stimuli and retronasal olfaction. Therefore, there is an association between taste input and retronasal olfaction such as increased taste intensities. Also, it is suggested that supertasters perceive more intense retronasal cues than nontasters.

Developed by Bartoshuk and others, the general Labeled Magnitude Scale (gLMS) allows valid across-group comparisons since supertasters rate bitterness at the top of the scale, medium tasters near the middle of the scale, and nontasters at the bottom of the scale (Bartoshuk and others 2003). In addition to bitter taste, it has been shown that supertasters tend to perceive higher intensities for the other four taste qualities than medium and nontasters. For example, the perception of sucrose is sweeter and has a higher intensity for supertasters than nontasters (Bartoshuk and others 1978).

Genetics of Taste

Individual differences in the perception of taste intensity exist due to specific taste gene expression. Variations in these genes can affect food perception, choice, and consumption. Genes express receptors found in the taste buds. Specialized taste receptors, which all have a specific coding mechanism, are responsible for detecting each of these taste qualities. For example, the TAS2R38 receptor responds to bitter taste stimuli and can be associated with preference for sweet taste (Duffy and others 2004).

For the purposes of this study, only bitter, sweet, and sour taste receptors will be further discussed. It is known that bitter and sweet tastes involve proteins from the T1R and T2R receptor families, which are a part of G protein-coupled receptors (GPCRs) (Bachmanov and Beauchamp 2007). Sour taste is unrelated to these genes. The main sites of expression are the taste receptor cells located in the circumvallate, foliate, palate, epiglottis, and fungiform taste buds.

Bitter Taste Receptor

The bitter taste receptor can indicate the presence of toxins in food and can signal spoiled food. Some individuals are genetically more sensitive to bitter compounds, as previously mentioned in the taste status section. Those who experience taste “blindness” detect the bitterness of some of these compounds at much lower thresholds or even not at all (Fox 1931).

In the early 2000’s, bitter taste receptor families named T2R’s were first discovered and characterized. The number of compounds perceived by humans as bitter is much larger than the number of human TAS2R genes since each of the T2R receptors responds to more than one bitter ligand (Bachmanov and Beauchamp 2007). Adler discovered perception of PROP with a novel GPCR, the TAS2R1 gene (Adler and others 2000). This suggested that this is a bitter taste receptor for PROP. Furthermore, specific receptors were identified to their specific taste stimuli: TAS2R16 responds to β-glucopyranosides, and TAS2R38 is a receptor identical to PTC bitter taste (Bachmanov and Beauchamp 2007). The identification of additional genes and their correspondence to genetic loci for bitter taste sensitivity as well as matching with individual variation in bitter taste perception are important areas for future studies.

Sweet Taste Receptor

Sweet taste is a highly liked food quality and commonly associated with pleasure-seeking behavior. It is responsible for consumption of naturally sweet and sweetened foods and beverages. The natural sweet taste stimuli are sugars, which are detected by the sweet taste receptor and indicate presence of carbohydrates in food. Some data suggest that human sweet taste responsiveness is associated with body mass index, particularly obesity (Donaldson and others 2009). Also, it is suggested that foods smelling of certain odors, like cherry and almond, are more likely to be associated with sweet taste based only on the odor (Dalton and others 2000).

Like bitter tastes, sweet tastes are activated by specific GPCRs, but associated with the T1R receptor families. In humans, the sweet receptor is a heterodimer of the T1R2 and T1R3 genes (Bachmanov and Beauchamp 2007; Jiang and others 2008). The heterodimer responds to an array of sweeteners including but not limited to sugars, sweet amino acids, artificial sweeteners, and sweet tasting proteins (Jiang and others 2008). The heterodimer utilizes multiple ligand binding sites. More specifically, T1R3 has been shown to participate in the sweet receptor's interaction with sweet proteins (Jiang and others 2004).

Sour Taste Receptor

The commonly accepted view is that taste receptors for sour taste are ion channels (DeSimone and Lyall 2006; Bachmanov and Beauchamp 2007). It is still poorly understood, but there are several candidate receptors such as ACCN1, HCN1 and HCN4 (Stevens and others 2001). The actual acid taste transduction is believed to involve intracellular acidification of the taste receptor cells which affects acid-sensitive ion channels. Like the receptors, it is also not completely understood, but there are candidate acid taste transducers.

Taste-Modifying Compounds

Taste-modifying compounds alter one or more of the basic tastes. Since there is a strong demand for artificial sweet and umami compounds, there is continuous research seeking enhancers of salty, sweet, and umami taste as well as bitter taste blockers. These can be used in the food and pharmaceutical industries to make food and drinks healthier without sacrificing their palatability, as well as drugs with improved sensory properties.

Although there are no odor-like properties produced by tastes, taste perceptions are relevant to flavor perception. Two taste-modifiers, miracle fruit and *Gymnema sylvestre*, will be used to determine their impacts on sweet and sour tastes of foods, as well as orthonasal and retronasal olfaction. Both of these taste-modifying compounds are not believed to affect bitter or salty tastes; therefore, these taste qualities will not be analyzed.

Miracle Fruit

The miracle fruit plant, scientifically known as *Synsepalum dulcificum* is indigenous to tropical West Africa (Daniell 1852; Bartoshuk and others 1974). It is highly abundant in the inland countries of the Gold Coast, including the regions of the Ashanté kingdom, as well as the Popo, Dahomy, and Yorruba kingdoms (Daniell 1852). Since its introduction to the United States, it has been grown successfully in Florida since 1957 (Bartoshuk and others 1974). It produces oblong or oval shaped, dusky red colored berries that are approximately one to two centimeters in size and contain a large seed clothed by a thin layer of pulp. The pulp itself has very little flavor and little sweetness associated with it.

The earliest known consumption of miracle fruit was by the African race known as the Fante. These natives used this fruit to their advantage to mask the taste of bitter and unpleasant medicines as well as to render stale and highly acidic foods and drinks more palatable by adding sweetness (Daniell 1852). These foods include stale and acidulated maize bread (kankies), gruel (guddoe), which is made from stale bread, sour palm wine, and beer (pito) (Daniell 1852; Bartoshuk and others 1974). When Fairchild sampled these berries, he also experienced these taste changes due to the miracle fruit. The beer he was drinking and lemon he was eating were excessively sweet, which sparked his interest to introduce the plant to the United States (Bartoshuk and others 1969).

Nicknamed miraculous berries by the Europeans, this fruit is known for its unique taste-modifying property which causes sour materials to taste pleasantly sweet after the tongue and mouth have been exposed to the fruit's pulp (Inglett and others 1965; Bartoshuk and others 1974). This exposure not only enhances the sweetness of any sour substances, including dilute organic and mineral acids, but also decreases the sourness for an hour or more (Inglett and others 1965; Bartoshuk and others 1974). Salty and bitter taste responses, such as sodium chloride and quinine hydrochloride, do not appear to be significantly influenced, as the berry only sweetens sour substances (Inglett and others 1965; Bartoshuk and others 1974). Sour and acidic substances such as citric or tartaric acids, lime juice, and vinegar all lose their unpleasant qualities and become intensely sweet (Daniell 1852). Attempts to preserve miracle fruit's taste-modifying characteristics in spirits, acetic acid, or syrup have been unsuccessful (Daniell 1852).

Early studies

Early studies focusing on isolating the active principle of miracle fruit and understanding its chemistry and the mechanism of action were performed in the 1960's by Inglett, Brouwer, Henning, and Bartoshuk. The active principle in miracle fruit was identified as a glycoprotein appropriately named miraculin (Inglett and others 1965; Bartoshuk and others 1974). This has been based on its solubility behavior and lability toward heat, acids, and bases (Inglett and others 1965).

Although unsuccessful, the first trials to isolate the active principle from the berries were performed by Inglett (Inglett and others 1965). Results indicated that the potent berry will replace some sourness with sweetness causing a sweetening effect on the following acids: citric, tartaric, acetic, hydrochloric, lactic, phosphoric, L-glutamic, D-glutarnic, D-glutamic, hydrochloride, L-aspartic, L-histidine dihydrocholoride, and α-pyrrolidone carboxylic while having no effect on solutions above pH 4 including ammonium citrate, ammonium phosphate, or ammonium chloride (Inglett and others 1965). There was a slight transient effect with aluminum potassium sulfate solution at pH 3.4, possibly due to a low pH value (Inglett and others 1965).

Brouwer and others were successfully able to extract the active principle and the first to study its chemical properties. Results showed a positive test for sugars before and after electrophoresis on polyacrylamide gel, which indicates that miraculin can be classified as a glycoprotein (Brouwer and others 1968). It is soluble in dilute buffers, thermolabile, and rather stable in solutions of pH 3 through 12 while inactivated at pH less than 2 (Brouwer and others 1968). It is mostly composed of glucose, ribose, arabinose, galactose, and rhamnose as well as the common amino acids glycine, arginine, and lysine (Brouwer and others 1968). The amount of glucose can vary from 7.5 to 21 percent (Brouwer and others 1968). Despite containing various types of sugars, miraculin has no taste on its own but approximately 100 µg is sufficient to change the sensation of sourness into sweetness for over an hour (Brouwer and others 1968). It was also determined that the sour taste response, which is ionic in character, and the sweet taste response, which is predominantly nonionic, is somehow interconnected (Henning and others 1969). Although the taste responses were not well understood, early studies believed that sour tastes changed into sweet tastes (Henning and others 1969).

Further work was performed on the effects of miracle fruit on the tastes of several different fruits and acids at the Natick Army Laboratories. It was known that a single berry could replace most of the sourness in a lemon slice with sweetness, so this warranted further investigation on sodium chloride, sucrose, quinine hydrochloride, hydrochloride, and citric acid (Bartoshuk and others 1969). Miracle fruit did not significantly affect perception of sodium chloride, quinine hydrochloride, or sucrose in this study while it did alter the sour taste of citric acid to part sweet and part sour. The total taste intensity did not change (Bartoshuk and others 1969). After an hour, the sweet taste was abolished and the intensity of the sour taste returned to its original value proving that the taste-modifying effects are temporary. The study showed that miracle fruit does not change the magnitude of the taste of citric acid directly, but rather changes the quality from sour to sweet and sour (Bartoshuk and others 1969).

Mechanism

The theory originally proposed by Kurihara, Kurihara, and Biedler remains the most widely accepted theory regarding miraculin's mechanism (Kurihara and Beidler 1968; Kurihara and others 1969). This theory proposes that this taste-modifying protein does not depress the sourness, but instead causes a sweet taste to be added to normally sour acids (Bartoshuk and others 1974). Additionally, their study confirmed previous work by others that the active principle is a protein based on the following characteristics: activity greatly decreased by exposure to pH above 12.0 or below 2.6 at room temperature, activity stable at pH 3.7 and 4°C for at least one month, and addition of trypsin or pronase destroyed the activity (Kurihara and others 1969). It is believed that sourness is mainly related to the proton concentration, but different acid solutions at the same pH give different intensities of sourness in the decreasing order of acetic, formic, lactic, oxalic, and hydrochloric acids (Kurihara and others 1969).

It is known that after application of a taste-modifying protein, the mechanism of sweet induction by acid is closely associated with the mechanism of sourness. This relationship can be explained in two ways. The first explanation, which is unlikely, suggests that the taste-modifying protein changes the coding of response from the taste-receptor cells so that sour taste is converted into sweet taste. The second and more accepted explanation suggests that the taste-receptor membrane changes conformation when a sour taste is induced at a low pH, which thereby allows the induction of a sweet taste at the sweet receptor site (Kurihara and others 1969). Results indicate that the taste-modifying protein does not affect thresholds for any qualities of tastes, including sourness, although human perception of the tastes suggests that there are changes to the sweet and sour taste intensities. The total intensity of the tastes did not change; a decrease in sourness is balanced by the increase in sweetness (Bartoshuk and others 1974).

Since the taste-modifying protein has a relatively high molecular weight, it is unlikely that it penetrates easily into the taste cells, but rather binds to the membrane surface of these cells. These proteins are classified as allosteric proteins since they contain more than one binding site for substrates. This particular protein binds to both the receptor membrane and to the sweet-receptor site. The sweet-receptor site is left unoccupied until an acid is applied to the tongue and mouth, which causes both sweet and sour receptor sites to fire. It then causes a conformational change to this site

(Bartoshuk and others 1974). Once a low pH that induces sourness causes this alteration, the result is a “fitting” of the sugar part of the glycoprotein into the sweet-receptor site (Kurihara and others 1969). Although pH may not be solely responsible for conformational change, it has been shown that this change is induced near the pK value (3.4-4.5) of carboxyl groups in proteins (Kurihara and others 1969). The sugar portion contains approximately 6.7 percent of arabinose and xylose, which are known to have a sweet taste and binding ability to the sweet receptor site on the taste buds (Kurihara and others 1969). Although the protein can bind to numerous places on the membrane, the sugar part of the protein will not “fit” the sweet-receptor site unless the protein is bound to a specific site (Kurihara and others 1969). The intensity of sourness of the acid relates to the sweet-inducing potency of the acid. This study suggests that the sweet taste of acid after taste modification was brought about by addition of a sweet taste to the sour taste. Over time, the protein molecules bound at the sites detach from the membrane which explains why this taste modification is temporary.

Recent research

In the past ten years, Japanese research groups have been working extensively on the insertion of the miraculin gene into foods. Early studies showed that the expression of the gene in yeast and tobacco failed (Kurihara and Nirasawa 1997). Despite those failures, there has been some success in genetically modified *Escherichia coli* bacteria, lettuce, strawberries, and tomatoes (Sun and others 2006; Sun and others 2007; Sugaya and others 2008; Matsuyama and others 2009). This increases the potential to insert the miraculin gene into other fruits and vegetables.

Gymnema Sylvestre

Gymnema sylvestre, which belongs to the *Ascelpiadoideae* subfamily, is a woody herb native to the tropical forests in southern and central India (Hooper 1887; Kurihara and others 1969; Imoto and others 1991). In Hindi, its name is *gurmar* and *sarkaraikolli* in Tamil and Malayalam which are translated to the “destroyer of sugar” since it is known to suppress sweet tastes (Shanmugasundaram and others 1990). The leaves have a slightly bitter taste associated with them and are not toxic to humans. When foods are tasted after consuming *G. sylvestre*, sugar tastes like sand. In a sweet orange, only the citric acid can be detected (Hooper 1887; Stoecklin 1969).

Early studies showed that *G. sylvestre* exerts a taste-modifying effect by suppressing sweet and bitter tastes in foods (Hooper 1887; Shore 1892). All sweet substances, particularly sucrose, glycerine, and saccharin, were either completely or greatly suppressed. In the late 1800s, Hooper, Shore, and Kiesow believed that there were effects on quinine sulfate, by suppressing its bitterness and made it tasteless like chalk (Hooper 1887). As early as 1887, Hooper concluded that the leaves contain an active principle identified as gymnemic acid, which is a type of glucoside (Hooper 1887).

Before the 1950’s, limited information was known about the chemical nature of gymnemic acids. Nearly a century after the previously mentioned studies by Hooper and Shore, additional studies have shown that gymnemic acid is specific to and only suppresses the response to sweet substances without affecting the responses to salty, sour, or bitter tastes (Bartoshuk and others 1969; Henning and others 1969; Imoto and others 1991). Sweet substances suppressed include, but are not limited to, sucrose, fructose, sodium saccharin, and sodium cyclamate, while there are no effects on other solutions such as sodium chloride, citric acid, quinine, hydrochloride, and quinine sulfate

(Diamant and others 1965). The early literature on bitter suppression was disproven due to cross-adaptation. Since *G. sylvestre* on its own has a bitter taste, it has been shown that a fairly long water rinse is necessary to prevent cross-adaptation between the quinine, sodium chloride, and hydrochloric acid (Bartoshuk and others 1969; Henning and others 1969). The sweetness is not recovered completely until approximately one hour has passed (Meiselman and Halpern 1970b). Additional chemical and physiological properties of the gymnemic acid were extensively studied by Stocklin showing that gymnemic acids A1, A2, A3, and A4 are probably β-D-glucuronides (Stoecklin 1969).

Mechanism

After better understanding that *G. sylvestre* only inhibits sweet taste, the mechanism of this taste-modifying action is of great interest. The detailed understanding of the inhibition remains unclear today, although there are some widely accepted explanations. It is possible that gymnemic acid blocks the chorda tympani response to sugars and saccharin (Henning and others 1969). Further studies have proven that the gymnemic acid blocks the sweet receptor sites, which can lead to an increase of the perception of sour tastes (Imoto and others 1991). Therefore, this prevents the interaction between a sweet substance and the receptor. When sucrose is directly mixed with a *G. sylvestre* solution, it does not interfere immediately with the receptor process (Meiselman and Halpern 1970b). Instead, it is a gradual action on the receptor membrane that either displaces the sucrose stimulus from its sites or by occupying the sites as soon as they are vacated by the sucrose (Meiselman and Halpern 1970b). Not only does it have an inhibitory action on the membrane sites involved with eliciting sweetness; additional research is needed to determine if other categories are also affected (Meiselman and Halpern 1970a).

G.sylvestre also suppresses the miraculin-induced sweetness of citric acid, which led to an increase in the sourness of the citric acid (Bartoshuk and others 1974). This sweetness increase is typically accompanied by a sourness reduction. This value was quantified, and was found to return to approximately its original value before miracle fruit. Compared with other taste-modifying proteins, the gymnemic acid effect decreases much faster (Kurihara and others 1969).

Potential uses

It is known that by adding sweetness, there is a suppression of other tastes. Decreasing sweetness might produce apparent enhancement through release of suppression (Meiselman and Halpern 1970a). Magnitude estimates of sweet and bitter tend to show reduction of one of the taste quality categories, along with growth of another. It is useful to use *G. sylvestre* in sweet foods and solutions to focus the effects on other taste, flavor, and sensory attributes. For example, a recent study used *G. sylvestre* to suppress the sweetness in sucrose and high fructose corn syrup solutions, since it aimed to compare the mouthfeel and viscosity between these two solutions (Kappes and others 2006).

