SENSORY AND CHEMICAL ANALYSIS OF HEIRLOOM TOMATOES: IN SEARCH OF A BETTER TOMATO

By

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To God and my dearly loved mother

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Although tomatoes remain popular in the fresh-fruit market, they are often criticized because of poor flavor. Tomato flavor depends on both volatile and non-volatile compounds and their interactions. The development of new varieties of tomatoes has been focused on obtaining high yields, longer shelf-life and resistance to diseases, but may have sacrificed flavor.

The objective of this project was to find the characteristics that need to be included in a variety of tomatoes for improved acceptability. Fifty varieties of heirloom or modern tomatoes were evaluated during this study by a panel of 137 tomato consumers. The General Labeled Magnitude Scale (gLMS) was used to measure the intensities of sweetness, sourness, bitterness, saltiness, umami, and overall tomato flavor. The gLMS ranges from 0 (no sensation at all) to 100 (the strongest sensation of any kind ever experienced). The Hedonic gLMS was used to assess overall liking. The anchors of this scale are -100 (the strongest disliking of any kind ever experienced), 0 (neutral) and 100 (the strongest liking of any kind ever experienced). The volatile and non-volatile components of each variety were analyzed on the same day as each panel session.

The average rating for “favorite food” was 60 on the Hedonic gLMS, while overall liking of the tomatoes tasted ranged from 3.5 to 34 corresponding to Marmande VFA and Cherry Roma varieties, respectively. Positive correlations between overall liking and texture, sweetness, umami, and tomato flavor intensity were found, as well as a negative correlation between overall liking and bitterness. Overall liking also showed significant correlations with multiple volatile and non-volatile compounds. This may imply that if these variables are modified the liking of tomatoes can be improved. Overall liking scores of “Tomato Lovers” correlated more strongly with attribute intensities, volatile and non-volatile components than those scores from “Non-tomato Lovers”. In the case of “High tasters” and “Low tasters”, they showed big differences in the amount of correlations found for each group. While “High tasters” showed a total of twenty seven correlations, “Low tasters” only showed eleven. “High tasters” also showed negative correlations between overall liking and Isobutyl acetate and 2-methylbutyl acetate, which was not the case for “Low tasters”.

CHAPTER 1
INTRODUCTION

Tomato (*Solanum lycopersicum* L.*)* belongs to the family of the *Solanaceae* (Nunes 2008; 2009) and originated in the coastal highlands of western South America, where wild tomato plants can still be found. However, there is no proof that South Americans cultivated or consumed tomato prior to the Spanish Conquest. Through unidentified means, tomatoes migrated to Central America, where Mayans and other Mesoamericans domesticated the plant and included it in their cuisine (Smith 2001).

Tomato is considered a berry fruit, but is typically cultivated and consumed as a vegetable (Petro-Turza 1986). It is also considered one of the most consumed horticultural crops in the world (Nunes 2008; 2009). According to the United States Department of Agriculture (USDA) (2009), the world's leading producer of tomatoes is China with 33,811,659.76 metric tons (t) in 2009, followed by the United States (U.S.) with 12,575,885.19 t.

In the U.S., fresh and processed tomatoes represent more than $2 billion in farm cash receipts annually. In terms of consumption, the tomato is the fourth most popular fresh-market vegetable after potatoes, lettuce, and onions. During the 1960's to 1970's, the consumption of fresh tomatoes was approximately 5.45 Kilograms (Kg) (12 lb) per capita ((Lucier and others 2000)) but it began to rise during the 1980's and 90's to at least 7.73 Kg (17 lb) per capita and by 2009 the consumption increased to 8.77 Kg (19.3 lb) per capita (USDA Economic Research Service. 2010). This increase has been attributed to a combination of factors, such as change in migration trends, increase in ethnic populations, increase in health awareness of consumers and changes in America's tastes and preferences (Lucier and others 2000) .

Regardless of the rise in the utilization pattern that has been observed, many studies ((Bruhn and others 1991); have reported that fresh tomatoes available in the retail marketplace have poor flavor, which can have consequences on consumption behavior (Hongsoongnern and Chambers 2008). The development of new varieties of tomatoes has focused on obtaining high yields, longer shelf-life and resistance to diseases (Hongsoongnern and Chambers 2008), which may have sacrificed flavor characteristics in fresh-market tomatoes (Hongsoongnern and Chambers 2008). Other researchers have reported that lack of tomato flavor is associated with various storage treatments, e.g. modified atmosphere ((Kader and others 1978b); (Maul and others 2000)), storage under nitrogen, low oxygen conditions, as well as low temperature storage (Boukobza and Taylor 2002). Kader and others (1977) stated that the poor flavor is also due to harvesting the tomatoes at a mature green-ripened stage so that the fruit is suitable for transport. Fresh tomatoes harvested at the red-ripe stage are considered to have the best flavor. However, fruits at this stage are very fragile and can become easily damaged during postharvest handling and treatments (Hongsoongnern and Chambers 2008).

The characteristic flavor of tomatoes is formed from both volatile and non-volatile compounds and also from their interactions. Over 400 volatile compounds have been identified in fresh tomatoes (Petro-Turza 1986). However, it is likely that only a limited number of those are actually important to the “tomato flavor” (Krumbein and others 2004). Based on odor threshold studies, only 17 compounds were found to be important in tomato (Buttery 1993). The same author also indicated that a combination of some volatiles at appropriate concentrations may contribute to the characteristic tomato flavor.

Those included *cis*-3-hexenal, *cis*-3-hexenol, hexanal, 1-penten-3-one, 3-methylbutanal, *trans*-2-hexenal, 6-methyl-5-hepten-2-one, methyl salicylate, 2-isobutylthiazole, and β-ionone. Buttery and Ling (1993) suggested a similar set of volatiles, which included the above components, plus hexanol, geranylacetone, 2-phenylethanol, β-ionone, 3-methylbutanol and 3-methylbutanal. Krumbein and Auerswald (1998) analyzed the odor-active volatiles of tomato using gas chromatography-olfactometry and aroma extract dilution analysis. They found that *cis*-3-hexenal, hexanal, 1-octen-3-one, methional, 1-penten-3-one and 3-methylbutanal belonged to the most odor-active aroma volatiles in fresh tomatoes.

Compounds in fresh tomatoes develop and change over the ripening stages of the fruit (Hongsoongnern and Chambers 2008). Many volatile compounds increased significantly as the fruits mature (Buttery 1993). Some of the factors that are responsible for differences in volatile compound content include tomato variety, growing conditions, and stage of ripeness. This represents a large variability and thus, enormous challenges for those trying to investigate the contribution of aroma compounds to the flavor characteristics of fresh tomatoes.

It is also necessary to consider the non-volatile compounds present in the fruits. These include sugars, minerals, organic acids, and free amino acids. Petro-Turza (1986) mentioned that the pleasant sweet-sour taste of tomatoes is mainly due to their sugar and organic acid content. Sugars, primarily glucose and fructose, contribute to about 50% of the dry matter content in tomatoes. Saccharose is also present in the fruit, but it rarely exceeds 0.1% of the fresh mass. Other sugars, including raffinose, arabinose, galactose, and the sugar alcohol myo-inositol, have also been identified in tomatoes (Petro-Turza 1986). During the different growth stages of the tomatoes there are significant compositional changes. In the initial stage of development the tomato contains <1% sugar, with a ratio of glucose: fructose of 1.8. During growth and ripening, the sugar content increases significantly and the glucose: fructose ratio gradually decreases. The total sugar content of the ripe tomato is between 1.7 and 4.7%, depending on the variety (Stevens and Rick 1986; Davies and Kempton 1975).

Organic acids form more than 10% of the dry content of tomatoes and citric and malic acids are predominant (Petro-Turza 1986). The acid content of tomatoes is also dependent on the stage of maturity. In the mature green stage the malic acid: citric acid ratio is above 1. After this the amount of citric acids exceeds that of malic acid and finally, in the ripe red tomato, the ratio is 0.5 or below (Davies and Kempton 1975).

Tomato flavor is a unique trait that has complex genetic control and strong environmental effects (Scott 2001), which makes finding a clear pathway to improve flavor attributes difficult. Although several studies have focused on trying to determine the characteristics that are important in tomato flavor, not enough has been found to establish a “recipe” for a great tomato. At present, it has been complicated to find a volatile pattern related with good flavor in tomatoes (Scott 2001), as well as appropriate levels of sugars and acids. So far, a clear pathway to solve the problem of poor flavor has not been found.

Furthermore, there are other factors that make the task even more complicated. “Taste” involves several sensory experiences: true taste, retronasal olfaction, and oral somatosensation (Duffy and Bartoshuk 2000). However, flavor experience depends on the combination of responses from the senses and the mental handling of these inputs (Reineccius 2006), which can vary greatly from individual to individual.

Acceptance of sweet and rejection of bitter appear to be hard-wired, but the effect of odors depends more on experience (Bartoshuk and Beauchamp 1994). Nutritional stimuli on human behavior are mostly understood, for example, the effect of carbohydrate consumption and hydrolysis, blood glucose levels and their consequences on appetite. However, this is not the case for flavor stimuli. Flavor perception depends on several senses, often called modalities (Taylor and Hort 2004). Other authors also mentioned that additional inputs (food matrix, volatile and nonvolatile release, composition, mastication, saliva, hearing, etc.) influences flavor perception (Reineccius 2006).

There is also genetic variation in taste that impacts food perception. Bartoshuk discovered that there are different taster groups (Bartoshuk 1991). She classified them as supertasters, those who experience the most intense taste sensations, medium tasters who perceive average taste intensities, and weak tasters, who perceive the weakest taste sensations. Supertasting is partially due to a high density of fungiform papillae (Duffy and others 2004), which are the structures that contain the taste buds of the anterior tongue (Bartoshuk 2000). It is well known that the way every person perceives flavor is critical when it comes to food preferences. The understanding of this variation in taste provides a great opportunity to further understand food selection, variability between supertasters, medium tasters and weak tasters (Duffy and Bartoshuk 2000).

At the beginning of the 20th century, threshold measurement was the technique mostly used in sensory research. This technique was (and is) used to identify those compounds that are important in terms of their odor unit, which is the ratio of the compound concentration to the odor threshold of the same compound (Buttery 1993). However, thresholds only provide a very limited view of the capacities of our senses. Threshold measures are claimed to be related to a variety of problems and also fail to describe an accurate image of suprathreshold sensitivity (Bartoshuk 1978). Fortunately, psychophysics has advanced significantly beyond these measurements and has developed new techniques that are promising in terms of measuring perceived intensity and to provide accurate comparisons across individuals (Bartoshuk 2000). These techniques are based on the validation of a generalized Labeled Magnitude Scale (gLMS) for taste comparisons across weak tasters, medium tasters, and supertasters (Bartoshuk and others 2004), as well as the use of the gLMS as a hedonic scale for food preferences (Bartoshuk and Snyder 2004).

The main objective of this study was to determine the biochemical attributes and sensory characteristics that are related to overall liking of tomatoes. To accomplish this objective, a sensory study was designed using the gLMS to measure sensory intensities and the Hedonic gLMS to measure hedonic responses. Forty two varieties of heirloom tomatoes showing a large chemical diversity were grown at the University of Florida and eight varieties were obtained from a local retail store. Heirloom tomatoes are non-hybrid cultivars and they were commonly grown during earlier periods in human history, but have not been used in modern large-scale agriculture (O'Donnell 2006). This sample represents great variability and offers the possibility to study the contributions of sugars, acids and volatiles to flavor.

Correlations between overall liking of the samples with sensory responses (texture liking, sweetness, sourness, saltiness, bitterness, umami, and flavor intensity) and biochemical components (volatile and nonvolatile compounds) were analyzed. Significant correlations may suggest that if these variables are modified the liking of tomatoes can be improved. Additionally, the differences between "Tomato Lovers" and "Non-tomato Lovers" were analyzed, as well as the differences between "High tasters" and "Low tasters". These analyses offer a big opportunity for scientists and researchers to develop or find the ideal tomatoes for target groups.

CHAPTER 2

LITERATURE REVIEW

Fresh Tomato Market

Tomato is a very popular item in the fresh fruit market. In the United States (U.S.), tomato has been reported as the fourth most consumed, after potatoes, lettuce, and onions (USDA Economic Research Service. 2010). It is a warm-season crop which originated in in the coastal highlands of western South America (Smith 2001). It is produced domestically year-round, but imports from Mexico during winter and spring are having an increased impact (Sargent and Moretti 2004).

In 2008, in terms of total production, the top five producers were China, United States, Turkey, India, and Italy. China produced 33,811,659.76 metric tons (t) while the U.S. produced about 12,575,885.19 t. (USDA Economic Research Service. 2010).

National fresh-market tomato acreage has decreased over the past decades. It has decreased from 463,020 acres in 1960 to 442,100 acres in 2009. From this acreage, 110,200 acres were used in 2009 to produce fresh-market tomatoes. The total production in 2009 was 1,414.192 t, and from this amount, 146.81 t were destined for the fresh-market (USDA Economic Research Service. 2010).

Fresh-market tomatoes are produced in every State in the U.S., with commercial-scale production in about 20 states. California and Florida produce fresh-market tomatoes on 30,000 and 40,000 acres, respectively. Together, these two states have about 66 percent of total U.S. fresh-tomato acreage. Ohio, Virginia, Georgia, and Tennessee are next in the top six in terms of planted area (Lucier and others 2000)

In 2009, the United States exported about 170,379.73 t of fresh tomatoes. This amount was divided into three types: Round (152,713.211 t), Roma (plum-type)

(11,874.14 t) and cherry tomatoes (5,792.37 t) (USDA Economic Research Service. 2010). These tomatoes were exported mostly to Canada (110,357.66 t) and Mexico (57,721.89 t). The rest were exported to Japan, Bermuda, Antigua, Hong Kong and other countries. The total amount of fresh tomatoes imported in 2009 was 1,189,599.97 t and came mainly from Mexico (1,046,867.60 t), Canada (130,310.28 t), and the Netherlands (5,307.94 t).

Consumption of fresh tomatoes has increased from 5.45 Kg (12 lb) per capita during the 1960's and1970's, to at least 7.73 Kg (17 lb) per capita during the 1980's and 1990's. By 2009 the consumption increased to 8.77 Kg (19.3 lb) per capita. (USDA Economic Research Service. 2010). This increment in consumption has been attributed to factors such as immigration trends, transformations in America's tastes and preferences, an increase in ethnic populations, as well as an increase in health awareness of consumers (Lucier and others 2000). However, it has been reported that consumers are dissatisfied with the flavor of fresh tomatoes available in the supermarket (Baldwin and others 2000), which in the future may have a negative effect on consumption trends (Hongsoongnern and Chambers 2008). Some of the reasons why tomatoes for fresh market have poor flavor range from poor genetic material to harvest and handling procedures (Baldwin and others 2000).

Background Information

Tomato (*Solanum lycopersicum* L.) belongs to the family of the *Solanaceae* and is considered a berry fruit, but it is cultivated and used as a vegetable (Petro-Turza 1986). Tomato is described as a two- to many-celled berry with fleshy placenta which contains several small kidney-shaped seeds covered with short firm hairs. The seeds are surrounded by jellylike parenchyma cells, which fill locular cavities (Madhavi and Salunkhe 1998).

Tomato is one of the main sources of lycopene, a major carotenoid without provitamin A activity (Rao and others 1998). Many population studies have established an association with dietary intake of tomatoes and reduced risk of chronic diseases (Rao and others 1998). The ability of lycopene to act as a potent antioxidant is thought to be responsible for protecting cells against oxidative damage (Rao and Agarwal 1999). In addition to its antioxidant properties, lycopene is also supposed to induce cellular communication, as well as to control hormonal, immune systems and other metabolic pathways (Zhang and others 1991).

Tomato is considered a climacteric fruit (Madhavi and Salunkhe 1998), which entails the presence of a peak in respiration and an associated burst of ethylene as part of its ripening mechanism. This ethylene burst is required for normal fruit ripening (Alexander and Grierson 2002) and also in subsequent changes (Madhavi and Salunkhe 1998). The changes in respiration and ethylene production are highly associated with the disappearance of starch, degradation of chlorophyll, synthesis of lycopene, development of flavor components, and polygalacturonase (a cell wall-hydrolyzing enzyme) (McGlasson 1993).

There are different tomato varieties available in the marketplace and even though the round red-flesh tomato prevails in the fresh-market, red and yellow-fleshed round, plum (Roma-type tomato), cluster, and small-sized kinds such as cherry, grape and mini-pear types are also available (Sargent and Moretti 2004).

Numerous cultivars have been developed in the last decades (Madhavi and Salunkhe 1998). The cultivars developed for fresh market and processing have different characteristics, each adjusted to the requirements of either the fresh or the processing market. Processing varieties require intrinsic rheological characteristics that make them appropriate for various processing applications (Madhavi and Salunkhe 1998) or the presence of a specific attribute for a particular product, for example, higher content of soluble solids (from 5-9%) to produce tomato sauce (USDA Economic Research Service. 2010). On the other hand, tomatoes destined for fresh-market must have acceptable flavor, color, and texture to satisfy consumer demands and handling requirements (Madhavi and Salunkhe 1998).

Tomato Quality

Quality has been defined as “the assessment from the relative values of several characteristics that considered together will determine the overall acceptability of the product” (Arthey 1975). Even though the term seems simple, quality can be very difficult to measure because of its subjectivity and thus, its variability in different markets. This is the case of tomato fruit quality for fresh consumption. For some authors (Kader and others 1978b; Sinesio and others 2010) tomato quality is related to visual appearance (visual, shape and color), texture (firmness, mealiness, juiciness), flavor attributes and nutritional value, while for others, a high quality fruit is defined only on the basis of firm and turgid appearance, uniform and shiny color, no signs of mechanical damage, shrinking or decay (Sargent and Moretti 2004). This is the main reason why maintaining optimal visual quality during production and marketing has been a priority (Maul and others 1997). However, at present more attention is being given to other quality factors to fulfill consumer demands (Kader 1986). This is in response to the fact that even when visual appearance plays an important role, it is sensory quality (flavor and texture) that has the greatest influence on consumer satisfaction and therefore, in repeat purchases (Kader and others 1978b).

A large inconsistency is encountered between consumer requests (acceptable flavor, color, texture) and production and handling requirements (Madhavi and Salunkhe 1998). The demand for fresh tomatoes has led to techniques that prolong shelf life of tomato fruit so that they can be shipped over long distances (Boukobza and Taylor 2002). Harvesting at immature green or early stages of ripening, and shipping to retailers under controlled conditions are also techniques used to prolong storage (Boukobza and Taylor 2002). However, the biochemical changes that occur under these conditions affect flavor quality (Ratanachinakorn and others 1997). These techniques (breeding practices that do not select for flavor, harvesting of green fruit, and temperature abuse) contribute to poor flavor quality in tomato fruit (Baldwin and others 2000).

Factors Influencing Quality

Breeding Practices

The onset of fruit ripening in tomatoes represents the start of several biochemical and physiological processes that affect the quality of the fruit (Madhavi and Salunkhe 1998). These changes include alteration in the structure and composition of cell walls, which affect fruit firmness, metabolism of sugars and acids, biosynthesis of carotenoids, and synthesis of hormones in charge of the rate of ripening (Schuch 1994).

Tomato research has mainly focused on the selection of new varieties with improved firmness and extended shelf life (Boukobza and Taylor 2002). A number of genes have been identified and isolated in ripening and ripe tomatoes. Some of these genes encode the enzymes polygalacturonase (PG) and pectinesterase (PE). These enzymes are critical in the determination of texture by affecting the metabolism of pectin in the cell wall. PG hydrolyzes the α-1,4 linkages in the polygalacturonic acid, reducing the chain length, while PE modifies the degree of esterification of pectin (Schuch 1994). These modified tomatoes were reported to be firmer, last longer on the vines, and are less prone to spoilage on and off the vine, which leads to better postharvest handling (Madhavi and Salunkhe 1998). However, cell wall structure can have an effect on aroma binding and release (Baldwin and others 2000). Some studies have shown that when PG is down regulated in red-ripe tomatoes, a lower level of volatiles is produced (Baldwin and others 2000).

Another way to extend shelf life is to postpone or decrease ethylene production (Baldwin and others 2000). This has been done by altering the ethylene biosynthesis pathway so that the key enzymes are down regulated. The ripening and softening process can also be slowed down by using ripening mutants, such as nonripening (*nor*), ripening inhibitor (*rin*), Never ripe (*Nr*), and alcobaca (*alc*). *Rin* and *nor* do not ripen, do not show the climacteric rise in carbon dioxide and ethylene, and contain reduced PG activity. The *rin* and *nor* fruit do not develop normal red color. *Alc* fruit have good storage qualities and can produce a light orange-red color on the plant, but do not ripen off the plant if harvested when mature green (Baldwin and others 2000). All these fruit have been developed by breeders using normal-ripening lines to produce hybrids with extended shelf life attributes, but *rin* hybrids have been more successful commercially (Baldwin and others 2000). However, *rin, nor* and *alc* hybrids have been reported to be bland in taste, which represents a flavor problem (Scott 2001).

Harvesting Methods

Harvesting tomatoes as near to “table-ripe” (TR) as possible, as well as reducing the time from the field to the consumer table, are the best ways to assure good flavor for the consumer. However, this is not practical within the current handling and marketing system (Kader and others 1978b). For this reason, depending on the transportation distance (Maul and others 1997), and market and production area (Sargent and Moretti 2004), tomatoes are harvested at different stages of maturity. In Florida, about 85% of the fresh market fruit is harvested at a mature-green stage, so it can be transported to distant markets (Maul and others 1997).

Figure 2-1 shows the different ripening stages on tomato fruit, which range from M1 to Breaker, corresponding to completely green fruit and fruit showing some pink color, respectively. Studies on the influence of level of maturity on aroma volatile profiles of ripe tomatoes (Maul and others 1998) have shown that tomatoes harvested at the mature-green stage (M-3 or M-4) will ripen to high quality if handled properly, while tomatoes harvested at the M-2 stage will ripen to moderate quality. Harvesting tomatoes at M1 will have a negative effect on chemical composition, overall sensory acceptance, and aroma volatiles profiles.

The USDA (1991) provides a description for the different ripening stages of tomato based on surface color (Figure 2-2). This description is divided into six types (green, breaker, turning, pink, light red and red). The definition for each ripening stage is as follows:

- Green Fruit: “Surface is completely green; the shade of green may vary from light to dark”.
- Breaker: “There is a definite break in color from green to tannish-yellow, pink or red on not more than 10% of the surface”.
- Turning: “10% to 30% of the surface is not green; in the aggregate, shows a definite change from green to tannish-yellow, pink, red, or a combination thereof”.
- Pink: “30% to 60% of the surface is not green; in the aggregate, shows pink or red color”.
- Light red: “60% to 90% of the surface is not green; in the aggregate, shows pinkish-red or red”.
- Red: “More than 90% of the surface is not green; in the aggregate, shows red color”.

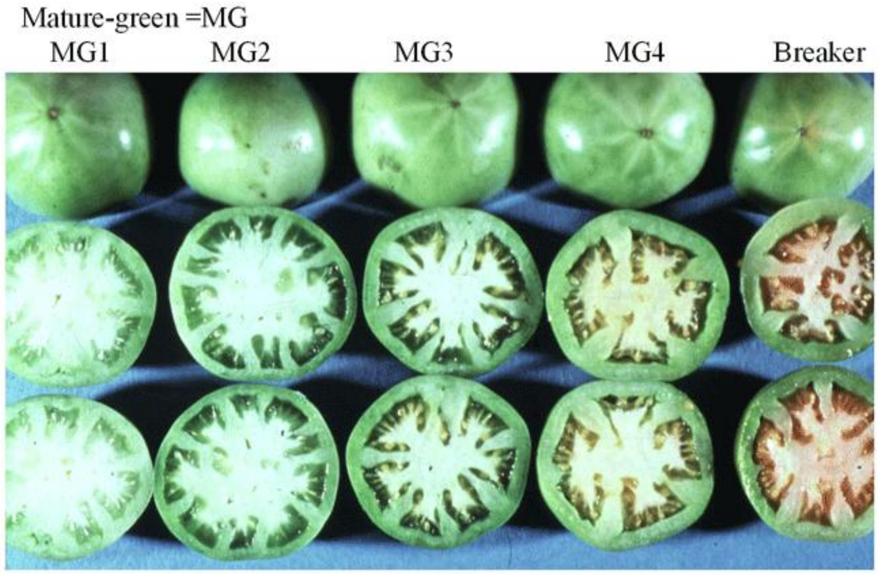


Figure 2-1. Different ripening stages on tomato fruit. Retrieved from: http://rics.ucdavis.edu/postharvest2/Produce/ProduceFacts/Veg/tomato.html

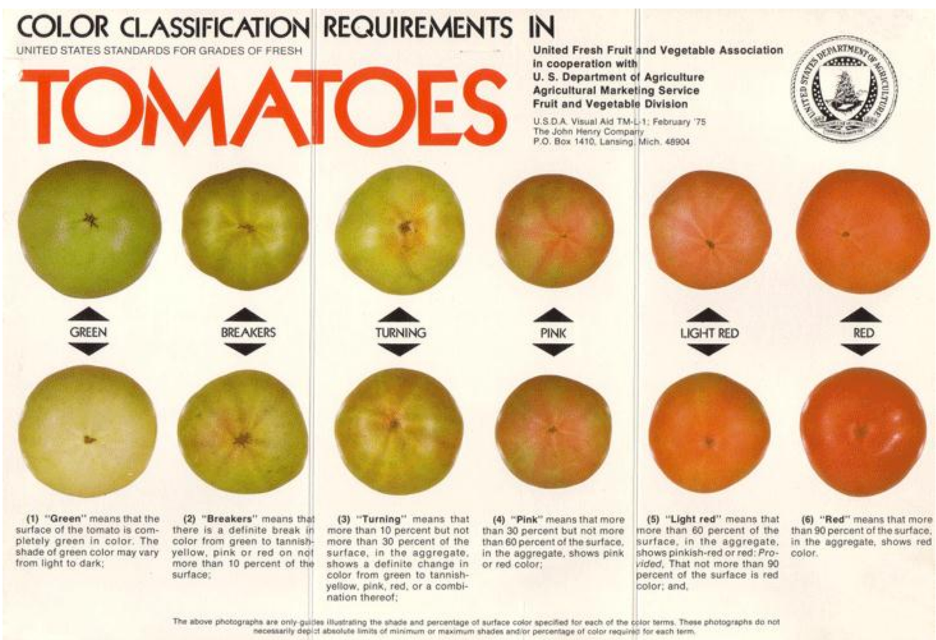


Figure 2-2. USDA Tomato Ripeness Color Chart. Photo by A. Kader. Retrieved from: http://postharvest.ucdavis.edu/Produce/producefacts/Veg/full_tomatousdacolor.shtml

Postharvest Practices

After harvesting, tomatoes undergo postharvest treatments to extend shelf life. Low temperature storage, modified atmosphere packaging, and ethylene treatment are some of the techniques most used commercially. A review of these techniques will be found in the following sections.

Low temperature

Postharvest storage, handling and distribution of fruit at low temperatures is the most common and convenient approach to control ripening, deterioration, and maximize shelf-life (Jackman and others 1992). Temperature has been determined to have a major effect on tomato quality (Nunes 2008; 2009). Freshly harvested tomatoes are pre-cooled to 15-20 °C to limit decay and extend postharvest shelf life. For this purpose, forced-air cooling is the most effective practice but room cooling is more common (Suslow and Cantwell 2009).After pre-cooling, optimum storage temperature will vary depending on the ripeness of the fruit at harvest. Tomatoes, as well as many other climacteric fruits, are susceptible to chilling injury (CI) (Jackman and others 1992). CI is a physiological damage incurred upon exposure of plant parts to low but nonfreezing temperatures. The manifestation of symptoms depends on temperature, time, species, and cultivar and they are only evident upon subsequent transfer of produce to non-chilling temperatures (Jackman and others 1992). Consequences of CI are failure to ripen and develop full color and flavor, premature softening, surface pitting, browning of the seeds, and increased decay (Nunes 2008; 2009). The development of mealiness and softening of fruit can increase their susceptibility to mechanical injury, pathogen invasion and loss of total solids during handling and distribution (Jackman and others

1992). Immature and mature-green tomatoes are more sensitive to chilling temperatures than pink or red tomatoes. If stored for more than 2 weeks below 10°C or for longer than 6 to 8 days at 5°C, they may develop CI (Nunes 2008; 2009). However, it has been reported that firm ripe tomatoes can be stored at temperature between 7 to 10°C for 3-5 days with no reduction in flavor and aroma quality (Sargent and Moretti 2004). On the other hand, when the production of volatiles was analyzed quantitatively on ripe fruit stored at 2°C, it showed a decrease on major flavor volatiles (Buttery and others 1987). Boukobza and others (2002) also demonstrated that storage at low temperatures caused a significant decrease in volatile concentrations and this effect is not reversed even after 72 hours recovery.

Ethylene treatment

Tomatoes are sensitive to exogenous ethylene and therefore, when picked at mature-green stages and exposed to ethylene, tomato fruit will initiate ripening (Suslow and Cantwell 2009). Ethylene triggers the respiratory climacteric and ripening response once the fruits have reached their destination (Boukobza and Taylor 2002). Ethylene treatment typically extends for 24-72 h. For commercial ripening, green tomatoes should be held at 20 to 21°C, 90% Relative Humidity (RH), and 50 $\mu L\ L^{-1}$ ethylene, which promotes uniform ripening. When reaching breaker stage, tomatoes will no longer need gassing, since the fruit will produce sufficient ethylene to complete the ripening process (Sargent and Moretti 2004). Sometimes a second ethylene treatment stage possibly will follow repacking if immature-green fruit were included during harvest. At a temperature of 20°C, tomatoes will ripen properly to ensure color development and retention of Vitamin C content. Tomatoes allowed to ripen off-the-vine above 25°C will show more yellow than red colors and the texture will be softer (Suslow and Cantwell 2009). It has been shown that an ethylene treatment to speed ripening of green tomatoes at 20°C reduced ascorbic acid levels at the table-ripe stage and did not influence flavor when compared with fruits ripened without added ethylene (Kader and others 1978b). Stern and others (1994) concluded that the effect of storage temperature and ethylene treatment on volatile development appears to be a function of final ripening temperatures and not of initial stage of ripeness and storage temperature or ethylene treatment. The authors also mentioned that the level of volatiles developed in the stored samples never reaches that of the fruit picked at the table ripe stage, which shows the flavor reduction due to low temperatures and ethylene treatment.

Controlled atmosphere storage

Controlled atmosphere (CA) storage offers the possibility of increasing shelf life of tomato fruit. At low oxygen levels (3-5%) ripening is delayed along with the development of surface and stem-scar mold. Sensory quality is not severely impacted at this oxygen level, however; low oxygen (1%) storage can cause off-flavors, unpleasant odors and other defects, such as browning (Suslow and Cantwell 2009).

Tomato Flavor

Tomato flavor is a complex trait and it is affected by many factors, including cultivar or variety, maturity, and environmental conditions (Madhavi and Salunkhe 1998). Furthermore, harvesting and handling procedures also have an impact on the flavor of ripened tomato fruit (Baldwin and others 2000). Fresh tomato flavor is the result of the interaction between non-volatile (sugars, organic acids and minerals) and volatile components (Buttery 1993)(Buttery 1993), which are described in the following sections.

Volatile Composition

It is believed that the most important tomato flavor volatiles are produced from a diverse set of precursors, including amino acids, lipids, and carotenoids (Tieman and others 2006). Those compounds derived from amino acids and lipids are formed during ripening, while others are produced by the breakdown of lipid, when the tissue is damaged, principally through an enzyme “cascade” that forms C6 compounds (Prestage and others 1999).

Several changes in physiological and biochemical characteristics occur during the development of tomato fruit (Yu and others 1967). The concentration of different volatiles will vary depending of the maturity stage.*cis*-3-hexenal, for example, exists in mature-green tomato, but its concentration is 20 times greater in table ripe form. Similar increases occur in most other tomato volatiles as the tomato ripens (Buttery 1993).

Over 400 volatiles have been identified in tomato fruit (Petro-Turza 1986) but not all are important to tomato flavor (Buttery 1993). Buttery (1993) used “Odor Units” to examine the contribution of different aroma compounds to the total odor of the tomato. “Odor unit” is the ratio of the compound concentration and the odor threshold. If the ratio is greater than 1, then the compound is present above its threshold and consequently, it should contribute to the odor. About 30 compounds are present in concentrations above 1 part per billion (ppb). From this set, 16 compounds have positive log odor units, and therefore they may contribute to tomato flavor (See Table 2-1). To confirm if the results were reasonable, the author created a synthetic mixture with 10 of the compounds with the greatest probability of being important to fresh tomato aroma. The compounds used were *cis*-3-Hexenal, *cis*-3-Hexenol, hexanal, 1-Penten-3-one, 3-Methylbutanal, *trans*-2-

Hexenal, 6-Methyl-5-hepten-2-one, methyl salicylate, 2-Isobutylthiazole and β-Ionone. When analyzed by a sensory panel they concluded that the mixture had an aroma very similar to that of sliced fresh tomato. A later study (Buttery and Ling 1993) reported similar results, listing hexanal, *cis*-3-hexenal, *trans*-2-hexenal, hexanol, *cis*-3-hexenol, 2-isobutylthiazole, 6-methyl-5-hepten-2-one, β-ionone, geranylacetone, 1-penten-3-one, 3-methylbutanal, 3-methylbutanol, phenylethanol, 2-pentenal, acetone, ethanol, and methanol, as the most important volatile compounds in tomato aroma. Furaneol was added to the list of the 10 compounds with the highest probability of contributing to fresh tomato flavor when it was discovered that its concentration occurs above its threshold (Buttery and others 1995). Buttery and Ling (1993) showed the origin of each compound grouping them by the precursor they are derived from:

- Lipid derived: Hexanal, hexanol, *cis*-3-hexenal, *trans*-2-hexenal, *cis*-3-hexenol. pentanal.
- Amino acid derived: From leucine (3-Methylbutanol, 3-Methylbutanal, 2-Isobutylthiazole) and phenylalanine (2-Phenylethanol).
- Carotenoid derived: β-Carotene (β-Ionone), lycopene (6-Methyl-5-hepten-2-one, Acetone, Geranylacetone).

Ethanol and methanol are found in small quantities, but their main effect was thought to be an influence on the perception of other compounds (Kazeniac and Hall 1970). It was later found that ethanol and methanol at concentrations present in ripe tomatoes do suppress the aroma of hexanal, 3-methylbutanol, phenylethanol, 1-penten-3-one, while promoting or enhancing *trans*-2-hexenal, hexanol and 3-methylbutanal

Table 2-1. Concentrations and odor thresholds of major components in fresh ripe tomatoes using a blending procedure (Adapted from Buttery, 1993).

Compound	Concentration (ppb)[a]	Odor Threshold (ppb in H_2O)[b]	Log Odor Units [c]
cis-3-Hexenal	12000	0.25	3.7
β-Ionone	4	0.007	2.8
Hexanal	3100	4.5	2.8
β-Damasceone	1	0.002	2.7
1-Penten-3-one	520	1	2.7
3-Methylbutanal	27	0.2	2.1
trans-2-Hexenal	270	17	1.2
2-Isobutylthiazole	36	3.5	1.0
1-Nitro-2-phenylethane	17	2	0.9
trans-2-Heptanal	60	13	0.7
Phenylacetaldehyde	15	4	0.6
6-Methyl-5-hepten-2-one	130	50	0.4
cis-3-Hexenol	150	70	0.3
2-Phenylethanol[d]	1900	1000	0.3
3-Methylbutanol	380	250	0.2
Methyl salicylate	48	40	0.008
Geranylacetone	57	60	-0.02
β-Cyclocitral	3	5	-0.2
1-Nitro-3-methylbutane	59	150	-0.4
Geranial	12	32	-0.4
Linalool	2	6	-0.5
1-Penten-3-ol	110	400	-0.6
trans-2-Pentenal	140	1500	-1
Neral	2	30	-1.2
Pentanol	120	4000	-1.5
Pseudoionone	10	800	-1.9
Isobutyl cyanide	13	1000	-1.9
Hexanol	7	500	-1.9
Epoxy-β-ionone	1	100	-2.0

a.Parts (milliliters) of compound per 10^9 parts (milliliters) of fresh tomato. b.Parts (milliliters) of compound per 10^9 parts (milliliters) of water. c. Log of odor unit value. d.Exact concentration and log Uo (Odor unit) value are uncertain.

(Tandon 1997). These interactions between ethanol, methanol and aromatic compounds may serve as enhancers of sensory perception (Tandon and others 2000).

While some fruits have one or two specific compounds that provide their characteristic aroma, tomato fruit has about 16 with odor units greater than zero, which makes them likely to contribute to its flavor. No single compound has been found in this fruit that represents ripe tomato since it is the combination of at least 16 compounds together gives tomato its particular odor features (Baldwin and others 2000).

Some researchers have focused their effort on finding the relationships between volatile and non-volatile components and sensory descriptors to finally understand the individual contribution of each component to overall flavor (Baldwin and others 2000). Compounds such as 6-methyl-5-hepten-2-one and β-ionone are thought to provide a "floral" character, while *cis*-3-hexenal and geranylacetone are described as "fruity". The "fresh" character is supposed to be provided by 3-methylbutanol and 1-penten-3-one. Hexanal, *trans*-2-hexenal, and 3-methylbutanol provide "stale" aroma, while 2-isobutylthiazole and 2-phenyl-ethanol provide "pungent" and "alcohol" characteristics, respectively. It has been suggested that an increase in compounds contributing to floral, fruity and fresh notes and/or a decrease in compounds contributing to stale, pungent and alcohol would likely benefit tomato flavor (Tandon and others 2000).

Some volatiles considered "sweet" and "floral" were found to enhance perception of sweetness, while volatiles described as "green" enhanced the perception of sourness (Baldwin and others 1998). In other fruits, such as kiwi, the addition of sugar to pulp has been found to affect panelists' perception of volatiles. The authors attributed this to the interaction in the mouth, which is related to memories and release of other volatiles in the mouth space (Marsh and others 2006). More studies on the interaction of sugars, acids and volatiles in tomato have shown that the addition of sugars and acids affects the perception of aroma. When aroma volatiles are added, the perception of aroma or taste is also affected for tomato fruit. This implies that sweet/ripe tomato, fruity, floral, and tropical or, viney, musty, and earthy aromas and tastes can be achieved by manipulation of volatiles, sugars, and acids (Baldwin and others 2008).

Non-volatile Components

Sugars and acids, as well as salts and free amino acids, are the main non-volatile components of tomato flavor. The sweet and sour tastes of tomatoes are caused by the sugars and acids present in the fruit, while bitter taste is caused by phenolics (Petro-Turza 1986). Approximately 50% of the dry matter of tomatoes is composed of sugars, mainly glucose and fructose. Sucrose is present as well, but only in trace amounts. Raffinose, arabinose, xylose, galactose, and myoinositol (sugar alcohol) are also present in small quantities in the fruit (Petro-Turza 1986). As described by Kader and others (1977), the quantity of reducing sugars in tomato presents a positive correlation with sweetness perception and soluble solids (SS) content.

The sugar content increases significantly as the fruit develops, but the ratio of glucose to fructose decreases slowly. Depending on the variety, total sugar content of a ripe tomato is between 1.7 and 4.7%, and the ratio of glucose to fructose has been found to be around 1 (Petro-Turza 1986). During fruit development light has the greatest effect on sugar concentration. The sugar concentration is directly proportional to the amount of sunlight the plant is exposed to, and thus, the more sunlight is absorbed by the fruit, the more sugar is produced (Petro-Turza 1986).

Citric and malic acids together represent about 10% of the dry content of tomatoes. Other acids (formic, acetic, lactic, mevalonic, pyruvic acid, *trans*-aconitic, dihydroxy tartaric acid, fumaric, malonic, oxalacetic, oxalic, 2-oxoglutaric, succinic, tartaric, galacturonic acid, and quinic acid) are found in lower quantities. During ripening and growth, the acid content increases up to the breaker stage, but later it declines (Petro-Turza 1986). This is also the case for ascorbic acid, which increases with the maturity of fruit but declines slightly in the later (red and red-ripe) stages of maturation (Dalal and others 1965).

The effects of adding sugar and acid to fresh tomatoes on the response by descriptive and consumer panels were studied. Regression analysis indicated that increasing total sugar and acid levels did not affect the impact of fresh tomato flavor, however it did significantly affect flavor acceptability. (Malundo and others 1995b). This study is relevant because it proposes that there is an optimum of acid content in tomato for preferred flavor quality, but when this level is reached and there is an increase it will decrease consumer acceptability. This study questioned the recommendations made by Kader (1977), who suggested that increasing sugar content and acid concentrations in tomato would improve flavor.

Free amino acids account for between 2 and 2.5% of the total dry matter content in tomatoes (Petro-Turza 1986). Glutamate, γ-aminobutyric, glutamine, and aspartate are the four amino acids that compose approximately 80% of the total amino acids in tomato (Kader and others 1978a). However, the content of amino acids in tomato is highly variable depending upon environmental conditions, cultivar and ripeness stage.

When studying the influence of fruit ripeness stage at harvest on amino acid composition and flavor. Kader (1978) showed that fruit harvested at the table-ripe stage contained more alanine and less glutamic acid than those picked green or at the breaker stage and ripened at 20°C to table ripe. Panelists did not detect flavor differences when monopotassium glutamate was added to table-ripe fruits. Finally, the author concluded that differences in amino acid composition related to ripeness stage when picked do not seem to be directly associated to differences in flavor.

Flavor Perception and Differences between Subjects

Humans consume food for mainly two reasons: nutritional benefit and pleasure. Both processes are associated with the interaction of food components with particular receptors in the body (Taylor and Hort 2004). Acceptance of sweet and rejection of bitter appear to be hard-wired, but the affect with odors depends more on experience (Bartoshuk and Beauchamp 1994). Nutritional stimuli on human behavior are mostly understood, for example, the effect of carbohydrate consumption and hydrolysis, blood glucose levels and their consequences on appetite. However, this is not the case for flavor stimuli. Flavor perception depends on several senses (modalities), but a comprehensive list of these senses is rarely provided in the literature (Taylor and Hort 2004).

Flavor experience depends on the combination of responses from the senses and the psychological handling of these inputs (Reineccius 2006). “Flavor” involves several sensory experiences: true taste, retronasal olfaction, and oral somatosensation. True taste refers to salty, sweet, sour, and bitter. Retronasal olfaction is the perception of volatiles from inside the oral cavity and finally, oral somatosensation is the perception of touch, temperature and pain (Duffy and Bartoshuk 2000). Other authors also mentioned that additional inputs, such as (Duffy and Bartoshuk 2000) food matrix, volatile and nonvolatile release, composition, mastication, saliva, hearing, etc., influences flavor perception (Reineccius 2006).

The perception of taste comes from specialized taste receptors located in the mouth, mainly found on the tongue (sweet, sour, bitter, and salty) (Reineccius 2006). These sensations are perceived because of the reactions of sugars or polyalcohols, hydronium ions, sodium ions, glucosides, and alkaloids with receptors located in certain regions of the tongue (Baldwin and others 2000). Some studies have suggested that of the four qualities that humans recognize, salty and sour tastes require the interaction with ion channels in the membrane of receptor cells while sweet and bitter compounds bind to receptor proteins (Bartoshuk and Beauchamp 1994). The nerves in the tongue are responsible for trigeminal responses (chemesthesis), such as texture, temperature, irritation, carbonation, and chemical heat from hot peppers (Baldwin and others 2000).

As mentioned before, taste interacts with olfaction, which is the result from the interaction of volatiles from food components with olfactory receptors in the nasal cavity. Olfaction can be orthonasal (stimulus enters directly from the nose by sniffing the food) or retronasal (odor stimulus enters the oral cavity by eating the food). However, taste interacts with retronasal olfaction but not with orthonasal olfaction (Duffy and Bartoshuk 2000).

The reactions between the odor receptors and the volatiles coming from the food are similar to an enzyme-substrate model (De Rovira 1997). Some of the complications with odorants come from their structure and the interaction with the receptors. Different theories about the relationship between volatile features and odor quality have been developed, however, the molecular basis of odor perception remains unclear (Nollet and Boylston 2007).

"Flavor perception" is complicated not only by the differences in volatile structure and their interaction with the food matrix and the olfaction system, but also the variation in the tasting abilities among subjects. Bartoshuk discovered that there are different taster groups (Bartoshuk 1991). She called them supertasters, who are those who experience the most intense taste sensations, medium tasters who perceive average taste intensities, and low or weak tasters, who perceive the weakest taste sensations. Bartoshuk has mentioned that "Supertasters live in a neon taste world, while low or weak tasters live in a pastel taste world" (Bartoshuk and others 2004), which refers to the big differences in perception between these two groups. More about the discovery and characteristics of these groups is discussed in the next section of this document.

Variability between subjects in taste perception is also linked to the occurrence of ageusia (taste loss), hypogeusia (decrease in taste) and dysgeusia (abnormal taste) (Nelson 1998). There are also disorders that affect the olfaction system, such as hyposmia (reduced sense of smell) or anosmia (loss of sense of smell). These conditions may play a role in quality of life because of taste changes and decreased pleasure from eating (Gaines 2010).

Differences in Taste Perception and its Measurement

Differences in tasting abilities were first observed by Fox in 1931, who measured individuals' ability to taste phenylthiocarbamide (PTC). Some individuals were able to taste the bitterness of this compound (PTC tasters), while others were not able to taste it (PTC nontasters). Fox reported that from a group of colleagues, 60% were PTC tasters and 40% were PTC nontasters Later studies showed that the ability to taste PTC resulted from a dominant allele (Snyder 1931). Individuals that carry two recessive alleles are PTC nontasters and those who carry one or both dominant alleles are PTC tasters (Blakeslee 1932). Later on, different studies led to the conclusion that supertasting involves variation produced by individual genes, but more importantly from a high density of fungiform papillae (Duffy and others 2004), which are the structures that contain the taste buds of the anterior tongue (Bartoshuk 2000).

Supertasters and others groups have been studied for several years and many of the characteristics of how each group perceives food have been identified. Supertasters, for example, perceive the most intense bitterness and sweetness, as well as saltiness and sourness. They also perceive the most intense burn from oral irritants, and the most intense tactile sensations from viscous solutions. The latter two sensations are supposedly also perceived in higher intensities for supertasters because taste buds of fungiform papillae are innervated by the trigeminal nerve (responsible for pain and touch sensations) and also by the chorda tympani nerve, which is responsible for taste (Bartoshuk and others 1998). These sensory differences influence food choice and health (Bartoshuk 2000). This is the case for the alcohol consumption pattern between these groups. Since supertasters have more fungiform papillae than other individuals, they also have been found to dislike alcohol. This dislike is justified by the fact that supertasters perceive more bitterness than others and alcohol is often associated with bitter flavors (Duffy and others 2004).

The findings about genetic variation in taste were facilitated by the development of psychological techniques that allow the comparisons across individuals. However, the knowledge of the existence of this genetic variation also contributed to the development of these methods (Bartoshuk 2000). At the beginning of last century, threshold measurement was the most popular technique in sensory studies. However, psychophysics has advanced significantly beyond these measurements and has developed new techniques that are promising in terms of measuring perceived intensity and to provide accurate comparisons across individuals (Bartoshuk 2000). These techniques are based on the validation of a generalized Labeled Magnitude Scale (gLMS) for taste comparisons across supertasters and others (Bartoshuk and others 2004), as well as the use of the gLMS as a hedonic scale for food preferences (Bartoshuk and Snyder 2004).

Labeled scales are used to compare across groups. The labels are adjectives to describe intensity, such as “very strong” or “very weak”. The problem with these scales it is not the relative distances among descriptors, since they are constant, but that the absolute perceived intensities of the descriptors vary depending on the context. For example, a “very strong" rose odor is weaker than a "very strong" headache” (Bartoshuk and others 2004). Bartoshuk and others (2004) described this situation as “an elastic ruler” that compresses or expands to fit the context. This compression or expansion is also caused by variation in individual experience and genetic variation (e.g., PROP supertasters, medium tasters and weak tasters). In this situation, taste descriptors represent different absolute perceived intensities which makes the comparison across the groups invalid (Bartoshuk and others 2004). The solution for this problem was “magnitude matching”, which consists of asking subjects to match tastes intensities to a standard not related to taste (sound, for example). Since this approach provides valid comparisons, it was the base for constructing a labeled scale with descriptors unrelated to taste (Bartoshuk and others 2004). The gLMS is a modified version of an existing scale, the Labeled Magnitude Scale (LMS), which was devised by Green, Shaffer, and Gilmore in 1993 to measure oral sensations. The LMS was the first scale to use magnitude estimation and to include a sensory maximum: “Strongest Imaginable Oral Sensation” (Bartoshuk and Snyder 2004). However, the labels of this scale mean different absolute intensities for supertasters, medium tasters and weak tasters (Bartoshuk and Snyder 2004).

To solve this issue, Bartoshuk and others (2000) changed the instructions and asked subjects to identify the “strongest imaginable sensation of any kind”. When this change was made, the differences between the groups (PROP supertasters, medium tasters and weak tasters) became the same size as the results obtained using magnitude matching when sound was used as the standard (Bartoshuk 2000). This scale was named *general LMS* (gLMS) (Bartoshuk and Snyder 2004). The most important assumption that is made with this scale is that absolute intensity represented by the top of the scale is not related to the variation in taste, which makes the top of the scale a standard that has the same average intensity for the three groups. “The gLMS is a valid sensory ruler as long as the strongest imaginable sensation of any kind is unrelated to that sensation” (Bartoshuk and Snyder 2004).

The gLMS was first used with anchors along the line to provide ratio properties to the scale. However, Snyder, Puentes, Sims and Bartoshuk (2008) showed that if the anchors were eliminated and the top of the scale was changed to “Strongest sensation of any kind ever experienced” the results showed less noise. The scale that is been used recently ranges from 0 (No sensation at all) to 100 (Strongest Sensation of any kind ever experienced” (see Bartoshuk 2000 and Bartoshuk and Snyder for a discussion on the evolution of the scales and important facts about across-groups and across-subjects comparison]. The gLMS was modified to measure hedonic responses as well. The current Hedonic gLMS ranges from -100 (Strongest Disliking of any kind ever experienced), 0 (Neutral), and 100 (Strongest liking of any kind ever experienced).

Other Studies

Despite the multiple studies on tomato chemistry, it is still unclear what characteristics are desirable in a good tomato. Efforts in trying to understand the complexity of predicting sensory descriptors as a function of volatile and nonvolatile components was done by Abegaz and others (2004). Their objective was to determine the effect of partitioning taste components from flavor during descriptive analysis on prediction of sensory descriptors as a function of volatile and nonvolatile compounds. The partitioning technique involved the separation of the taste from flavor components by blocking the nose for taste components (sweet, salty, sour, and bitter) with nose clips followed by evaluation of the aromatic and chemical feeling factors when unplugging the nose. Volatile analysis was done by GC and the components analyzed were those published by Buttery in 1993. This study concluded that taste descriptors were significantly correlated to nonvolatile components when partitioned from flavor perception. Aroma descriptors were more pronounced when following taste perception than when evaluated simultaneously with taste descriptors. Regression models were more effective at predicting sensory descriptors when taste descriptors were partitioned than when they were not partitioned (Abegaz and others 2004).

Also, different aroma profiling techniques have been evaluated to map consumer liking of tomatoes (Berna and others 2005). The volatile data considered in this study consisted of the most important volatiles in tomatoes according to Buttery (1993). During the study 54 Flemish consumers were asked to rate overall liking of the eight varieties evaluated. The study did not inquire about liking of other characteristics, such as texture, or intensity perception of sweetness, sourness, and others. However, the authors found a high correlation between aroma profile and acceptance. This study also reported four different segments of consumers that have different liking characteristics.

Some studies addressed the interaction of volatiles, sugars and acids on perception of tomato aroma and flavor (Baldwin and others 2008), leading to the conclusion that the addition of sugar decreases the perception of sour and bitter tastes, and citrus and green aroma, while enhancing the perception of flavors associated with ripe, tropical, and aromatic tomatoes.

Other research has characterized three different varieties (traditional types and hybrids) of Spanish tomatoes using aroma composition and discriminant analysis (Alonso and others 2009). For volatile analysis, this study evaluated the volatile compounds published by Buttery (1993) as being the most important compounds for tomato flavor. The sensory analysis was done with 30 consumers using a scale that ranged from 0 (none) to 10 (extremely high) to measure acceptability. The authors showed that traditional tomatoes have higher contents of most of the volatiles studied and that they were also more accepted by the consumer panel.

Most recently, Sinesio and others (2010) conducted a study about sensory quality of fresh French and Dutch market tomatoes, which was a preference mapping study with Italian consumers. This study provides a very good insight of the different preferences that existed in this population. Sixteen tomato cultivars were described in terms of their sensory properties, consumer preferences, and physicochemical measurements. These varieties were evaluated by 179 consumers, who were plotted in a “preference map” that identified the preferred varieties and the reasons for the choice. A hierarchical analysis of the clusters allowed four segments with different preferences within the sampled Italian consumers. The authors concluded that both texture and flavor descriptors were important drivers of consumer preferences, but the relevance of individual descriptors to model tomato liking was different for each consumer segment.

One of the issues with experiments conducted in the past is the limitation of the volatile analysis. These studies have examined only those volatiles (about 17 compounds) that were published more than ten years ago as being important for tomato flavor, not taking into account the great volatile variability in the fruit and among varieties. It is important to mention that these volatiles were determined as important based on threshold methods. Threshold methods were used in the past to identify those compounds that were important in terms of their log odor units. However, thresholds only provide a very limited view of the capacities of our senses. Threshold measures are claimed to be related to a variety of problems and also to fail describing an accurate image of suprathreshold sensitivity (Bartoshuk 1978).

Furthermore, there is a failure to determine consistent volatile patterns linked with great flavor (Scott 2001). Questions still remain about the possibility of interaction between volatiles not only in the tomato matrix, but also during eating. It has been proven than some compounds (ethanol and methanol) affect the perception of other compounds. However, it has not been proven if this is the case for the other volatiles present in tomatoes. In addition to this issue, differences between taste abilities between subjects have not been taken into account in previous studies. The way every person perceives flavor is critical when it comes to food preferences. It is necessary to understand patterns of food acceptance between these groups to further understand food selection variability between supertasters and others (Duffy and Bartoshuk 2000).

CHAPTER 3
MATERIALS AND METHODS

Tomatoes

For this project, fifty varieties of heirloom and modern commercial tomatoes were cultivated at the University of Florida by the staff of the Horticultural Science Department. Tomatoes were harvested at a “table ripe” stage one or two days before sensory evaluation and no postharvest treatment was applied. The tomatoes were washed in 10% bleach solution followed by several water rinses. The samples were kept at room temperature until testing.

The first segment of this study was conducted in February and March of 2010 [Harvest 1 (H1)]. The tomatoes used for during this season were grown under greenhouse conditions. The second section was completed during the months of June and July of 2010 [Harvest 2 (H2)]. These tomatoes were cultivated in a field environment. The varieties tasted during both seasons can be found in Table 3-1 and 3-2.

Panelists

Ninety-two and eighty-six panelists were recruited for H1 and H2, respectively. The recruiting was done by e-mails, announcements and signs around University of Florida (UF) campus. The panel was comprised mostly of students and staff from UF. For H2, 51 of the panelists were also in the H2 panels, and 35 new panelists were recruited following the procedure described above.

Every panelist consented to participate by signing a form previously approved by the Institutional Review Board (IRB).

Questionnaire Development

The questionnaire was developed to inquire about both hedonic responses and intensity attributes of each tomato variety. The test included the following sections: Demographic questions, development of the Hedonic gLMS and practice questions, overall and texture liking assessment, gLMS development and practice questions, sensory attributes intensity measurement, solutions (sweet, salty, sour, and bitter) tasting. The questionnaire is presented in Appendix A and described in more detail in the subsequent sections.

Panelists Training

A training session was held to familiarize the panelists with both the gLMS and the Hedonic gLMS scales and also, to provide an idea on how the test was structured. At the beginning of the session panelists were asked to give written consent (IRB approved) to perform the test and a registration code was assigned to each panelist. This registration code remained the same for the rest of the study. Panelists were scheduled to come in groups of 10 and it took from 40 to 50 minutes to complete the training. Panelists were placed in individual booths equipped with a computer data entry system, where they answered the questionnaire using Compusense Five 3.6 Sensory Analysis Software for Windows. An instructor provided verbal instructions to the panelists throughout the test.

Once in the booth, panelists registered with the assigned code and then proceeded to answer demographic questions. One known variety (Campari) and four unknown varieties (Premium, Beefsteak, Tomato on the Vine, and Plum) were used during the training session. These were obtained at a local retail store the day before the training session.

Each sample was assigned two 3-digit random codes for both hedonic and attributes intensity evaluation. Tomatoes were chopped into fourths or halves depending on the size of the variety and each panelist was provided with two pieces for tasting. The fruit pieces were randomized so that the panelists received pieces that did not come from the same fruit.

The first scale used for this test was the Hedonic gLMS (Figure 3-1). With this scale the panelists rated overall liking and texture liking of each sample. In order to use this scale, each individual had to create his own scale. On this scale, the center at zero represents “neutral”. The most extreme value to the right of the scale corresponds to 100, which is the “Strongest Liking of any kind ever experienced” and the most extreme value to the left of the scale corresponds to -100, which was labeled as “Strongest Disliking of any kind ever experienced”. Panelists were asked to identify the strongest Liking and Disliking of any kind that they have ever experienced. Some examples were provided for both cases. Once they identified their own experiences, they recorded them in the computer. Next, they answered questions about the liking and disliking of a variety of experiences from memory using a line scale. The panelists rated from memory the experience of being with their loved ones, listening to their favorite music, eating their favorite food, least favorite food, the most intense annoyance and anger they have ever experienced, and best and worst tomato they have ever tasted. Then, they received five tomato samples and judge how much they liked or disliked each sample in terms of overall liking and texture.

The second part of the test was intended to measure intensities of sweetness, sourness, saltiness, umami and overall tomato flavor intensity of the samples. To accomplish this purpose, the panelists had to develop a second scale, the gLMS (Figure 3-2). The intensity scale is graded from 0 (no sensation at all) to 100 (the strongest sensation of any kind that they have ever experienced). The panelists were asked to identify and record the strongest sensation of any kind that they had ever experienced. Once developed, this scale was used as a “sensory ruler” to measure the attributes of each tomato. Each person rated the loudest sound ever heard, loudness of a conversation, brightness of a well-lit room, brightest light ever seen, loudness of a whisper, and brightness of a dimly-lit restaurant. These experiences were included as part of the test as practice before they rated the samples.

Tomatoes have been widely investigated because of their glutamate content. For this reason one of the attributes rated on this test was “Umami”. To familiarize the panelists with this attribute, a sample of monosodium glutamate (MSG) was provided at a concentration of 10 mM in water. Saltiness and umami intensities of the sample were evaluated using the gLMS scale.

Panelists were provided with a second set of the same tomato samples coded differently and in random order. Keyboard entry was used to judge the intensity of sweetness, sourness, saltiness, bitterness, umami, and overall tomato flavor.

In order to evaluate the differences between “high-tasters” and “low-tasters”, 1 M (molar) NaCl solution, 1 M sucrose solution, 0.032 M citric acid solution, and 0.001 M quinine solution, were served in 2 oz containers at room temperature to each panelist. Panelists used the gLMS scale to evaluate the intensities of the samples. With these ratings, an average of the four solutions was obtained and a pooled mean was obtained as well.

Evaluation of the Sample

After the training, eight sessions were scheduled, four sessions for each harvest. The varieties tasted in H1 and H1 are shown in Table 3-1 and Table 3-2, respectively. Varieties tasted in more than one session were codified with their name followed by a number. This number corresponds to the time each variety was tasted. For instance, Alisa Craig 1 was tasted the first time in Panel 1 and it was tasted the second time (Alisa Craig 2) during Panel 3.

Subjects kept the same panelist number throughout this study and an average of 85 panelists evaluated per session. Panelists evaluated 6 samples for both hedonic and intensity aspects. The tomatoes were sliced into wedges or halves, as described previously, depending on the size of the sample, and each panelist was provided with two pieces of each sample for evaluation. The samples were presented following William's design, so each of the samples in the test is given to each of the subjects.

Biochemical Analysis

The biochemical analysis was performed by the staff at the Horticultural Science Department of the University of Florida. Soluble solids (Brix) and pH were measured using a refractometer and pH meter, respectively. Glucose, fructose, citric and malic acid, as well as glutamate content were measured in every sample. For these tests, pooled tomato fruit were homogenized in a blender for 30 s and frozen at -80 °C until analysis. Samples were thawed, centrifuged at 16 000 g for 5 min. The supernatant was analyzed for these components using analysis kits (R-Biopharm, Marshall, MI) according to the manufacturer's instructions.