Methods of Sensory Evaluation

When humans communicate sensory experiences, it is difficult to describe their perceived sensations without a common domain or terminology usage. Attempts to quantify sensations by applying numerical values led to the development of scales by psychologists and psychophysicists (Lawless and Heymann 1999). These scaling techniques incorporate intensity descriptors, which are used as anchors in many psychophysical scales to quantify the perceived sensation. Scaling is particularly useful for measuring the intensity of tastes and smells in foods.

The older tradition of sensory evaluation depends on scales of various types labeled with adjective/adverb intensity descriptors. Most commonly, category and some labeled scales are very basic and can include the terms “weak,” “medium,” and “very strong (Lawless and Heymann 1999). The newer tradition strays from these descriptors and focuses more on direct scaling methods. Direct scaling methods focus on ratio properties that originated with magnitude estimation, which are the basis of magnitude matching and hybrid labeled/ratio scales (Jones and others 1955). These methods derive primarily from the work of S.S. Stevens, who has significantly advanced scientific taste studies.

Since humans cannot share experiences, direct comparisons of sensory or hedonic (likeability) perceived intensities across individuals is difficult. Numerous studies have proven that the strongest taste experienced varies genetically while the strongest pain varies with experience (Bartoshuk and others 2004). For example, there are definite gender differences for the strongest pain since only women experience childbirth. In order to make indirect comparisons among varying experiences, it is necessary to identify a standard that is assumed to be equal for everyone. Recent advanced scaling techniques such as the general Labeled Magnitude Scale (gLMS) attempt to solve this issue. This scale allows for comparisons among groups of individuals (e.g., sex, age, race, clinical status, genetic status) (Bartoshuk and others 2004). The gLMS shows great use for taste research and other fields of study, especially since recent studies show genetic variation in taste.

Category Scales

The oldest and most widely used scales are the 9-point category scales. The United States Natick Laboratories were the first to develop a scale to quantify sensations. Specifically, they measured the soldiers' acceptance of foods by rating sensations according to their perceived intensities (Jones and others 1955; Jones and others 1955). The 9-point scale ranges from 1 "none", 3 "slight", 5 "moderate", 7 "strong", to 9 "extreme." These numerical values do not have ratio properties, meaning that a rating of "8" is greater than a rating of "4", but not necessarily twice as great. Due to this problem, this scale is rarely used for measuring intensities, but rather it is extremely useful for hedonic testing with a large number of subjects since it requires little instruction.

Direct Scaling Methods

Humans are able to estimate magnitude differences for sensations but may have difficulty quantifying these differences with category scales. To overcome this problem, scales with ratio properties were developed and introduced in the 1950s by S.S. Stevens and his colleagues (Stevens 1957). Magnitude estimation (ME) was the first of these direct scaling methods. Unlike the category scale, this technique did not contain any labels or anchors. Instead, individuals were instructed to assign numerical values to their sensations as long as the values reflected the ratio among their sensations. More specifically, if one sensation is twice as intense as another, then it is assigned a number that is twice as large.

Further developments with ME expanded from the matching of one sensation to the matching of different sensations for intensities. This means that individuals can rate tastes relative to another sensation (non-taste related) that is used as a standard.

Known as the “gold standard method,” magnitude matching of unrelated sensations is extremely useful for making valid across-group comparisons (Stevens 1957). When used with unrelated standards, the data should show differences between taste status groups – nontasters and supertasters. Data also show the rate of growth of perceived sensory intensities with increases in the stimulus, but the absolute magnitude estimates cannot be compared across subjects or groups (Green and others 1993). There is a belief that individuals would benefit from having adjective/adverb descriptors on the scale, which led to further developments of labeled scales.

Labeled Scales

While Stevens and colleagues were working on magnitude estimation and matching scales, other psychologists continued working on developments with the category scale. Category scales were replaced by other labeled scales including the visual analog scale (VAS), Likert scale, and Borg scale (Bartoshuk and others 2003). These all vary in number and type of descriptors as well as the labels for the anchors.

More importantly for labeled scales, improvements of the descriptors were necessary. Previously, the intensity adjectives/adverbs were the labeled descriptors used as standards. There was a major need to select labels not related to the sensation of interest in order for the same scale to be used to measure and compare various sensations. Borg’s scale is the most powerful out of all of these types since he anchored the top of his scale to “maximal sensation” (Borg 1982).

The issues of the spacing of the labels and absolute intensities denoted by the scale labels for the experience described and the individual experiencing it continued to remain major problems. Moskowitz was the first to implement empirical spacing of intensity adjectives (Moskowitz 1977). These new locations are useful to allow some comparisons for a variety of sensory domains as well as for a hedonic domain.

Like category scales, labeled scales also are widely used because of their assumed simplicity. Recent studies suggest that there are issues with several of their key features. It is false that the intensity labels denote the same perceived intensities to all individuals, so comparisons can be invalid. Therefore, the absolute intensities associated with a descriptor can vary across individuals depending on their differences in experience or physiology. This leads to a major development in scaling – the Labeled Magnitude Scale (LMS).

Labeled Magnitude Scale (LMS)

A major breakthrough in sensory evaluation was the development of a hybrid of ratio/labeled scales called the Labeled Magnitude Scale (LMS) devised by Green and colleagues (Green and others 1993). Green recognized that the sensory intensities of experiences differ between individuals and depend on the context to which it is applied. The LMS is a labeled scale with ratio properties that was created by empirically spacing descriptors (Green and others 1993). It is a vertical linear scale ranging from the bottom anchor at zero “no sensation” to the top anchor 100 “strongest imaginable oral sensation” (Green and others 1993). Also, it includes adjective/adverb descriptors between these anchors with intermediate labels for “barely detectable,” “weak,” “moderate,” “strong,” and “very strong.” This allows an oral sensation that is rated 80 to be perceived twice as intense as one that is rated 40. Therefore, the LMS has been used to study the sensory characteristics of foods and link these behaviors of genetic variation in taste, food behavior, and health.

The top anchor of the scale is limited to oral sensations including pain assuming that oral pain is equivalent across groups of individuals. If it were opened to other domains besides oral sensations, there was concern that the strongest possible sensation may vary across sensory modalities. In actuality, if perception of burn determined a maximal oral sensation, then the top anchor of the LMS would not be equivalent for nontasters, medium tasters, and supertasters (Bartoshuk and others 2003). It does not fully solve the problem of relativity of descriptors across context and experiences. Therefore, the LMS is not a universal scale and is not perfect. This suggests the need for a more general version of the LMS that is not limited to oral sensations.

General Labeled Magnitude Scale (gLMS)

Modifications to the LMS were necessary to create a more general and universal sensory ruler that stretches or compresses to fit the domain of interest. This modified LMS scale was termed the general Labeled Magnitude Scale (gLMS) by Bartoshuk and colleagues (Bartoshuk and others 2003). Like the LMS, the gLMS still borrowed the logic of magnitude matching, but is a labeled scale that has descriptors unrelated to taste. The scale is a horizontal line ranging from the left anchor labeled zero “no sensation” to the right anchor labeled 100 “strongest imaginable sensation of any kind” (Bartoshuk and others 2003). As a personalized scale, the individual creates his or her top anchor. Although this top anchor cannot be assumed to be equal to all, the top anchor is rarely taste so it is independent of taste. Any variation in the top anchor across different taster groups should be equivalent. Also, the gLMS retained the intermediate descriptors from the LMS. As a control, panelists rate the intensity of an ascending series of remembered visual and auditory experiences on the gLMS. The experiences are from different modalities including loudness of a sound (whisper, conversation, loudest sound ever heard) and brightness of a light (dimly lit restaurant, well lit room, brightest light ever seen).

To strengthen the power of the gLMS, it underwent recent modifications. Removing the term "imaginable" from the top anchor was essential since it detracts from its universality (Snyder and others 2008). Although there are correlations between intensities of imagined and experienced sensations, "individual differences in imagery may confer different meanings (Snyder and others 2008)." Thus, the top anchor is now the "strongest sensation of any kind ever experienced (Snyder and others 2008)." In addition, intermediate labels appeared extraneous and thus were removed (Snyder and others 2008). Whether it is linear or numerical, a simple labeled scale allows group comparisons and is useful as long as it contains endpoint labels expressed in terms of all sensation experienced.

Currently, the gLMS is the best and most powerful scale that allows valid comparisons among groups, thus permitting associations between oral sensations, preferences, intake, and health outcomes (Bartoshuk and others 2004). It reflects very large effects produced by bitter compounds such as PTC, PROP, caffeine, or quinine and their significant correlations between fungiform papillae density (Bartoshuk and others 2003). Therefore, perceived taste intensities are associated with fungiform papillae density, which can evaluate the power of this scale and provide valid comparisons across nontasters and supertasters. This scale is extremely valuable to measure absolute intensities of various sensations and compare them among groups.

CHAPTER 3

RESEARCH METHODS AND MATERIALS

Panelist Recruitment

The University of Florida Health Science Center Institutional Review Board (IRB) approved the study protocol. One hundred twenty panelists comprised of students and staff were recruited from the University of Florida. Flyers and advertisements were posted at the sign-in area of the Food Science and Human Nutrition (FSHN) Sensory laboratory and bulletin boards located throughout the FSHN building to inform potential panelists about the study. All ages above 18 were considered for participation. After obtaining contact information from interested panelists, each panelist was screened for eligibility based on taste preference and possible allergens to ensure consumption of samples (Appendix A). Twenty of the recruited panelists were ineligible for the study due to one of the following reasons: they were vegetarians and refused to consume the chicken sausage, did not like one or more of the food samples, had an allergy to one or more of the food samples, moved to a different location, and/or were no longer interested in the study. During the first orientation session of the study, the one hundred eligible panelists reviewed the study details, including possible side effects, and signed the IRB approved consent form (Appendix B). The panelists were free to withdraw from the study at any time with no consequences. Panelists were compensated for participating in each session of the study.

Taste-Modifying Compounds

Two different types of taste-modifying compounds were used in the study to alter the sweet taste of foods. Miracle fruit was used to add sweetness to acids while *Gymnema sylvestre* was used to suppress sweetness. Informal preliminary panels were held to test various forms of freeze-dried miracle fruit tablets and concentrations of brewed *G.sylvestre* tea prior to the formal panel sessions.

The miracle fruit tablets selected, mberry™, were obtained from the company My M Fruit Inc, LLC. Each tablet contained an amount of taste-modifying compound equivalent to the amount one miracle fruit berry and dissolves fairly quickly in the mouth. They are composed of miracle fruit powder and corn starch, which is used as a binding agent.

Loose *G. sylvestre* tea leaves were obtained from Penn Herb Company, Ltd. These were used to create a brewed tea beverage based on the recipe originally created by Meiselman, which uses 1500 mL of hot water and 100 grams of tea leaves stirred for 1 hour at 95°C (Meiselman and Halpern 1970b; Kappes and others 2006). The tea was cooled in the refrigerator prior to serving.

Food Selection

This study investigated a variety of foods with different associations to sweet and sour tastes. Since it is important to prevent overwhelming the panelists with too many foods, informal panels were carried out to narrow down the food selection. The following ten food items were selected and purchased from a local grocery store for the formal panels: apple cider vinegar, cherry tomatoes, Armour® chicken Vienna sausages, lemons, French's® yellow mustard, Planters® unsalted peanuts, Mt. Olive® hamburger dill chips pickles, strawberries, Hershey's® Kisses dark chocolate, and Aunt Jemima® original syrup.

The food samples, including their taste associations and predicted flavor intensity after miracle fruit and *G. sylvestre* are seen in Table 3-1. Foods that are commonly associated with sweetness, but not sourness include dark chocolate and syrup. The flavor intensity of these foods are expected to change after *G. sylvestre*. In contrast, foods that are typically associated with sourness, but not sweetness include apple cider vinegar, lemons, yellow mustard, and pickles. These are expected to change after miracle fruit. A combination of both sweetness and sourness are typically associated with cherry tomatoes and strawberries. These are both expected to change after miracle fruit and *G. sylvestre*. Chicken sausage and peanuts are not typically associated with sweetness nor sourness, which serve as neutral foods in this study and are expected to have no change in flavor intensity.

Sensory Laboratory

Panelists evaluated samples at the Sensory laboratory in individual booths, equipped with computer workstations with the sensory software program (CompuSense® five Sensory Analysis Software for Windows, Compusense, Guelph, Canada). A personal scale and pencil was provided at each booth to allow panelists to generate and remember their top anchor throughout the duration of the study. Also, unsalted soda crackers and purified water were provided for every panelist to encourage rinsing of their palate as often as necessary between samples. Randomized, three-digit codes were assigned to each sample type and a representative amount (e.g., one strawberry, one lemon wedge, etc.) was placed in individual soufflé cups with lids. All panelists were presented samples in random order for evaluation.

Questionnaire Design

At the beginning of every taste session, each panelist answered a series of demographic questions. The following demographic data were collected from the panelists: gender, age, height (in feet and inches), weight (in lbs), ethnic background, and incidence of otitis media (ear infection). The panelist’s height and weight were used to calculate their body mass index (BMI). BMI was calculated using the following equation: ((weight (lbs) / height^2 (inches)) x 703) (National Institute of Diabetes and Digestive and Kidney Diseases. National Institutes of Health. November 2008).

All panelists were trained to use the general Labeled Magnitude Scale (gLMS) to measure and quantify intensities of attributes of each food sample before and after miracle fruit and *G. sylvestre* (Bartoshuk and others 2004). The gLMS allows individuals to develop a personalized scale ranging from “no sensation” (0) to their own “strongest sensation ever experienced” (100), with the flexibility to allow the panelist to select any numerical integer value on this scale between these anchors. Each panelist identified and recorded their own “strongest sensation ever experienced,” which is typically not food related. Some examples of sensations that were mentioned to the panelists included the strongest light ever seen (the sun), loudest sound ever heard (a jet plane taking off), and a particular pain (childbirth in women), although not limited to these experiences. The panelist’s recorded sensation represented their top anchor (100) in the newly developed gLMS for the remainder of the study. After this scale was developed, the panelists practiced magnitude matching to experiences from memory including the loudest sound ever heard, loudness of a conversation, brightness of a well-lit room, brightest light ever seen (usually the sun), loudness of a whisper, and brightness of a dimly-lit restaurant. The scale was further used to rate the intensity of attributes – smell (aroma), sweet, sour, and overall flavor (retronasal olfaction) – of each food sample in relation to the amount of the sensation that is experienced. The same procedure was repeated for all food samples prior to and after consumption of miracle fruit and *G. sylvestre*.

Miracle fruit and *Gymnema sylvestre* are known to not affect bitter taste. In addition, the reaction to bitterness is one of the methods used to classify panelists by taster status. Older methods use PTC or PROP, but since there are potential side effects with these chemicals, they were replaced with quinine. A 0.001 molar quinine solution was prepared for use at the end of each session to determine supertaster status. Panelists were served approximately 5 mL of the solution at room temperature to taste. They then rated the intensity of the bitter solution using the gLMS.

Training Session

All panelists attended a 30 min training session prior to the first tasting session. Panelists were instructed to read through and sign the IRB consent form to understand the test requirements, especially with regards to the taste modifications. Verbal instructions were given throughout this session.

This practice panel followed the same test design as the tasting sessions in Study One and Study Two with the exception of the taste-modifying compounds and quinine solution. First, panelists answered demographic questions. The gLMS was introduced and the top anchor generated was written on the personal scale as well as typed into the computer program (Appendix C). Panelists were continuously reminded that their top anchor represents the value 100, strongest sensation of any kind. The panelists practiced using this scale with the experience questions described above. Next, panelists were presented with two very different food samples, strawberry and lemon, for evaluation. They used the gLMS and rated the attributes smell, sweet, sour, and overall flavor intensity (i.e. strawberry flavor) of the food samples from 0 to 100. This training session was beneficial to the panelists, by familiarizing them with the gLMS, and allowing for questions to be asked, minimizing procedural confusion in future panels. Since the main purpose was to train the panelists prior to Study One, the data from this session were not analyzed.

Study One

Ninety-seven panelists attended the first study. There was an even representation of both genders, which included 48 females and 49 males. Their ages ranged from 18 to 55. The average age was 26 while most panelists were 23 years old, due to the fact that the majority of panelists were undergraduate and graduate students. Panelists identified their ethnic background, race, and incidence of ear infections as seen in Table 3 -2.

Each panelist was assigned an hour long time period to perform the test. Panelists were advised to not consume large meals or heavily flavored products prior to and after their appointment due to any potential lingering effects. Although the panelists were previously trained, verbal instructions were given throughout this session since there were special instructions pertaining to the treatments (for the taste-modifiers).

The panelists followed the same test design as in the training session, including the demographic questions, gLMS generation, and answering the experience questions with the gLMS (Appendix D). They were presented with the ten food samples in a randomized order and asked to rate intensity of each of the attributes. Each panelist received a different random order. After rating all of these foods, the miracle fruit tablet and a new, randomized order of the set of the same ten food samples were given to each of the panelists. Panelists were instructed to let the tablet dissolve in the mouth and roll it around with the tongue, without any chewing. In approximately five minutes after the tablets dissolved, panelists were instructed to start tasting and rating the ten food samples with the gLMS. After this second set of food samples, panelists were given a *G. sylvestre* tea sample and another set of the same ten food samples in a new, randomized order. They were instructed to swish the tea in the mouth for 30 seconds and expectorate into a cup. Right after rinsing the mouth well with water, the food samples were tasted and rated with the gLMS. A quinine solution was given at the end and panelists were asked to rate the intensity of the bitterness, also using the gLMS. Panelists were advised that their tastes may be modified for up to 2 hours after the study.

Study Two

The second study was repeated with the same panelists. However, this study was split into two sessions to reduce possible fatigue. Some panelists were unable to attend the following two sessions, mostly due to schedule conflicts. The demographics of the panelists are also seen in Table 3-2. In the first session of study 2, there were 88 panelists who were divided into 40 males and 44 females. In the second session, there were 80 panelist who were divided into 38 males and 42 females. Since the same panelists were used, the same demographic data were reported.