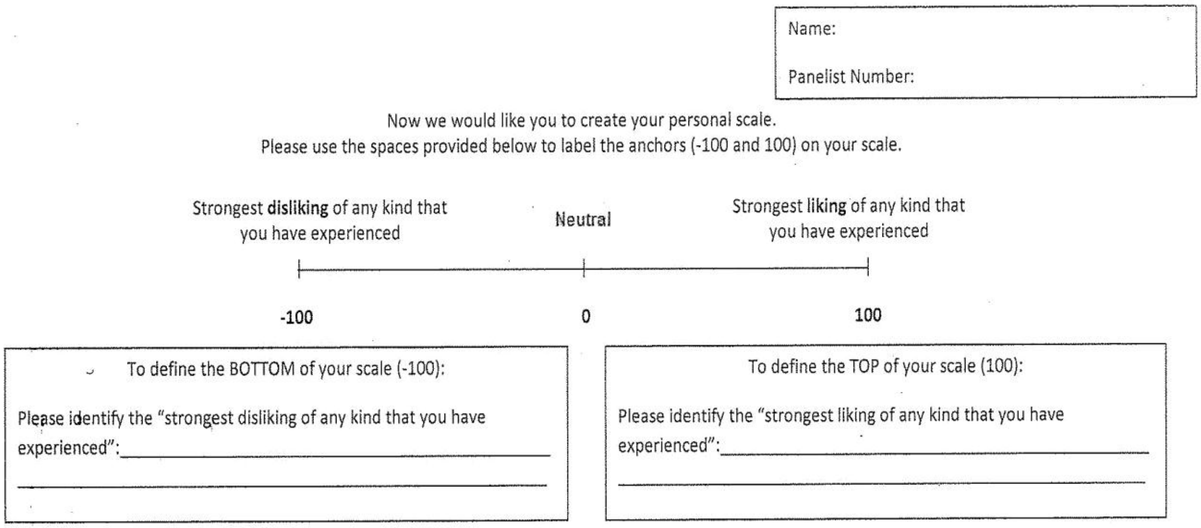
Volatile analysis was done the same day as the taste panel was conducted. Three replicates were analyzed per sample. The samples were chopped and 100 grams (g) were placed in glass tubes (Figure 3-3). Air filtered through a hydrocarbon trap (Agilent, Palo Alto, CA) flowed through the tubes for one hour. The volatiles were collected on a Super Q column and nonyl acetate was added as an internal standard. The volatiles were eluted with methylene chloride and separated on an Agilent (Palo Alto, CA) DB-5 column and analyzed on an Agilent 6890N gas chromatograph with retention times compared to known standards (Sigma Aldrich, St Louis, MO). Volatile levels were calculated as ng g-1 FW h-1. Identified volatile peaks were confirmed by Gas Chromatography-Mass Spectrometry (GC-MS) (Tieman and others, 2005).

Statistical Analysis

Taste panel data were collected using Compusense Five 3.6 Sensory Analysis Software for Windows. Once collected, the data were transferred into an EXCEL spreadsheet. Analysis of variance (ANOVA) was performed using the program SAS™ for Windows™ and differences among means were determined by Least Significant Difference (LSD). Means of all the attributes evaluated for each variety were obtained and biochemical data was added to the data set. A correlation matrix was also obtained and regression lines were obtained for every significant correlation.

The data set was sorted into two classification variables: “taster status” (high tasters or “low-tasters”) and “tomato affinity” (“tomato lovers” or “non-tomato lovers”). To determine the level in which panelists perceive the intensity of the four basic tastes (sweet, sour, salty and bitter), “high taster” and “low taster” variables were created. To decide whether the panelists were “high tasters” or “low tasters” an average of the ratings of the four solutions was obtained for each individual. A pooled mean of 63 classified the panelist as “High taster” or “Low taster”. The people whose average scored above 63 were considered “High tasters”, while those that scored below this mean were considered “Low tasters”. Similarly, each individual was classified as a “tomato lover” or “non-tomato lover”. For this classification, a ratio of the scores of “best tomato ever tasted” and “favorite food” was obtained. The pooled mean from these ratios was 0.64 and it classified each panelist either as “Tomato lover” or “Non-tomato lover”. Panelists whose ratios were above 0.64 were considered “Tomato lovers” and those, whose ratios were below this value, were considered “Non-tomato lovers”. Note that by using this ratio, the data were normalized, showing the proportion of how much people like tomatoes compared to their favorite food.

Analysis of variance (AOV) was performed on the 50 varieties of tomatoes tasted for all measured attributes by “taster status” and “tomato affinity”. Differences were considered significant at an alpha level of less than or equal to 0.05. Correlation and regression analyses were done on each group to identify relationships between overall liking and sensory attributes (texture liking and sweetness, sourness, bitterness, saltiness, umami, and tomato flavor intensity) as well as with biochemical components. Regression lines were plotted on every correlation using SAS™.



Name:

Panelist Number:

Now we would like you to create your personal scale.
Please use the spaces provided below to label the anchors (-100 and 100) on your scale.

Strongest **disliking** of any kind that you have experienced | **Neutral** | Strongest **liking** of any kind that you have experienced

-100 | **0** | **100**

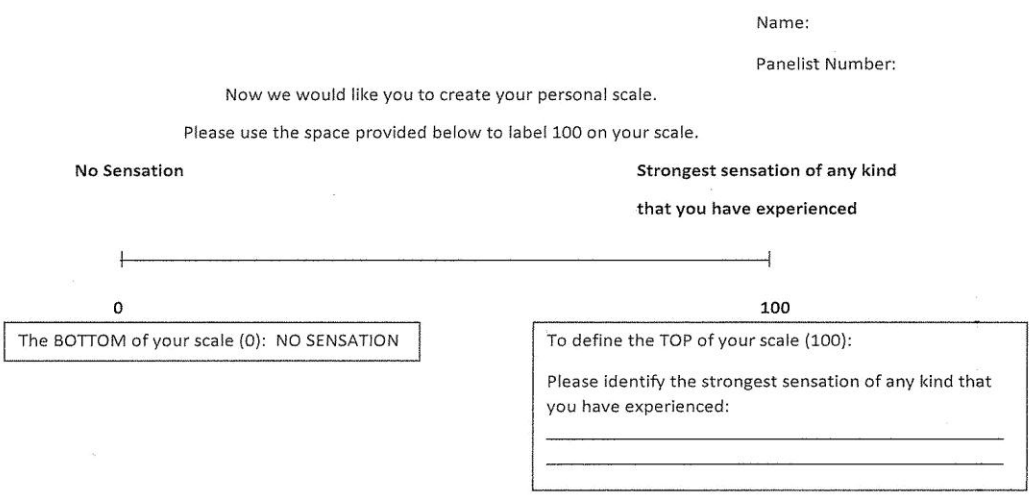
To define the BOTTOM of your scale (-100):

Please identify the "strongest disliking of any kind that you have experienced":____________________

To define the TOP of your scale (100):

Please identify the "strongest liking of any kind that you have experienced":____________________

Figure 3-1. Hedonic gLMS (General Labeled Magnitude Scale) used to measure affective responses.



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:

Figure 3-2. gLMS (General Labeled Magnitude Scale) used to measure intensity of different attributes.

Figure 3-3. Tomato samples in glass tubes where air flowed through for one hour.

Table 3-1. Varieties tasted in H1 (sessions 1 to 4). Sessions were conducted on February and March of 2010.

Panel 1	Panel 2	Panel 3	Panel 4
Ailsa Craig 1	Bloody Butcher 1	Ailsa Craig 2	Aunt Ruby's German Green
Cherry Roma	Chadwick Cherry	Bloody Butche 2r	Brandywine
Porter	Large Red Cherry	Giant Belgium	Dixie Golden Giant
Red Pear	Matina	Marmande VFA	Store B
Tommy Toe	Peacevine Cherry	Store B	Red Calabash
Store A Cherry Berries	Stupice	Thessaloniki	Thessaloniki
	Thai Pink Cherry		
	Store A Cherry		

Table 3-2. Varieties tasted in H2 (sessions 5 to 8). Sessions were conducted on November and December of 2010.

Panel 5	Panel 6	Panel 7	Panel 8
ClearPinkSlicer	AilsaCraig 3	GreenZebra	LA1482
StoreB1	AmishSalad	KentuckyBeefsteak	LemonDrop
SkorospelkaRed	BloodyButcher 3	StoreB3	Matt'sWildCherry
ThreeSisters	GardenPeach	St.Pierre	MexicoMidget
TigerellaOrange	GulfStateMarket	SuperSioux	StoreB4
YellowPerfection	StoreB2	Zapotec	YellowJellyBean

CHAPTER 4
RESULTS AND DISCUSSION

General Results

Overall Liking values ranged from 33.67 to 3.51 on the Hedonic gLMS, corresponding to Cherry Roma and Marmande VFA, respectively. From the varieties tasted, Cherry Roma, Matina, Ailsa Craig 1, Red Calabash and Ailsa Craig 2 obtained the highest ratings in overall liking. Conversely, StoreB6, LA1482, StoreB1, Matt's Wild Cherry, and Marmande VFA were the least liked varieties during this experiment (Table 4-1).

Texture liking ranged from 33.96 to -2.68, for Cherry Roma and Marmande VFA varieties, respectively. Sweetness intensity was rated between 26.37 (Chadwick Cherry) and 7.43 (StoreB1).Sourness intensity ranged from 29.37 (Green Zebra) to 7.59 (Store B4). Saltiness was also rated and ranged from 13.83 (Large Red Cherry) to 7.2 (Yellow Jelly Bean). On the other hand, bitterness intensity was rated between 15.56 (Stupice) to 4.29 (StoreB4). Umami intensity ranged from 16.35 (Matina) to 8.34 (LA1482) and tomato flavor intensity from 35.05 (Matina) to 18.58 (Zapotec).

Cherry Roma is a mid-season variety that produces plum-cherry fruits of about one inch diameter. In this study, it obtained the highest rating in overall liking (33.67) and also in texture liking (33.96). It ranked fourth in sweetness intensity, eighth in sourness and second in tomato flavor intensity. Regarding its chemical composition, it was high in glucose, fructose, and soluble solids in comparison with the other varieties studied. It also contained the highest amounts of some of the volatile compounds in this group of tomatoes. For instance, it contained 37.37 ng/gfw/hr of isovaleronitrile, compared to Store B5, which contained 1.81 ng/gfw/hr of the same compound. The chemical composition of this variety, as well as of the other varieties tasted, can be found in Appendix B.

Marmande VFA was the least liked variety. It produces large, firm, scarlet-red, and round fruits. During this experiment it obtained the lowest rating in overall liking (3.51) and texture liking (-2.68). It ranked thirty-five on sweetness intensity, forty-six in sourness and forty-nine in tomato flavor intensity. This variety had lower amounts of sugars, acids, and volatiles, which made it very bland and thus unattractive to the panelists. This variety also showed low concentrations of certain volatiles, such as isovaleronitrile. This compound was found in a concentration of 10.73 ng/gfw/hr compared to 37.37 ng/gfw/hr of the same compound in the Cherry Roma variety.

The chemical composition that these fifty varieties represent is very diverse. The standard deviation of each compound can be found on the third row of Table Appendix B. These values show large variation there the average in each compound. A good example is 3-methyl-1-butanol, which ranges from 2.51 ng/gfw/hr to 155.28 ng/gfw/hr, corresponding to Kentucky Beefsteak and Store A2 varieties, respectively (See Appendix B).

Analysis for All Panelists Combined

Correlations between Overall Liking and Sensory Variables

Table 4-1 shows all the varieties tasted and their ratings for overall liking, texture liking, sweetness, sourness, saltiness, bitterness, umami, and tomato flavor intensity. The LSD value for mean separation for each attribute can be found in the second row of each column. The significant correlations between overall liking and the variables analyzed can be found in Table 4-2.

From all these sensory variables, overall liking was correlated significantly with texture liking (r=0.712), sweetness (r=0.780), umami (r=0.361), and tomato flavor intensity (r=0.601) and negatively correlated with bitterness (r=-0.339). No correlation was found between liking and sourness and saltiness, which may indicate that these two components are not critical to increase acceptability in these varieties. Regression lines for the significant correlations were obtained and are shown in Figures 4-1, 4-2, and 4-3.

Texture is definitely an important attribute in tomato acceptability. The importance of texture was also shown by Sinesio and others (2010), who concluded that texture in one of the most important drivers of consumer preferences in tomatoes. Another study found texture to be a common characteristic in different consumers segments. Regardless of other unique characteristics of these groups, texture was important for all segments (Lê and Ledauphin 2006).

Tomato flavor is obviously an important characteristic in likeability. As its intensity increases, acceptability also increases, and thus a variety of tomato is liked better. The importance of tomato flavor was also found by Lê and Ledauphin (2006) and Sinesio and others (2010), who have shown that good flavor represents increases in acceptability.

In the case of sweetness and umami, both were found related to overall liking. This is not true for bitterness, which had a negative influence on liking. As bitterness increases, likeability decreases. Acceptance of sweetness and rejection of bitterness is expected since they appear to be hard-wired (Bartoshuk and Beauchamp 1994). “Umami” comes from the Japanese for “good taste” (Klein and Thorne 2007). A good example for this stimulus is monosodium glutamate (MSG) and it is also described as the taste of protein. Glutamate is abundant in foods such as tomatoes, green vegetables, and fish (De Araujo and others 2003). Umami has been also related to saltiness perception. A research study in 2002 showed that from 109 subjects, 73% were able to discriminate between the taste of NaCl and MSG. However, 27% did not. In this study, a positive correlation between saltiness and umami was found (p=0.0013) (Figure 4-3), which led us to suspect that subjects were not distinguishing between these two characteristics. It is also important to mention that these values are based on sensory data obtained from a consumer panel, and that the differences between tasting abilities or consumption behavior can influence how the subjects perceived these attributes. Also, for regular consumers is very difficult to identify specific attributes, such as umami, without intensive training.

Correlations between Overall Liking and Nonvolatile Compounds

It is well known that tomato flavor depends greatly not just on volatile compounds, but also on nonvolatile components and the interaction between these two (Petro-Turza 1986). Glucose, fructose, soluble solids, glutamic acid, malic acid, citric acid, as well as the ratios of sugar (glucose plus fructose) to acid (malic plus citric acid), and citric to malic acid ratios were evaluated. The Pearson correlation coefficients and the probability (p) values of the significant correlations are shown in Table 4-2.

Glucose (r=0.665), fructose (r=0.643), and soluble solids (r=0.530) were positively correlated with overall liking. The regression lines for these compounds are shown in Figures 4-4, and 4-5. As the concentrations of these compounds increases, acceptability increases. Previous studies have shown that liking of tomato flavor can probably be improved by varying the amount of sugar and acids (Malundo and others 1995a). Other studies have addressed the effect of sugars on aroma perception. Sugars added to tomato puree were found to reduce the perception of overall aroma, ripe tomato aroma, and ripe tomato taste perception (Baldwin and Thompson 2001). However, acceptability was not measured in a consumer panel and thus, the effect of these changes in aroma perception by the addition of sugar was not assessed. In this study, the relationship of sweetness intensity and tomato flavor intensity (both measured by panelists) (Figure 4-5) was found significant at an alpha (α) of 0.05. The Pearson correlation coefficient was 0.492. This may suggest that sweetness increases tomato flavor intensity, which is important to improve acceptability of tomatoes.

No relationship was found between glutamic acid content and acceptability. Umami, the characteristic associated with glutamic acid content, was related to overall liking ($r=0.361$). However, the lack of correlation between glutamic acid and overall liking, and the positive correlation between umami and saltiness, led us to believe that the consumers were not distinguishing between these two characteristics. On the other hand, malic acid, citric acid, and their ratio (malic:citric) were not significantly correlated with overall liking of tomatoes. The lack of correlation between acids (malic and citric) and overall liking validates the absence of correlation between perceived sourness intensity and overall liking, as mentioned in the previous section. Earlier studies suggested that there is an optimal acid concentration to achieve increments in consumer acceptability. Acid levels above this optimum level could have a negative effect in acceptability of tomatoes (Malundo and others 1995a).

Conversely, the ratio of sugar to acid (sugar:acid) was positively correlated (r=0.566) and thus, as the ratio increases, acceptability increases (Figure 4-6). However, earlier reports challenge the assumption that an increase in sugar and acid concentrations will improve tomato flavor (Malundo and others 1995a). It would be tempting to conclude that the best way to improve acceptability in tomatoes is by increasing sugar content. However, flavor is a complicated trait that depends on more than one factor, and therefore other variables, such as volatile components, need to be considered when trying to improve tomato flavor. Moreover, sugar levels can be increased only to a certain level without affecting production. Several efforts have been aimed at increasing sugar concentration in different hybrids, but the possibilities of more increases in sugar amounts in tomato are limited by a reduction in yield (Klee 2011). If changes in sugar concentration are not practical, there is still the opportunity to change volatile concentrations to achieve good acceptability without affecting yield.

Correlations between Overall Liking and Volatile Compounds

From the 62 volatiles analyzed, 25 were positively correlated with overall liking. When grouped according their precursors, five come from amino acids, five from carotenoids, eight from lipids, one from phenylpropanoid, and six from unknown pathways (Baldwin and others 2000; Tieman 2011). In the following paragraphs the figure number of the regression lines for these compounds can be found in parenthesis following the name of the volatile.

- Amino acids: Isovaleronitrile (Figure 4-5), isovaleraldehyde (Figure 4-7), 3-methyl-1-butanol (Figure 4-7), isovaleric acid (Figure 4-8), and phenylacetaldehyde (Figure 4-8).
- Carotenoids: 6-methyl-5-hepten-2-ol (Figure 4-9), 6-methyl-5-hepten-2-one (Figure 4-9), β-ionone (Figure 4-10), β-cyclocitral (Figure 4-10), geranial (Figure 4-11).

- Lipids: 1-penten-3-one (Figure 4-11), *trans*-2-heptenal (Figure 4-12), 1-penten-3-ol (Figure 4-12), *cis*-2-penten-1-ol (Figure 4-13), *trans*-2-pentenal (Figure 4-13), *trans*-3-hexen-1-ol (Figure 4-14), 3-pentanone (Figure 4-14), and 1-pentanol (Figure 4-15).
- Phenylpropanoids: Benzyl cyanide (Figure 4-15).
- Unknown: Nonyl aldehyde (Figure 4-16), *cis*-4-decenal (Figure 4-16), methional (Figure 4-17), 2,5-dimethyl-4-hydroxy-3(2H)-furanone (Figure 4-17), 1-octen-3-one (Figure 4-18.A), and benzothiazole (Figure 4-18).

Negative correlations were only found with 2-methylbutyl acetate and isobutyl acetate (Figure 4-19). While 2-methylbutyl acetate has been found to be derived from amino acids, the pathway in which isobutyl acetate is produced is still unknown. The negative effect of 2-methylbutyl acetate on acceptability in this study differs greatly from the effect of the same compound in apples. 2-methylbutyl acetate is one of the most abundant compounds in Gala apples and it has been found to be positively correlated with “overall aroma” and “overall flavor” (Young and others 1996). Isobutyl acetate is a common solvent, with medium volatility. At low concentrations it is known to provide fruity ester odor, but as its concentrations increases the odor becomes unpleasant. This compound is known to be important for the characteristic flavor of bananas (Jordan and others 2001).

Most of the studies conducted on tomato volatiles have focused on the effect of about 17 volatiles on tomato flavor. These compounds were reported to be important to tomato flavor based on threshold analysis and odor units (Table 2-1). In this study only six of those volatiles were found to be significantly correlated with overall liking: 6-methyl-5-hepten-2-one, β-ionone, 1-penten-3-one (ethyl vinyl ketone), 3-methylbutanal (Isovaleraldehyde), 3-methylbutanol (3-methyl-1-butanol), and 2-pentenal (*trans*-2-pentenal). Research on the impact of carotenoid-derived volatiles on tomato flavor has shown that β-Cyclocitral and β-Ionone presented the strongest correlations with overall acceptability from the carotenoid-derived compounds.(Vogel and others 2010) Positive correlations with these two compounds were also found in this study. However, the same paper reported negative correlations between overall acceptability and guaiacol and methylsalicylate, which were not observed in in this study.

Interestingly, none of the lipid-derived volatiles (hexanal, *cis*-3-hexenal, *trans*-2-hexenal, hexyl alcohol, and *cis*-3-hexen-1-ol) reported by Buttery and Ling (1993) as important to tomato flavor were correlated with overall liking. This lack of correlation between these volatiles and acceptability of tomatoes highlights the importance of reevaluating the threshold method. Thresholds only provide a very limited view of the capacities of our senses. Threshold measurements are claimed to be related to a variety of problems and also to fail to describe an accurate image of suprathreshold sensitivity (Bartoshuk 1978).

The individual aroma properties of some of the compounds included in this study have been investigated, while the contributions of others to the characteristic aroma of tomato are yet to be studied. Studies on spiked tomato homogenates or puree have generated a series of terms to describe each compound (Baldwin and others 2008):

- 6-methyl-5-hepten-2-one: sweet, floral
- β-ionone: floral, sweet
- 1-penten-3-one: fresh, sweet, fruity taste, grassy
- 3-methylbutanal: stale, rotten
- 3-methylbutanol: sweet, fresh.
- 2-pentenal: stale, oil.

However, the aroma character of these compounds varies depending on the medium for delivery. For instance, 1-penten-3-one is perceived as glue, oil, and/or pungent when smelled in deionized water; rancid in a mixture of ethanol or methanol and water, but fresh and/or sweet when smelled in a tomato homogenate (Tandon and others 2000). This variability illustrates the complexity of aroma compounds, the importance of selection of the appropriate media to evaluate these chemicals, and more importantly, the existence of interactions between the volatiles.

Tomato Lovers vs. Non Tomato Lovers

A classification variable was created to analyze differences between consumers who enjoy eating tomatoes and those who do not like tomatoes as much as the other group. To accomplish this goal, each panelist was classified as a “tomato lover” or “non-tomato lover”. A ratio of the scores of “best tomato ever tasted” and “favorite food” was obtained. The pooled mean from these ratios was 0.64 and panelists whose scores were above 0.64 were considered “Tomato Lover” and those whose ratings were below this value were considered “Non-tomato Lovers”. From this point on, these names will be used to refer to these groups. Both groups showed common relationships between acceptability and certain compounds. However, these groups also exhibited unique significant correlations that may indicate that some characteristics are important for one group, but not for the other.

Correlations between Overall Liking and Sensory Variables

Tomato Lovers as well as Non-Tomato Lovers showed significant correlations between overall liking and texture liking, sweetness, and tomato flavor intensity. The regression lines for these attributes are shown in Figures 4-20, 4-21, and 4-22, respectively. Tomato Lovers showed a significant correlation between overall liking and umami (Figure 4-23), which was not found for Non-tomato Lovers. Non-tomato Lovers, on the other hand, presented a negative correlation with bitterness (Figure 4-24) that was not observed for the other group. For the correlations that were common in both groups, Tomato Lovers always showed higher Pearson correlation coefficients, which may indicate that the presence of these characteristics in tomatoes is more important for this group than for Non-tomato Lovers.

Correlations between Overall Liking and Non-Volatile Compounds

Both Tomato Lovers and Non-tomato Lovers showed significant correlations between overall liking and glucose, fructose, and soluble solids. However, Non-tomato Lovers showed higher correlation coefficients, which may indicate their preference for tomatoes with higher sugar content. The regression lines for these variables are shown in Figures 4-25, 4-26, and 4-27.

These two groups did not show any significant correlation between overall liking and glutamic acid, malic acid, citric acid, and the ratio of citric to malic acid. Conversely, the ratio of sugar (glucose plus fructose) to acid (malic plus citric acid) was significant for both groups, where Tomato Lovers showed a higher correlation coefficient for this characteristic. Figure 4-28 shows the positive correlation of both groups, as well as their regression lines.

Correlations between Overall Liking and Volatile Compounds

Both groups shared significant correlations for some volatiles, however, they also showed unique volatiles related to overall liking. From the shared list of volatiles, three are derived from lipids and four from unknown precursor:

- Lipids: 1-penten-3-one (Figure 4-29), *trans*-2-heptenal (Figure 4-30), and 3-pentanone (Fig. 4-31).
- Unknown: Nonyl aldehyde (Figure 4-32), *cis*-4-decenal (Figure 4-33), methional (Figure 4-34), and 2,5-dimethyl-4-hydroxy-3(2H)-furanone (Figure 4-35).

The correlation coefficients for these compounds were always higher for Tomato Lovers than those from Non-tomato Lovers, which suggests that the existence of these compounds in tomatoes is more important for Tomato Lovers than for Non-tomato Lovers. On the other hand, both groups show a list of volatiles that were not shared with the other. Tomato Lovers showed significant correlations between liking of tomatoes, and the following volatiles:

- Amino acids: Isovaleronitrile (Figure 4-36), isovaleraldehyde (Figure 4-37), 3-methyl-1-butanol (Figure 4-37), and isovaleric acid (Figure 4-37).
- Carotenoids: 6-methyl-5-hepten-2-ol (Figure 4-38), 6-methyl-5-hepten-2-one (Figure 4-38), β-cyclocitral (Figure 4-39), and geranial (Figure 4-39).
- Lipids: 1-penten-3-ol (Figure 4-40), *cis*-2-penten-1-ol (Figure 4-40), *trans*-2-pentenal (Figure 4-41), *trans*-3-hexen-1-ol (Figure 4-41), and 1-pentanol (Figure 4-42).
- Lignin and miscellaneous: guaiacol (Figure 4-42)
- Unknown: 1-octen-3-one (Figure 4-43), benzothiazole (Figure 4-43), and 4-carene (Figure 4-44).

Negative correlations were found between overall liking and isobutyl acetate (Figure 4-44), 2-methylbutyl acetate and benzyl alcohol (Figure 4-45). In the general analysis, negative correlations were also found with the two first compounds, but not with benzyl alcohol. Benzyl alcohol is commonly found in plant materials (Buttery and others 1987) and it is derived from benzoic acid (Tieman and others 2006). It has also been reported as being one of the major components present in the bound fraction of tomatoes (Marlatt and others 1992). However, its contribution to tomato flavor has not been investigated. The negative correlation found with overall liking may indicate that the occurrence of this compound in tomato leads to decreases in acceptability for Tomato Lovers. Non-tomato Lovers did not show a significant correlation with any of these compounds, which may suggest that this group does not show any preference for these particular group of volatiles. Guaiacol has been reported as being a negative factor in tomato flavor. Its aroma profile has been described as “pharmaceutical” (Vogel and others 2010). However, this study failed to find a negative correlation between overall liking and this compound.

Non-tomato Lovers showed a smaller number of significant correlations between liking of tomatoes and volatiles. Overall liking correlated significantly with the following compounds:

- Amino acids: 2-isobutylthiazole (Figure 4-46), phenylacetaldehyde (Figure 4-47), and 2-phenyl ethanol (Figure 4-47).
- Phenylpropanoids: Benzyl cyanide (Figure 4-47) and benzaldehyde (Figure 4-48).

This list of volatiles was unique to Non-tomato Lovers. This group did not show any negative correlations between liking and the volatiles analyzed. “Non-tomato Lovers” seem to be more interested in other characteristics, such as sugar content, rather than in tomato aromatics.

High Tasters vs. Low Tasters

Differences in taste perception greatly affect the way subjects perceive foods. A common method to classify a subject according his tasting abilities is counting the amount of fungiform papillae. This is done by dyeing the subject’s tongue with blue food coloring, which does not stain fungiform papillae. Then, the papillae are counted under magnification.

Since it is already known that supertasters perceive the highest intensities of flavor, a different criterion was used to classify subjects according to their tasting abilities. Instead of using the dyeing method, the average intensity ratings of four solutions (sweet, sour, salty, and bitter) were calculated. All the panelists whose rating scored above the pooled mean was a “High taster”, while those who scored below the mean were considered “Low taster”.

Correlations between Overall Liking and Sensory Variables

Both High tasters and Low tasters showed positive correlations between overall liking and texture liking, sweetness intensity, and tomato flavor intensity. The regression lines for these variables can be found in Figures 4-49, 4-50, and 4-51, respectively. For sweetness and flavor intensity, High Tasters showed higher correlation coefficients. However, Low Tasters had a higher correlation coefficient for texture liking. Although both groups are interested in texture, sweetness and flavor intensity, “high tasters” may be more influenced by sweetness intensity and tomato flavor intensity than “low tasters”. On the other hand, “low tasters” may be more inclined to like tomatoes based on their texture, rather than in sweetness and flavor intensity. “Low tasters” also presented a positive correlation between liking of tomatoes and umami (Figure 4-52). These groups did not have significant correlations between overall liking and saltiness, sourness, and bitterness.

Correlations between Overall Liking and Non-Volatile Compounds

Glucose, fructose, and soluble solids were positively correlated to overall liking for both High Tasters and Low Tasters (Figures 4-53, 4-54, and 4-55). Higher correlation coefficients were observed in High Tasters, which may imply that this group is more influenced by these attributes than Low tasters.

No significant correlations were found between liking and malic acid, citric acid, glutamatic acid, or the ratio of citric to malic acid. However, a positive correlation was found between overall liking and the ratio of sugar (glucose plus fructose) to acid (malic plus citric acid). (Figure 4.56). The relationship between the ratio of sugar to acid was observed for all the groups analyzed in this project, as well as in the general analysis.

Correlations between Overall Liking and Volatile Compounds

"High tasters" and "Low tasters" showed common relationships between overall liking of tomatoes and the following compounds, which have are listed according to their precursor:

- Phenylpropanoids acids: benzyl cyanide (Figure 4-57).
- Lipid: 1-penten-3-one (Figure 4-58).
- Carotenoid: 6-methyl-5-hepten-2-ol (Figure 4-59).
- Unknown: nonyl aldehyde (Figure 4-60), methional (Figure 4-61), and 3-pentanone (Figure 4-62).

High Tasters had higher correlation coefficients for 1-penten-3-one, nonyl aldehyde, and 3-pentanone. Low Tasters had stronger relationships between overall liking and benzyl cyanide, 6-methyl-5-hepten-2-ol, and methional.

An extended list of correlations was found for High Tasters. In addition to the volatiles listed above, 21 compounds were correlated positively with overall liking and two negatively correlated. The volatiles that were positively correlated are listed next according to their precursor:

- Amino acids: Isovaleronitrile (Figure 4-63), isovaleraldehyde (Figure 4-64), 3-methyl-1-butanol (Figure 4-64), isovaleric acid (Figure 4-65), 1-nitro-3-methylbutane (Figure 4-65)
- Carotenoids: 6-methyl-5-hepten-2-one (Figure 4-66), β-ionone (Figure 4-66), β-cyclocitral (Figure. 4-67), geranial (Figure 4-67), and guaiacol (Figure 4-68).
- Lipids: *trans*-2-pentenal (Figure 4-68), *trans*-2-heptenal (Figure 4-69), *trans*-3-hexen-1-ol (Figure 4-69), 1-pentanol (Figure 4-70), 1-penten-3-ol (Figure 4-70), and *cis*-2-penten-1-ol (Figure 4-71).

- Unknown: *cis*-4-decenal (Figure 4-71), 2,5-dimethyl-4-hydroxy-3(2H)-furanone (Figure 4-72), 4-carene (Figure 4-72), 1-octen-3-one (Figure 4-73), and benzothiazole (Figure 4-73).

Isobutyl acetate and 2-methylbutyl acetate were found again as negative correlations with overall liking. The regression lines of these compounds are shown in Figure 4-74. The undesirable impact of these compounds in flavor needs to be evaluated to achieve an improvement in acceptability of tomatoes. Low Tasters showed only four extra correlations with overall liking: benzaldehyde, phenylacetaldehyde, geranylacetone, and 2-phenylethanol, and no negative correlations. The regression lines for these four compounds are shown in Figures 4-75 and 4-76.

There is a big difference in the number of volatiles that influence liking between the groups. While High Tasters show a link between acceptability and a total of 27 volatiles, Low Tasters are influenced only by 11 volatiles. There is a belief that supertasters also have more sensitivity during retronasal olfaction. If this is true, it is definitely a factor to be considered in explaining the higher amount of volatiles that influences liking for those that what we have called High Tasters.

Table 4-1. Sensory ratings for all 50 varieties evaluated. Varieties are organized from best to worst in terms of Overall Liking.

Variety	Overall Liking	Texture Liking	Sweetness Intensity	Sourness Intensity	Saltiness Intensity	Bitterness Intensity	Umami Intensity	Tomato Flavor Intensity
LSD value	6.6631	6.5116	4.303	3.9263	2.848	3.2351	3.6821	4.6651
Cherry Roma	33.67	33.96	25.51	18.06	12.82	9.82	12.73	33.32
Matina	28.78	27.49	25.27	16.35	12.43	10.92	16.35	35.05
Ailsa Craig 1	27.01	20.75	19.96	17.08	11.11	11.33	13.43	30.67
Red Calabash	26.49	21.15	24.87	16.56	11.43	7.59	8.86	29.97
Ailsa Craig 2	26.36	18.1	21.51	11.96	9.78	6.84	9.86	26.53
Red Pear	25.75	23.18	24.28	12.79	10.34	6.78	10.08	30.01
Bloody Butcher 1	25.28	17.64	25.85	10.78	9.99	7.78	11.9	30.03
Bloody Butcher 2	25	19.69	26.18	9.69	9.72	4.53	8.98	28.87
Brandywine	24.12	23.67	24.62	13.97	10.49	5.45	10.89	28.57
Tommy Toe	23.6	17.2	19.75	13.2	11.39	8.23	11.39	30.46
Store B3	22.96	24.62	15.11	11.74	10.41	9.03	12.57	27.16
Chadwick Cherry	22.9	14.98	26.37	11.33	10.46	7.09	11.88	30.17
Store B6	22.77	22.94	18.89	7.59	7.62	4.29	8.65	25.75
Store A1	21.79	24.97	14.14	18.02	12.16	10.37	13.36	27.92
Super Sioux	21.29	14.79	15.66	12.98	7.46	6.56	10.54	28.06
St. Pierre	21.19	15.35	20.32	10.89	8.11	5.35	11.04	27.67
Store B5	19.99	19.24	14.41	11.51	7.25	6.95	10.01	22.42
Thai Pink Cherry	19.95	18.78	13.57	15.35	10.14	9.7	11.22	24.11
Giant Belgium	19.34	8.13	17.57	9.74	8.94	6.88	12.04	24.26
Yellow Jelly Bean	19.09	22.52	12.84	8.01	7.2	7.33	8.77	21.66

Table 4-1. Continued.

Variety	Overall Liking	Texture Liking	Sweetness Intensity	Sourness Intensity	Saltiness Intensity	Bitterness Intensity	Umami Intensity	Tomato Flavor Intensity
LSD value	6.6631	6.5116	4.303	3.9263	2.848	3.2351	3.6821	4.6651
Dixie Golden Giant	18.79	9.17	22.11	9.98	7.95	5.51	9.67	22.09
Mexico Midget	18.46	18.1	20.17	9	7.77	5.97	10.29	26.26
Thessaloniki 1	18.23	11.69	17.79	10.44	8.37	7.18	9.27	22.73
Aunt Ruby's German Green	18.02	18.71	19.12	12.31	10.44	6.87	11.16	27.54
Gulf State Market	17.68	14.09	16.48	17.45	11.78	9.22	14.18	32.89
Peacevine Cherry	17.62	18.98	20.53	14.38	11.22	8.53	12.55	28.98
Store A2	17.16	18.71	11.34	23.41	13.73	13.11	11.15	30.19
Kentucky Beefsteak	16.69	18.31	16.91	19.09	10.58	9.09	10.26	29.06
Thessaloniki 2	16.31	13.42	19.89	9.57	8.37	7.81	9.19	22.72
Three Sisters	15.99	18.21	13.03	16.05	10.22	9.44	9.81	27.78
Stupice	15.89	19.06	10.53	15.27	11.24	14.56	12.34	23.58
Bloody Butcher 3	15.68	22.29	10.62	19.16	8.69	8.96	10.59	26.32
Skorospelka Red	15.33	11.09	18.71	12.96	9.21	7.72	12.39	28.11
Yellow Perfection	15.11	18.64	18.64	14.61	10.9	9.85	14.19	31.64
Garden Peach	14.62	12.79	15	12.83	8.54	9.18	11.72	24.65
Lemon Drop	13.94	18.12	16.27	14.09	7.74	5.58	9.27	26.55
Clear Pink Slicer	13.78	8.69	20.03	8.19	7.77	5.7	11.16	27.01
Porter	13.42	9.87	15.69	8.94	7.91	8.25	11.11	21.15
Amish Salad	12.5	9.61	14.78	11.57	7.24	6.18	10.37	23.38
Ailsa Craig 3	12.38	12.06	12.56	25.95	13.11	12.91	10.86	32.61
Green Zebra	11.35	19.43	8.19	29.37	10.94	10.81	9.46	32.19

Table 4-1. Continued.

Variety	Overall Liking	Texture Liking	Sweetness Intensity	Sourness Intensity	Saltiness Intensity	Bitterness Intensity	Umami Intensity	Tomato Flavor Intensity
LSD value	6.6631	6.5116	4.303	3.9263	2.848	3.2351	3.6821	4.6651
Large Red Cherry	9.84	9.15	11.78	14.8	13.82	12.2	9.2	21.6
Store B2	9.54	18.39	7.78	19.02	10.74	12.67	11.21	25.42
Zapotec	7.89	14.82	10.04	7.86	8.43	7.2	9.53	18.58
Tigerella Orange	7.35	11.75	11.42	16.09	11.37	11.82	10.35	22.91
Store B4	7.11	14.37	8.81	13.06	8.65	9.09	10.94	21.05
LA1482	6.12	13.29	9.39	19.08	9.95	11.84	8.34	26.83
Store B1	5.8	8.81	7.43	14.71	10.14	11.4	10.26	19.68
Matt's Wild Cherry	4.53	6.58	13.13	11.68	7.52	10.91	8.96	22.4
Marmande VFA	3.51	-2.68	13.41	8.84	8.26	8.14	9.51	18.91

Table 4-2. Pearson correlation coefficients (r) between Overall Liking and of the attributes evaluated for all panelists, tomato lovers, non-tomato lovers, high tasters and low tasters. Only significant correlations are shown. α=0.05.

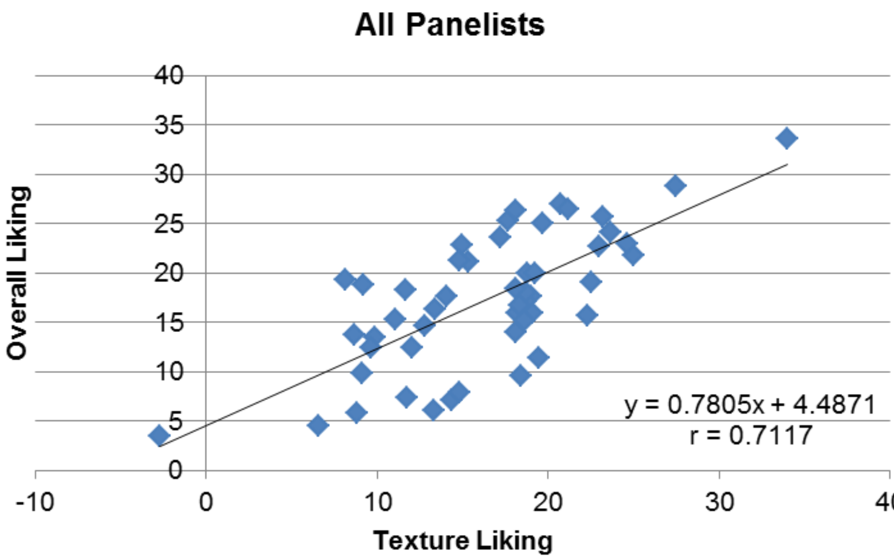
	All Panelists	Tomato Lovers	Non-Tomato Lovers	High Taster	Low Taster
Texture Liking	0.7117	0.77767	0.62321	0.71964	0.7242
Sweetness Intensity	0.7803	0.73111	0.69475	0.76623	0.66216
Sourness Intensity	-	-	-	-	-
Saltiness Intensity	-	-	-	-	-
Bitterness Intensity	-0.33974	-	-0.30887	-	-
Umami Intensity	0.3606	0.3363	-	-	0.49824
Tomato Flavor Intensity	0.60089	0.62453	0.47298	0.67016	0.35797
Glucose	0.66457	0.59844	0.63693	0.65455	0.56304
Fructose	0.64348	0.58789	0.5931	0.64139	0.53731
Soluble Solids	0.53029	0.46936	0.50503	0.53239	0.42908
Sugar:Acid	0.56577	0.57269	0.39441	0.58878	0.3044
Malic Acid	-	-	-	-	-
Glutamatic acid	-	-	-	-	-
Citric:Malic	-	-	-	-	-
Citric Acid	-	-	-	-	-
1-penten-3-one	0.54906	0.5587	0.38508	0.57382	0.34553
isovaleronitrile	0.35162	0.3194	-	0.35368	-
trans-2-pentenal	0.34376	0.3367	-	0.3627	-
trans-2-heptenal	0.34793	0.32659	0.28545	0.34219	-
trans-3-hexen-1-ol	0.32832	0.302	-	0.3328	-
6-methyl-5-hepten-2-ol	0.38171	0.38794	-	0.34678	0.34858
nonyl aldehyde	0.4835	0.49738	0.29014	0.49203	0.34272
cis-4-decenal	0.45313	0.49059	0.28344	0.49176	-
isovaleraldehyde	0.32956	0.31584	-	0.36316	-
3-methyl-1-butanol	0.31962	0.28358	-	0.33599	-
methional	0.343	0.31776	0.28307	0.3019	0.35755
2,5-dimethyl-4-hydroxy-3(2H)-furanone	0.35125	0.35384	0.28028	0.3767	-
3-pentanone	0.58774	0.60874	0.37203	0.62292	0.37079

Table 4-2. Continued.

	All Panelists	Tomato Lovers	Non-Tomato Lovers	High Taster	Low Taster
1-pentanol	0.35907	0.37427	-	0.38328	-
benzyl cyanide	0.33534	-	0.3847	0.28419	0.37782
isovaleric acid	0.32764	0.36427	-	0.32844	-
2-isobutylthiazole	-	-	0.31591	-	-
1-nitro-3-methylbutane	-	-	-	0.29977	-
benzaldehyde	-	-	0.28561	-	0.28989
6-methyl-5-hepten-2-one	0.2888	0.36753	-	0.28454	-
b-ionone	0.3126	-	-	0.34466	-
b-cyclocitral	0.31063	0.37228	-	0.36923	-
geranial	0.30031	0.34969	-	0.2882	-
phenylacetaldehyde	0.29353	-	0.35085	-	0.36964
eugenol	-	-	-	-	-
geranylacetone	-	-	-	-	0.28141
2-phenyl ethanol	-	-	0.33025	-	0.33081
neral	-	-	-	-	-
salicylaldehyde	-	-	-	-	-
isobutyl acetate	-0.30691	-0.29617	-	-0.36518	-
butyl acetate	-	-	-	-	-
cis-3-hexen-1-ol	-	-	-	-	-
1-nitro-2-phenylethane	-	-	-	-	-
1-penten-3-ol	0.31744	0.38284	-	0.3906	-
2-methylbutyl acetate	-0.28571	-0.2858	-	-0.35605	-
heptaldehyde	-	-	-	-	-
trans,trans-2,4-decadienal	-	-	-	-	-
2-methylbuteraldehyde	-	-	-	-	-
4-carene	-	0.2844	-	0.27912	-
hexyl alcohol	-	-	-	-	-
guaiacol	-	0.2817	-	0.29465	-
propyl acetate	-	-	-	-	-
hexanal	-	-	-	-	-

Table 4-2. Continued.

	All Panelists	Tomato Lovers	Non-Tomato Lovers	High Taster	Low Taster
cis-2-penten-1-ol	0.33948	0.39056	-	0.39336	-
2-butylacetate	-	-	-	-	-
1-octen-3-one	0.4202	0.44097	-	0.45784	-
cis-3-hexenal	-	-	-	-	-
methylsalicylate	-	-	-	-	0.35099
trans-2-hexenal	-	-	-	-	-
b-damascenone	-	-	-	-	-
2-methyl-1-butanol	-	-	-	-	-
2-methyl-2-butenal	-	-	-	-	-
prenyl acetate	-	-	-	-	-
hexyl acetate	-	-	-	-	-
3-methyl-1-pentanol	-	-	-	-	-
2-ethylfuran	-	-	-	-	-
isopentyl acetate	-	-	-	-	-
cis-3-hexenyl acetate	-	-	-	-	-
benzothiazole	0.30572	0.3457	-	0.34981	-
benzyl alcohol	-	-0.29457	-	-	-
3-methyl-2-butenal	-	-	-	-	-
p-anisaldehyde	-	-	-	-	-



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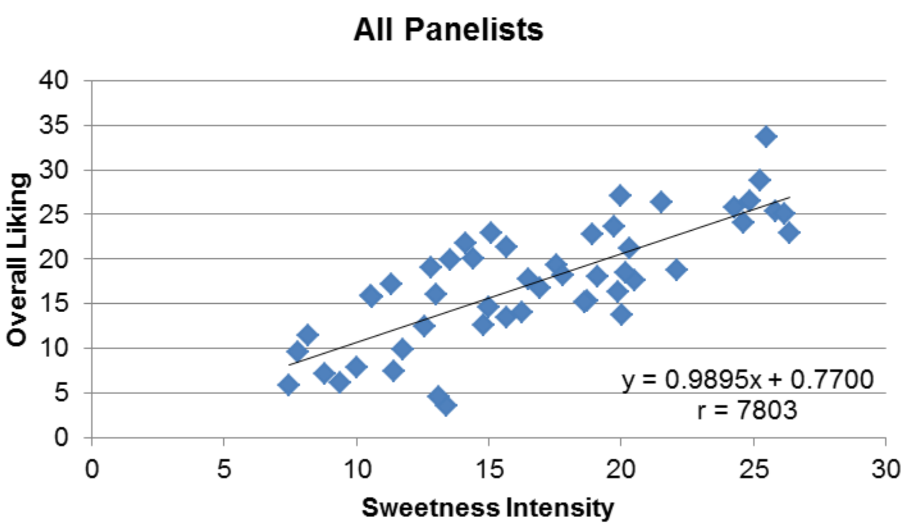
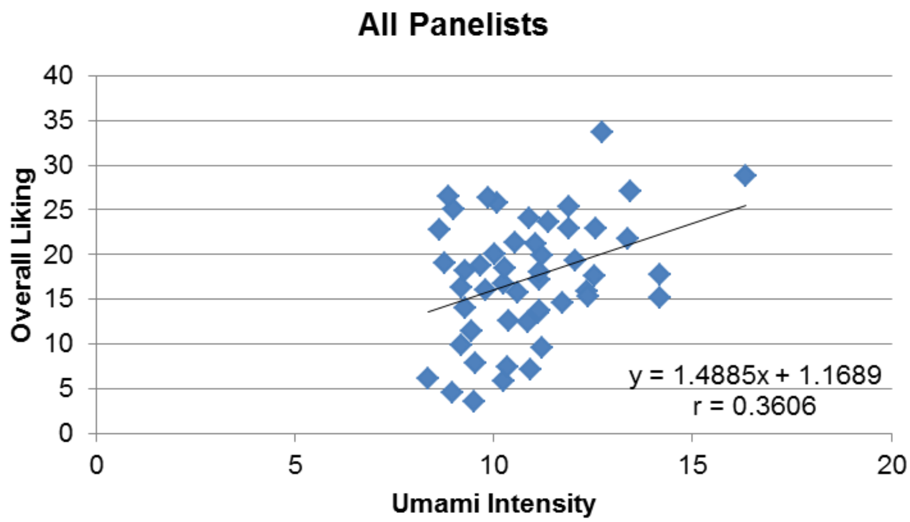


B

Figure 4-1. Correlation and regression for all panelists between overall liking and A) texture liking and B) sweetness intensity.



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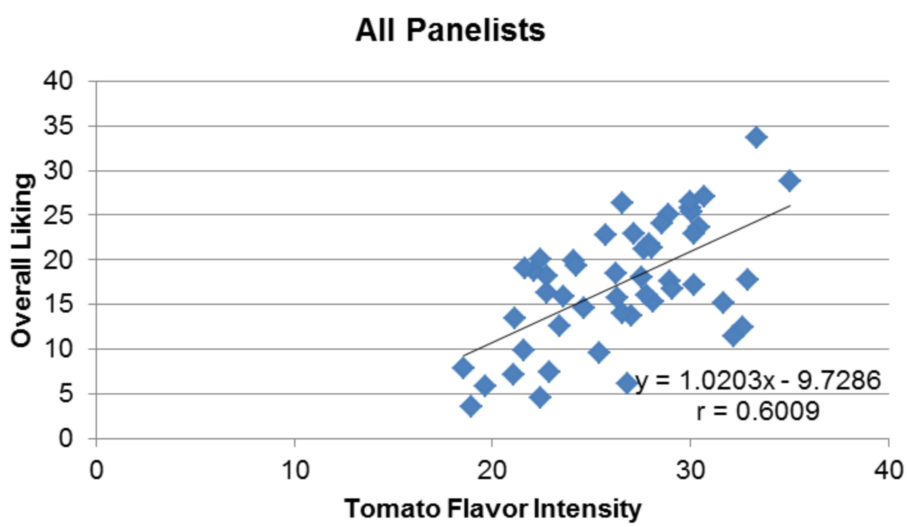

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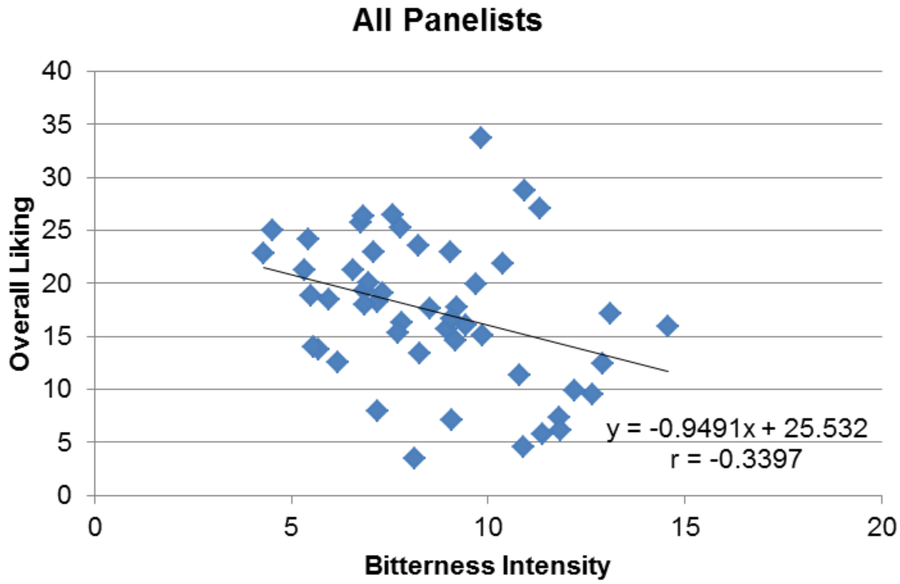
Figure 4-2. Correlation and regression for all panelists between overall liking and A) umami intensity and B) tomato flavor intensity.



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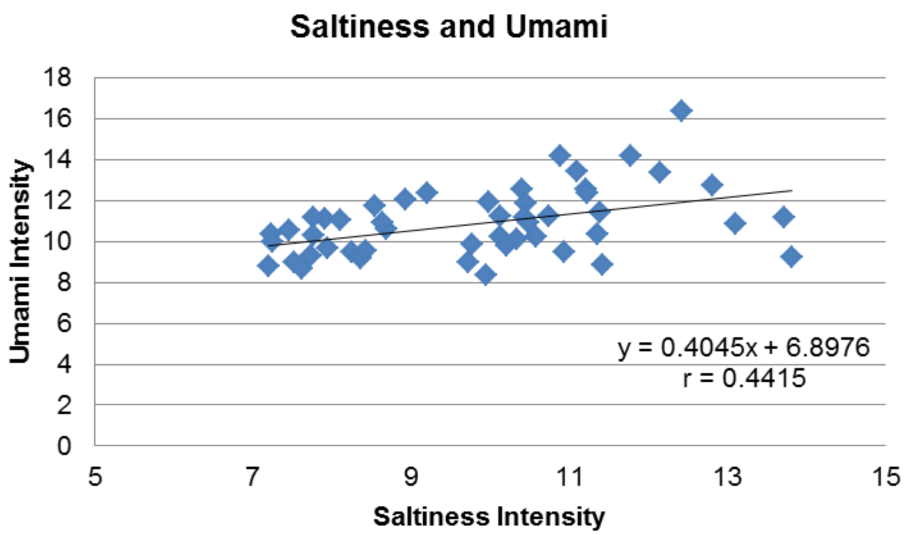

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Figure 4-3. Correlation and regression for all panelists between overall liking and A) bitterness intensity and B) relationship between saltiness intensity and umami intensity.

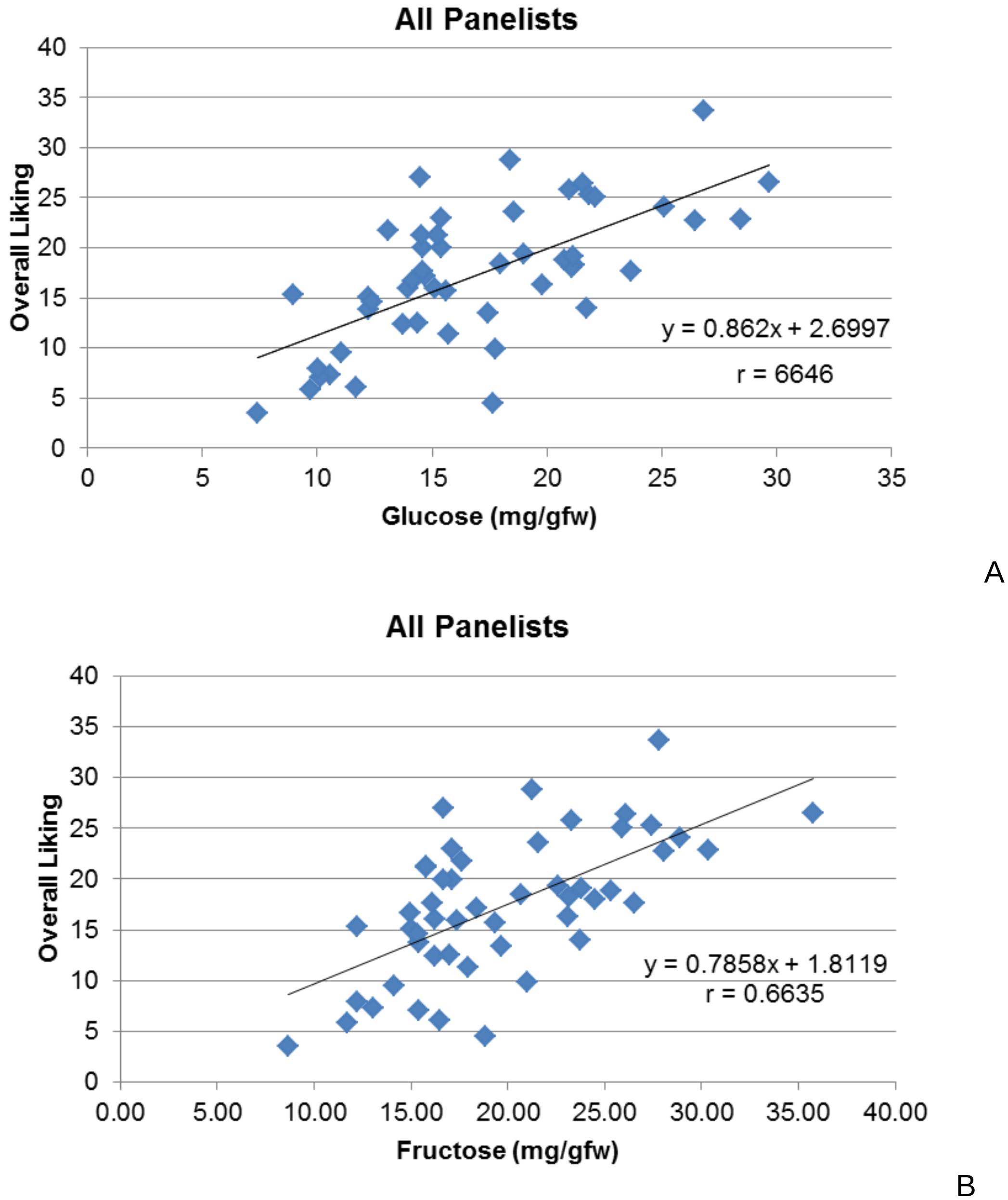
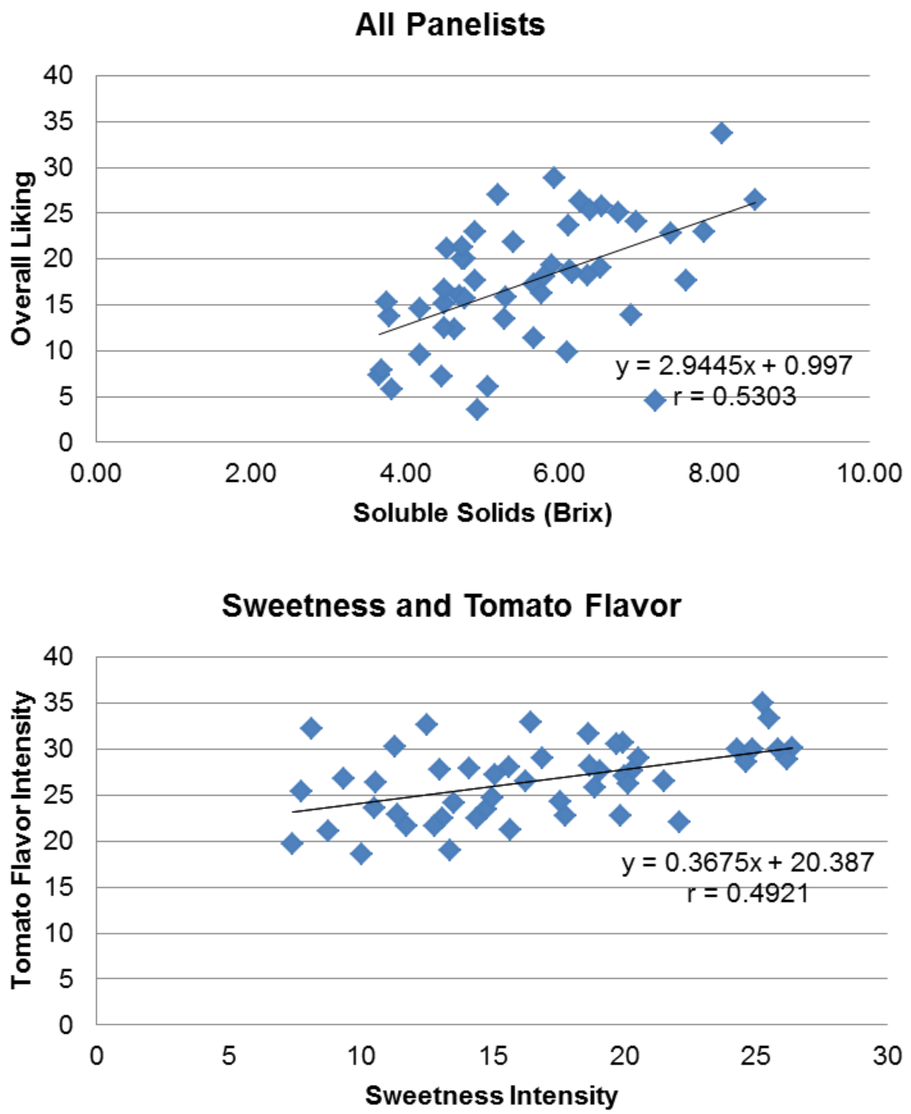


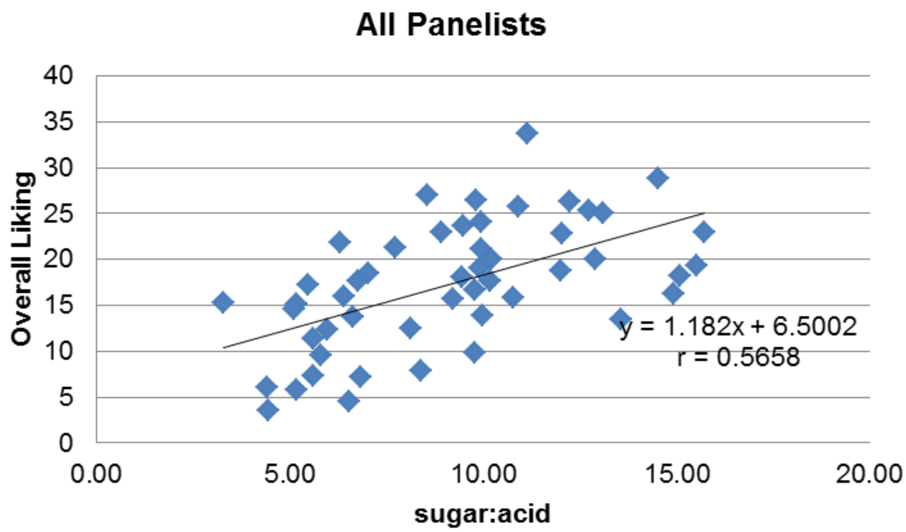
Figure 4-4. Correlation and regression for all panelists between overall liking and A) glucose and B) fructose



A

B

Figure 4-5. Correlation and regression for all panelists between overall liking and A) soluble solids and B) relationship between sweetness intensity and tomato flavor intensity



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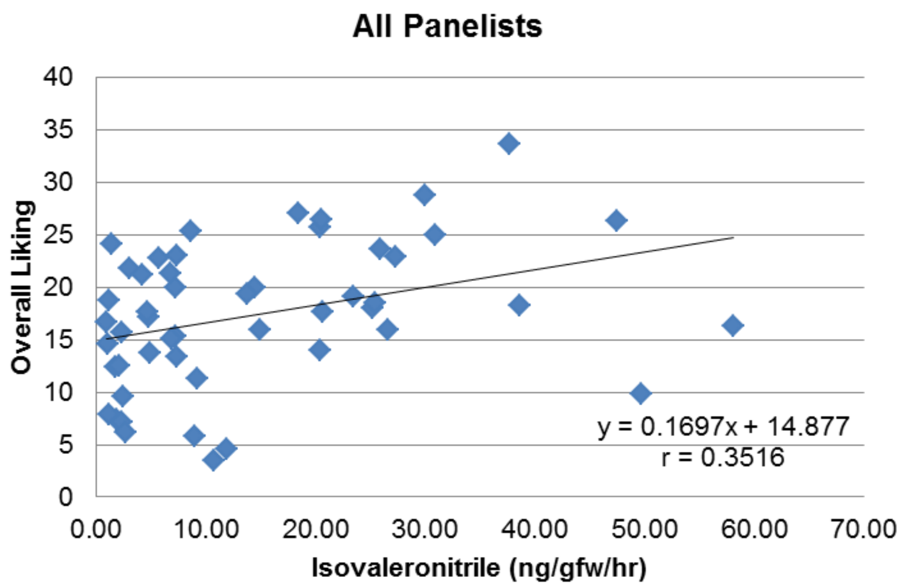