Minimal verbal instructions were given for these sessions. Panelists were presented the same exact food items (in random order), with some seasonal variation among the produce items, and same taste-modifying compounds as in the first study. In the first of these sessions, panelists evaluated the ten food samples as in study 1, then had the *G. sylvestre* treatment, and subsequently evaluated the food samples again (different random order of presentation), and rated the intensity of each of the attributes after the treatment. Finally, panelists tasted and rated the intensity of bitterness of the quinine solution. In the second session, panelists tasted and rated the same ten food samples, had the miracle fruit treatment, then tasted and rated the food samples again, followed by the quinine solution.

Statistical Analysis

The main objective of this study was to determine the differences in flavor intensity of each food sample before and after miracle fruit and *Gymnema sylvestre*. Raw data was collected by the sensory software program CompuSense®. This data were transferred to Microsoft Excel for sorting and preparation for statistical analysis.

The statistical analysis was performed using SAS 9.2 (SAS Institute Inc. Cary NC, USA). Analysis of variance (ANOVA) using Fisher's least significant difference (LSD) was conducted to determine if there were significant differences at a p-value < 0.05 among the means of aroma, sweetness, sourness, and flavor intensity between control and miracle fruit or *G. sylvestre* treatment. For the LSD separation, the differences in the means were denoted by a different letter. Data were also sorted based on gender (males versus females) and BMI using ANOVA. Two different BMI groups were created that compared normal weight, which includes underweight, (BMI value was less than 25) and overweight (BMI was 25 or more) (National Institute of Diabetes and Digestive and Kidney Diseases. National Institutes of Health. November 2008). In addition, correlation coefficients and regression analyses were performed on selected food items with the most significant differences in Excel and SAS to identify any relationships between the taste attributes and flavor.

When panelists were sorted by taster status based on their bitterness rating of the quinine sample, the supertaster and nontasters groups showed similar comparisons of control versus the miracle fruit and *Gymnema sylvestre*. The additional classification variables including race, ethnic background, and incidence of ear infection were also not studied due to insufficient population totals or no significant differences.

Table 3-1. Food samples with typical taste associations and expected flavor changes.

Food sample	Taste association	Expected flavor after MF	Expected flavor after GS
Apple cider vinegar	Sour	Increase flavor	No change
Cherry tomatoes	Sweet and sour	Increase flavor	Decrease flavor
Armour chicken Vienna sausages	None (neutral)	No change	No change
Lemons	Sour	Increase flavor	No change
French's yellow mustard	Sour	Increase flavor	No change
Planter's unsalted peanuts	None (neutral)	No change	No change
Mt. Olive hamburger dill pickle chips	Sour	Increase flavor	No change
Strawberries	Sweet and sour	Increase flavor	Decrease flavor
Hershey's dark chocolate Kiss	Sweet	No change	Decrease flavor
Aunt Jemima's original syrup	Sweet	No change	Decrease flavor

Table 3-2. Demographic information of all panelists from study one and study two.

	Study 1	Study 2, Session 1	Study 2, Session 2
	N = 97	N = 88	N = 80
Gender			
Male	49	40	38
Female	48	44	42
Ethnic Background			
Hispanic	12	9	8
Non-Hispanic	85	75	72
Race			
White or Caucasian	68	59	60
Black or African-American	8	6	4
Native American, Alaska Native, Aleutian	3	1	1
Asian/Pacific Islander	14	13	12
Other	0	5	3
Incidence of ear infection			
No	78	66	61
Yes, no serious	11	11	13
Yes, required antibiotics more than once	5	4	3
Yes, required tubes in ears	3	3	3

CHAPTER 4
RESULTS AND DISCUSSION

There were three treatments in both Study one and two including control (C), after miracle fruit (MF), and after *Gymnema sylvestre* (GS). By increasing the intensity of sweet taste with MF, we expected to see an increase in overall flavor of foods that were associated with sweet and sour tastes. By decreasing the intensity of the sweet taste with GS, we expected to see a decrease in overall flavor of foods that were associated with sweet taste. Since the orthonasal odor of food samples is not strongly influenced by tastes, it is expected that there would be no differences in the odor attribute among all treatments. Therefore, the ratings for this attribute served as controls to ensure that panelists were using the scale correctly.

Data were analyzed as an overview of all panelists and subsequently separated into groups based on gender and body mass index (BMI) to see if there were any group effects. Taster status was not analyzed since there was not a large enough population size. Study one was repeated as Study two to determine if the panelists would rate the same intensities for all foods at all treatments, assuming all conditions remained the same. No data was removed since the high number of panelists accounted for normal variation and any potential sources of error. Possible error sources, excluding sample to sample variation, which could impact the intensity ratings that a sample received included lingering effects from previous samples or treatments, palate exhaustion, personal likeability of samples, and setting. The remainder of this chapter will discuss the results from each study focusing on the relationships within each category of taste associations. The intensity ratings of individual food samples will also be discussed.

The hypothesis was accepted for those foods that are associated with sweet and sour tastes (e.g., cherry tomatoes and strawberries), but does not apply to those foods that are associated with sour and not sweet tastes. After MF, in sweet and sour taste associated foods, there is an addition of sweet taste, a decrease of sour taste, and additionally, an increase of overall flavor. This can be explained since these foods are more associated with more intense sweet taste than sour taste, but both are required for the typical flavor. This supports early taste research focusing on mixtures of taste constituents – the sum of the intensities of unmixed constituents when tasted on their own tended to be much higher than the intensity of a mixture of the constituents (Kiesow 1896). Conversely, after GS, the sweet taste intensity was greatly suppressed and the overall flavor also decreased. These foods require both sweet and sour tastes associated so when sweet taste was nearly removed, the overall flavor was not perceived the same way since it was lacking this major taste component.

Since the hypothesis was not accepted for those foods associated with not sweet and sour tastes, different results were shown from their expected results. When sweet taste was added through miracle fruit to those foods that were not typically associated with sweet taste but only with sour taste (e.g., apple cider vinegar, lemons, pickles, and yellow mustard), there was a decrease the sour taste and in overall flavor. This can be explained by early taste mixture research that shows that substances experience the most suppression when other types of substances are added to it, such as in this case where sweet taste was added to foods that are not typically sweet and the sour taste decreased (Bartoshuk 1975). Additionally, GS suppressed the sweet taste that occurred after the miracle fruit treatment, causing the sweet and sour taste intensity values to decrease and increase, respectively, close to their original values. This data are important in the understanding of the importance of the association of sour taste with flavor. There were no significant changes in sweet, sour, and overall flavor attributes in those foods that were not associated with sweet or sour tastes (e.g., chicken sausage and peanuts).

Additional evidence that has showed that mixtures of very different qualities (e.g., sweet and salty) may show some amount of suppression, such as referring to those foods that have both sweet and sour tastes (Moskowitz 1972). In contrast, mixtures that contain similar tasting substances (e.g., caffeine and quinine) would show less suppression and show addition of the same intensity (Moskowitz 1972). This can help explain why when sweet taste was added to the cherry tomatoes and strawberries, this amount of addition to sweet taste was nearly equivalent to the amount of addition to the overall flavor. Also, since the sweet taste appears to be much stronger than the sour taste, it tends to mask some of the sour taste that remains present in the foods. Once sour taste returned close to the original value, through GS, this showed that sour taste did not actually change after MF. The actual changes in intensity values for all attributes of all foods consumed in this study will be further discussed throughout this chapter.

Study One

Ninety-seven trained panelists participated in Study One. They consumed and rated all ten food samples after each of the three treatments – control (C), miracle fruit (MF), and *Gymnema sylvestre* (GS) – as previously described in the methods. The results of each food are classified based on their typical taste associations, which were intended to show similar trends when comparing the sensory attributes and treatments.

The means for the attribute intensity ratings are presented in Table 4-1. Significant differences were found between foods for all attributes at $p \leq 0.05$. Panelists tended to use the lower to middle portion of the gLMS. The lowest average intensity rating was 1.0 for sourness of maple syrup after MF and the highest average intensity rating was 61.3 for flavor of apple cider vinegar after C. The average intensity ratings for odor ranged from 9.2 to 54.4, sweetness from 3.2 to 48.6, sourness from 1 to 53.6, and flavor from 14.9 to 61.3. Further analysis of the attributes when separated by treatments showed different ranges. For C, the average intensity ratings for odor ranged from 9.2 to 54.4, sweetness from 4.6 to 44.6, sourness 2.7 to 53.6, and flavor from 21.2 to 61.3. For MF, the ranges were slightly narrower where the average intensity ratings for odor ranged from 11.1 to 52.4, sweetness from 19.3 to 48.4, sourness 1 to 28.1, and flavor from 19.3 to 48.4. For GS, the ranges were also narrower than C where the average intensity ratings for odor ranged from 11.6 to 49.6, sweetness from 3.2 to 12.3, sourness from 2.4 to 46.7, and flavor from 14.9 to 52.2. There was a substantial decrease in the upper range value of sweetness.

Sour, but not Sweet

The food samples that are typically associated with the tastes “sour, but not sweet” include apple cider vinegar, lemons, pickles, and yellow mustard. These foods are not typically consumed singly since their sourness is so intense; they are instead used as ingredients, condiments, or garnishes in other foods. It was expected that the panelists would perceive the same intensity values of the odor and that their responses would show no statistical differences for these foods at all treatments. After MF, there would be expected changes to the intensity of the sweetness, sourness, and overall flavor of all of these foods. Since there were no associated sweet tastes with any of these foods, after the GS treatment, there were no expected changes to the intensities of the sweetness, sourness, and flavor.

Apple cider vinegar is made from fermented apples and contains a high amount of acetic acid. As expected, there were statistically significant differences among the sweet intensities between C (5.0) and MF (27.4) which greatly increased by 22.4, and between the MF (27.4) and GS (3.9) where a decrease of 23.5 was calculated. After the GS, the sweet intensity returned close to the original value which showed that there were no statistical differences among treatments for C (5.0) and GS (3.9). There were statistical differences among all treatments for sourness intensity, especially a great decrease from C (53.6) to MF (28.1). There was a small difference between C (53.6) and GS (46.7), which showed that the sourness intensity increased after the GS treatment and almost back to the original C value. Changes in the sweet and sour tastes affected the overall flavor intensity of each food, which caused the flavor to be statistically different among all treatments. After C (61.3), both MF (48.4) and GS (52.2) decreased flavor although GS increased after MF, but not as large as C. Thus, it was observed that when the sweetness of the apple cider vinegar was increased, this caused a decrease of sourness; this combination of changes to both sweet and sour tastes was thought to cause a decrease in flavor.

Lemons are very sour citrus fruits that contain a high level of citric acid. As expected, there were significant statistical differences for sweetness among all of the treatments. Sweet intensity greatly increased from C (4.6) to MF (41.1) by a value of 36.5. After GS (9), the sweet intensity decreased immensely and returned close to the original value. When sour intensity was rated, there were also significant differences among all treatments. Sour intensity greatly decreased from C (52.6) to MF (16.5) since the enhanced sweetness masked some of the sour taste. After GS (41.6), it increased again close to the original value, which shows that the sour taste was not actually changed by MF. Since the intensities of the sweet and sour tastes were affected by the treatments, it is believed that these influenced the overall flavor of the lemons. The C (52.6) had the highest overall flavor intensity when compared to the MF (44.4) and GS (43.8) treatments. There were statistical differences between C (52.6) and MF (44.4), where it decreased by 8.2, and between C (52.6) and GS (43.8), where it decreased by nearly the same amount. There were no statistical differences between MF (44.4) and GS (43.8), which showed that increasing the sweetness and then reducing that change in sweetness did not alter the overall flavor intensity. Some panelists commented on the lemon sample after MF stating that its taste was extremely sweet and its flavor was comparable to a highly sweetened lemonade or lemon candy. Furthermore, this helped explain that extremely high sweetness is not representative of normal lemon tastes so increasing sweetness does not necessarily enhance flavor. This suggests that sour taste is also an important factor for flavor, especially in lemons.

Pickles are cucumbers fermented in vinegar and contain some lactic acid. When the sweet intensity was rated, there were statistical differences among all of the treatments. There was low sweet intensity at C (6.6), but it increased after MF (18.4). This change in intensity was not as large when compared to other foods such as apple cider vinegar and lemons. The sweet intensity decreased again after GS (3.8), but was slightly lower than the original value at C (6.6). Similar to the sweet taste, there were also significant statistical differences among all of the sour taste intensities. The initial sour taste was the highest intensity at C (30.3), decreased after MF (13.2), and then increased after GS (21.8). The increase in sourness after GS was higher than MF, but not as high as it was at C. This suggests that there was some sweet taste associated with the pickles although it is relatively small. When flavor intensity was rated, there were statistical differences between C (37.5) and MF (27.5), which was when sweetness increased. There were also differences between C (37.5) and GS (27.1), where flavor also decreased and sweetness was decreased close to the original value. Since MF and GS both decreased flavor and were shown to have no statistical differences, the amount of sweetness did not have a significant impact on flavor intensity of pickles.

Yellow mustard is a condiment made from mustard seeds and vinegar so it contains a variety of acids. There was very low sweet taste associated with the C (6), but this increased significantly after MF (24.9) to show statistical differences. After GS (4.9), the sweet intensity then decreased to a low value close to C. Since the ratings between C and GS were so similar, there were no significant differences between these two treatments. In contrast to sweet taste, when sour intensity was rated, there was a statistical difference between the initial value at the C (28.9) and after MF (15.8) due to the decrease of 13.1. There was also a difference between MF (15.8) and GS (26.9), where the sourness increased to a value close to the original value. Therefore, there were no differences between C and GS. There were no significant differences among all of the flavor intensities. There were significant differences at a greater alpha than 0.05 between C (38.4) and MF (34.1) and also, between C (38.4) and GS (32.5). There were no statistical differences between MF and GS. This shows that there is very low sweet taste associated with yellow mustard since the flavor was not greatly impacted. These results suggest that increasing sweetness with MF does not impact the overall flavor of yellow mustard since its intensity rating is approximately the same as C and GS.

Apple cider vinegar, lemon, pickles, and yellow mustard all performed similarly. After MF, the sweet taste increased, the sour taste decreased and went back to the original value at C or slightly lower, and overall flavor either stayed the same or decreased. After GS, the sweet taste decreased to a similar or lower value as C, the sour taste was the same or slightly lower, and the flavor stayed the same or slightly decreased. This suggests that increasing sweetness does not increase flavor in foods that are associated with sourness but not with sweetness. Therefore, there is a strong positive correlation between sour taste and overall flavor.

Sweet, but not Sour

The food samples that are typically associated with the tastes “sweet, but not sour” include the dark chocolate Kiss and Aunt Jemima’s maple syrup. Like the foods associated with the tastes “sour, but not sweet,” it was expected that the panelists would perceive the same intensity values of the odor with no statistical differences. Since there is no sour taste associated with any of these foods, there are no expected changes to the intensity of the sweetness, sourness, and overall flavor of these foods after the MF treatment. After GS, the foods are expected to have significant changes to the intensities of the sweetness and overall flavor, but not to the sourness.

The dark chocolate Kiss is a chocolate candy that is considered to be very sweet. When sweet taste intensity was rated, there were no statistical differences between C (36.4) and MF (37.8) since MF did not affect the sweet taste. GS (10.1) greatly decreased the sweet taste by 27.7 and was significantly different from both the C (36.4) and MF (37.8) treatments. Since sour taste was not associated with this food, it was not affected by the taste-modifying treatments. Therefore, there were no significant differences between C (3.1) and MF (2.3) nor between C (3.1) and GS (4). There were statistical differences between MF (2.3) and GS (4), although the actual difference was 1.7, which is extremely small. Since the sweet and sour tastes were approximately the same between C and MF treatments, there were also no statistical differences in the overall flavor between C (38.3) and MF (37.3). Behaving similarly, when the GS treatment decreased sweetness, there was also a decrease in flavor intensity for GS (18.8), which was statistically different from both C and MF. When sweetness was decreased, there was also a large decrease in flavor.

Aunt Jemima's maple syrup is a condiment commonly used to enhance flavor in breakfast foods. It was also considered to be the sweetest food sample in this study. The sweetness intensity ratings were very high for C (44.6) and MF (42.4), which did not show any statistical differences. However, the sweet taste was decreased dramatically by GS (11.4). Like the dark chocolate, there was also very little sour taste intensity which showed no statistical differences between C (1.2) and MF (1.9) and between C (1.2) and GS (2.4). Also for sour taste, there was a statistical difference between MF (1.0) and GS (2.4), but the actual difference was very small (1.4). Also similar to the dark chocolate results, there were no statistical differences between C and MF for sweet taste, which led to no significant differences for overall flavor between C (37.6) and MF (38.6). The large decrease in flavor rated after GS (16.5) was significantly different from both the C and MF.

The dark chocolate Kiss and maple syrup performed similarly. After MF, the sweet taste and overall flavor intensity were not affected since they had similar values to those rated at C. The sweet taste and overall flavor decreased after the GS for both foods. There were no significant differences or minimal differences to odor and sourness after MF and GS. This shows that decreasing sweetness in foods that are associated with high sweetness will decrease overall flavor intensity. Therefore, there appears to be a link between sweet taste and overall flavor.

Sweet and Sour

The food samples that are commonly associated with the tastes “sweet and sour” include cherry tomatoes and strawberries. Since these are produce items, there is greater variation in these samples when compared to the other food samples due to harvesting and post-harvesting conditions. After both the MF and GS treatments, there were expected changes to sweetness, sourness, and flavor but not odor. More specifically, after the MF, the sweet taste intensity was expected to increase, sour taste to decrease, and overall flavor to increase. In contrast, after the GS, the sweet taste intensity was expected to decrease, sour taste was to return close to the original value, and the flavor to decrease.