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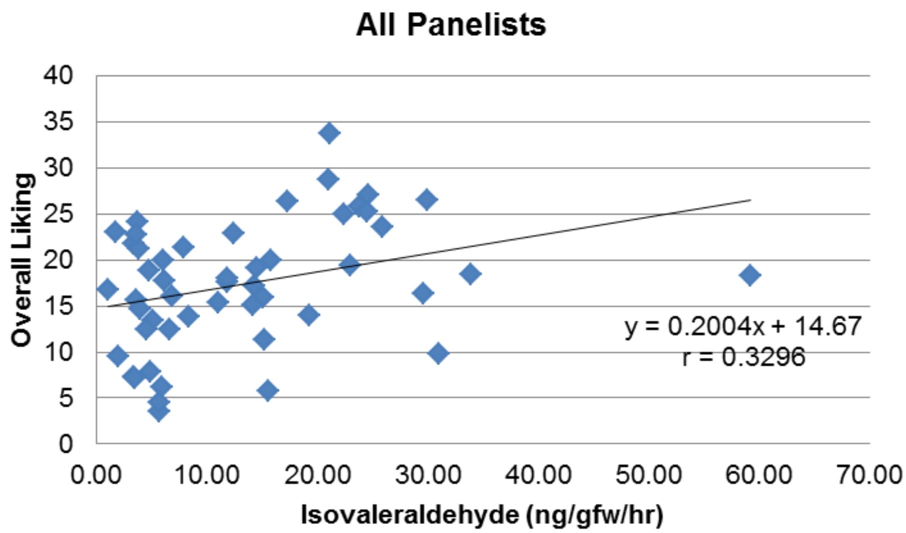
Figure 4-6. Correlation and regression for all panelists between overall liking and A) sugar:acid and B) isovaleronitrile



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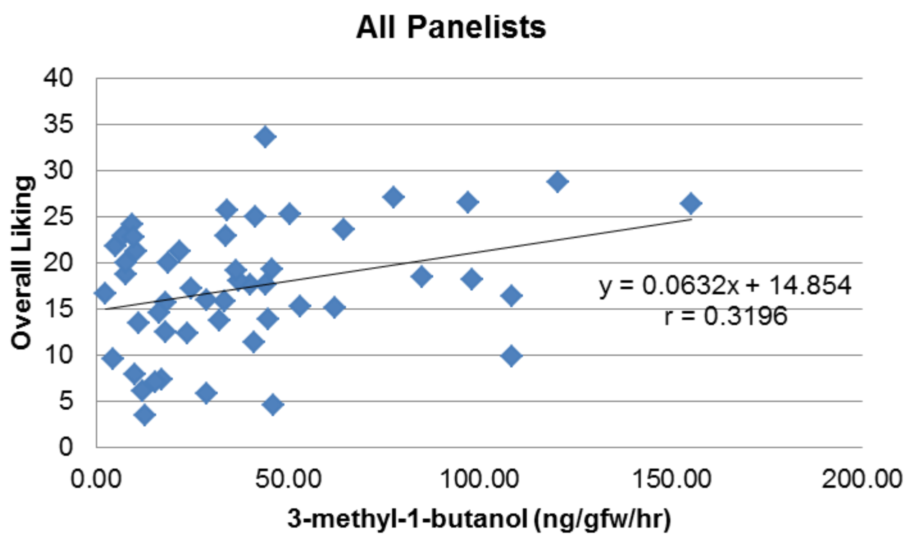

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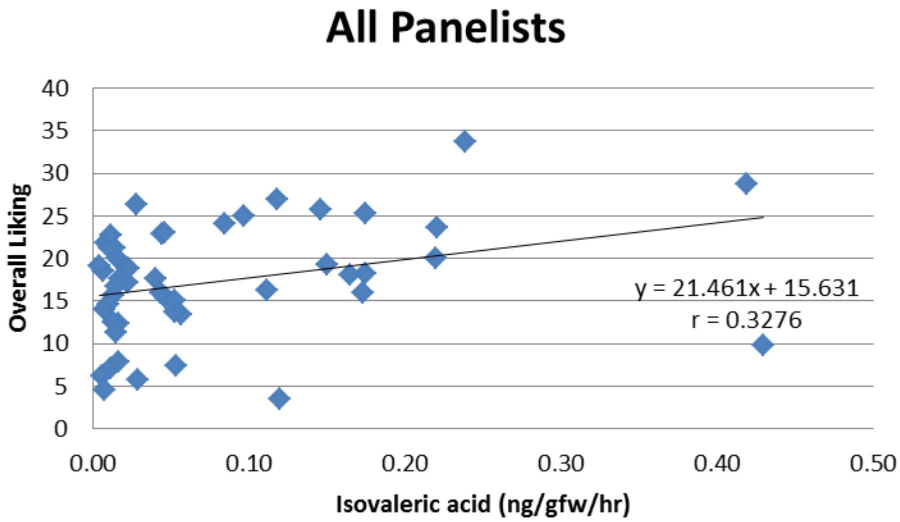
Figure 4-7. Correlation and regression for all panelists between overall liking and A) isovaleraldehyde and B) 3-methyl-1-butanol



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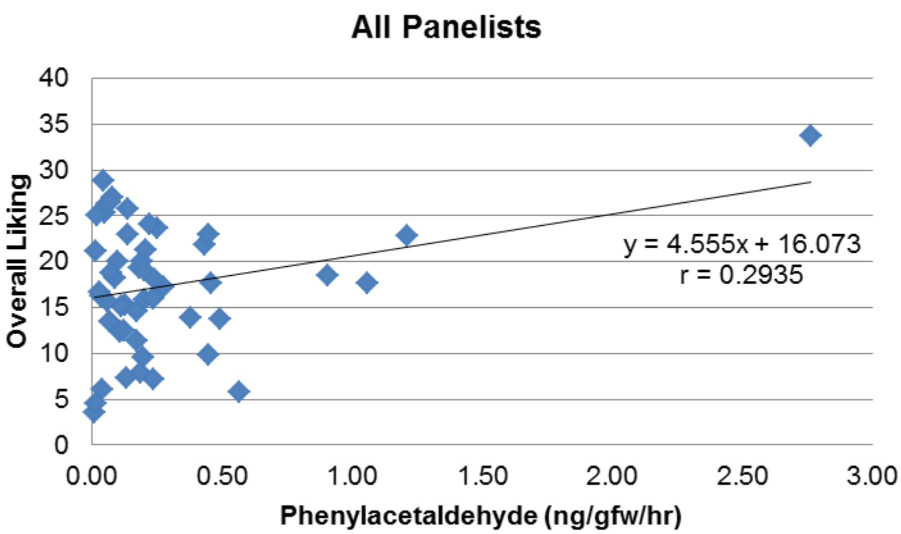
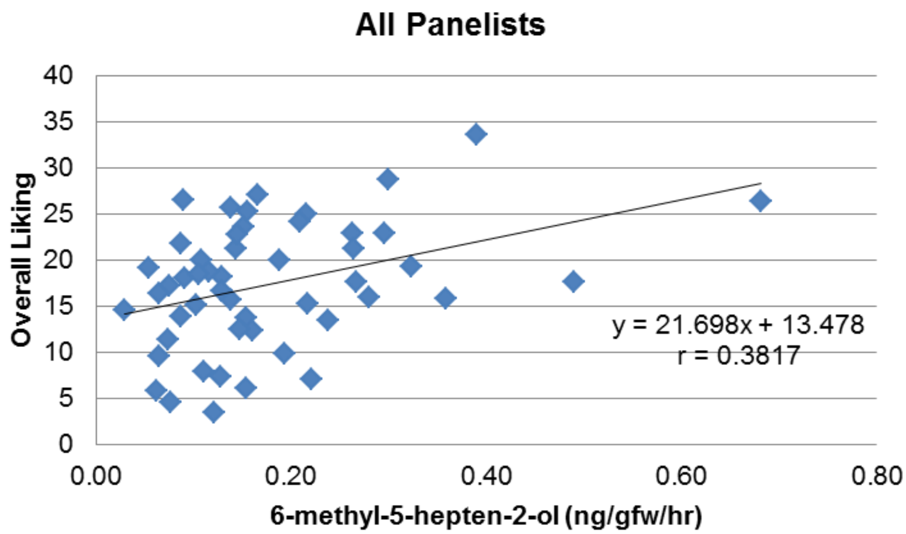


B

Figure 4-8. Correlation and regression for all panelists between overall liking and A) isovaleric acid and B) phenylacetaldehyde



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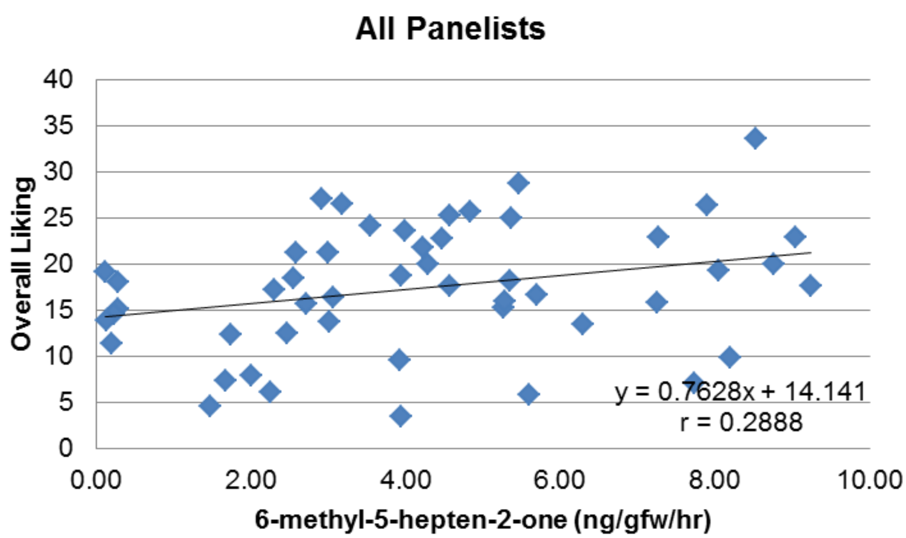
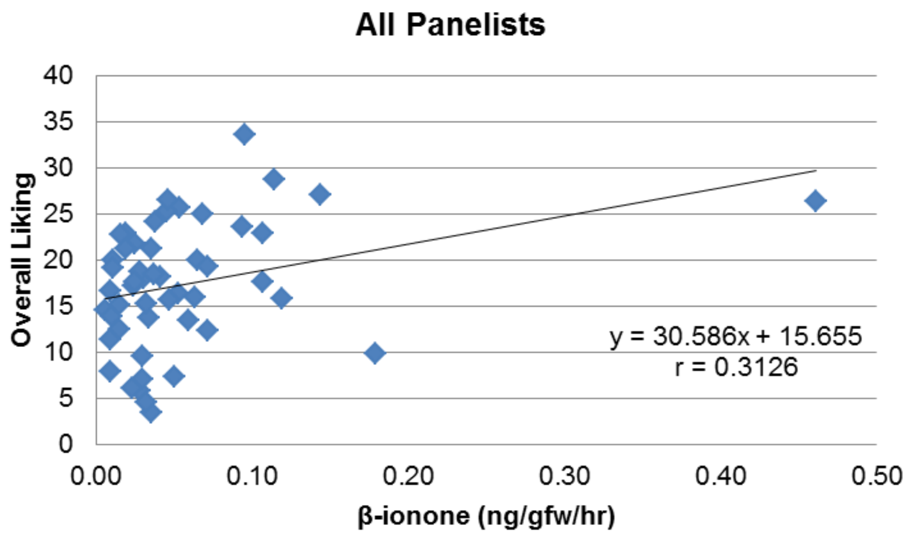


B

Figure 4-9. Correlation and regression for all panelists between overall liking and A) 6-methyl-5-hepten-2-ol and B) 6-methyl-5-hepten-2-one



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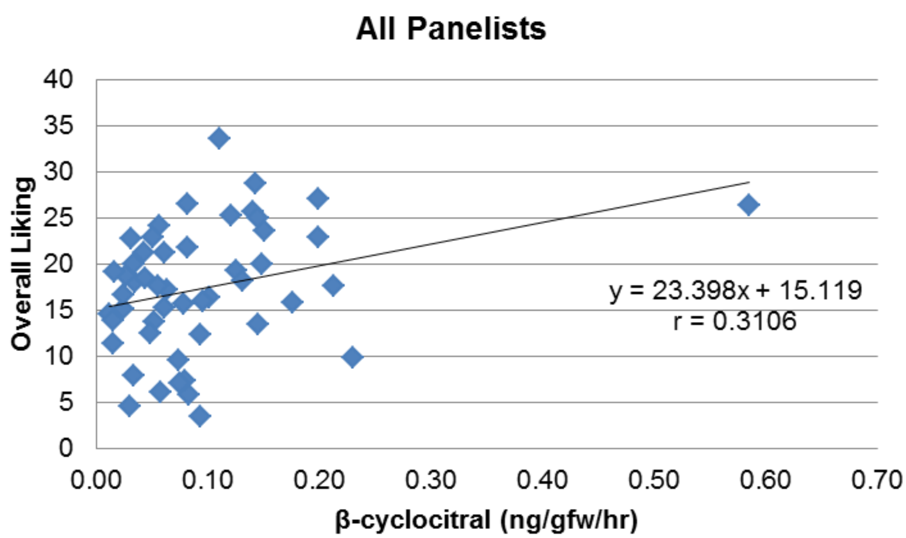

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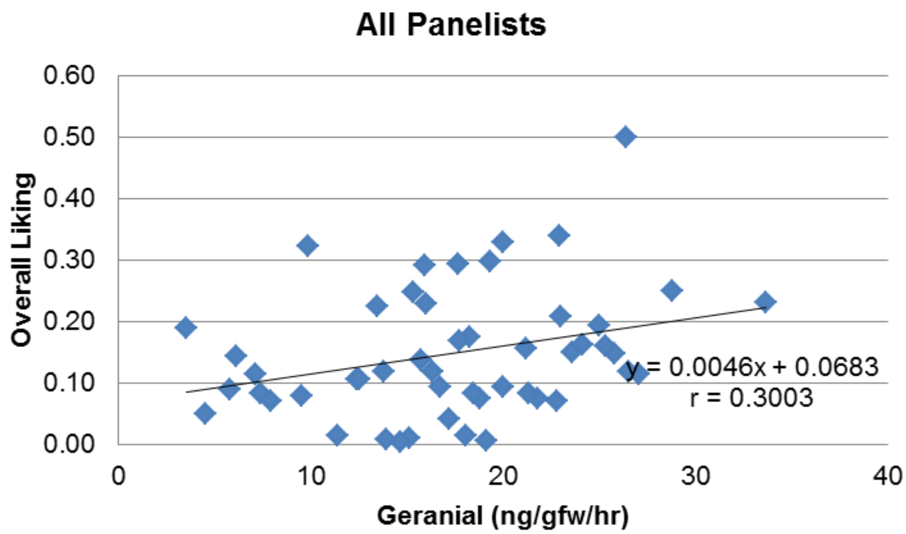
Figure 4-10. Correlation and regression for all panelists between overall liking and A) β-ionone B) β-cyclocitral



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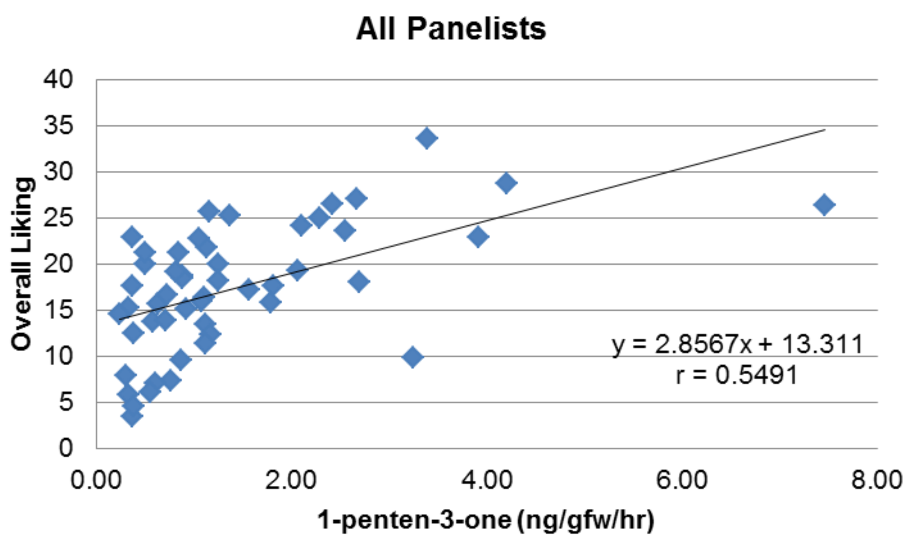

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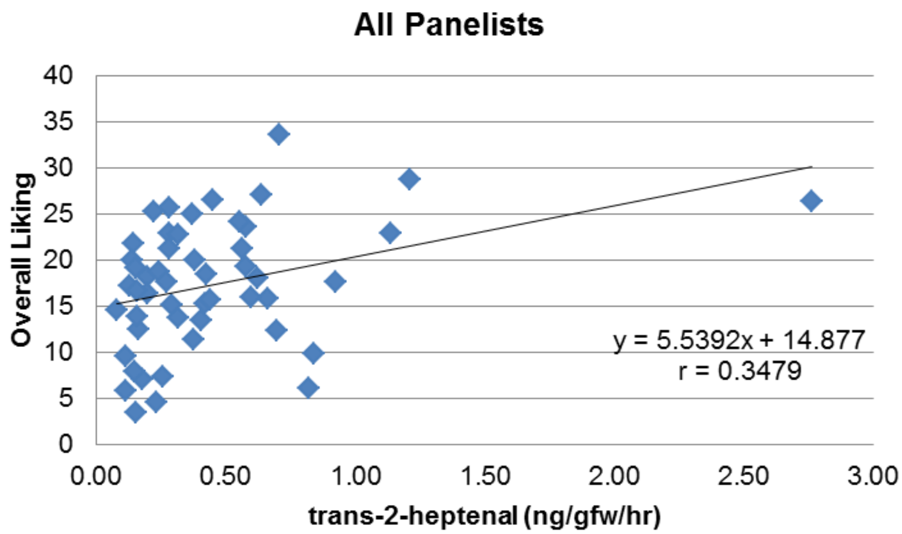
Figure 4-11. Correlation and regression for all panelists between overall liking and A) geranial B) 1-penten-3-one



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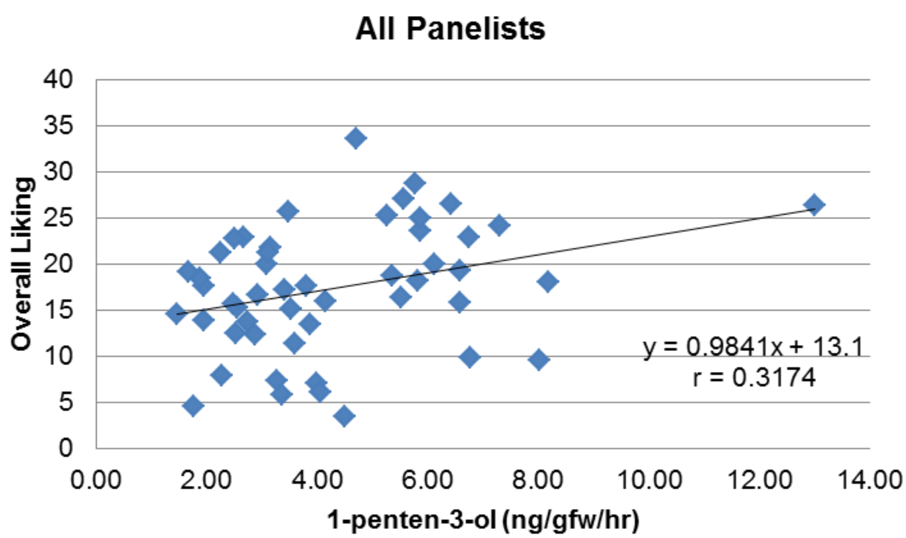

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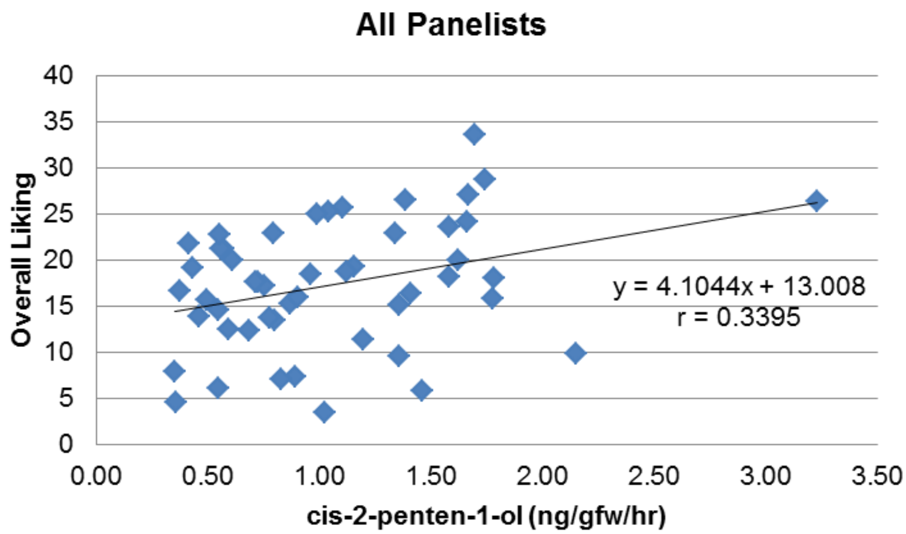
Figure 4-12. Correlation and regression for all panelists between overall liking and A) *trans*-2-heptenal B) 1-penten-3-ol



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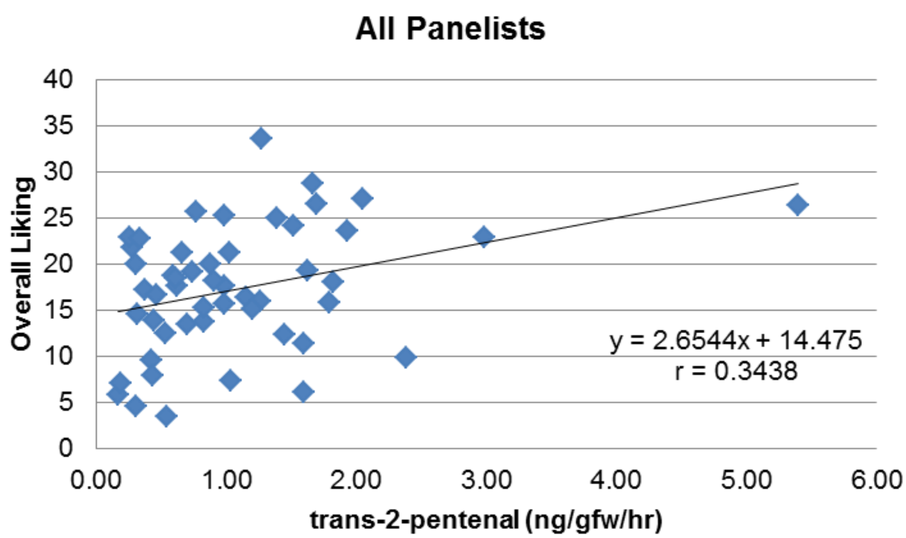

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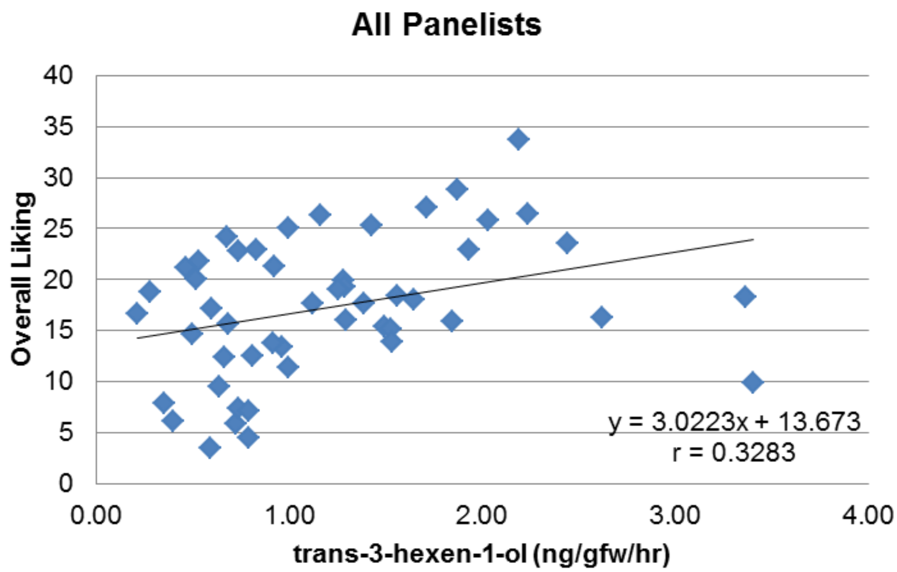
Figure 4-13. Correlation and regression for all panelists between overall liking and A) *cis*-2-penten-1-ol B) *trans*-2-pentenal



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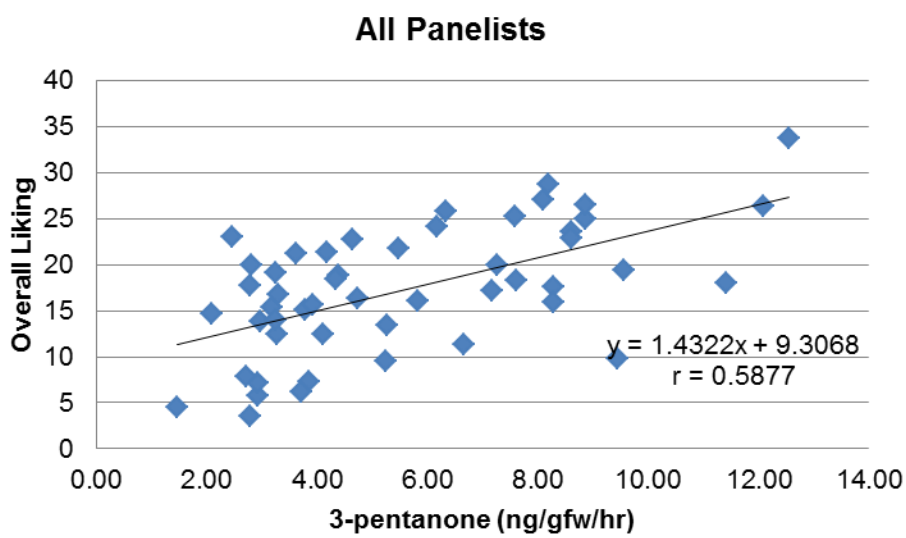

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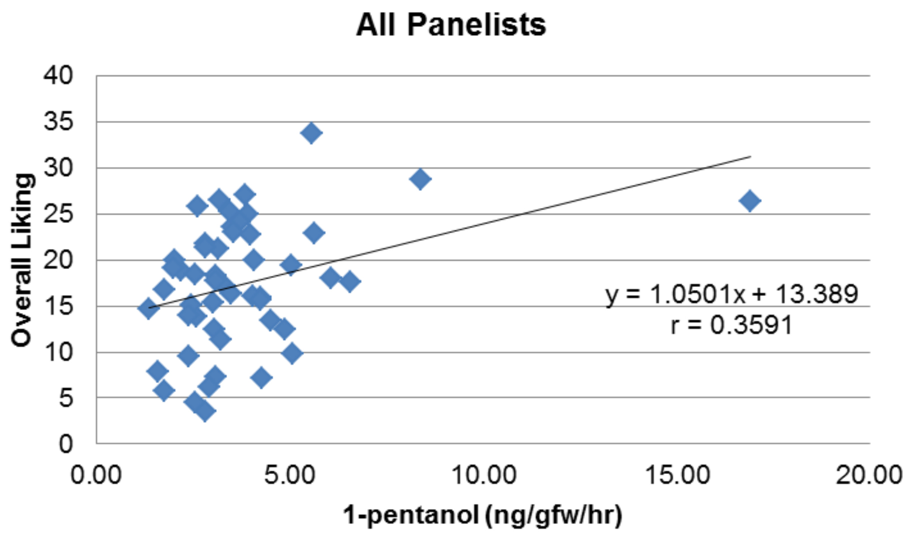
Figure 4-14. Correlation and regression for all panelists between overall liking and A) *trans*-3-hexen-1-ol B) 3-pentanone



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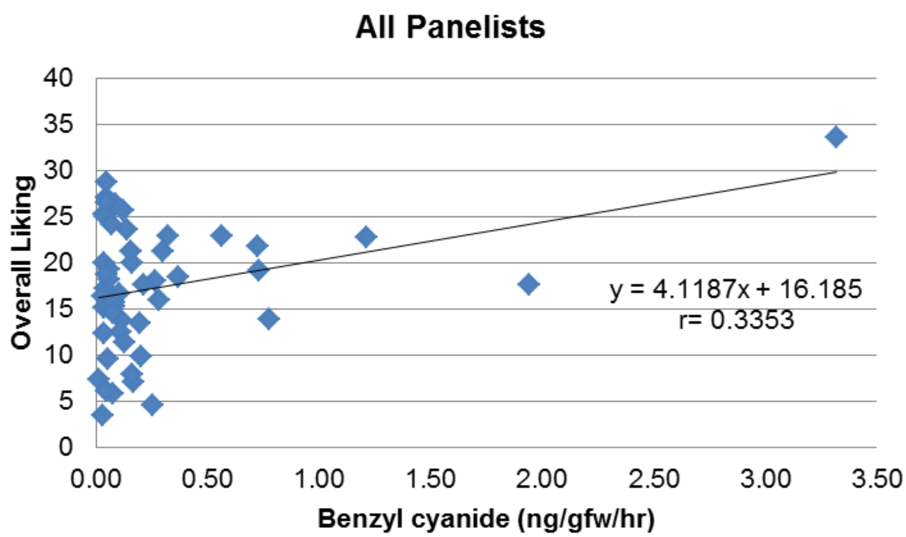

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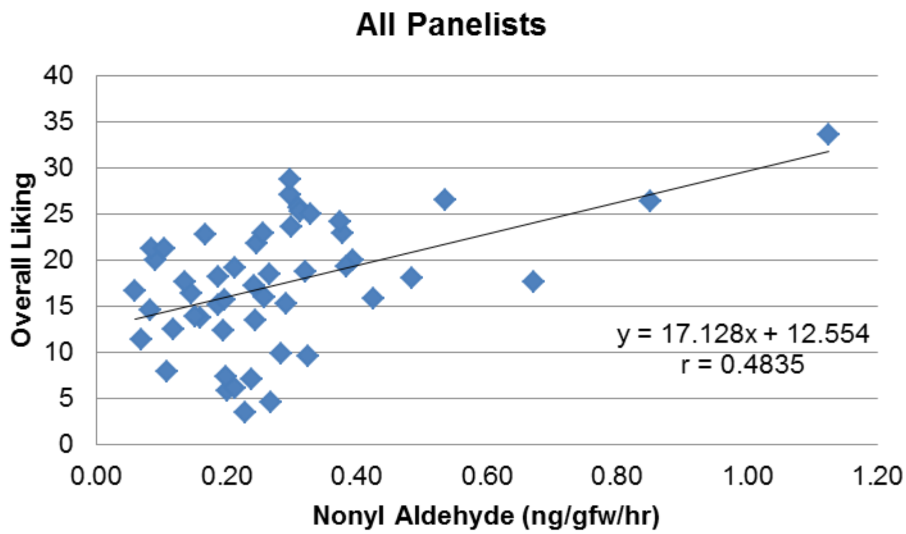
Figure 4-15. Correlation and regression for all panelists between overall liking and A) 1-pentanol B) Benzyl cyanide