Cherry tomatoes are a sweet and sour fruit that are very popular in salads and as snacks. There were significant statistical differences among the sweet intensity ratings for all treatments. The initial sweetness value at C (11.5) greatly increased after MF (32.4) and then decreased again after GS (6.3) to a value that was lower than at C. There was slightly higher sourness than sweetness intensity associated with tomatoes as seen at C (13.8). There was a significant decrease to only slight level of sourness after the MF (4). When GS was applied after the MF, the sour taste returned to approximately the same value as C. Therefore, there were no statistical differences between C (13.8) and GS (13.6) for the sour taste. This shows that the sour taste does not disappear after MF, but appears to be masked by the enhanced sweet taste. The sweet and sour tastes had an effect on flavor intensity. There were differences in flavor between C (23.6) and MF (32.2), where the flavor increased after MF, and between MF (32.2) and GS (20.5), where the flavor decreased after GS. There were no significant differences in the overall flavor between C (23.6) and GS (20.5), which was when the sweet intensity decreased although it was lower for GS.

Strawberries are also a sweet and sour fruit that are more sweet than sour as they ripen. Like the cherry tomatoes, there were also significant statistical differences among the sweet intensity ratings for all of the treatments. The initial sweet taste intensity value C (29.8) increased after MF (48.6) and decreased after GS (12.3). The sweet intensity rated after GS significantly decreased below the original value. There were also differences among the sour tastes. There was a considerable amount of sourness associated at C (14.9), which decreased after MF (3.1), and then increased after GS (14.8). Since the values between C and GS were approximately the same, there were no significant differences. This showed that the sour taste returned back to the original value, although sweet taste intensity was extremely low. Since there were significant differences among the treatments for the sweet and sour tastes, there were also significant differences among the overall flavor intensities. There was relatively high flavor at C (33.4), which increased to a higher intensity after MF (45.2). After GS (24), it decreased below the C. When the sweet intensity value increased, flavor increased and vice versa – when the sweet intensity value decreased, then the flavor decreased.

The cherry tomatoes and the strawberries performed similarly. There were no significant differences or minimal differences in intensity values to odor after MF and GS. After MF, the sweet taste and overall flavor intensity both increased while the sour taste decreased. This shows that enhanced sweet taste leads to higher perceived flavor, since they are both associated with more sweet taste than sour taste. After GS, the sweet taste and overall flavor intensity both decreased but the sour taste was rated close to the original value. This shows that decreasing sweet taste in a food that is associated with sweet and sour tastes will decrease the overall flavor intensity. Also, if more sour taste is perceived than sweet taste, then the overall flavor is also decreased.

Not Sweet and not Sour

The food samples that are typically associated with the tastes “not sweet and not sour” include chicken sausage and peanuts. Since these foods were selected as controls, there were no expected differences among odor, sweet taste, sour taste, and overall flavor intensities among any of the treatments.

Chicken sausage is a processed meat product that contains numerous ingredients, but mostly chicken. It was not considered to be sweet or sour. When the sweet taste intensity was rated, there were statistical differences between the C (8.6) and MF (12.9), although the difference of 4.3 was relatively small. Also, there were also statistical differences between the MF (12.9) and GS (7.4), but the difference was relatively small. This also showed that there were no differences between C (8.6) and GS (7.4). When sour taste intensity was rated, there were no significant differences among the treatments C (5.9), MF (5.1), and GS (6). Since sweet and sour tastes did not show major differences among the treatments, there were also no significant differences among the flavor. The intensity ratings between C (27.1) and MF (25.2), as well as between MF (25.2) and GS (23.3) were not significantly different. There was a small statistical difference between C (27.1) and GS (23.3).

Peanuts are usually consumed as a snack that is not associated with sweet or sour tastes. Due to this, there were low intensity ratings for the sweet taste. There were small statistical differences among all of the treatments C (7.4), MF (10), and GS (3.2) for sweet. When the sour taste was rated, no differences were found between the C (2.7) and MF (1.6) and between the C (2.7) and GS (2.9). There were small statistical differences between the MF (1.6) and GS (2.9), although these are not significant since the values are so low. When flavor was rated, there were no differences between the C (21.2) and MF (19.3). There were statistical differences between the C (21.2) and GS (14.9), and also between the MF (19.3) and GS (14.9). These flavor values were not considered to be significant since sweet and sour tastes did not strongly influence the flavor.

The chicken sausage and peanuts performed similarly. The results showed that odor, sweet taste, sour taste, and overall flavor were not substantially affected by either MF or GS. Although there were differences among some of the treatments, the actual difference in intensity values were very small.

Odor

The odor of the samples was defined as the orthonasal olfaction that occurs before food enters the mouth. Since this attribute is not affected by taste, it is not expected to change after the taste-modifying treatments of MF and GS. Therefore, this served as a control attribute in the study. Generally, the odor intensities of all of the foods tended to be rated lower than the overall flavor intensities.

There were differences in the odor intensity, as rated by the panelists in this study, due to the difficulty in replicating the exact same rating as well as variability between sessions. Although there were some statistical differences between and among treatments, the actual differences were rather small since they were usual within ± 5 units. For example, when apple cider vinegar was rated, there were no statistical differences between the C (54.4) and MF (52.4) and between the MF (52.4) and GS (49.6). A small statistical difference of 4.8 between the C (54.4) and GS (49.6) was observed.

Taste and Overall Flavor Correlations

Three food items were selected for correlation and regression analyses, as seen in Table 4-2 based on their significant differences in intensity ratings among treatments. Strawberries were selected to represent “sweet and sour,” lemons were selected to represent “sour and not sweet,” and maple syrup was selected to represent “sweet and not sour.” No food samples were selected for “not sweet and not sour” since they did not show significant differences among treatments. Correlations (r values) with a p-value less than 0.05 were considered significant. Similar correlations were reflected in the other food samples that were found in the same taste association category.

Strawberry

Strawberries are associated with both sweet and sour tastes, and the previous results show that these both influence flavor. Figure 4-1 shows that sweet taste is positively correlated with overall flavor before miracle fruit, after miracle fruit, and after *G. sylvestre*. The sweet taste intensity ratings were the highest after the miracle fruit treatment, showing the strongest correlation (R=0.92) with flavor intensity among these treatments. Sour taste is also correlated with overall flavor, but only before miracle fruit and after *G. sylvestre*, as shown in Figure 4-2. The sour intensity ratings were the highest at these treatments. After miracle fruit, there was no significant correlation between sour taste and overall flavor since most panelists rated the sour taste with extremely low intensity values. Therefore, this shows that a combination of sweet and sour tastes is necessary for perception of normal strawberry flavor although sweet taste is the major driving force in the overall flavor.

Lemon

Lemons are primarily associated with sour taste. Therefore, sweet taste should not influence flavor as greatly as sour taste. Before miracle fruit, there was no significant correlation between sweet taste and overall flavor. There were significant correlations after miracle fruit, where the sweetness greatly increased and after *G. sylvestre*, where it had a significant, but low correlation value (R=0.27) in Figure 4-3. Figure 4-4 shows that sour taste is correlated positively with overall flavor before miracle fruit, after miracle fruit, and after *G. sylvestre*. It had the highest correlation values before miracle fruit and after *G. sylvestre*, where the R=0.90. After miracle fruit, there was much less sour taste associated with the lemons than the other treatments although there was still a low, but significant correlation (R=0.47). Since lemons are not typically associated with sweet taste, sour taste is the major driving force in the overall flavor.

Maple syrup

Maple syrup is associated with sweet taste and has very little to no sour taste, as shown by the previous results. Therefore, the sweet taste had a strong influence on flavor. This was explained by the high, positive correlations between sweet and overall flavor at all treatments before miracle fruit, after miracle fruit and after *G. sylvestre* as seen in Figure 4-5. This showed that increasing sweet taste will also increase flavor.

Since there is little to no sour taste associated with the maple syrup, sour taste was not expected to correlate with overall flavor. The correlation between sour taste and flavor is seen in Figure 4-6. In Figures 4-6 A and C, there were some outliers which were possibly due to human error in measuring a different attribute besides sour taste. After *G. sylvestre*, there was a positive correlation between sour and overall flavor at R=0.46. Since there was low sweet taste associated at this treatment which is not typical of this products, panelists may have felt frustrated and used the dumping effect. This shows that sweet taste is the major driving force in overall flavor of maple syrup.

Gender and Body Mass Index (BMI)

The same data set was separated by gender and body mass index (BMI). Previous studies have shown that there is a strong interaction between PROP status and gender as well as between PROP status and BMI (Tepper and Ullrich 2002).

Females are known to have more fungiform papillae on their tongue, which may affect their taste status and cause them to experience more intense taste sensations. Similar studies have shown gender differences in taste intensities and likings, so gender classification was included (Bartoshuk and others 1994; Lucchina and others 1998). Tables 4-3 and 4-4 show the separation between males and females, respectively. Approximately half of the panels were males and the other half were females. The results suggest that there are no significant differences in the intensities values of all attributes of the food samples between males and females since similar intensities were reported.

BMI separation was selected since it is known that responses to sweet and fat containing foods are correlated with adiposity. For BMI, Tables 4-5 and 4-6 show the separation between normal weight and overweight panelists. Sixty-four panelists (75%)

of the panelists were considered normal weight, and thirty-three (25%) were classified as overweight. Similar studies have shown there is an association between taste sensitivity and BMI; nontasters usually had higher BMI values than supertasters, which tended to be the lowest (Tepper and Nurse 1998; Tepper and Ullrich 2002). We expected that normal weight individuals perceived greater intensity values than those that are overweight. Our results found that there were no associations between BMI values and intensity of sweet taste, sour taste, and flavor. Since all panelists self-reported their weight, it is possible that some values were incorrect and lower than their actual weight. Females, especially, are prone to underreport their weight since they are more conscious about their body image (Tepper and Nurse 1998).

The same trends and correlations were found for all food samples regardless of weight or gender classification. A larger number of panelists could provide more significant differences, especially based on BMI. Therefore, the relationship among taster status, gender, and body weight remains open for future studies.

Study Two

Study two followed the same test design as Study one, except that it was divided into two sessions each containing two treatments. These sessions took place two months after Study one was performed so panelists were familiar with the panels. Eighty-eight panelists participated in the first session where the two treatments were control (C) and *Gymnema sylvestre* (GS). Eighty panelists participated in the second session where the two treatments were control (C) and miracle fruit (MF). Similar results were expected since there were no changes in the design nor the food samples. The only difference was separating MF and GS treatments into separate sessions, which was hypothesized to result in more accurate and precise intensity ratings since the panelists would have more practice using the gLMS.

The values and mean separations for the attribute intensity ratings from the two sessions from Study two are seen in Tables 4-7 and 4-8. Significant differences were found between foods for all attributes at $p \leq 0.05$. The same general trends and correlations were observed for the associated tastes categories.

Sour, but not Sweet

The same brands and types of food samples were selected including the apple cider vinegar, lemons, pickles, and yellow mustard. New, unopened samples were used to minimize any shelf life concerns from previously used samples. All food samples had similar trends and correlations when compared to Study one.

Apple cider vinegar performed similarly as in Study one, but there were some additional small differences found between treatments. Sweet significantly increased from C (5.7) after MF (32.3) and slightly decreased from C (5.7) after GS (3.2). The slight decrease after GS was such a small difference that it was not taken into great consideration, especially since there was no sweetness in the control sample of apple cider vinegar. The opposite trend was exhibited in sour taste after MF. Sour greatly decreased from C (47.8) after MF (20.5) and slightly decreased from C (51.5) after GS (47.2). Like the sweet taste after GS, there was also a small difference in sour intensity values after GS but was not actually immensely different. Flavor decreased from C (52.5) after MF (44.9) and also decreased from C (55.7) after GS (51.4). This is due to the fact that sweet taste is not typically associated with apple cider vinegar, so increasing sweetness does seem to have an effect on overall flavor. The significant differences that had differences in intensity values that were less than 5 were most likely due to difficulty in replicating exact values.

Although there may have been some seasonal variation associated with lemons, they also performed similarly as the samples used in Study one. Sweet greatly increased from C (4.9) after MF (38.4) and slightly decreased from C (4.9) after GS (2.3). The actual difference between C and GS was rather small, so it was not deemed significant. Sour greatly decreased from C (47.3) after MF (12.9) and had no differences between C (43.9) and GS (44.7). Flavor slightly decreased from C (47.5) after MF (40.5) and there were no differences between C (46.6) and GS (45.0). This showed that increasing sweetness did not increase overall flavor, but rather, caused it to decrease.

The pickles were also the same samples as previously used in Study one and performed similarly. The sweet intensity increased from C (6.0) after MF (19.3) and slightly decreased from C (6.7) after GS (3.7). Alternatively, the sour intensity decreased from C (25.8) after MF (9.5), slightly decreased from C (25.1) after GS (22.2). Both overall flavor intensities slightly decreased after MF and GS; it decreased from C (28.1) after MF (25.1) and also slightly decreased from C (29.7) after GS (26.2). These are rather small differences thus showing that the flavor remained approximately the same whether or not sweetness was changed.

The yellow mustard also had overall low intensity values when compared to the other foods classified with these taste associations. The sweet intensity increased from C (6.2) after MF (25.5) and slightly decreased from C (5.9) after (3.3). This difference was not that large, so it was also not taken into additional consideration. The sour intensity decreased from C (25.9) after MF (11.0) and there were no differences between C (27.0) and GS (28.0). There were no differences between C (32.5) and MF (30.8) and between C (35.4) and GS (32.5) for overall flavor intensity.

Sweet, but not Sour

There same brands and food samples including dark chocolate Kiss and Aunt Jemima's maple syrup were also used. The dark chocolate showed different results than in Study one while the maple syrup performed similarly. This difference is unlikely due to differences in the samples used in Study one and Study two, but rather based on panelist ratings.

The dark chocolate Kiss was the only food sample that showed a difference from Study one. For the sweet taste intensity, there was a statistical difference in the ratings between C (31.7) and MF (36.1). This showed that the sweet taste intensity increased after MF by 4.4. Since the sweetness increased, it also showed an increase in overall flavor. For the overall flavor intensity, there were differences between C (33.6) and after MF (36.2). Since these were relatively small differences, they are not likely to be significant. Study one showed that there were no differences between C and MF for both the sweet taste and flavor. It is suggested that the values are very similar to each other, so the differences found in Study two are not substantial.

Unlike the dark chocolate, the maple syrup performed similarly to Study one. The sweet intensity slightly increased from C (31.7) after MF (36.1) and greatly decreased from C (33.3) after GS (9.4). The differences between C and MF were rather small (less than 5 intensity values), so it was not a major difference in values. There was an extremely small difference in the sour intensity between C (2.4) and MF (1.2) and no differences between C (2.3) and GS (3.4).

Sweet and Sour

There may have been some seasonal variation associated with the cherry tomatoes and strawberries since they are produce items. There was approximately a two month difference between Study one and Study two, which can affect the tastes and flavor. Although there may have been some differences, they performed similarly.

The cherry tomatoes showed many differences between treatments for the different attributes. The sweet intensity greatly increased from C (10.4) after MF (30.9) and greatly decreased from C (12.9) after GS (3.7). Contrasting sweet taste, the sour intensity decreased from C (9.6) after MF (1.9) and showed no differences between C (9.3) and GS (10.2). Like Study one, this showed that after GS, the same amount of acid was associated with the product and it was not actually changed by the MF. The overall flavor changed; it greatly increased from C (16.7) after MF (30.1) and slightly decreased from C (18.8) after GS (14.3).

The strawberries also showed similar results as the cherry tomatoes. The sweet intensity greatly increased from C (23.9) after MF (45.4) while it greatly decreased from C (22.3) after GS (8.2). The opposite effects were shown in the sour intensity where it decreased from C (9.8) after MF (1.9) and also, did not show differences between C (14.7) and GS (15.4). The overall flavor intensity was changed; it greatly increased from C (26.5) after MF (42.4) and decreased from C (28.5) after GS (21.3).

Not Sweet and not Sour

The chicken sausage and peanuts remained great controls in Study two. They exhibited similar results as seen in Study one, especially since the same brands and food samples were used. New, unopened samples were also used for this study.

The chicken sausage did show large differences between any of the treatments. The sweet taste intensity only showed small differences from C (8.0) after MF (12.7) and no differences between C (8.8) and GS (7.7). Whereas in sour intensity, there were no differences between C (4.9) and MF (3.9) and between C (5.9) and GS (6.0). The same was true for the overall flavor intensity – there were no differences between C (23.0) and MF (24.6) and between C (25.6) and GS (41.1).

The peanuts also did not show large differences between any of the treatments. For the sweet intensity, it also showed small differences from C (6.0) after MF (8.6) and a small decrease from C (6.4) after GS (2.6). There were no differences between C (1.5) and MF (1.0) and between C (1.7) and GS (1.9) in the sour intensity. There overall flavor was not greatly impacted by the treatments since there were no differences between C (17.0) and MF (16.3) and a small decrease from C (16.8) after GS (11.2).

Gender and BMI

The same data set from Study two was also separated by gender and BMI. For session one, Tables 4-9 and 4-10 showed the mean separations for males and females, respectively, while for session two, this was shown in Tables 4-11 and 4-12. For session one, Tables 4-13 and 4-14 showed the mean separations for normal weight and overweight, while for session two, this was shown in Tables 4-15 and 4-16. Tables 4-9 through 4-16 showed similar results as found in Study one since the same trends and correlations were found for all food samples. Therefore, there were also no significant differences between males and females nor between those classified as normal weight and overweight.