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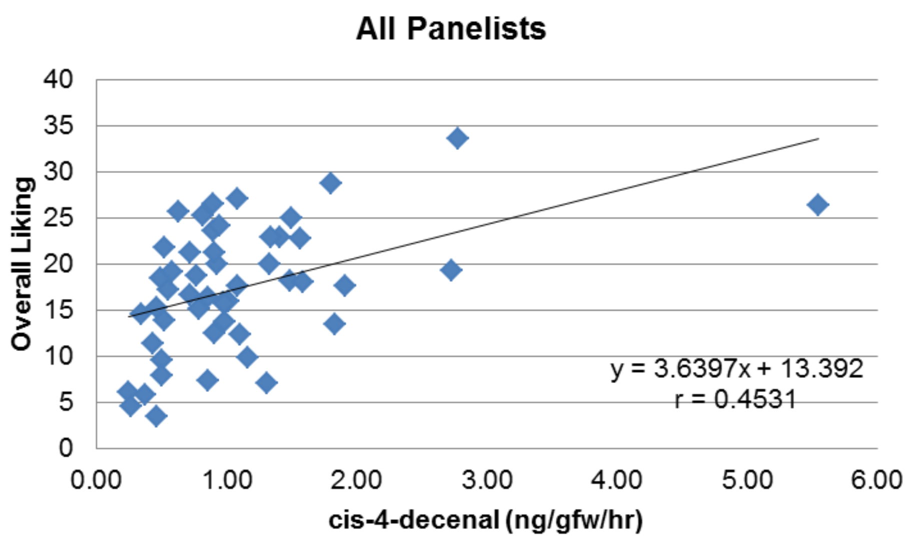

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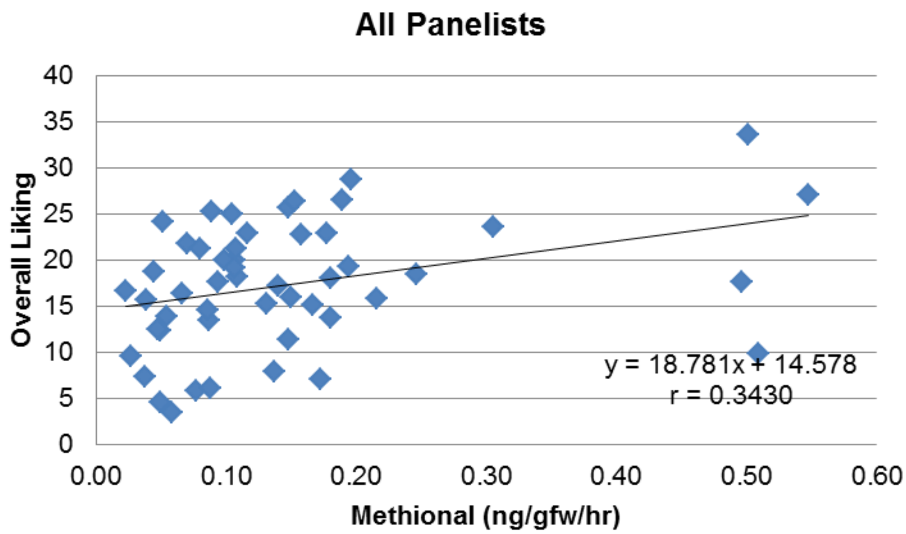
Figure 4-16. Correlation and regression for all panelists between overall liking and A) Nonyl aldehyde B) *cis*-4-decenal



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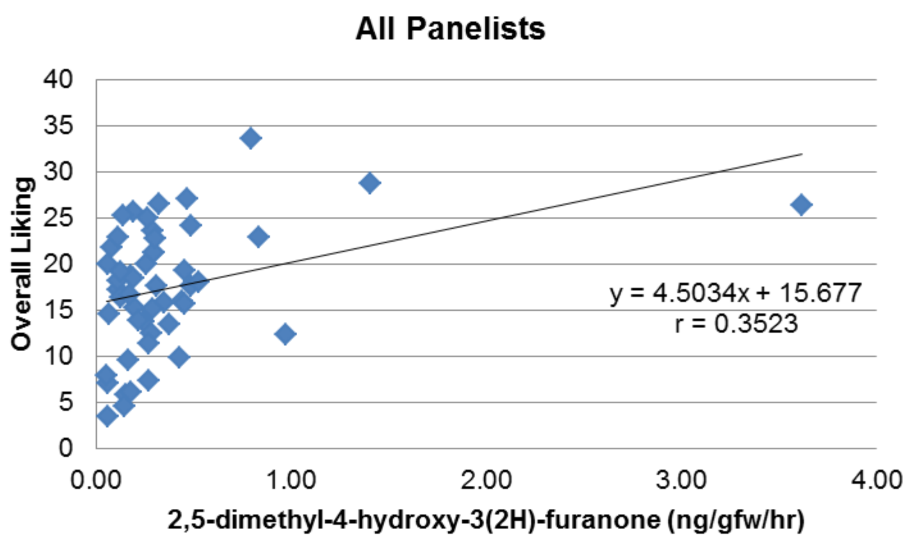
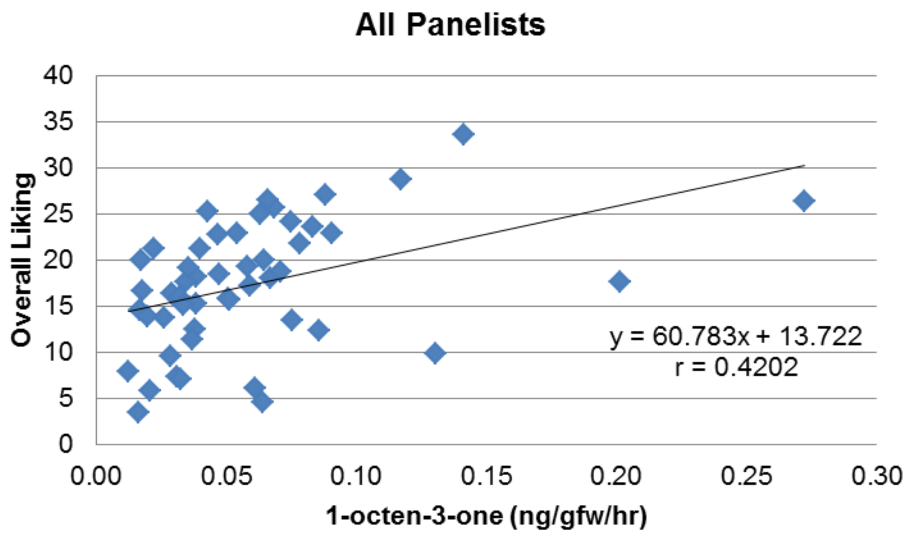
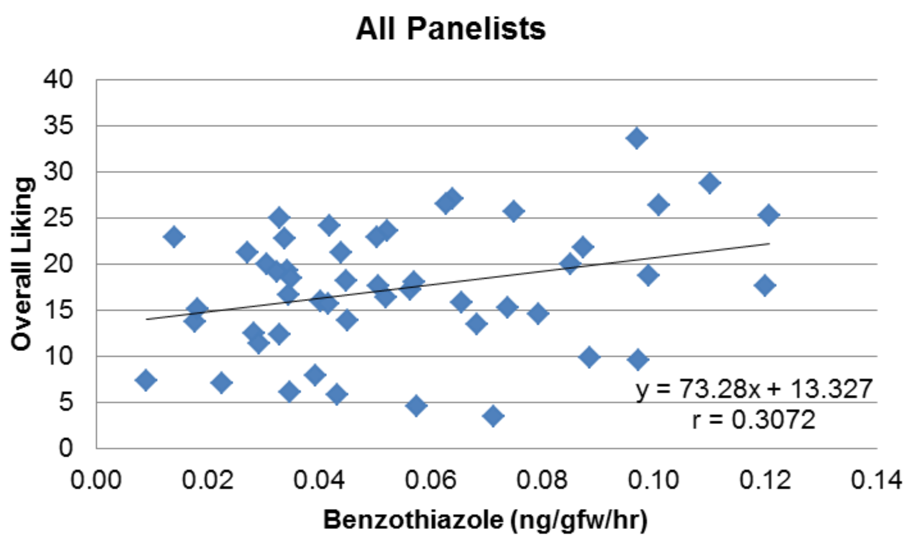


B

Figure 4-17. Correlation and regression for all panelists between overall liking and A) methional B) 2,5-dimethyl-4-hydroxy-3(2H)-furanone

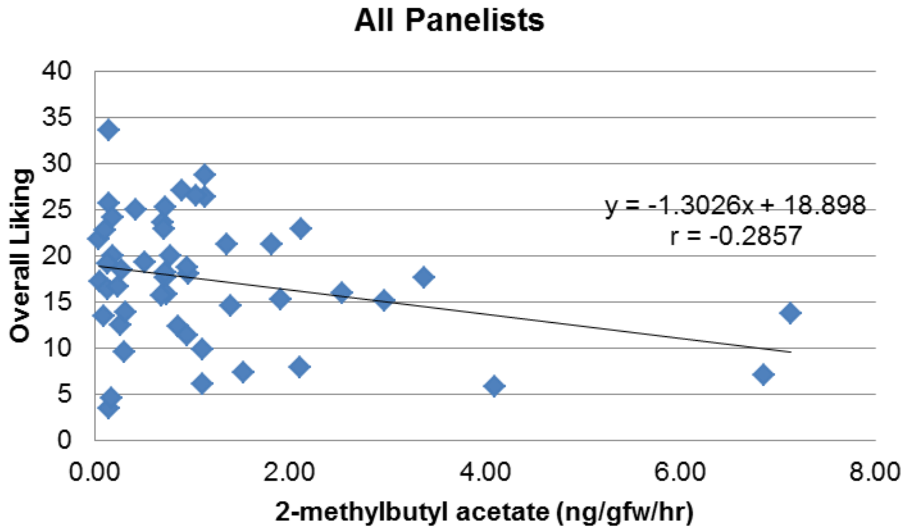


A

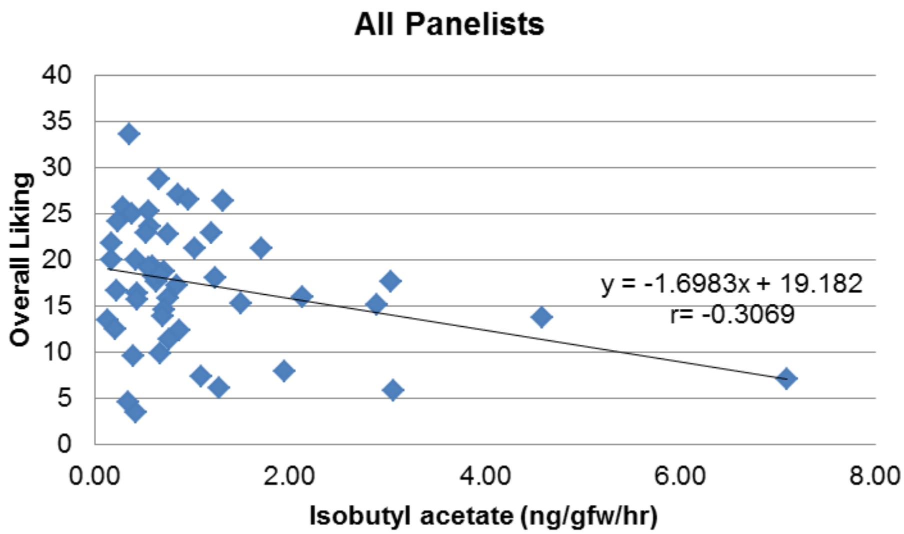


B

Figure 4-18. Correlation and regression for all panelists between overall liking and A) 1-octen-3-oneB) benzothiazole



A



B

Figure 4-19. Correlation and regression for all panelists between overall liking and A) 2-methylbutyl acetate B) isobutyl acetate

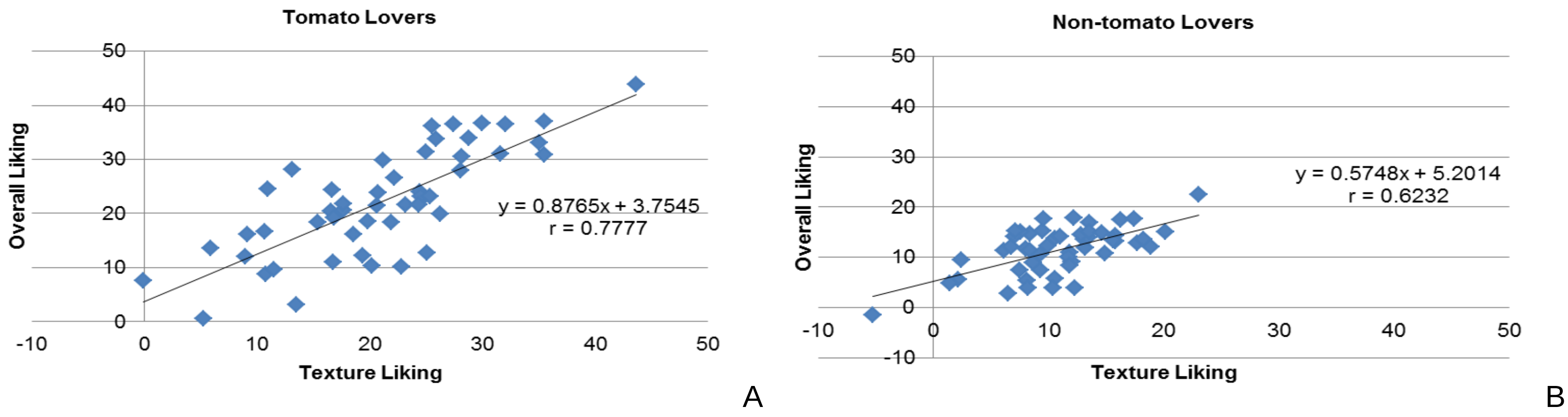


Figure 4-20. Correlation and regression between overall liking and texture liking for A) tomato lovers and B) non-tomato lovers

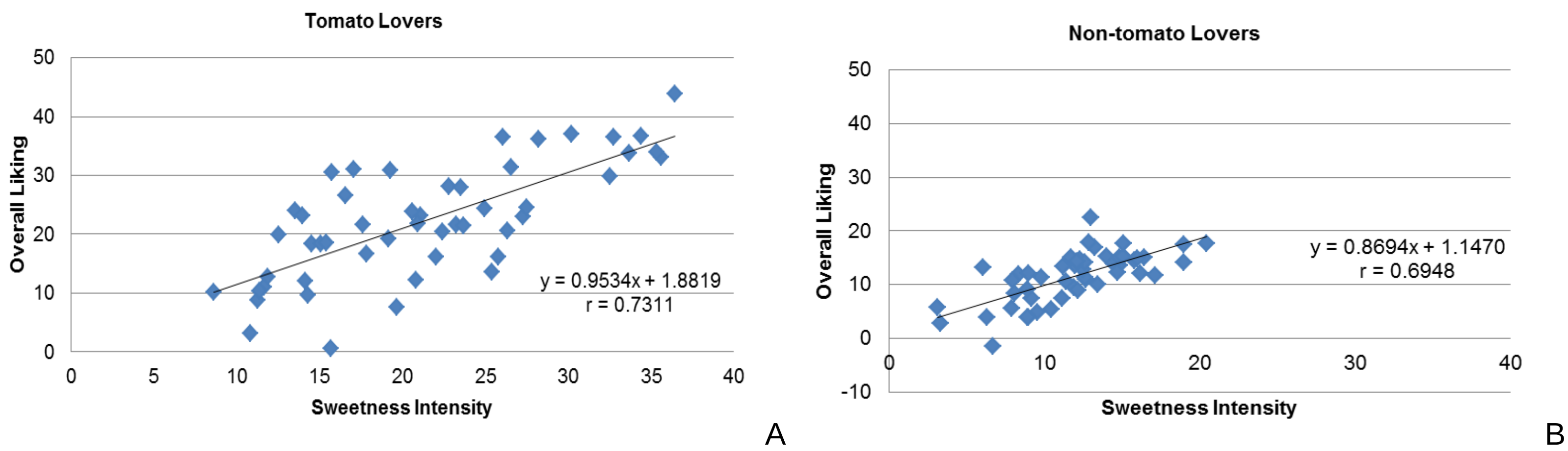
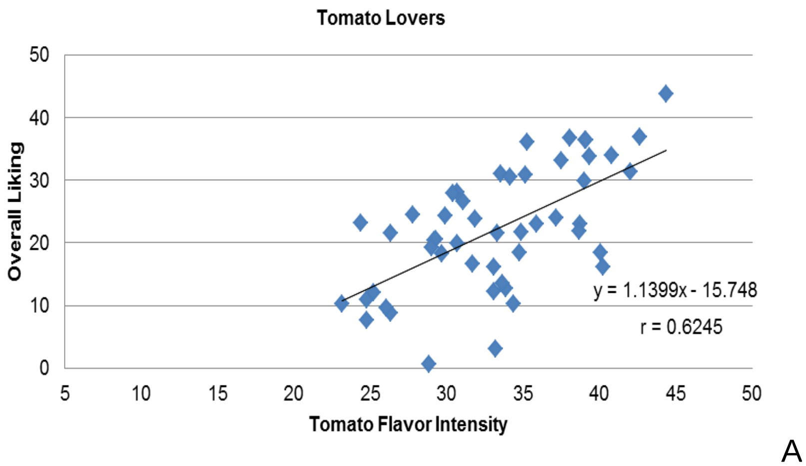


Figure 4-21. Correlation and regression between overall liking and sweetness intensity for A) tomato lovers and B) non-tomato lovers



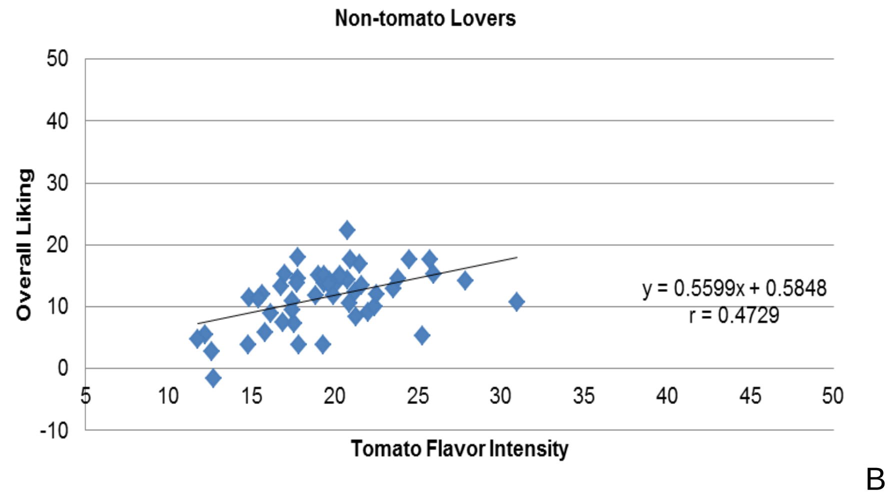


Figure 4-22. Correlation and regression between overall loking and tomato flavor intensity for A) tomato lovers and B) non-tomato lovers

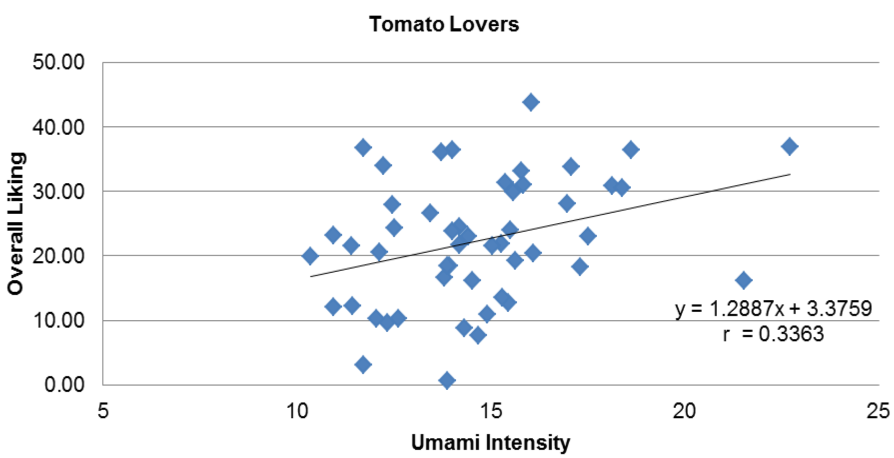


Figure 4-23. Correlation and regression between overall liking and umami intensity for tomato lovers.

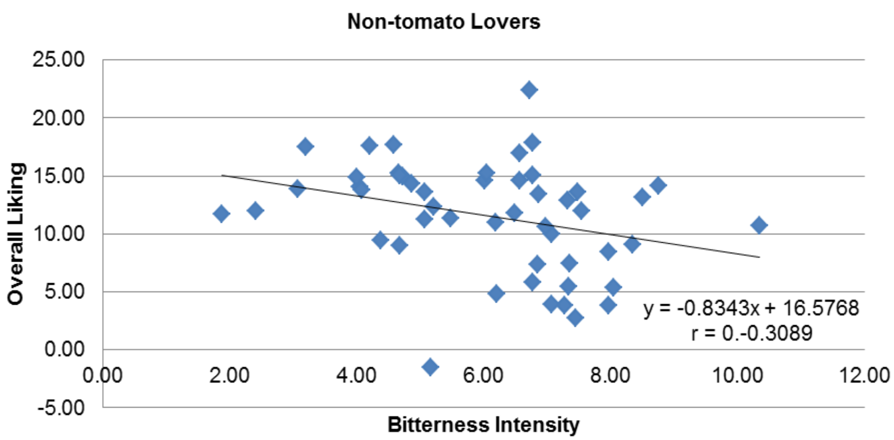


Figure 4-24. Correlation and regression between overall liking and bitterness intensity for non-tomato lovers.

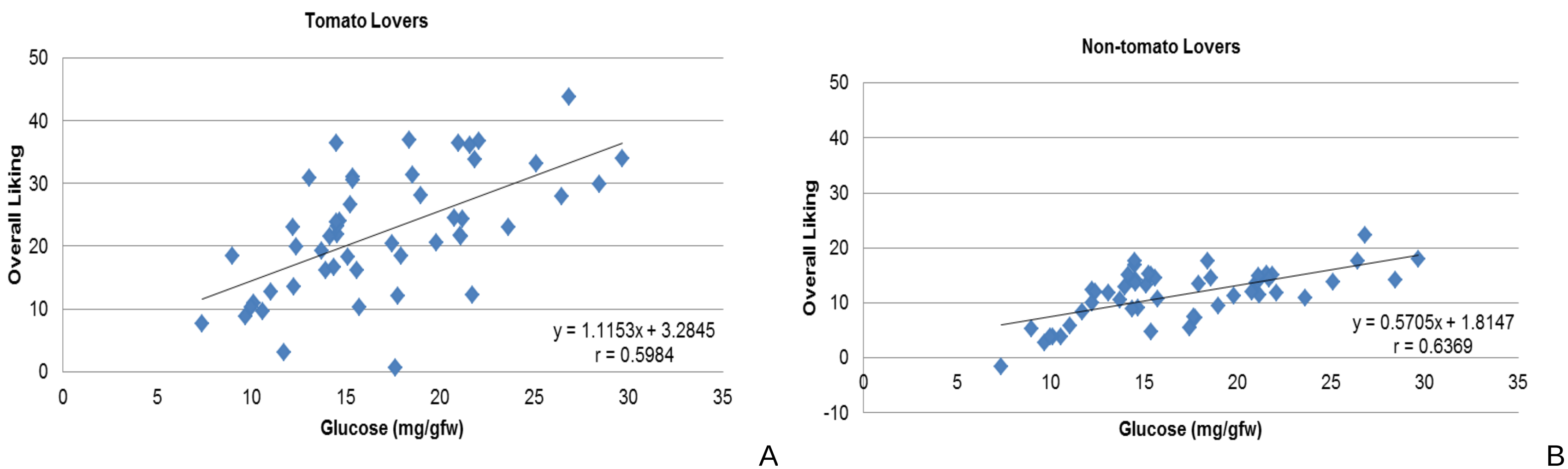


Figure 4-25. Correlation and regression between overall liking and glucose for A) tomato lovers and B) non-tomato lovers.

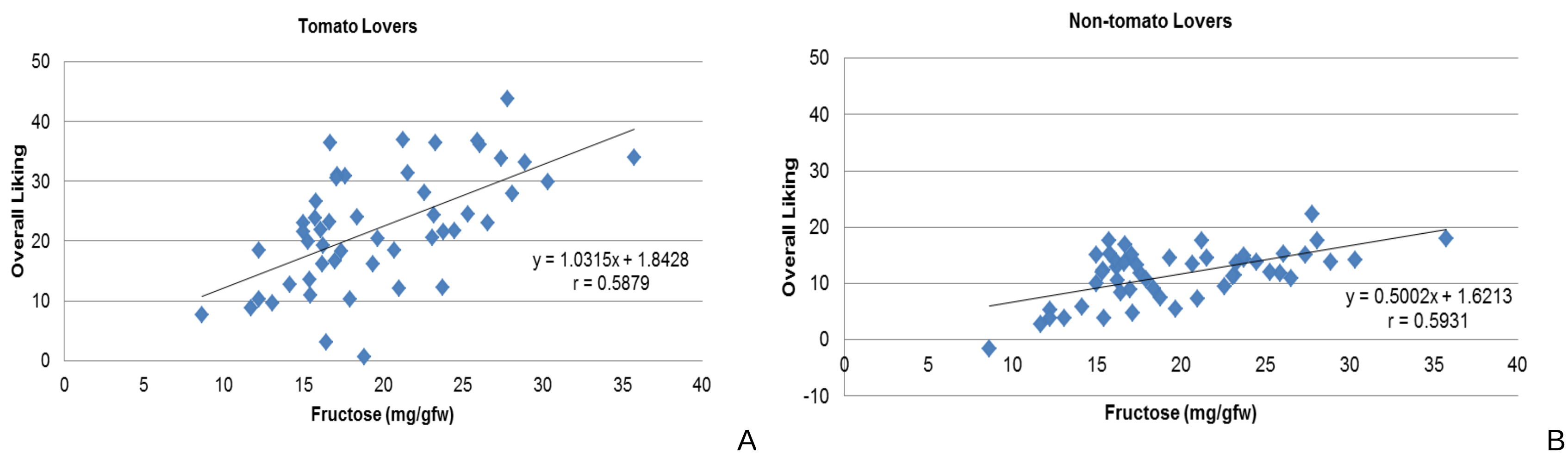


Figure 4-26. Correlation and regression between overall liking and fructose for A) tomato lovers and B) non-tomato lovers.

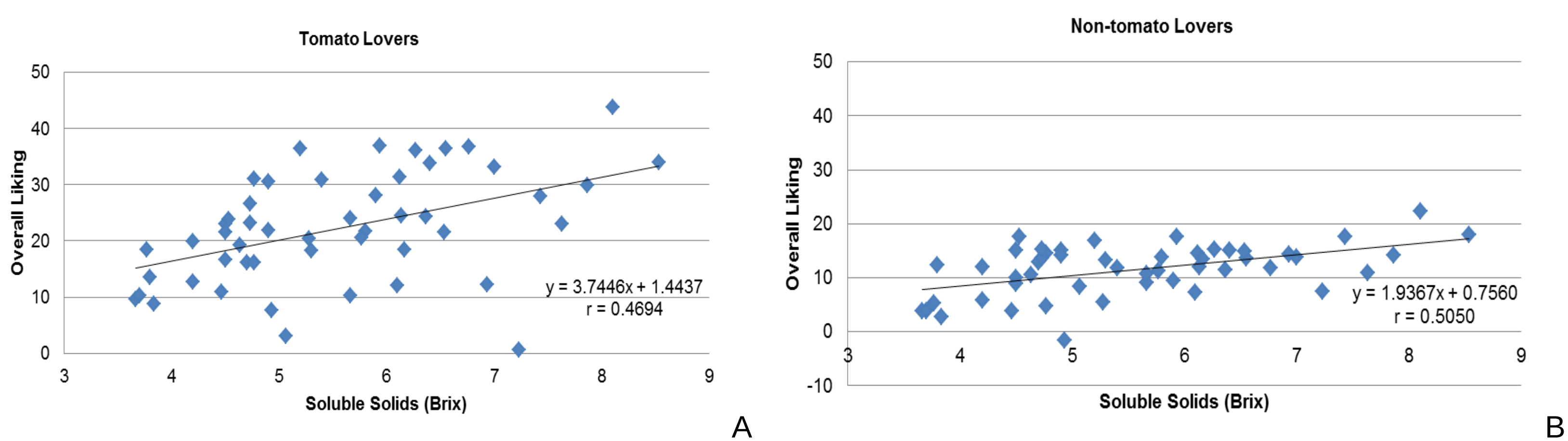


Figure 4-27. Correlation and regression between overall liking and soluble solids for A) tomato lovers and B) non-tomato lovers.

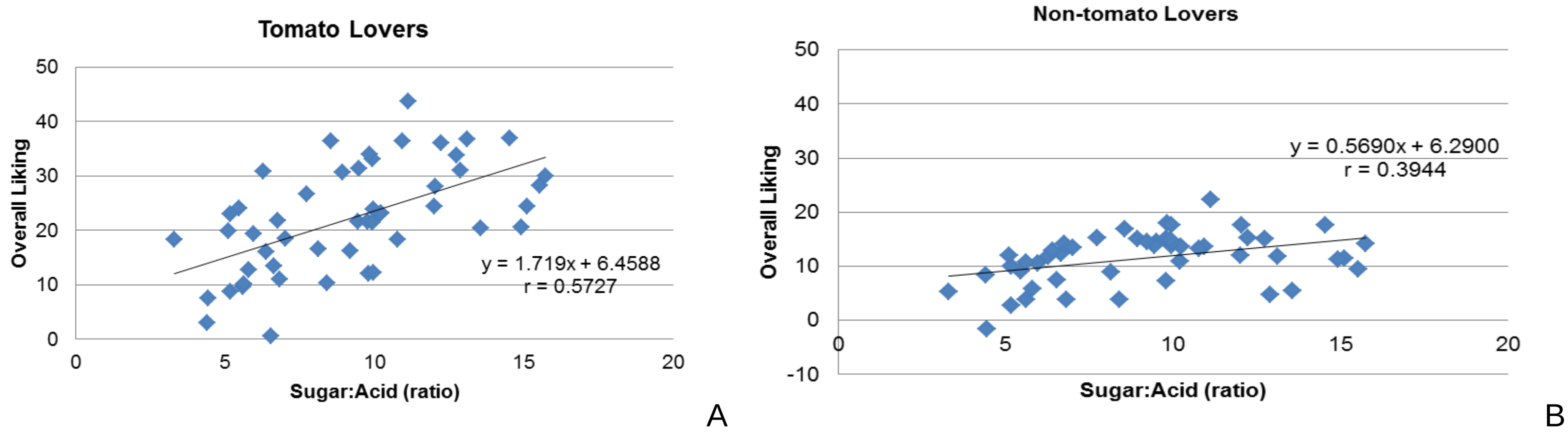


Figure 4-28. Correlation and regression between overall liking and sugar to acid ratio (sugar:acid) for A) Tomato lovers and B) non-tomato lovers.

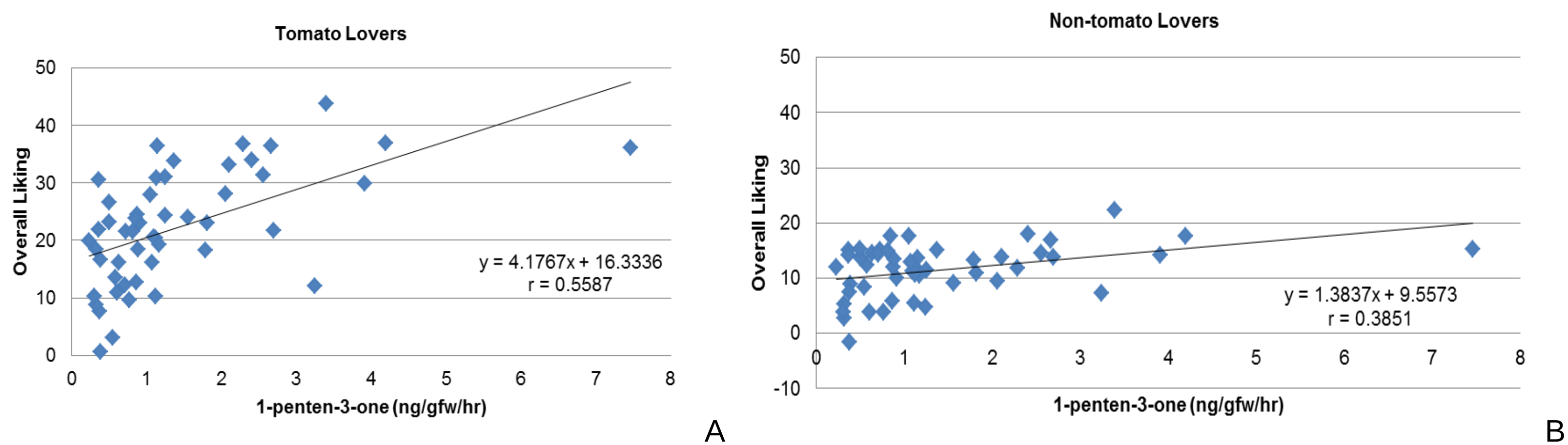


Figure 4-29. Correlation and regression between overall liking and 1-penten-3-one for A) tomato lovers and B) non-tomato lovers.

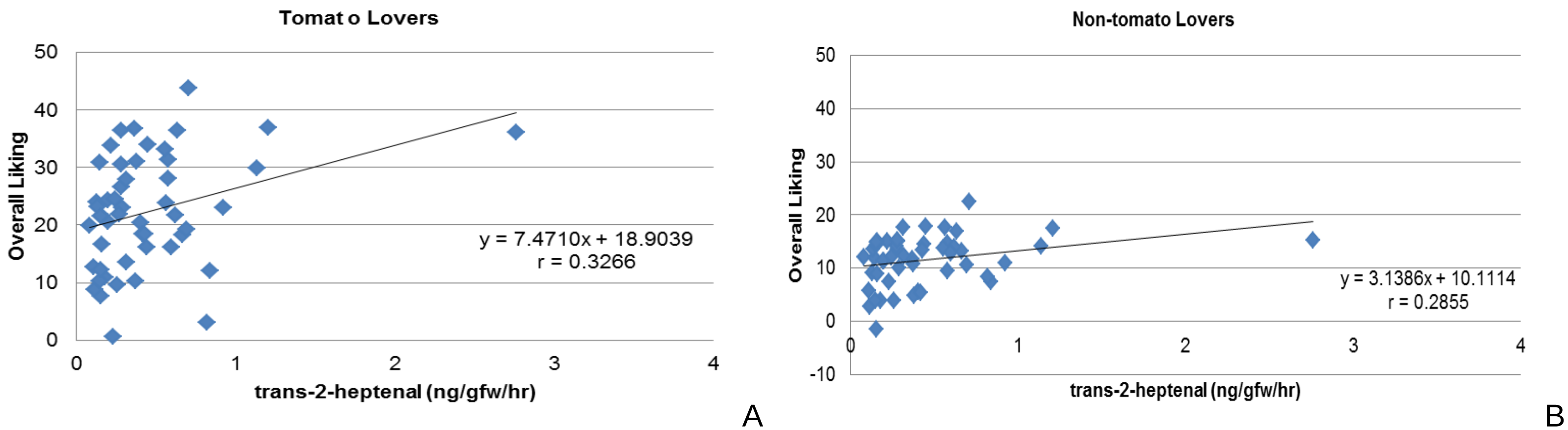


Figure 4-30. Correlation and regression between overall liking and *trans*-2-heptenal for A) tomato lovers and B) non-tomato lovers.

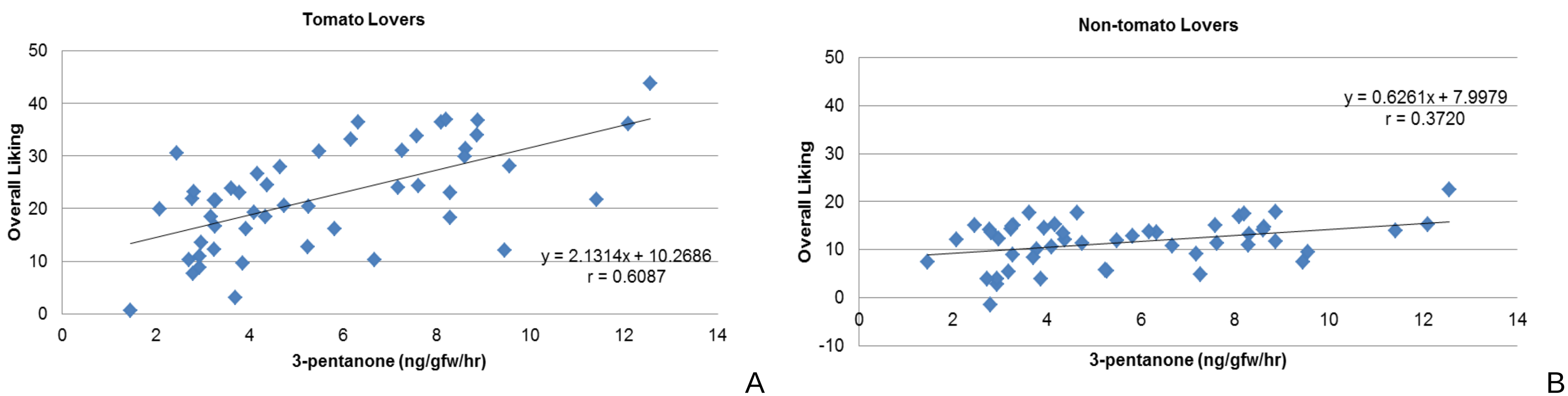


Figure 4-31. Correlation and regression between overall liking and 3-pentanone for A) tomato lovers and B) non-tomato lovers.

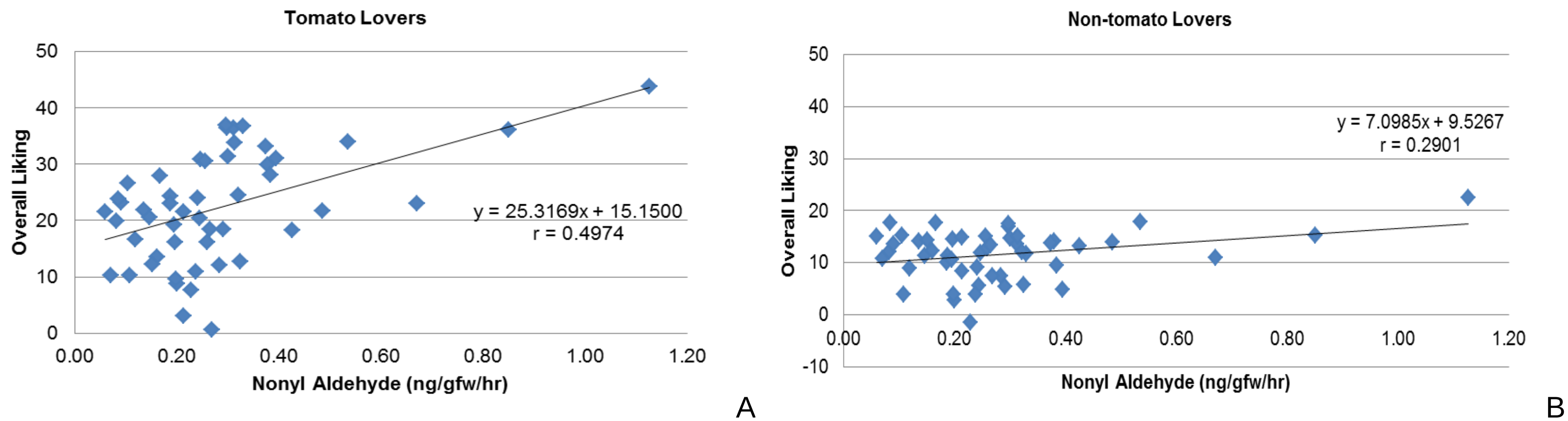


Figure 4-32. Correlation and regression between overall liking and nonyl aldehyde for A) tomato lovers and B) non-tomato lovers.

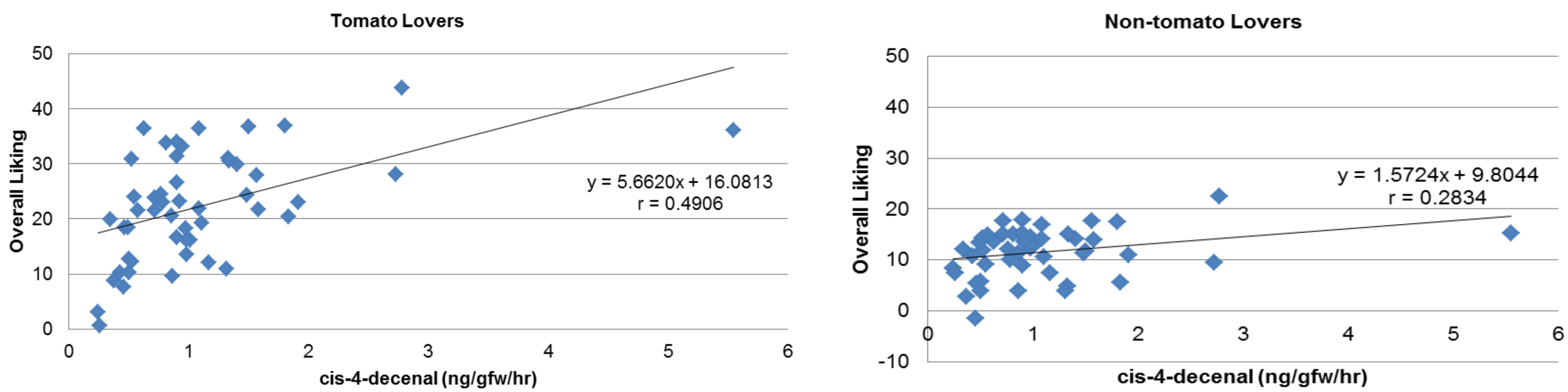


Figure 4-33. Correlation and regression between overall liking and *cis*-4-decenal for A) tomato lovers and B) non-tomato lovers.

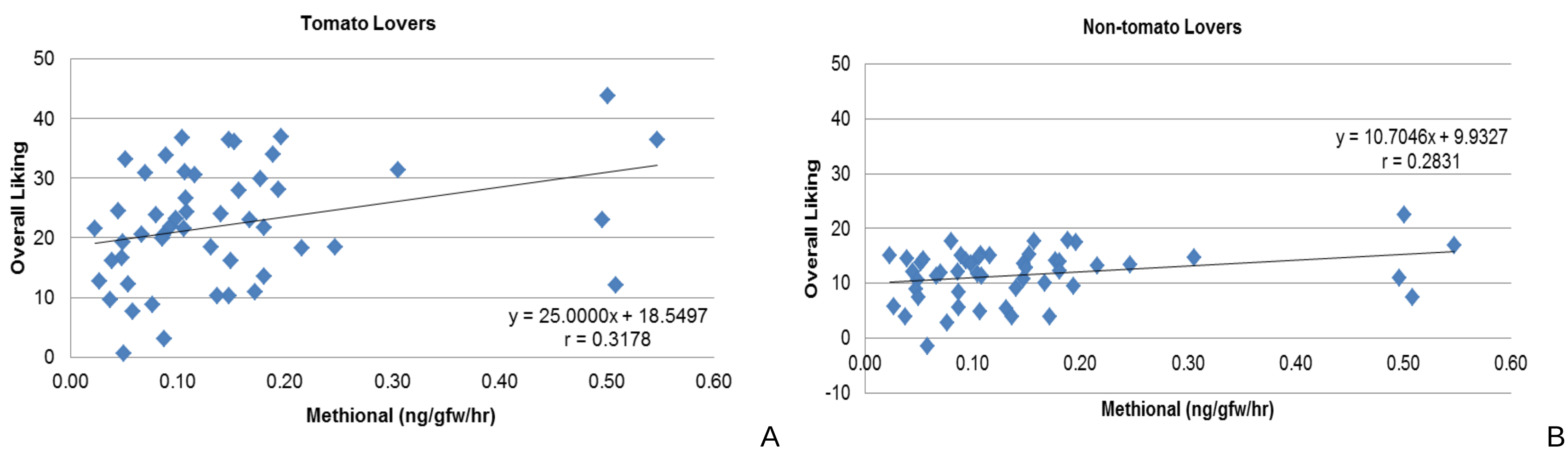


Figure 4-34. Correlation and regression between overall liking and methional for A) tomato lovers and B) non-tomato lovers.

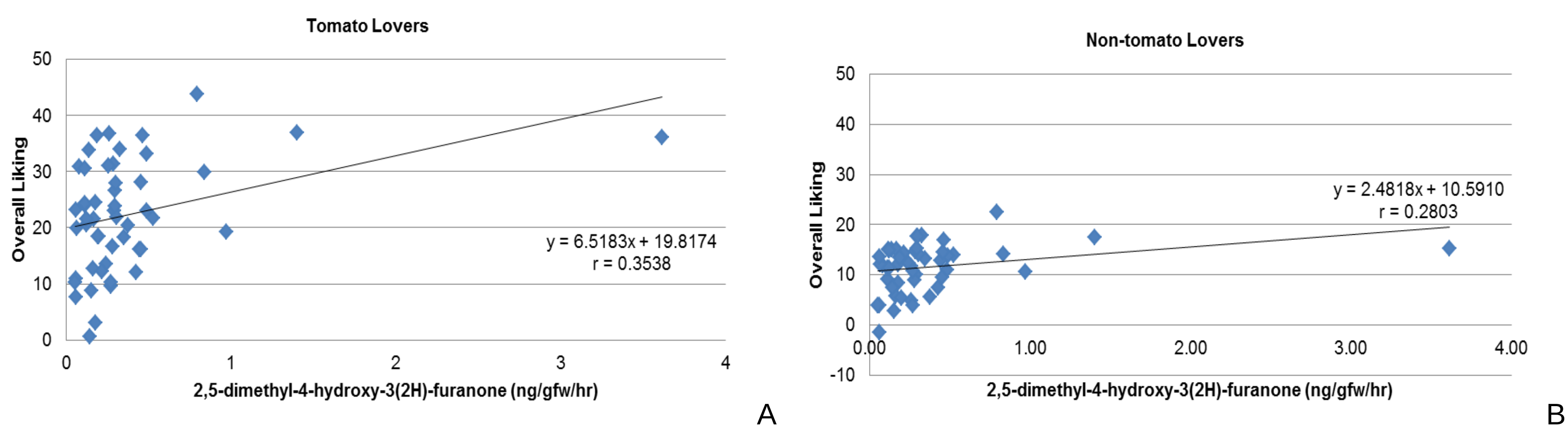
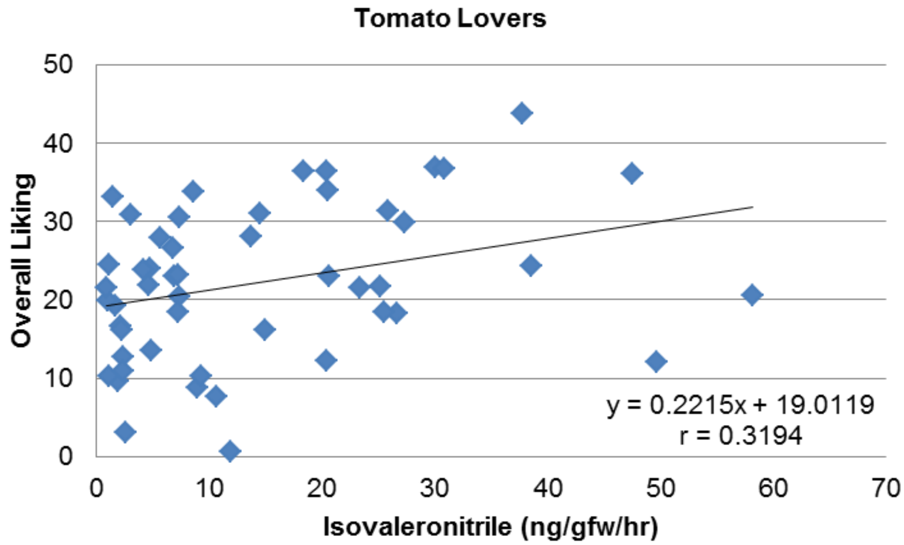
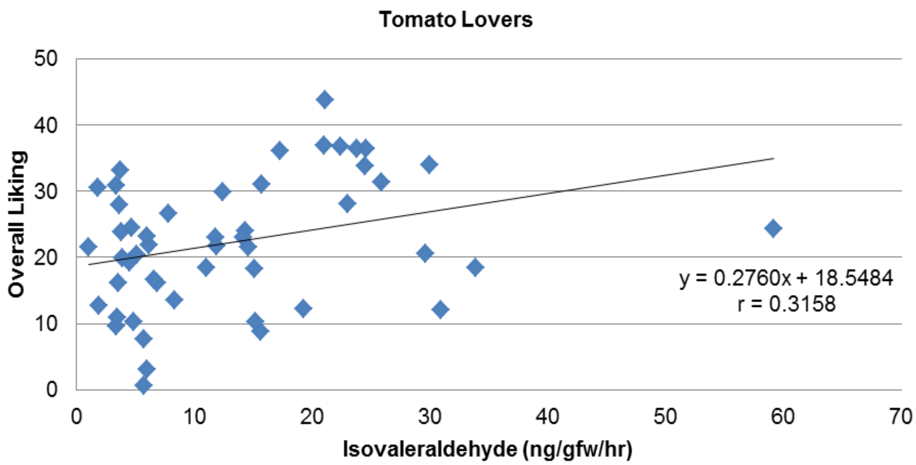


Figure 4-35. Correlation and regression between overall liking and 2,5-dimethyl-4-hydroxy-3(2h)-furanone for A) tomato lovers and B) non-tomato lovers.

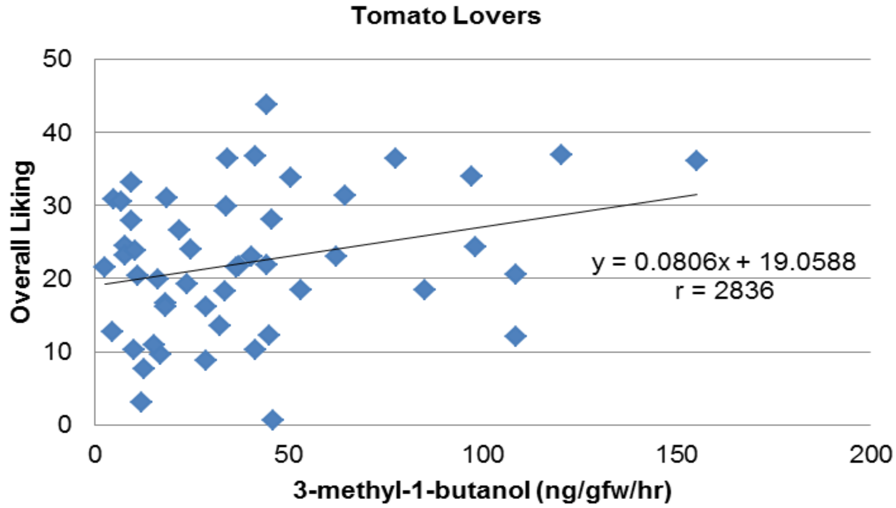


A

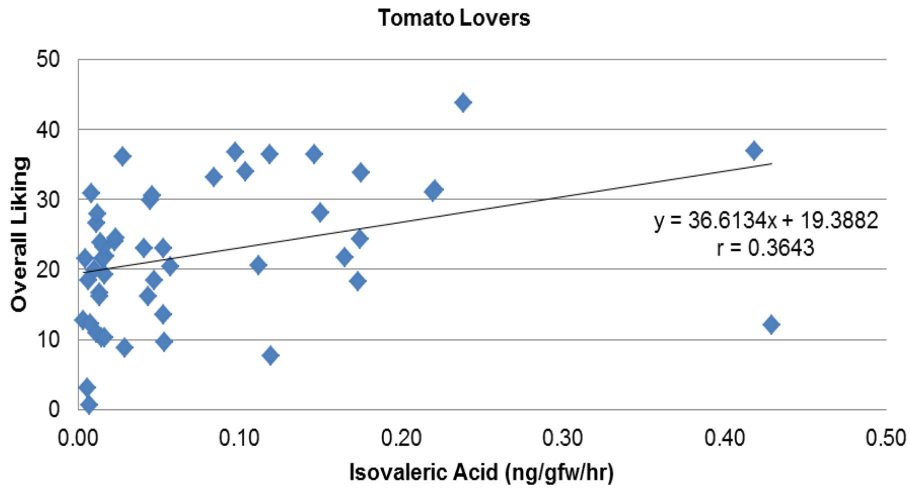


B

Figure 4-36. Correlation and regression for tomato lovers between overall liking and A) isovaleronitrile B) isovaleraldehyde

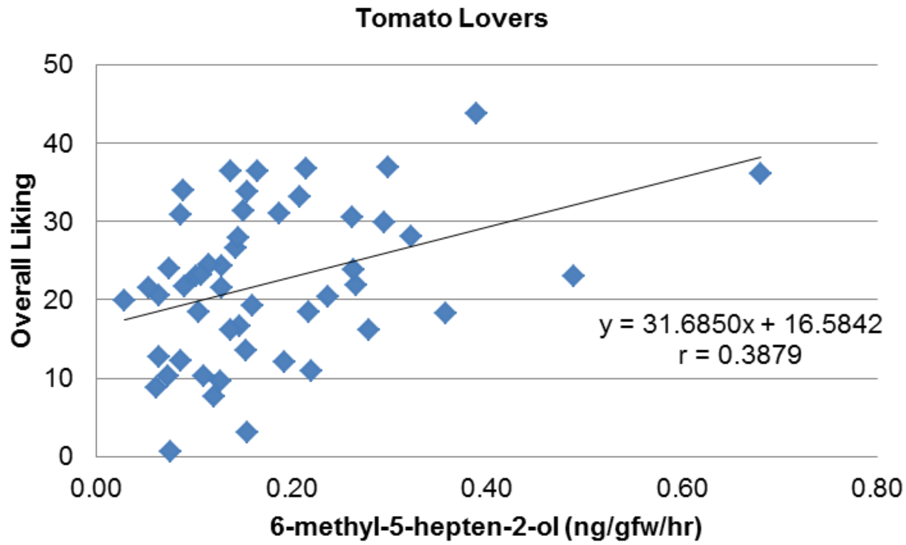


A

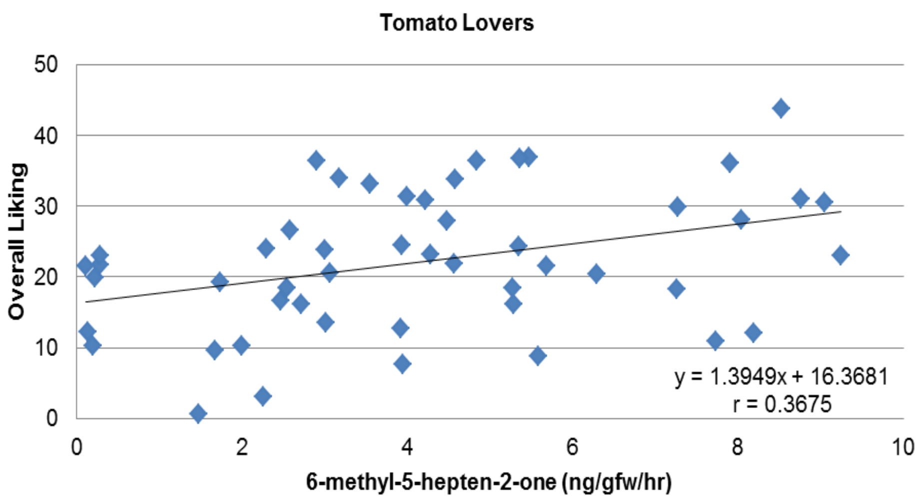


B

Figure 4-37. Correlation and regression for tomato lovers between overall liking and A) 3-methyl-1-butanol B) isovaleric Acid.

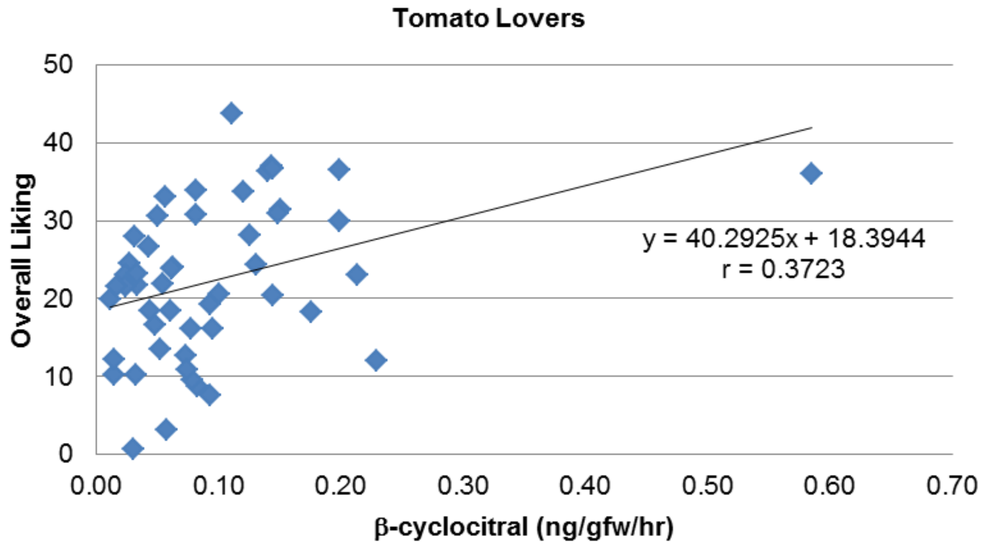


A



B

Figure 4-38. Correlation and regression for tomato lovers between overall liking and A) 6-methyl-5-hepten-2-ol B) 6-methyl-5-hepten-2-one.



A

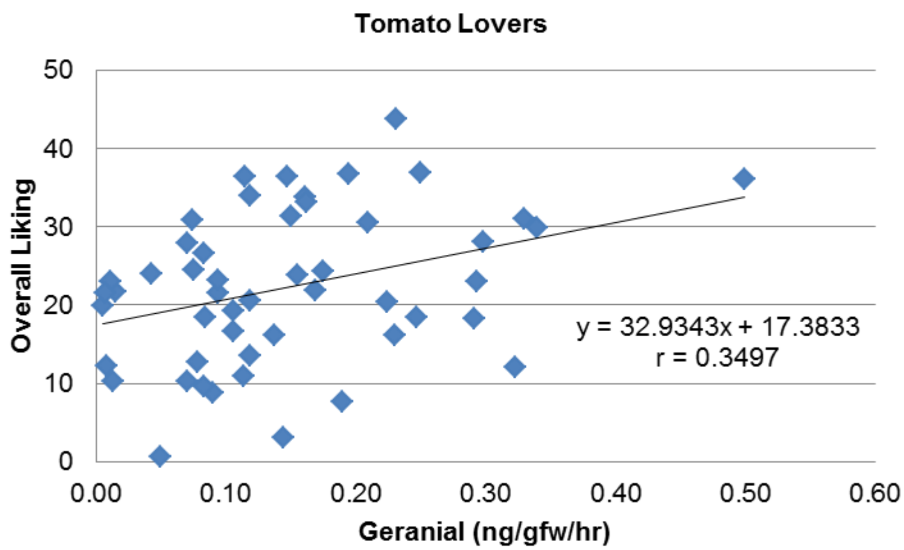
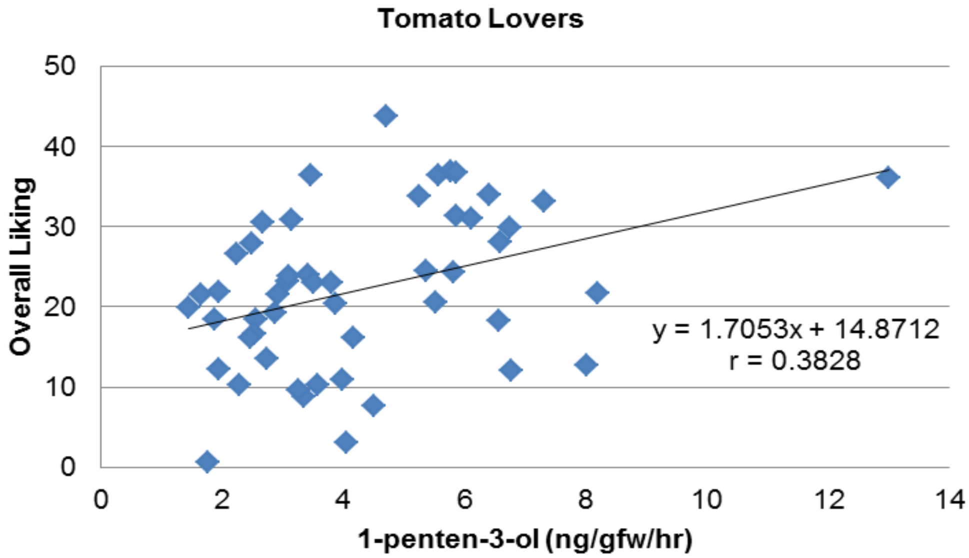
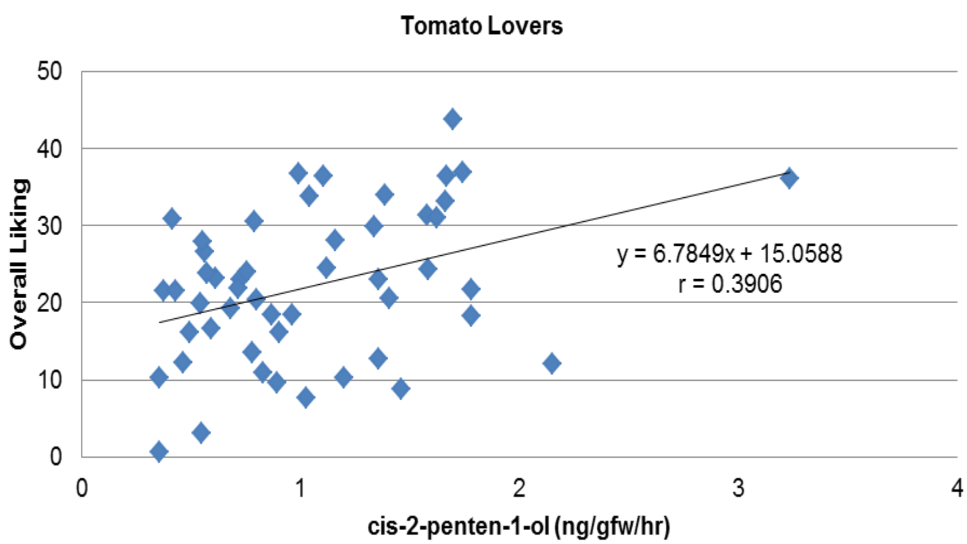


Figure 4-39. Correlation and regression for tomato lovers between overall liking and A) β-cyclocitral B) geranial.