Table 4-1. Significant means differences for study one

Product	Treatment	Odor		Flavor		Sweet		Sour	
Apple cider vinegar	Control	54.4	a[1]	61.3	a	5	b	53.6	a
	MF	52.4	ab	48.4	c	27.4	a	28.1	c
	GS	49.6	b	52.2	b	3.9	b	46.7	b
Cherry tomatoes	Control	9.2	b	23.6	b	11.5	b	13.8	a
	MF	11.1	a	32.2	a	32.4	a	4	b
	GS	11.6	a	20.5	b	6.3	c	13.6	a
Chicken sausage	Control	29.1	a	27.1	a	8.6	b	5.9	a
	MF	28.8	a	25.2	ab	12.9	a	5.1	a
	GS	26.5	b	23.3	b	7.4	b	6	a
Dark chocolate Kiss	Control	26.8	a	38.3	a	36.4	a	3.1	ab
	MF	26.4	a	37.3	a	37.8	a	2.3	b
	GS	24.4	a	18.8	b	10.1	b	4	a
Lemon	Control	33	a	52.6	a	4.6	c	52.6	a
	MF	32.7	a	44.4	b	41.4	a	16.5	c
	GS	29.2	b	43.8	b	9	b	41.6	b
Maple syrup	Control	26.7	a	37.6	a	44.6	a	1.2	ab
	MF	25.8	ab	38.6	a	42.4	a	1	b
	GS	23.5	b	16.5	b	11.4	b	2.4	a
Yellow mustard	Control	34.4	a	38.4	a	6	b	28.9	a
	MF	34.8	a	34.1	b	24.9	a	15.8	b
	GS	31.2	a	32.5	b	4.9	b	26.9	a
Peanuts	Control	23.3	a	21.2	a	7.4	b	2.7	ab
	MF	19.5	b	19.3	a	10	a	1.6	b
	GS	20.4	b	14.9	b	3.2	c	2.9	a
Pickles	Control	32.9	a	37.5	a	6.6	b	30.3	a
	MF	31.9	a	27.5	b	18.4	a	13.2	c
	GS	28.9	b	27.1	b	3.8	c	21.8	b
Strawberries	Control	23.7	a	33.4	b	29.8	b	14.9	a
	MF	23.3	a	45.2	a	48.6	a	3.1	b
	GS	29.3	a	24	c	12.3	c	14.8	a

[1]Treatment means within a modality followed by different letters are significantly different from each other.

Table 4-2. Significant correlations for study one for selected food samples

Food	Treatment	Taste and flavor	R value	P-value
Strawberries	Before MF	Sweet and flavor	0.789	<0.0001
	Before MF	Sour and flavor	0.448	<0.0001
	After MF	Sweet and flavor	0.919	<0.0001
	After MF	Sour and flavor	0.021	0.837
	After GS	Sweet and flavor	0.613	<0.001
	After GS	Sour and flavor	0.581	<0.001
Lemons	Before MF	Sweet and flavor	0.019	0.85
	Before MF	Sour and flavor	0.9	<0.001
	After MF	Sweet and flavor	0.731	<0.0001
	After MF	Sour and flavor	0.471	<0.0001
	After GS	Sweet and flavor	0.271	0.007
	After GS	Sour and flavor	0.903	<0.0001
Maple syrup	Before MF	Sweet and flavor	0.773	<0.001
	Before MF	Sour and flavor	0.048	0.638
	After MF	Sweet and flavor	0.901	<0.0001
	After MF	Sour and flavor	0.078	0.447
	After GS	Sweet and flavor	0.704	<0.0001
	After GS	Sour and flavor	0.461	<0.0001

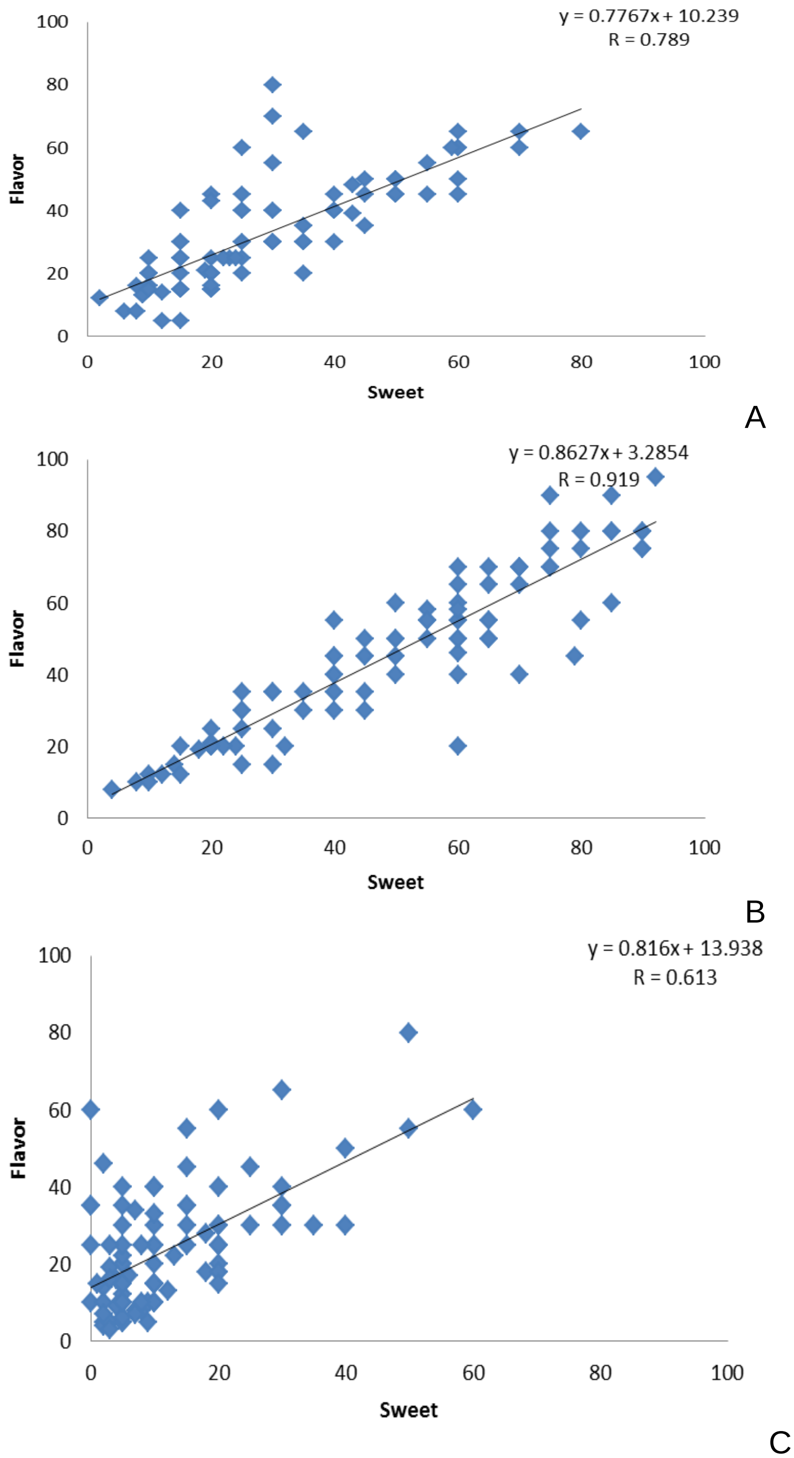

Figure 4-1. Correlation and regression between sweet and strawberry flavor in study one. A) Before MF. B) After MF. C) After GS.

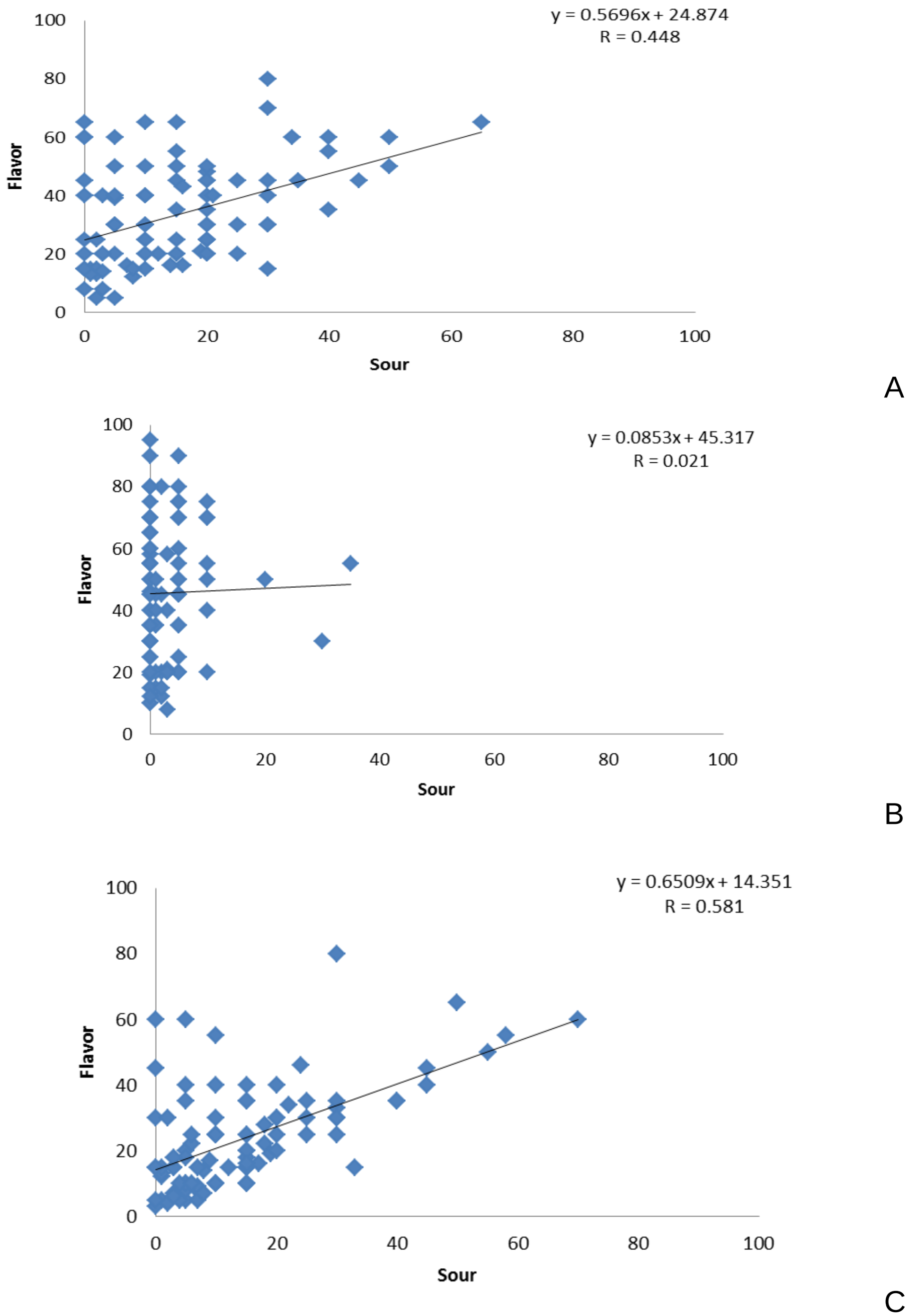

Figure 4-2. Correlation and regression between sour and strawberry flavor in study one. A) Before MF. B) After MF. C) After GS.

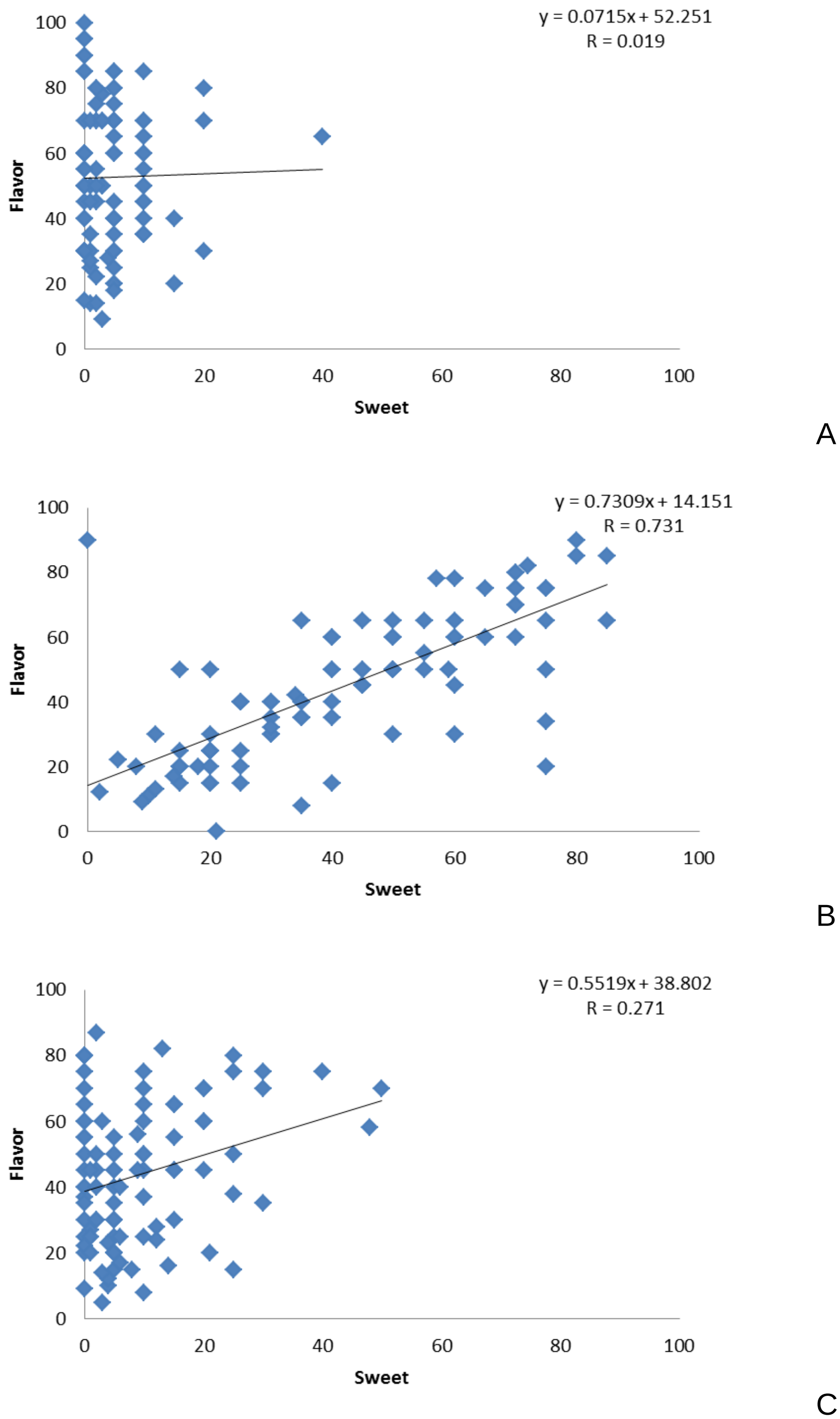

Figure 4-3. Correlation and regression between sweet and lemon flavor in study one. A) Before MF. B) After MF. C) After GS.

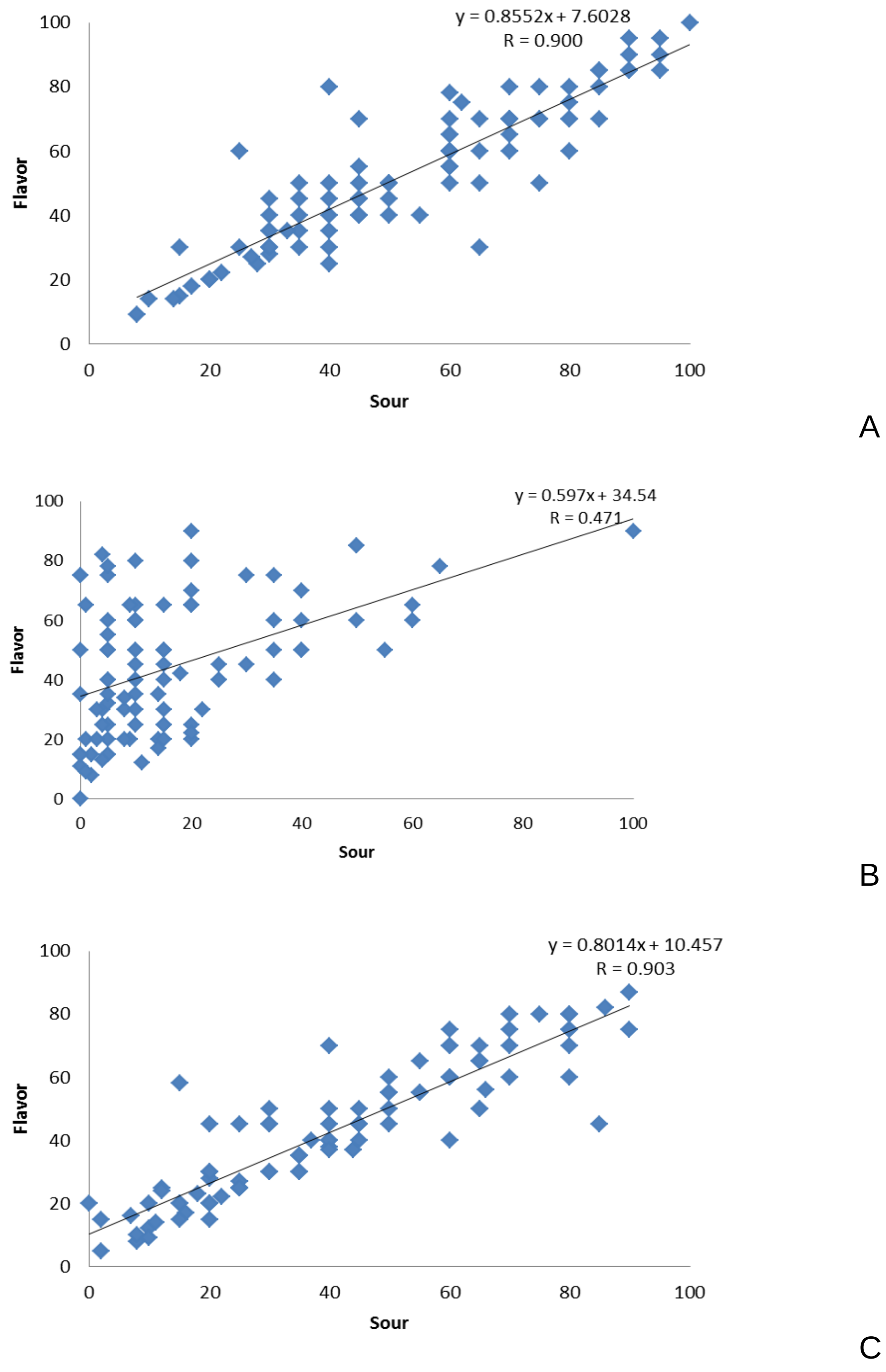

Figure 4-4. Correlation and regression between sour and lemon flavor in study one. A) Before MF. B) After MF. C) After GS.

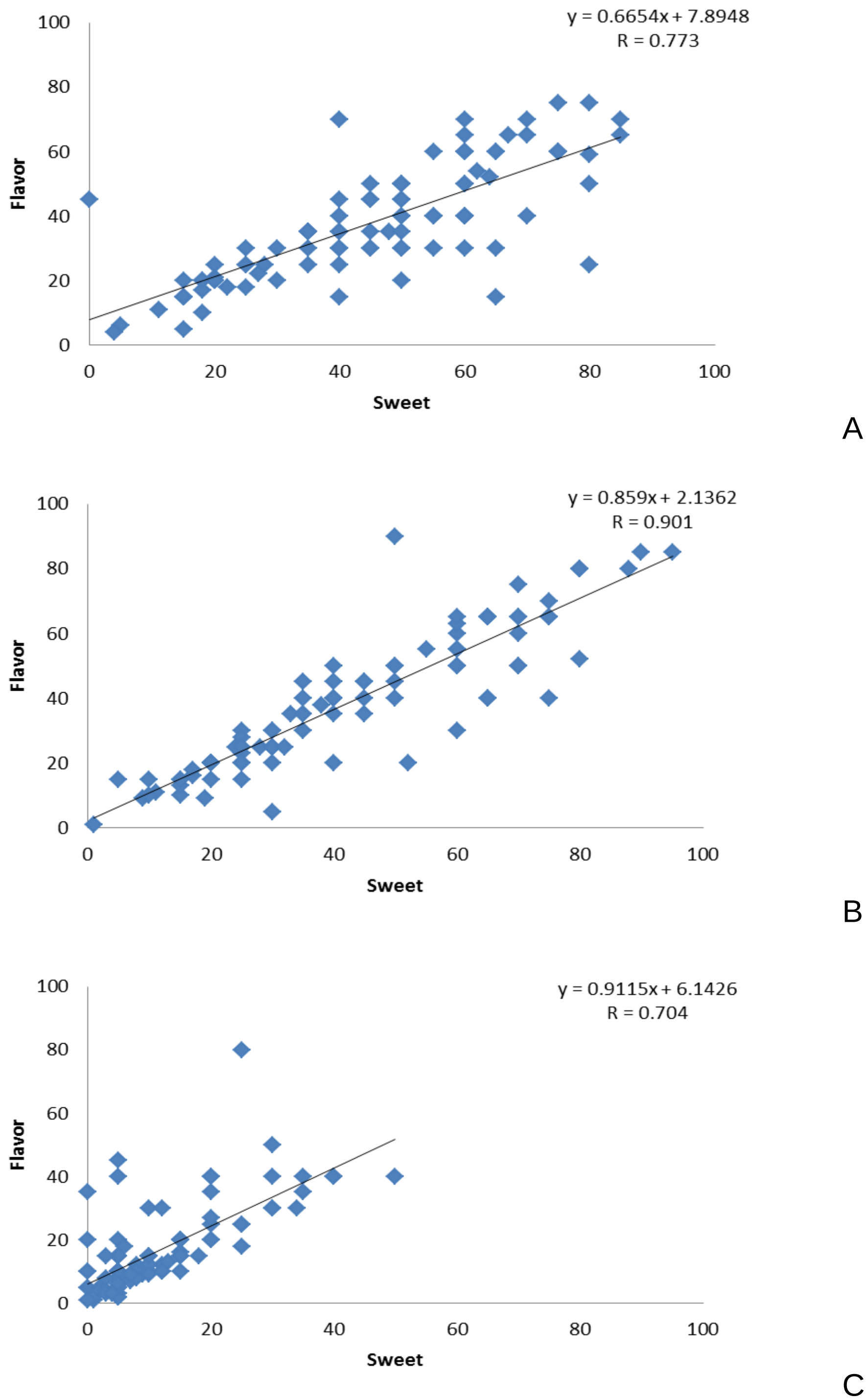

Figure 4-5. Correlation and regression between sweet and maple syrup flavor in study one. A) Before MF. B) After MF. C) After GS.

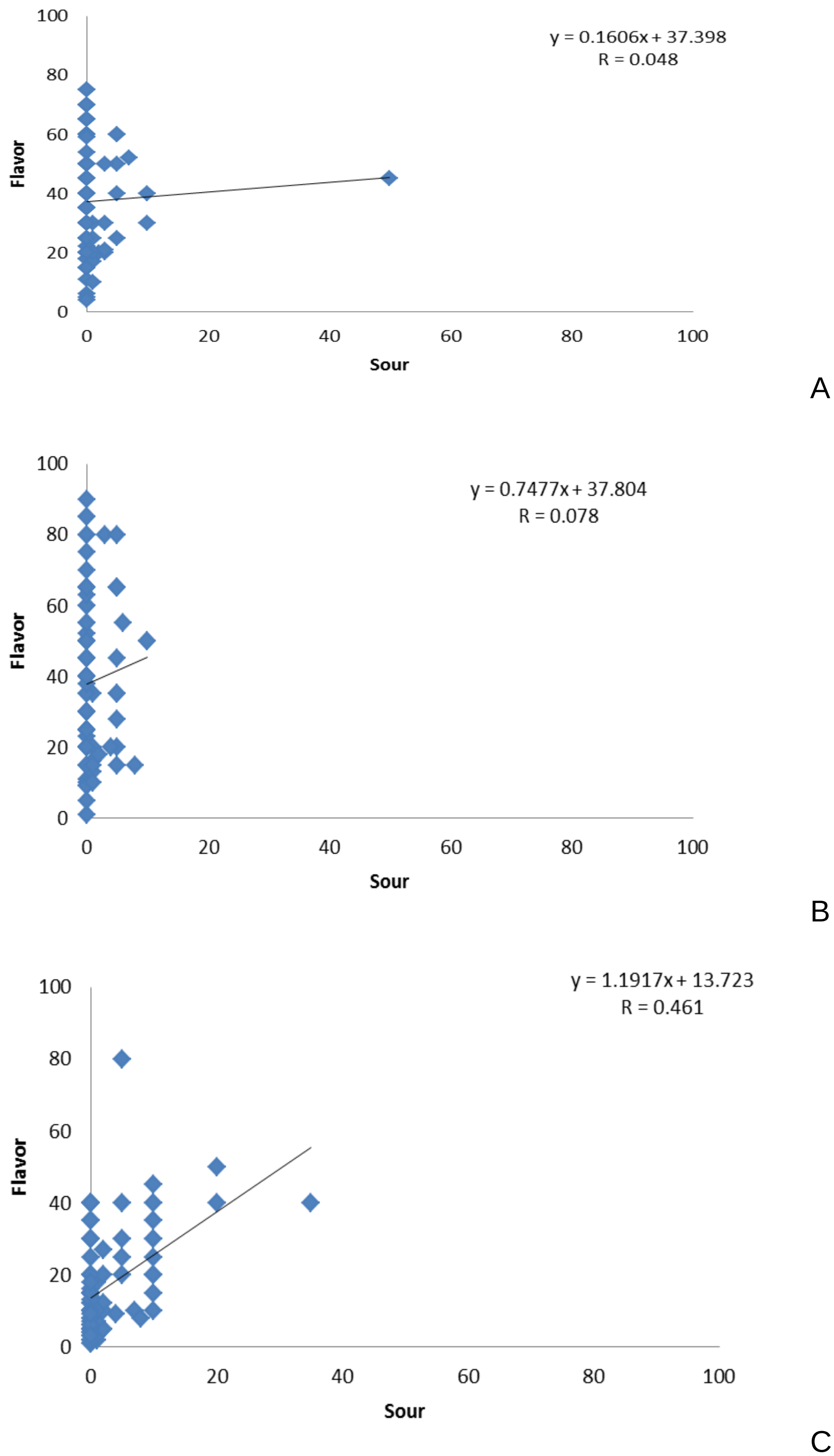

Figure 4-6. Correlation and regression between sour and maple syrup flavor in study one. A) Before MF. B) After MF. C) After GS.

Table 4-3. Significant means differences in study one by male gender

Product	Treatment	Odor		Flavor		Sweet		Sour	
Apple cider vinegar	Control	51.3	a[1]	58.3	a	6.2	b	51	a
	MF	48.8	A	46	b	25.1	a	26.6	c
	GS	47.7	A	50.1	b	3.2	b	44.3	b
Cherry tomatoes	Control	10.1	A	23.6	b	13.8	b	13.4	a
	MF	11.3	A	30.8	a	29.9	a	4.3	b
	GS	11	a	19.1	c	6.5	c	12.9	a
Chicken sausage	Control	24.9	a	26.1	a	8.8	ab	6.1	a
	MF	27.4	a	23.9	ab	10.7	a	4.9	a
	GS	25.4	a	21.8	b	7.7	b	5.1	a
Dark chocolate Kiss	Control	28.1	a	37.8	a	37.6	a	3.1	a
	MF	25.6	a	37.6	a	38.4	a	1.9	b
	GS	24.7	a	16.1	b	8.8	b	3.9	a
Lemons	Control	30.7	a	50.2	a	4.8	b	51.4	a
	MF	30.3	a	42.1	b	37.8	a	15.3	c
	GS	28.9	a	42.4	b	7.6	b	40.9	b
Yellow mustard	Control	35.9	a	39.7	a	5.4	b	29.2	a
	MF	33.9	ab	32.5	b	21.8	a	26.3	b
	GS	30.9	b	31.4	b	4	b	15.9	a
Peanuts	Control	22.3	a	20.5	a	8.7	a	2.1	a
	MF	19.1	b	17.9	b	8.9	a	1.4	a
	GS	19.3	ab	13.1	c	3.3	b	2.8	a
Pickles	Control	31.9	a	33.7	a	6.6	b	30.3	a
	MF	31.1	a	25.2	b	15	a	12.9	c
	GS	28.9	a	25.6	b	3	c	19.8	b
Strawberries	Control	23.4	a	33.9	b	32.4	b	13.6	a
	MF	24.4	a	41.5	a	46	a	3.7	b
	GS	22.2	a	23.1	c	10.8	c	13.8	a
Maple syrup	Control	29.2	a	37.9	a	43.2	a	1.9	a
	MF	25.1	b	35.8	a	40	a	1.2	a
	GS	23.6	b	14.9	b	10.2	b	2.2	a

[1]Treatment means within a modality followed by different letters are significantly different from each other.

Table 4-4. Significant means differences in study one by female gender

Product	Treatment	Odor		Flavor		Sweet		Sour	
Apple cider vinegar	Control	57.6	a[1]	64.4	a	3.8	b	56.2	a
	MF	56.1	a	50.8	b	29.8	a	29.5	c
	GS	51.5	b	54.5	b	4.8	b	49.2	b
Cherry tomatoes	Control	8.2	b	23.5	b	9.1	b	14.2	a
	MF	10.9	a	33.6	a	34.9	a	3.7	b
	GS	12.3	a	21.9	b	6.2	b	14.4	a
Chicken sausage	Control	33.3	a	28.2	a	8.4	b	5.7	a
	MF	30.2	ab	26.5	ab	15.2	a	5.3	a
	GS	27.6	b	24.9	b	7.1	b	6.9	a
Dark chocolate Kiss	Control	25.5	a	38.9	a	35.1	a	3	a
	MF	27.2	a	37	a	37.1	a	2.6	a
	GS	24.1	a	21.7	b	11.6	b	4.6	a
Lemon	Control	35.4	a	55	a	4.3	c	53.8	a
	MF	35.1	a	46.8	b	45.1	a	17.8	c
	GS	29.5	b	45.2	b	10.4	b	42.2	b
Yellow mustard	Control	32.9	a	37.2	a	6.6	b	28.7	a
	MF	35.7	a	35.6	a	28.2	a	15.8	b
	GS	31.6	a	33.7	a	5.7	b	27.5	a
Peanuts	Control	24.2	a	21.9	a	6.1	b	3.4	a
	MF	19.9	b	20.7	a	11.5	a	1.8	a
	GS	21.6	ab	16.8	b	3.2	c	3	a
Pickles	Control	32.1	a	35.2	a	6.6	b	30.3	a
	MF	32.8	ab	29.9	b	21.9	a	13.5	c
	GS	28.8	b	28.6	b	4.6	b	23.9	b
Strawberries	Control	24	a	32.8	b	27.1	b	16.2	a
	MF	22.3	a	49	a	51.3	a	2.5	b
	GS	22.4	a	24.9	c	13.9	c	15.9	a
Maple syrup	Control	24	a	37.3	a	46.1	a	0.6	b
	MF	26.5	a	41.3	a	44.8	a	0.9	b
	GS	23.5	a	18.2	b	12.6	b	2.5	a

[1]Treatment means within a modality followed by different letters are significantly different from each other.

Table 4-5. Significant means differences in study one by normal weight panelists (BMI < 25)

Product	Treatment	Odor		Flavor		Sweet		Sour	
Apple cider vinegar	Control	55	a[1]	63.6	a	4.8	b	55.9	a
	MF	52.6	ab	49.1	c	26.9	a	30.8	c
	GS	51.5	b	55	b	3.6	b	49.8	b
Cherry tomatoes	Control	7.7	b	23.3	b	10.2	b	13.5	a
	MF	10.2	a	31.9	a	32.4	a	4	b
	GS	11.5	a	19.8	b	5.9	c	13.6	a
Chicken sausage	Control	29.7	a	27.6	a	8.2	b	6	a
	MF	27.5	ab	24.9	b	13.1	a	4.3	a
	GS	25.4	b	24.2	b	6.9	b	5.9	a
Dark chocolate Kiss	Control	25.4	ab	38.7	a	36.3	a	2.6	a
	MF	26.5	a	36.7	a	37.1	a	1.2	b
	GS	23.7	b	19.6	b	10.8	b	3.6	a
Lemon	Control	32.7	a	53.2	a	4.7	c	52.1	a
	MF	32.8	a	45.3	b	42.5	a	17.7	c
	GS	28.9	a	43.7	b	9.3	b	41.5	b
Yellow mustard	Control	32.6	a	38.6	a	5.9	b	29.3	a
	MF	34.3	a	34.7	ab	25.2	a	15.8	b
	GS	31	a	32.5	b	5.1	b	27.4	a
Peanuts	Control	22.1	a	21	a	7	b	2.2	a
	MF	17.5	b	19.3	a	10	a	1.3	a
	GS	19.5	ab	15.6	b	2.8	c	2.9	a
Pickles	Control	32.2	a	33.7	a	6.7	b	29.9	a
	MF	30.6	ab	26.6	b	18.9	a	12.4	c
	GS	28.2	b	25.6	b	4.4	b	21.2	b
Strawberries	Control	22.2	a	32.1	b	28	b	15.3	a
	MF	23.4	a	46.6	a	50	a	2.6	b
	GS	21.5	a	23.7	c	11.9	c	15.7	a
Maple syrup	Control	25.1	a	38.5	a	45.1	a	1.2	a
	MF	25	a	39.4	a	42.8	a	0.8	a
	GS	24.3	a	17.2	b	11.5	b	2.5	a

[1]Treatment means within a modality followed by different letters are significantly different from each other.

Table 4-6. Significant means differences in study one by overweight panelists (BMI ≥ 25)

Product	Treatment	Odor		Flavor		Sweet		Sour	
Apple cider vinegar	Control	53.2	a[1]	56.8	a	5.5	b	49.1	a
	MF	51.9	a	47	b	28.4	a	22.9	c
	GS	46	b	47	b	4.7	b	40.7	b
Cherry tomatoes	Control	12.1	a	24.1	b	13.9	b	14.3	a
	MF	12.7	a	32.8	a	32.3	a	3.9	b
	GS	12	a	21.7	b	7.2	C	13.7	a
Chicken sausage	Control	27.8	a	26.4	a	9.5	ab	5.6	a
	MF	31.2	a	25.7	a	12.6	a	6.7	a
	GS	28.5	a	21.7	b	8.3	b	6.2	a
Dark chocolate Kiss	Control	29.6	a	37.6	a	36.5	a	3.9	a
	MF	26.3	a	38.5	a	39.1	a	4.4	a
	GS	25.8	a	17.3	b	8.9	b	5.3	a
Lemon	Control	33.6	a	51.3	a	4.2	b	53.6	a
	MF	32.7	a	42.7	b	39.3	a	14.3	c
	GS	29.8	a	43.9	b	8.5	b	41.6	b
Yellow mustard	Control	38	a	38	a	24.4	b	28.2	a
	MF	36.8	ab	32.9	b	6.1	a	5.9	b
	GS	31.6	b	32.6	b	4.3	b	15.9	a
Peanuts	Control	25.5	a	21.7	a	8.2	a	3.6	a
	MF	23.4	a	19.4	a	10.5	a	2.1	a
	GS	22.2	a	13.7	b	4	b	2.8	a
Pickles	Control	34.4	a	35.8	a	6.5	b	31	a
	MF	34.5	a	29.4	b	17.5	a	14.7	c
	GS	30.2	a	30.1	b	2.7	b	23.1	b
Strawberries	Control	26.7	a	35.8	b	33.2	b	14.2	a
	MF	23.3	a	42.5	a	45.7	a	4	b
	GS	23.8	a	24.5	c	13.1	C	13.2	a
Maple syrup	Control	29.7	a	35.9	a	43.7	a	1.3	a
	MF	27.2	ab	36.9	a	41.6	a	1.5	a
	GS	22	b	15.1	b	11.1	b	2.1	a

[1]Treatment means within a modality followed by different letters are significantly different from each other.

Table 4-7. Significant means differences in study two by GS treatment

Food	Treatment	Odor		Flavor		Sweet		Sour	
Apple cider vinegar	Control	51.5	a[1]	55.7	a	5.7	a	51.5	a
	GS	45.5	b	51.4	b	3.2	b	47.2	b
Cherry tomatoes	Control	6.7	a	18.8	a	12.8	a	9.3	a
	GS	6.2	a	14.3	b	3.7	b	10.2	a
Chicken sausage	Control	27.1	a	25.6	a	8.8	a	5.9	a
	GS	23.8	b	24.1	a	7.7	a	6	a
Dark chocolate Kiss	Control	22.7	a	36.9	a	33.3	a	2.3	a
	GS	22.1	a	16.6	b	9.4	b	3.4	a
Lemon	Control	27.8	a	46.6	a	4.9	a	45.9	a
	GS	25.2	a	45	a	2.3	b	44.7	a
Yellow mustard	Control	30.9	a	35.3	a	5.9	a	27	a
	GS	29.1	a	32.5	a	3.3	b	28	a
Peanuts	Control	17.9	a	16.8	a	6.4	a	1.7	a
	GS	17.7	a	11.2	b	2.6	b	1.9	a
Pickles	Control	29.6	a	29.7	a	6.7	a	25.1	a
	GS	27.1	a	26.2	b	3.7	b	22.2	b
Strawberry	Control	17.4	a	28.5	a	22.3	a	14.7	a
	GS	16.5	a	21.3	b	8.2	b	15.4	a
Maple syrup	Control	24.4	a	36.6	a	39.4	a	1.2	a
	GS	23.2	a	14.7	b	10.3	b	1.8	a

[1]Treatment means within a modality followed by different letters are significantly different from each other.

Table 4-8. Significant means differences in study two by MF treatment

Food	Treatment	Odor		Flavor		Sweet		Sour	
Apple cider vinegar	Control	50.3	a[1]	52.5	a	5.7	b	47.8	a
	MF	47.2	b	44.9	b	32.3	a	20.5	b
Cherry tomatoes	Control	7.3	b	16.7	b	10.4	b	9.6	a
	MF	8.6	a	30.1	a	30.9	a	1.9	b
Chicken sausage	Control	26.4	a	23	a	8	b	4.9	a
	MF	27.9	a	24.6	a	12.7	a	3.9	a
Dark chocolate Kiss	Control	22.5	a	33.6	b	31.7	b	2.4	a
	MF	22.7	a	36.2	a	36.1	a	1.2	b
Lemon	Control	29.1	a	47.5	a	4.9	b	47.3	a
	MF	25.8	b	40.5	b	38.4	a	12.9	b
Yellow mustard	Control	33	a	32.5	a	6.2	b	25.9	a
	MF	30.8	a	30.8	a	25.5	a	11	b
Peanuts	Control	18	a	17	a	6	b	1.5	a
	MF	17.7	a	16.3	a	8.6	a	1	a
Pickles	Control	28.1	a	28.1	a	6	b	24.8	a
	MF	25.8	a	25.1	b	19.3	a	9.5	b
Strawberry	Control	20	a	26.5	b	23.9	b	9.8	a
	MF	18.5	a	42.4	a	45.4	a	1.9	b
Maple syrup	Control	25	a	35.5	a	38.4	a	0.7	a
	MF	24	a	37.8	a	40.1	a	0.7	a

[1]Treatment means within a modality followed by different letters are significantly different from each other.

Table 4-9. Significant means differences in study two by GS treatment and male gender

Food	Treatment	Odor		Flavor		Sweet		Sour	
Apple cider vinegar	Control	53	a[1]	56.7	a	7	a	51.2	a
	GS	43.4	b	49.5	b	3.5	b	45.8	b
Cherry tomatoes	Control	8.5	a	20.1	a	14.2	a	10.4	a
	GS	8	a	14.6	b	4.4	b	11.4	a
Chicken sausage	Control	27.3	a	26.5	a	10	a	8.2	a
	GS	25.1	a	25.4	a	7.2	b	9.2	a
Dark chocolate Kiss	Control	24.3	a	39	a	36.3	a	2.4	a
	GS	23.9	a	17.6	b	9.5	b	4.3	a
Lemon	Control	31.2	a	46.8	a	5.8	a	47.1	a
	GS	27.4	a	41.3	b	3.3	b	41	b
Yellow mustard	Control	33.2	a	38.3	a	6.2	a	31.1	a
	GS	31.6	a	31.6	b	3.9	b	27.3	a
Peanuts	Control	19.9	a	18.4	a	7.5	a	2.4	a
	GS	18.6	a	12	b	2.9	b	3	a
Pickles	Control	29.7	a	31	a	7.1	a	25	a
	GS	28.5	a	27.7	a	3.6	b	23.3	a
Strawberry	Control	18.6	a	29.8	a	27.8	a	12.2	a
	GS	17	a	21.5	b	10.9	b	13.6	a
Maple syrup	Control	27.7	a	39.2	a	42.9	a	1.4	a
	GS	23.9	a	16	b	10.4	b	1.6	a

[1]Treatment means within a modality followed by different letters are significantly different from each other.

Table 4-10. Significant means differences in study two by GS treatment and female gender

Food	Treatment	Odor		Flavor		Sweet		Sour	
Apple cider vinegar	Control	50.2	a[1]	54.8	a	4.5	a	51.7	a
	GS	47.4	a	53	a	2.8	a	48.5	a
Cherry tomatoes	Control	5	a	17.7	a	11.5	a	8.3	a
	GS	4.6	a	14	a	3	b	9.2	a
Chicken sausage	Control	26.9	a	24.8	a	7.7	a	3.7	a
	GS	22.7	b	22.9	a	8.2	a	3.1	a
Dark chocolate Kiss	Control	21.4	a	35	a	30.7	a	2.3	a
	GS	20.4	a	15.7	b	9.3	b	2.5	a
Lemon	Control	24.8	a	46.4	a	4.2	a	44.8	a
	GS	23.2	a	48.2	a	1.3	b	48.2	a
Yellow mustard	Control	28.9	a	32.5	a	5.7	a	23.2	a
	GS	26.7	a	33.3	a	2.7	b	28.6	a
Peanuts	Control	16.1	a	15.3	a	5.5	a	1	a
	GS	16.9	a	10.5	b	2.4	b	0.9	a
Pickles	Control	29.5	a	28.5	a	6.4	a	25.3	a
	GS	25.9	a	24.8	a	3.7	a	21.1	b
Strawberry	Control	16.3	a	27.3	a	17.4	a	17	a
	GS	16.1	a	21.1	b	5.8	b	16.9	a
Maple syrup	Control	21.5	a	34.2	a	36.3	a	1.1	a
	GS	22.5	a	13.5	b	10.2	b	2	a

[1]Treatment means within a modality followed by different letters are significantly different from each other.

Table 4-11. Significant means differences in study two by MF treatment and male gender

Food	Treatment	Odor		Flavor		Sweet		Sour	
Apple cider vinegar	Control	50.4	a[1]	50.4	a	6.2	b	46.3	a
	MF	44.7	b	40.7	b	28.6	a	20.1	b
Cherry tomatoes	Control	7.8	a	15.6	b	10.7	b	10.1	a
	MF	9.1	a	26.3	a	28.6	a	2.4	b
Chicken sausage	Control	22.7	a	20.6	a	7.4	b	6.2	a
	MF	25.9	a	21.5	a	12.1	a	4.3	b
Dark chocolate Kiss	Control	23.6	a	32.2	a	30.7	b	2.4	a
	MF	23.7	a	32.6	a	35.4	a	1	b
Lemon	Control	28.9	a	44.1	a	5.5	b	45	a
	MF	27.1	a	36.1	b	35.7	a	11.6	b
Yellow mustard	Control	32.9	a	31.2	a	5.8	b	25.5	a
	MF	27.8	b	26.4	b	23.4	a	11.4	b
Peanuts	Control	16.6	a	16.9	a	7	b	1.7	a
	MF	17	a	16.9	a	10	a	1.3	a
Pickles	Control	25.9	a	25.7	a	5.6	b	23.2	a
	MF	24.5	a	23.3	a	18.3	a	10	b
Strawberry	Control	19.4	a	26.4	b	24.9	b	9	a
	MF	18.1	a	39.7	a	43.3	a	1.6	b
Maple syrup	Control	24	a	33.6	a	37.3	a	1	a
	MF	24.4	a	34.5	a	36.7	a	0.6	a

[1]Treatment means within a modality followed by different letters are significantly different from each other.

Table 4-12. Significant means differences in study two by MF treatment and female gender

Food	Treatment	Odor		Flavor		Sweet		Sour	
Apple cider vinegar	Control	50.2	a[1]	54.3	a	5.3	b	49.2	a
	MF	49.5	a	48.6	a	35.7	a	20.8	b
Cherry tomatoes	Control	6.8	b	17.8	b	10.1	b	9.2	a
	MF	8.3	a	33.7	a	33	a	1.4	b
Chicken sausage	Control	29.7	a	25.1	a	8.5	b	3.8	a
	MF	29.7	a	27.5	a	13.2	a	3.6	a
Dark chocolate Kiss	Control	21.5	a	34.9	a	32.7	a	2.3	a
	MF	21.8	a	37.5	a	36.8	a	1.5	a
Lemon	Control	29.3	a	50.6	a	4.3	b	49.5	a
	MF	24.6	b	44.6	b	40.7	a	14.1	b
Yellow mustard	Control	33	a	33.7	a	6.5	b	26.2	a
	MF	33.6	a	34.7	a	27.5	a	10.7	b
Peanuts	Control	19.2	a	17	a	5.1	a	1.2	a
	MF	18.3	a	15.8	a	7.4	a	0.9	a
Pickles	Control	30.1	a	30.3	a	6.4	b	26.3	a
	MF	26.9	a	26.8	a	20.2	a	9.1	b
Strawberry	Control	20.6	a	26.7	b	23	b	10.5	a
	MF	19	a	44.8	a	47.3	a	2.2	b
Maple syrup	Control	25.9	a	37.3	a	39.4	a	0.5	a
	MF	23.7	a	40.9	a	43.2	a	0.9	a

[1]Treatment means within a modality followed by different letters are significantly different from each other.

Table 4-13. Significant means differences in study two by GS treatment and normal weight panelists (BMI < 25)

Food	Treatment	Odor		Flavor		Sweet		Sour	
Apple cider vinegar	Control	54.1	a[1]	57.1	a	6.3	a	54	a
	GS	48.8	b	52.6	a	3	b	49	a
Cherry tomatoes	Control	6.8	a	19.7	a	13.7	a	9.9	a
	GS	6.4	a	14.4	b	3.4	b	10.2	a
Chicken sausage	Control	27.3	a	26	a	8.6	a	5.4	a
	GS	22.6	b	22.9	b	7.8	a	4.6	a
Dark chocolate Kiss	Control	22.8	a	36.8	a	33.9	a	2.6	a
	GS	22.1	a	15.7	b	9.1	b	3.8	a
Lemon	Control	30.4	a	48.7	a	4.5	a	48.3	a
	GS	25.1	b	48.2	a	2.1	b	27.6	a
Yellow mustard	Control	33.5	a	36.3	a	6.2	a	28.4	a
	GS	30.4	a	33.1	a	3.4	b	28.4	a
Peanuts	Control	18.6	a	17	a	6	a	1.8	a
	GS	18.2	a	11.4	b	2.5	b	1.3	a
Pickles	Control	32.4	a	30.7	a	7.5	a	26.4	a
	GS	27.8	a	27.4	a	3.4	a	22.8	a
Strawberry	Control	17.8	a	27.7	a	21.8	a	16	a
	GS	16.2	a	20.4	b	7.4	b	16.4	a
Maple syrup	Control	24.7	a	38.2	a	41	a	1.9	a
	GS	22.9	a	14.3	b	10.2	b	1.5	a

[1]Treatment means within a modality followed by different letters are significantly different from each other.

Table 4-14. Significant means differences in study two by GS treatment and overweight panelists (BMI ≥ 25)

Food	Treatment	Odor		Flavor		Sweet		Sour	
Apple cider vinegar	Control	46.3	a[1]	52.8	a	4.6	a	47	a
	GS	38.8	b	48.9	a	3.6	a	43.7	a
Cherry tomatoes	Control	6.4	a	17.1	a	10.8	a	8.1	a
	GS	5.7	a	14.1	a	4.3	b	10.2	a
Chicken sausage	Control	26.7	a	24.9	a	9.2	a	6.7	a
	GS	26.3	a	26.3	a	7.7	a	8.8	a
Dark chocolate Kiss	Control	22.8	a	37.1	a	32.2	a	1.9	a
	GS	22	a	18.3	b	10	b	2.5	a
Lemon	Control	25.3	a	42.5	a	5.9	a	41.1	a
	GS	22.7	a	38.4	a	2.6	b	39	a
Yellow mustard	Control	25.8	a	33.2	a	5.4	a	24.1	a
	GS	26.4	a	31.3	a	3	b	27.2	a
Peanuts	Control	16.7	a	16.3	a	7.4	a	1.5	b
	GS	16.7	a	10.7	b	2.9	b	3.1	a
Pickles	Control	24	a	27.8	a	5.2	a	22.7	a
	GS	25.8	a	23.8	a	4.1	a	20.9	a
Strawberry	Control	16.7	a	30	a	23.4	a	12	a
	GS	17.2	a	23.1	b	9.8	b	13.2	a
Maple syrup	Control	24	a	33.2	a	36.3	a	0.8	a
	GS	23.8	a	15.5	b	10.6	b	1.6	a

[1]Treatment means within a modality followed by different letters are significantly different from each other.

Table 4-15. Significant means differences in study two by MF treatment and normal weight panelists (BMI < 25)

Food	Treatment	Odor		Flavor		Sweet		Sour	
Apple cider vinegar	Control	52	a[1]	53.2	a	6.2	b	48.6	a
	MF	49.6	a	46.7	b	34.1	a	22.6	b
Cherry tomatoes	Control	7.4	a	16.5	b	10.8	b	9.8	a
	MF	8.7	a	31.9	a	33	a	2	b
Chicken sausage	Control	26.6	a	22.7	a	8.7	b	5.1	a
	MF	27.9	a	25	a	13.2	a	4.1	a
Dark chocolate Kiss	Control	22	a	33.8	a	32.3	a	2.4	a
	MF	22.1	a	36.9	a	27.3	b	1.5	a
Lemon	Control	28.8	a	49	a	5.2	b	49	a
	MF	25.2	b	41.8	b	38.9	a	14.2	b
Yellow mustard	Control	33.8	a	32.8	a	6.8	b	26.6	a
	MF	32.6	a	32.6	a	26.4	a	12.3	b
Peanuts	Control	18.9	a	17	a	6	b	1.7	a
	MF	17.3	a	15.7	a	9.1	a	1.1	a
Pickles	Control	28.5	a	28	a	6.5	b	24.8	a
	MF	25.9	a	25.7	a	20.6	a	9.7	b
Strawberry	Control	19.9	a	26.1	b	24	b	10.3	a
	MF	17.9	a	43.4	a	47.2	a	2.2	b
Maple syrup	Control	25.9	a	36.1	a	39.4	a	0.8	a
	MF	24	a	39.4	a	41.9	a	0.9	a

[1]Treatment means within a modality followed by different letters are significantly different from each other.

Table 4-16. Significant means differences in study two by MF treatment and overweight panelists (BMI ≥ 25)

Food	Treatment	Odor		Flavor		Sweet		Sour	
Apple cider vinegar	Control	46.3	a[1]	50.7	a	4.5	b	46	a
	MF	41.8	a	40.6	b	28.1	a	15.5	b
Cherry tomatoes	Control	6.9	a	17.2	b	9.4	b	9.2	a
	MF	8.6	a	26.2	a	26	a	1.5	b
Chicken sausage	Control	26	a	23.5	a	6.2	b	4.4	a
	MF	28	a	23.9	a	11.5	a	3.4	a
Dark chocolate Kiss	Control	23.7	a	33	a	30.4	a	2.3	a
	MF	23.9	a	34.5	a	33.2	a	0.7	a
Lemon	Control	29.9	a	44	a	4	b	43.4	a
	MF	27.1	a	37.5	a	37	a	9.8	b
Yellow mustard	Control	31.2	a	31.8	a	4.6	b	24.2	a
	MF	26.8	b	26.5	a	23.6	a	8.1	b
Peanuts	Control	15.7	a	17	a	6.1	a	1	a
	MF	18.6	a	17.9	a	7.5	a	0.9	a
Pickles	Control	27.2	a	28.5	a	4.9	b	24.8	a
	MF	25.5	a	23.8	b	16.2	a	9	b
Strawberry	Control	20.4	a	27.5	b	23.9	b	8.8	a
	MF	20.1	a	40.1	a	41	a	1.3	b
Maple syrup	Control	22.9	a	34.2	a	35.9	a	0.6	a
	MF	24.1	a	34.1	a	35.8	a	0.4	a

[1]Treatment means within a modality followed by different letters are significantly different from each other.

CHAPTER 5
CONCLUSION

It was shown that in foods that have greater sweet tastes than sour tastes (such as strawberries) that increasing sweetness and decreasing sourness will increase flavor, while decreasing sweetness will decrease flavor. This was held true for both Study one and Study two. The latter is especially true for foods that are primarily associated with sweetness, particularly the maple syrup. Additionally, it was shown that in foods that have greater sour tastes than sweet tastes (such as lemon) that increasing the sweetness, which will also depress the sourness, will decrease flavor. There is little to no sweetness that is normally associated with the foods, so the *G. sylvestre* treatment had little to no effect on flavor. For foods that do not have sweet and sour taste associations (such as the chicken sausage and peanuts), the miracle fruit and *G. sylvestre* treatments had little to no effect on flavor. Since there were no sour taste associations, the miracle fruit was unable to add sweet taste to these foods. Also, since were no sweet taste associations, the *G. sylvestre* did not alter the sweet taste of the chicken sausage and peanuts.

The results also show that there are associations between sweet and sour tastes. When sweetness was increased by miracle fruit, the perceived sourness was masked since the perceived sweet taste was so overwhelming. Although the rating of sour taste was decreased, the actual amount of sour taste was not changed and was still present in the food sample. This is emphasized by the *G. sylvestre* treatment that was applied right after miracle fruit treatment. The sweet taste intensity rating decreased to a value that was lower than the original sweet taste and the sour taste intensity returned to nearly the same as the original value.

Since there were no significant differences in the intensity ratings among all food samples at all treatments and separations between the first and second studies, it showed that this study can be replicated to show similar results. This is partly due to the fact that the gLMS is a powerful scale that can result in accurate intensity ratings that can be replicated when used by the same panelists. It is possible that increasing the population size can lead to significant differences between genders, BMI status, and taster status. Future investigations that use similar methodology can include analyzing additional food items and the effect of miracle fruit on food-related acids. This research can lead to further understanding of the interactions between sweet and sour tastes and between tastes and flavors. Also, investigating the likeability of the food products when the sweet taste is increased and decreased would provide further information in the understanding of the intensity of sweet taste and likeability.

APPENDIX A
QUESTIONNAIRE

Miracle fruit and *Gymnema sylvestre* Panel

DIRECTIONS: Please fill out questionnaire and return to sdhudson@ufl.edu
or drop off at Taste Panel in Building 120 by **Friday, August 27th**.

Name: ____

E-mail address: ____

Are you a vegetarian? YES NO

Do you have any known food allergies? YES NO

If yes, please explain.

____

FOOD ITEM	**Would you eat or drink this? YES/NO**	**If no, please explain why.** (E.g. allergy, vegetarian, etc.)
Apple cider vinegar		
Chicken sausage		
Dark chocolate		
Lemon		
Mustard		
Peanuts		
Pickles		
Strawberry		
Syrup		
Tomato		

Have you ever heard of **miracle fruit**? YES NO

If yes, do you have any experience with it? Please explain.

____
____

Have you ever heard of ***Gymnema sylvestre***? YES NO

If yes, do you have any experience with it? Please explain.

____
____

****After you submit this form, you will be contacted soon with further details regarding this study.****

APPENDIX B
IRB FORM

Miracle Berry and *Gymnema syylvestre* Sensory Panel Consent Form

I, Charles Sims (Professor, Food Science and Human Nutrition Department), am requesting your consent to participate in sensory tests with the miracle berry (*Synsepalum dulcificum*), *Gymnema sylvestre*, and fresh and processed foods. You will be given a small amount of either the miracle berry (as either a dried powder or one berry) or *Gymnema* (in the form of a tea or candy), and then given several samples of commercial food products. The miracle berry will temporarily (typically 1 hour) cause an acid to taste sweet. The *Gymnema* will temporarily (typically 1 hour) suppress sweetness. You will be asked to rate the flavor intensity of several commercial food products following the miracle berry or *Gymnema*. Instructions on the use of the scale will be given during the panel. This should take about 20-30 minutes of your time. However, keep in mind that the effects of the miracle berry or *Gymnema* may last for up to 2 hours and may alter your taste of foods during this time. Your name will not appear on the ballot that you fill out to keep your responses confidential to the extent provided by the law.

The miracle berries, *Gymnema*, and food products were obtained from commercial sources and are available in retail markets or via the internet. You will be given verbal instructions during the sensory test on all procedures. Products will be served at temperatures generally associated with the food products, including cool temperatures for some, heated and/or room temperature for others. We will handle and present the products to you in a sanitary manner. You will be asked to evaluate the products in a private booth, and water to rinse your mouth and crackers will be provided. You may swallow the products if you want, or you may spit out the samples. To the best of our knowledge, there are no known risks associated with tasting these products, nor are there any immediate benefits. Your participation is voluntary, and you are free to withdraw at any time. You will be given a small reward (food coupons worth $10) for your participation.

Questions or concerns about research participants' rights can be directed to the UFIRB Office, PO Box 112250, University of Florida, Gainesville, FL 32611-2250.

If you need further information about this project, please contact me at 392-1991 x 211 or come by my office at 349 Food Science and Human Nutrition Building.

Principal Investigator's Signature   9/9/10
Date

I have read the procedure described above and have been offered a copy of this description, and I agree to participate in the procedure.

Participant's Signature: Date:

Approved by
University of Florida
Institutional Review Board 02
Protocol # 2009-U-0998
For Use Through 10-01-2010

APPENDIX C
GLMS

Name:

Panelist Number:

Now we would like you to create your personal scale.

Please use the space provided below to label 100 on your scale.

No Sensation **Strongest sensation of any kind that you have experienced**

0 100

The BOTTOM of your scale (0): NO SENSATION

To define the TOP of your scale (100):

Please identify the strongest sensation of any kind that you have experienced:

____

____

APPENDIX D
COMPUSENSE TEST BALLOT

Today's Sample: Miracle fruit and *Gymnema sylvestre*

To start the test, click on the Continue button below:

CONTINUE

Panelist Registration Number: ________________________

Please indicate your gender.

- ❍ Male
- ❍ Female

Please enter your age.

Age ________

Please enter your height (For example: If you are 5 feet and 3 inches in height, enter 5.3).

Height ________

Please enter your weight in pounds.

Weight ________

What is your ethnic background?

- ❍ Hispanic
- ❍ Non-Hispanic

Which of the following best describes you?

- ❍ Asian/Pacific Islander
- ❍ Black or African-American
- ❍ White or Caucasian
- ❍ Native American, Alaska Native, Aleutian
- ❍ Other

Have you ever suffered from middle ear infections?

- ❍ No
- ❍ Yes, but not serious
- ❍ Yes, required antibiotics more than once
- ❍ Yes, required tubes in ears

Now, we would like you to rate sensory intensities rather than liking/disliking. Rate the following sensations from no sensation (0) to the strongest sensation of any kind that you have ever experienced (100). For example, for some individuals, the brightest light ever seen (usually the sun) is the most intense sensation they have ever experienced. For others, the loudest sound ever heard (e.g., like a jet plane taking off nearby) might be the most intense. For still others, a particular pain might be the most intense. Whatever, the most intense sensation is for you, that is the intensity that goes at the top of the scale.

Keep in mind that the scale is like a sensory ruler. If the sweetness of the sample is a 10th of the way from zero to maximum (100), then enter it at 10. If it is twice as intense as that, it should be entered at 20, etc.

Please write your most intense sensation experienced (100 on your scale) on the paper ballot provided.

Please click on the 'Continue' button below.

CONTINUE

Please type your most intense sensation experienced (100 on your scale) in the space provided below.

____

____

____

Please enter a number from zero (no sensation) to 100 (strongest sensation of any kind you've had) that best describes the experiences listed below.

Loudest sound ever heard	__________
Loudness of a conversation	__________
Brightness of a well-lit room	__________
Brightest light ever seen (usually the sun)	__________
Loudness of a whisper	__________
Brightness of a dimly-lit restaurant	__________

PLEASE LIFT THE WINDOW TO RECEIVE YOUR FIRST SET OF SAMPLES

Take a bite of cracker and a sip of water to rinse your mouth.

Remember to do this before you taste each sample.

WHEN ANSWERING ANY QUESTION, MAKE SURE THE NUMBER ON THE CUP MATCHES THE NUMBER ON THE MONITOR.

Please click the 'Continue' button below.

CONTINUE

Please enter a number from zero (no sensation) to 100 (strongest sensation of any kind) that best describes **SAMPLE <<Sample1>>** for each of the attributes listed below.

SMELL __________

SWEET __________

SOUR __________

OVERALL FLAVOR INTENSITY __________

Please enter a number from zero (no sensation) to 100 (strongest sensation of any kind) that best describes **SAMPLE <<Sample2>>** for each of the attributes listed below.

SMELL __________

SWEET __________

SOUR __________

OVERALL FLAVOR INTENSITY __________

Please enter a number from zero (no sensation) to 100 (strongest sensation of any kind) that best describes **SAMPLE <<Sample3>>** for each of the attributes listed below.

SMELL __________

SWEET __________

SOUR __________

OVERALL FLAVOR INTENSITY __________

Please enter a number from zero (no sensation) to 100 (strongest sensation of any kind) that best describes **SAMPLE <<Sample4>>** for each of the attributes listed below.

SMELL __________

SWEET __________

SOUR __________

OVERALL FLAVOR INTENSITY __________

Please enter a number from zero (no sensation) to 100 (strongest sensation of any kind) that best describes **SAMPLE <<Sample5>>** for each of the attributes listed below.

SMELL __________

SWEET __________

SOUR __________

OVERALL FLAVOR INTENSITY __________

Please enter a number from zero (no sensation) to 100 (strongest sensation of any kind) that best describes **SAMPLE <<Sample6>>** for each of the attributes listed below.

SMELL __________

SWEET __________

SOUR __________

OVERALL FLAVOR INTENSITY __________

Please enter a number from zero (no sensation) to 100 (strongest sensation of any kind) that best describes **SAMPLE <<Sample7>>** for each of the attributes listed below.

SMELL __________

SWEET __________

SOUR __________

OVERALL FLAVOR INTENSITY __________

Please enter a number from zero (no sensation) to 100 (strongest sensation of any kind) that best describes **SAMPLE <<Sample8>>** for each of the attributes listed below.

SMELL __________

SWEET __________

SOUR __________

OVERALL FLAVOR INTENSITY __________

Please enter a number from zero (no sensation) to 100 (strongest sensation of any kind) that best describes **SAMPLE <<Sample9>>** for each of the attributes listed below.

SMELL __________

SWEET __________

SOUR __________

OVERALL FLAVOR INTENSITY __________

Please enter a number from zero (no sensation) to 100 (strongest sensation of any kind) that best describes **SAMPLE <<Sample10>>** for each of the attributes listed below.

SMELL __________

SWEET __________

SOUR __________

OVERALL FLAVOR INTENSITY __________

PLEASE LIFT THE WINDOW TO RECEIVE YOUR SECOND SET OF SAMPLES

Miracle fruit

Miracle fruit is a berry known to have taste-modifying effects in many individuals. You will be given a tablet of freeze-dried miracle fruit to eat. DO NOT SWALLOW OR CHEW. You will need to let it dissolve in your mouth.

Take a bite of cracker and a sip of water to rinse your mouth.

Remember to do this before you taste each sample.

WHEN ANSWERING ANY QUESTION, MAKE SURE THE NUMBER ON THE CUP MATCHES THE NUMBER ON THE MONITOR.

Please click the 'Continue' button below.

CONTINUE

Please enter a number from zero (no sensation) to 100 (strongest sensation of any kind) that best describes **SAMPLE <<Sample1>>** for each of the attributes listed below.

SMELL __________

SWEET __________

SOUR __________

OVERALL FLAVOR INTENSITY __________

Please enter a number from zero (no sensation) to 100 (strongest sensation of any kind) that best describes **SAMPLE <<Sample2>>** for each of the attributes listed below.

SMELL __________

SWEET __________

SOUR __________

OVERALL FLAVOR INTENSITY __________

Please enter a number from zero (no sensation) to 100 (strongest sensation of any kind) that best describes **SAMPLE <<Sample3>>** for each of the attributes listed below.

SMELL __________

SWEET __________

SOUR __________

OVERALL FLAVOR INTENSITY __________

Please enter a number from zero (no sensation) to 100 (strongest sensation of any kind) that best describes **SAMPLE <<Sample4>>** for each of the attributes listed below.

SMELL __________

SWEET __________

SOUR __________

OVERALL FLAVOR INTENSITY __________

Please enter a number from zero (no sensation) to 100 (strongest sensation of any kind) that best describes **SAMPLE <<Sample5>>** for each of the attributes listed below.

SMELL __________

SWEET __________

SOUR __________

OVERALL FLAVOR INTENSITY __________

Please enter a number from zero (no sensation) to 100 (strongest sensation of any kind) that best describes **SAMPLE <<Sample6>>** for each of the attributes listed below.

SMELL	__________
SWEET	__________
SOUR	__________
OVERALL FLAVOR INTENSITY	__________

Please enter a number from zero (no sensation) to 100 (strongest sensation of any kind) that best describes **SAMPLE <<Sample7>>** for each of the attributes listed below.

SMELL	__________
SWEET	__________
SOUR	__________
OVERALL FLAVOR INTENSITY	__________

Please enter a number from zero (no sensation) to 100 (strongest sensation of any kind) that best describes **SAMPLE <<Sample8>>** for each of the attributes listed below.

SMELL	__________
SWEET	__________
SOUR	__________
OVERALL FLAVOR INTENSITY	__________

Please enter a number from zero (no sensation) to 100 (strongest sensation of any kind) that best describes **SAMPLE <<Sample9>>** for each of the attributes listed below.

SMELL	__________
SWEET	__________
SOUR	__________
OVERALL FLAVOR INTENSITY	__________

Please enter a number from zero (no sensation) to 100 (strongest sensation of any kind) that best describes **SAMPLE <<Sample10>>** for each of the attributes listed below.

SMELL	__________
SWEET	__________
SOUR	__________
OVERALL FLAVOR INTENSITY	__________

PLEASE LIFT THE WINDOW TO RECEIVE YOUR THIRD SET OF SAMPLES

Gymnema

***Gymnema sylvestre* is an herb known to have taste-modifying effects in many individuals. You will be given a brewed tea sample to swish around your mouth for at least 30 seconds. DO NOT SWALLOW. You should expectorate the sample back into the cup and rinse your mouth out with water.**

Take a bite of cracker and a sip of water to rinse your mouth.

Remember to do this before you taste each sample.

WHEN ANSWERING ANY QUESTION, MAKE SURE THE NUMBER ON THE CUP MATCHES THE NUMBER ON THE MONITOR.

Please click the 'Continue' button below.

CONTINUE

Please enter a number from zero (no sensation) to 100 (strongest sensation of any kind) that best describes **SAMPLE <<Sample1>>** for each of the attributes listed below.

SMELL	__________
SWEET	__________
SOUR	__________
OVERALL FLAVOR INTENSITY	__________

Please enter a number from zero (no sensation) to 100 (strongest sensation of any kind) that best describes **SAMPLE <<Sample2>>** for each of the attributes listed below.

SMELL	__________
SWEET	__________
SOUR	__________
OVERALL FLAVOR INTENSITY	__________

Please enter a number from zero (no sensation) to 100 (strongest sensation of any kind) that best describes **SAMPLE <<Sample3>>** for each of the attributes listed below.

SMELL	__________
SWEET	__________
SOUR	__________
OVERALL FLAVOR INTENSITY	__________

Please enter a number from zero (no sensation) to 100 (strongest sensation of any kind) that best describes **SAMPLE <<Sample4>>** for each of the attributes listed below.

SMELL	__________
SWEET	__________
SOUR	__________
OVERALL FLAVOR INTENSITY	__________

Please enter a number from zero (no sensation) to 100 (strongest sensation of any kind) that best describes **SAMPLE <<Sample5>>** for each of the attributes listed below.

SMELL	__________
SWEET	__________
SOUR	__________
OVERALL FLAVOR INTENSITY	__________

Please enter a number from zero (no sensation) to 100 (strongest sensation of any kind) that best describes **SAMPLE <<Sample6>>** for each of the attributes listed below.

SMELL __________

SWEET __________

SOUR __________

OVERALL FLAVOR INTENSITY __________

Please enter a number from zero (no sensation) to 100 (strongest sensation of any kind) that best describes **SAMPLE <<Sample7>>** for each of the attributes listed below.

SMELL __________

SWEET __________

SOUR __________

OVERALL FLAVOR INTENSITY __________

Please enter a number from zero (no sensation) to 100 (strongest sensation of any kind) that best describes **SAMPLE <<Sample8>>** for each of the attributes listed below.

SMELL __________

SWEET __________

SOUR __________

OVERALL FLAVOR INTENSITY __________

Please enter a number from zero (no sensation) to 100 (strongest sensation of any kind) that best describes **SAMPLE <<Sample9>>** for each of the attributes listed below.

SMELL __________

SWEET __________

SOUR __________

OVERALL FLAVOR INTENSITY __________

Please enter a number from zero (no sensation) to 100 (strongest sensation of any kind) that best describes **SAMPLE <<Sample10>>** for each of the attributes listed below.

SMELL __________

SWEET __________

SOUR __________

OVERALL FLAVOR INTENSITY __________

PLEASE LIFT THE WINDOW TO RECEIVE YOUR LAST SAMPLE

Take a bite of cracker and a sip of water to rinse your mouth.

Remember to do this before you taste each sample.

WHEN ANSWERING ANY QUESTION, MAKE SURE THE NUMBER ON THE CUP MATCHES THE NUMBER ON THE MONITOR.

Please click the 'Continue' button below.

CONTINUE

Please enter a number from zero (no sensation) to 100 (strongest sensation of any kind) that best describes the bitterness of **SAMPLE <<Sample1>>**.

OVERALL BITTER INTENSITY __________

Please lift your window to let the server know you have finished.

Thank you. ☺

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BIOGRAPHICAL SKETCH

Sonia Hudson was born in Miami, Florida to Terrance and Ramonne Hudson. She grew up in the suburbs of Fort Lauderdale in Davie, Florida. After she graduated high school, she attended the University of Florida from 2005 to 2009 where she graduated with a bachelor in science degree in food science and human nutrition, with a specialization in food science. She extended her stay at the University of Florida for two more years and received her master of science degree in food science with a minor in packaging science in August 2011. Throughout her academic career, she was involved in the Food Science and Human Nutrition Club, Food Science and Human Nutrition Graduate Student Association, and the Florida Section of the Institute of Food Technologists.