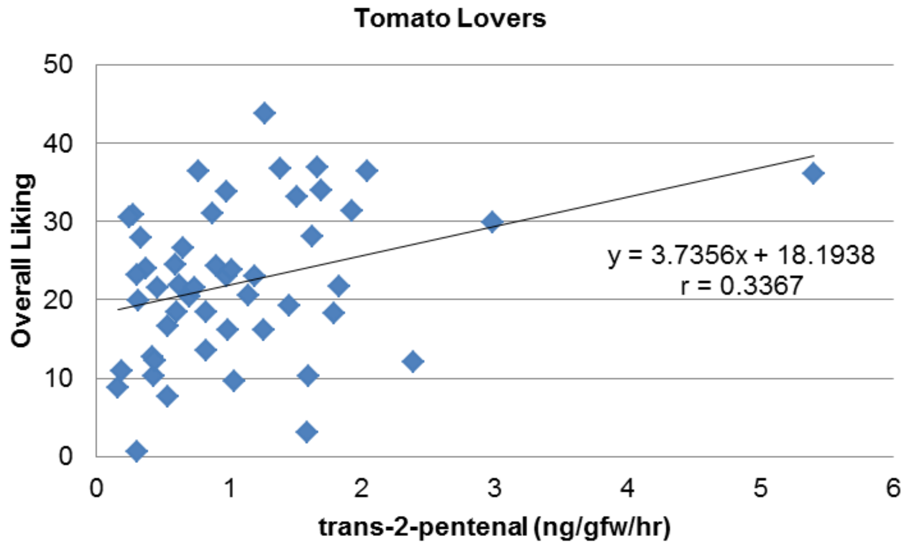


A

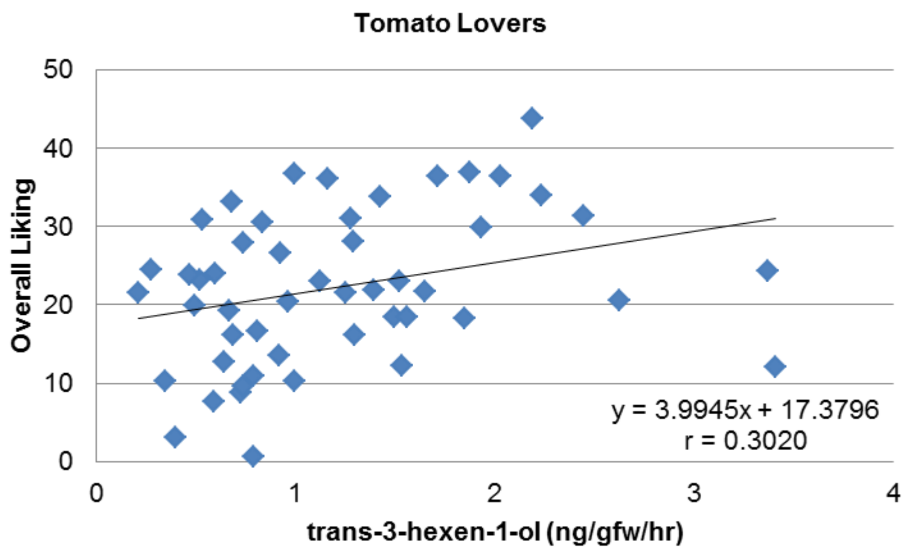


B

Figure 4-40. Correlation and regression for tomato lovers between overall liking and A) 1-penten-3-ol B) *cis*-2-penten-1-ol.

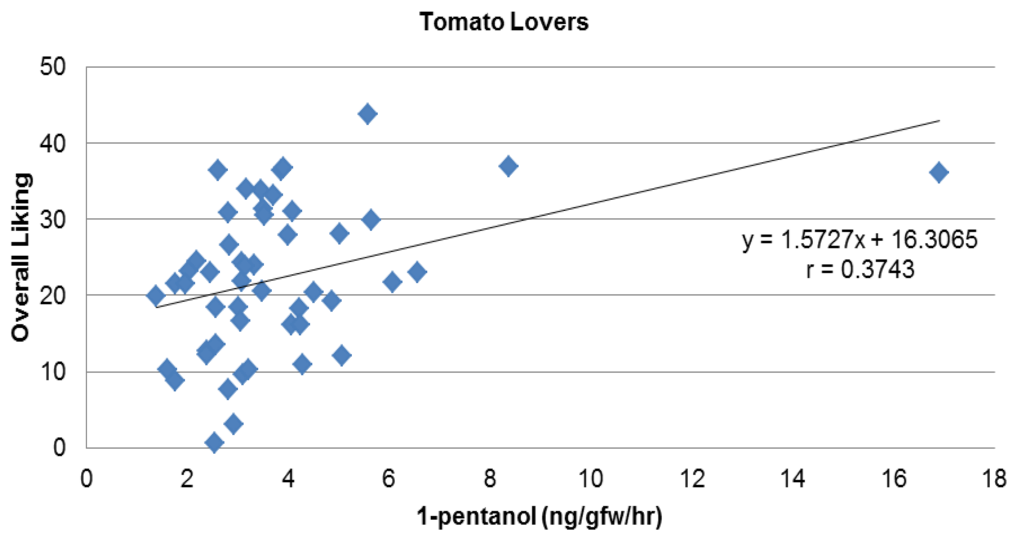


A

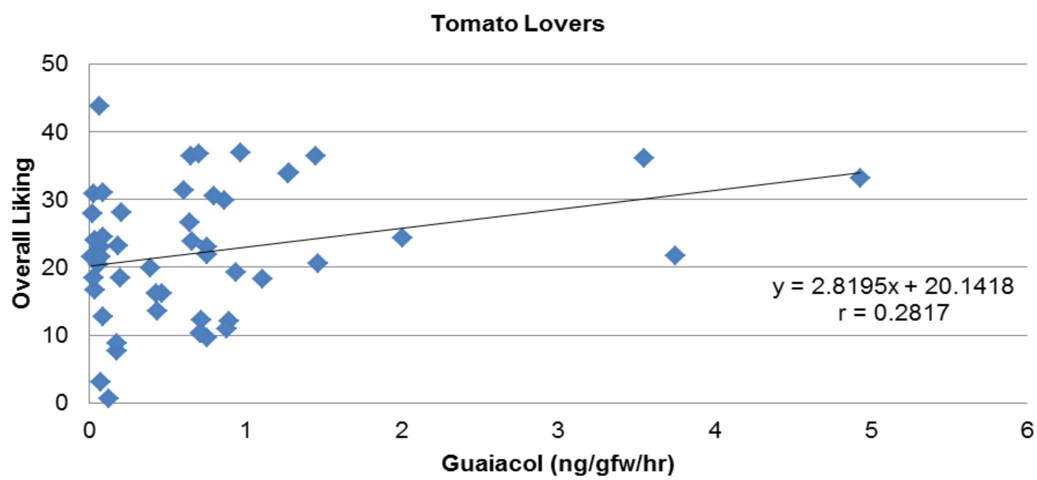


B

Figure 4-41. Correlation and regression for tomato lovers between overall liking and A) *trans*-2-pentenal B) *trans*-3-hexen-1-ol.

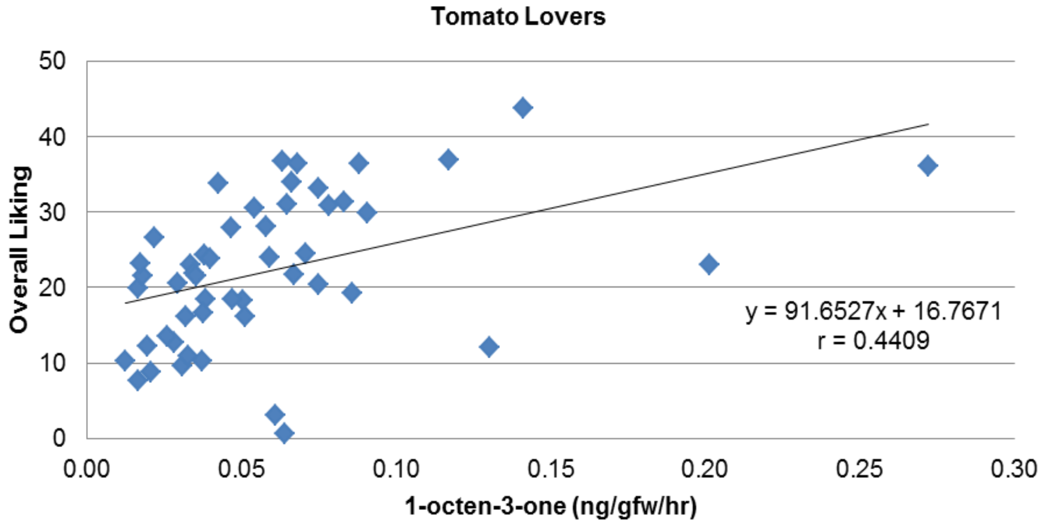


A

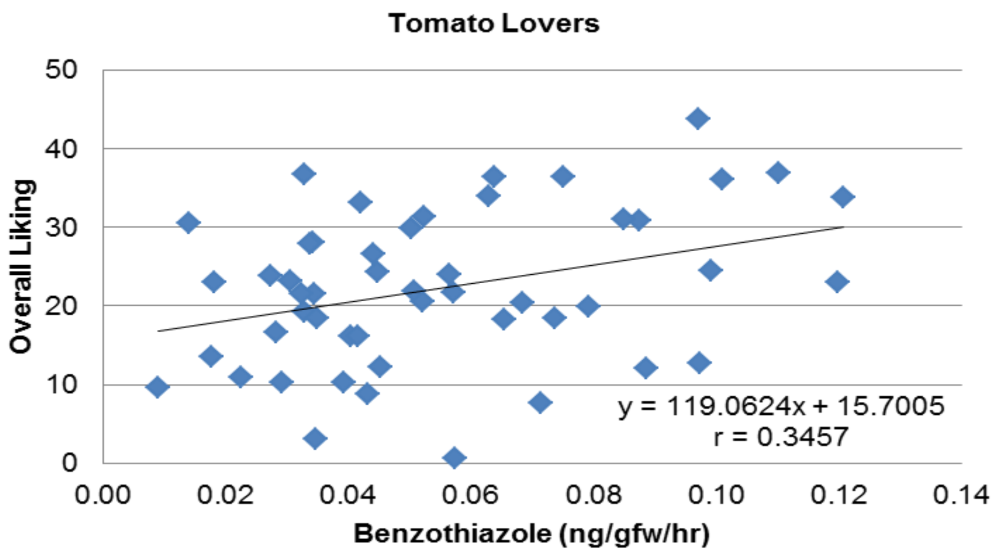


B

Figure 4-42. Correlation and regression for tomato lovers between overall liking and A) 1-pentanol B) guaiacol.

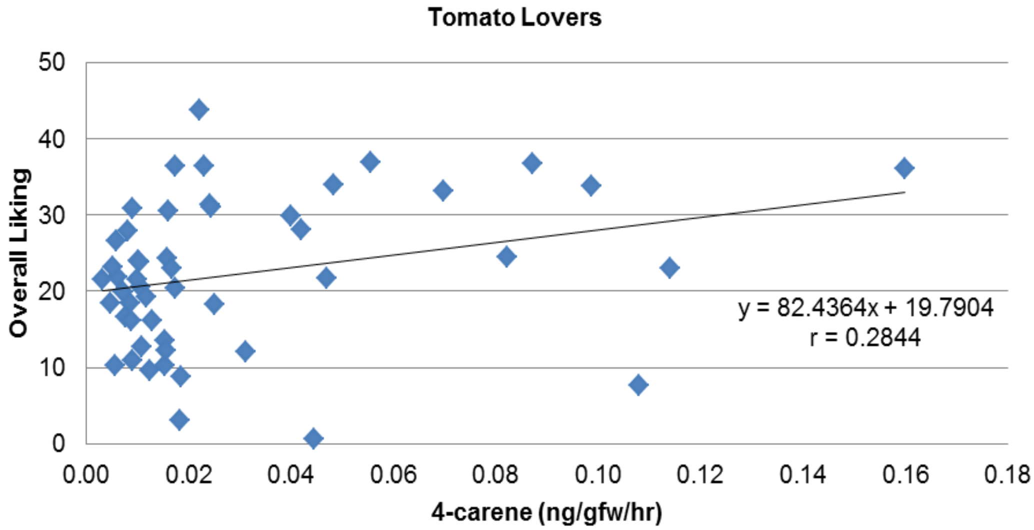


A

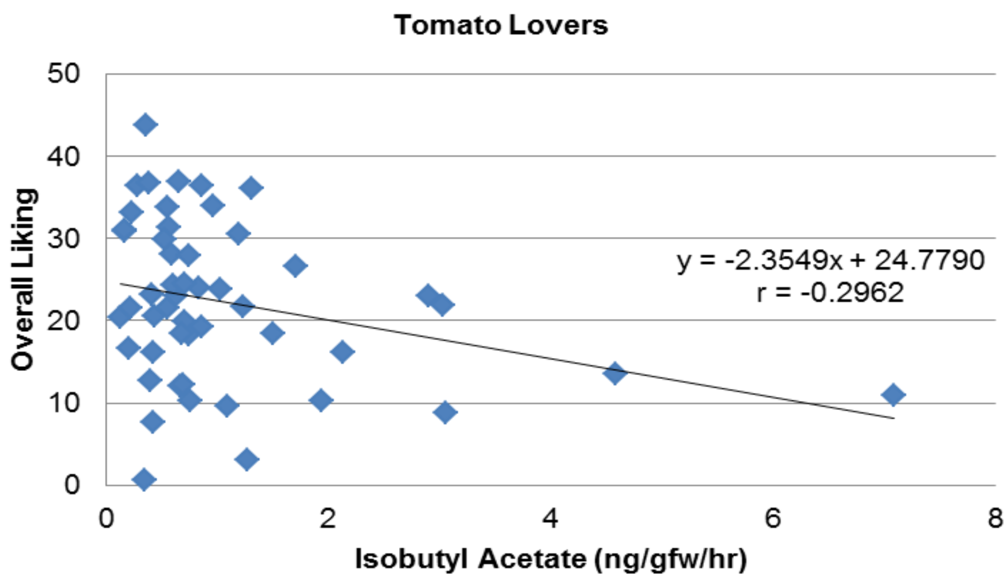


B

Figure 4-43. Correlation and regression for tomato lovers between overall liking and A) 1-octen-3-one B) benzothiazole.



A



B

Figure 4-44. Correlation and regression for tomato lovers between overall liking and A) 4-carene B) isobutyl acetate.

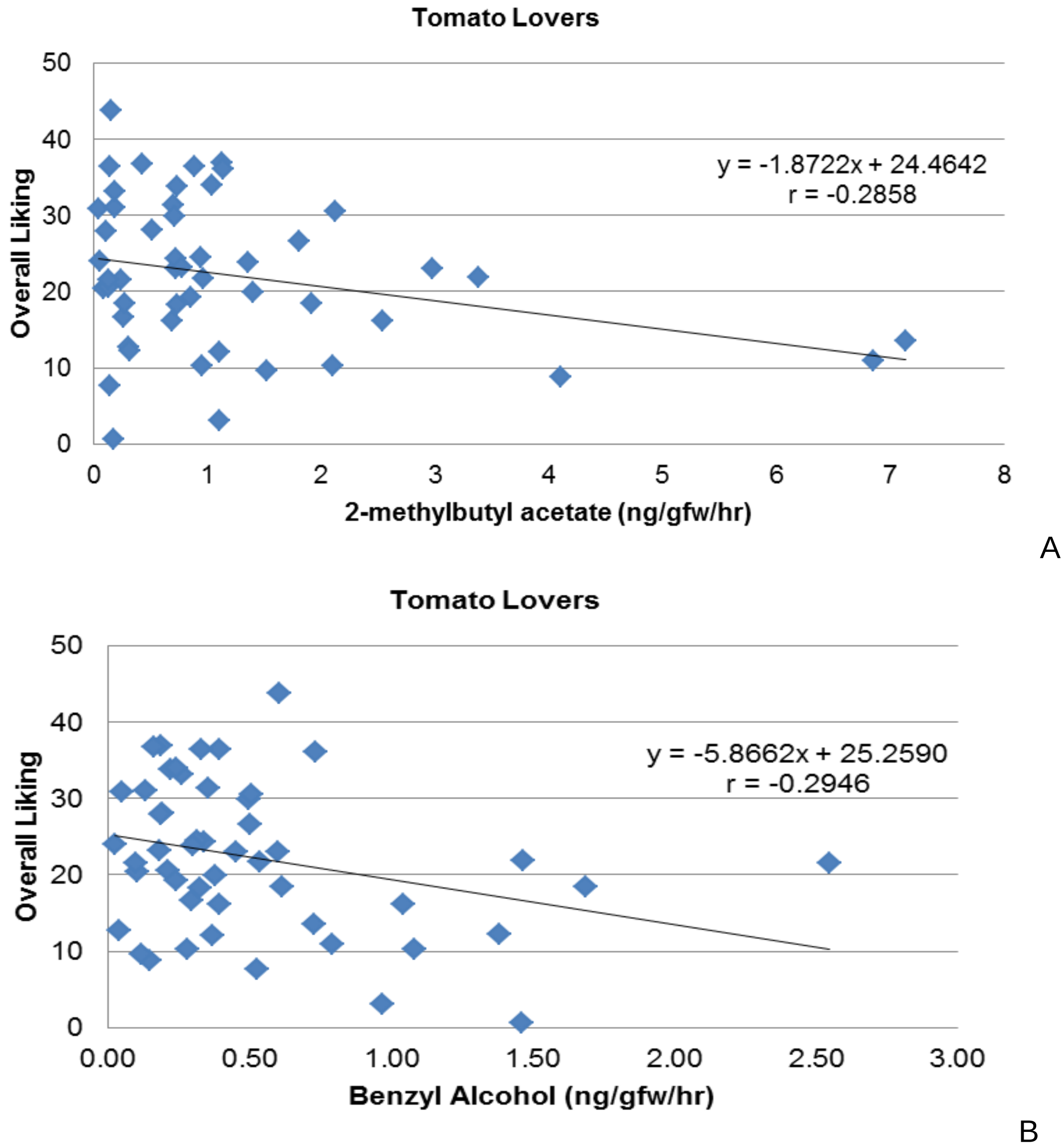
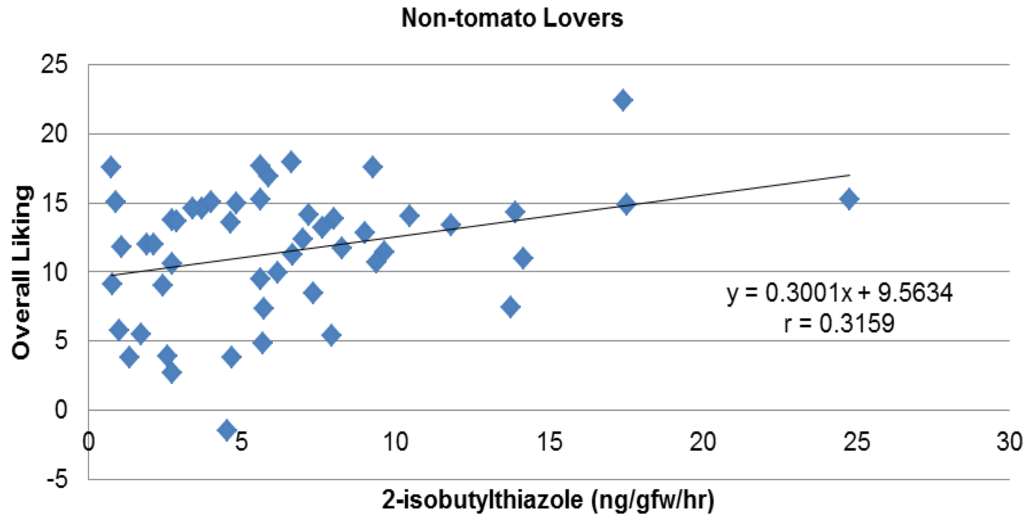
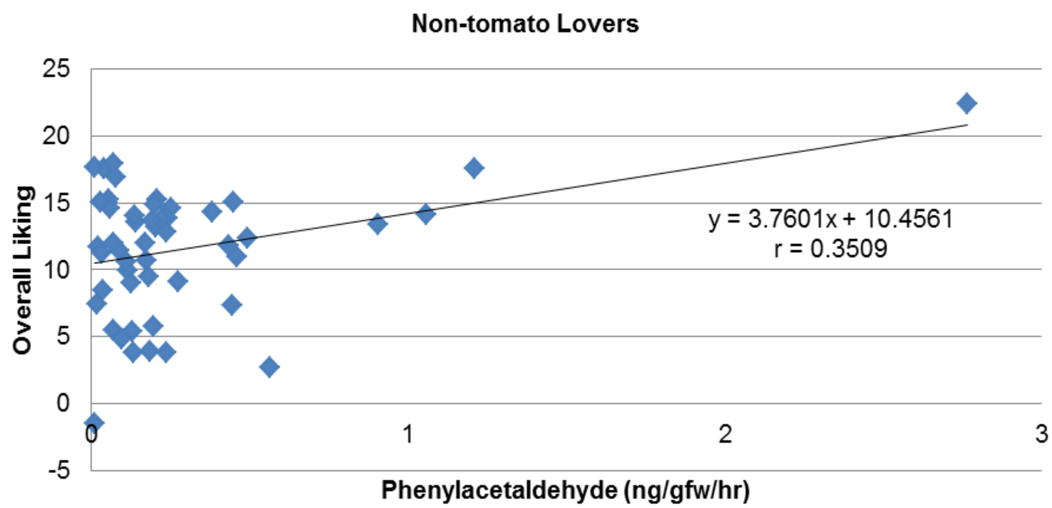


Figure 4-45. Correlation and regression for tomato lovers between overall liking and A) 2-methylbutyl acetate B) benzyl alcohol.

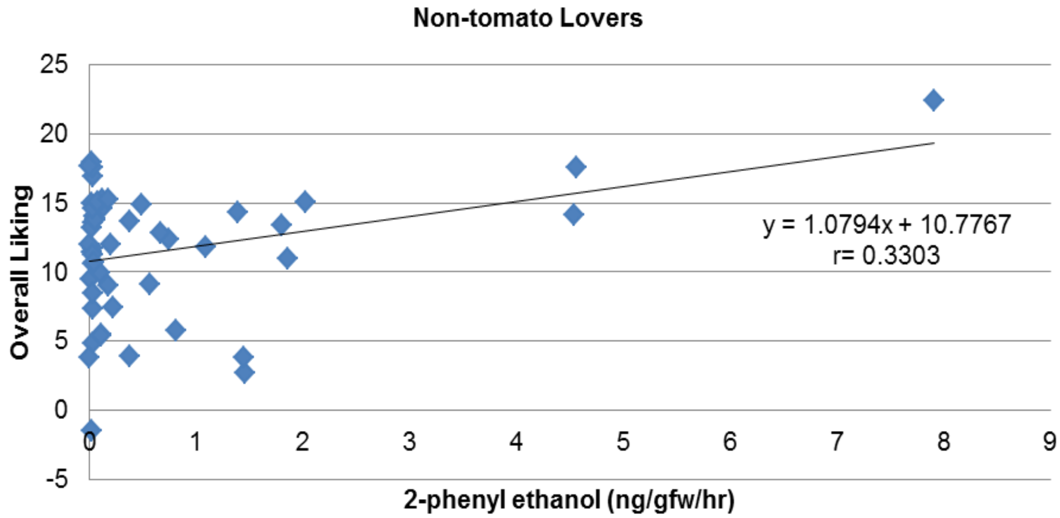


A

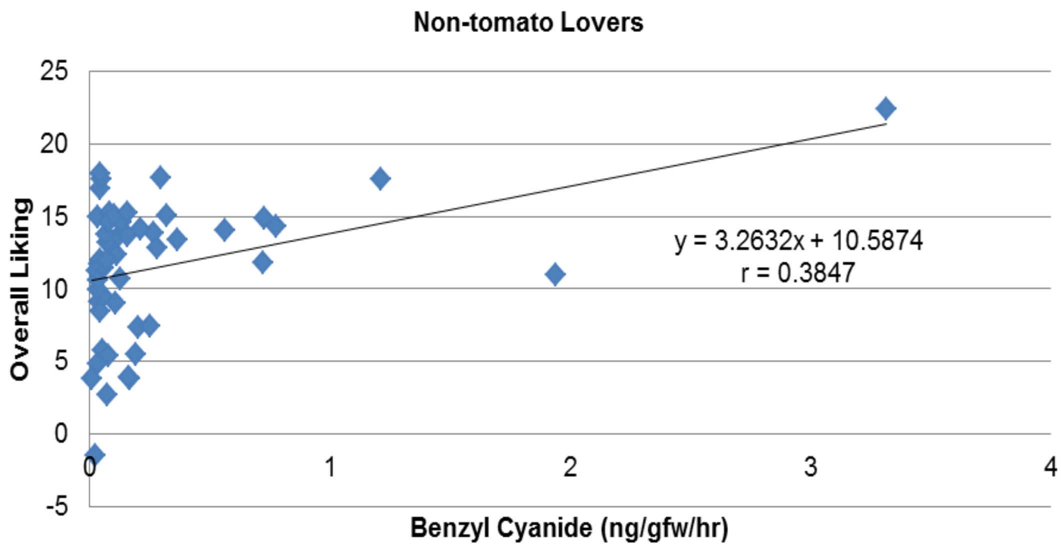


B

Figure 4-46. Correlation and regression for non-tomato lovers between overall liking and A) 2-isobutylthiazole B) phenylacetaldehyde.



A



B

Figure 4-47. Correlation and regression for non-tomato lovers between overall liking and A) 2-phenyl ethanol B) benzyl cyanide.

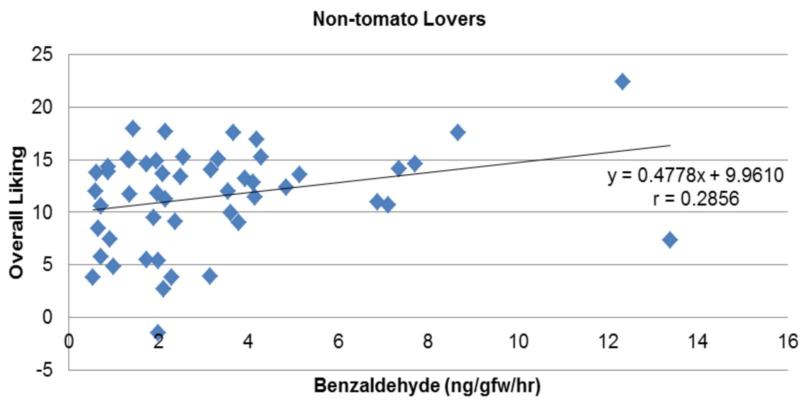


Figure 4-48. Correlation and regression for non-tomato lovers between overall liking and benzaldehyde.

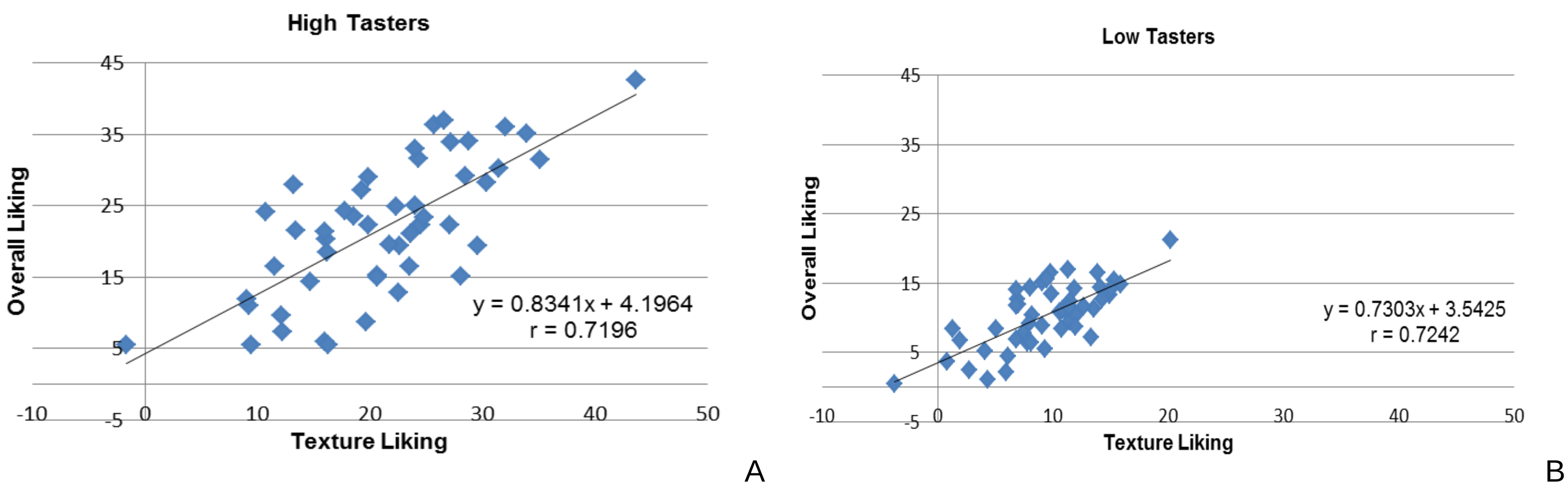


Figure 4-49. Correlation and regression between overall liking and texture liking for A) high tasters and B) low tasters.

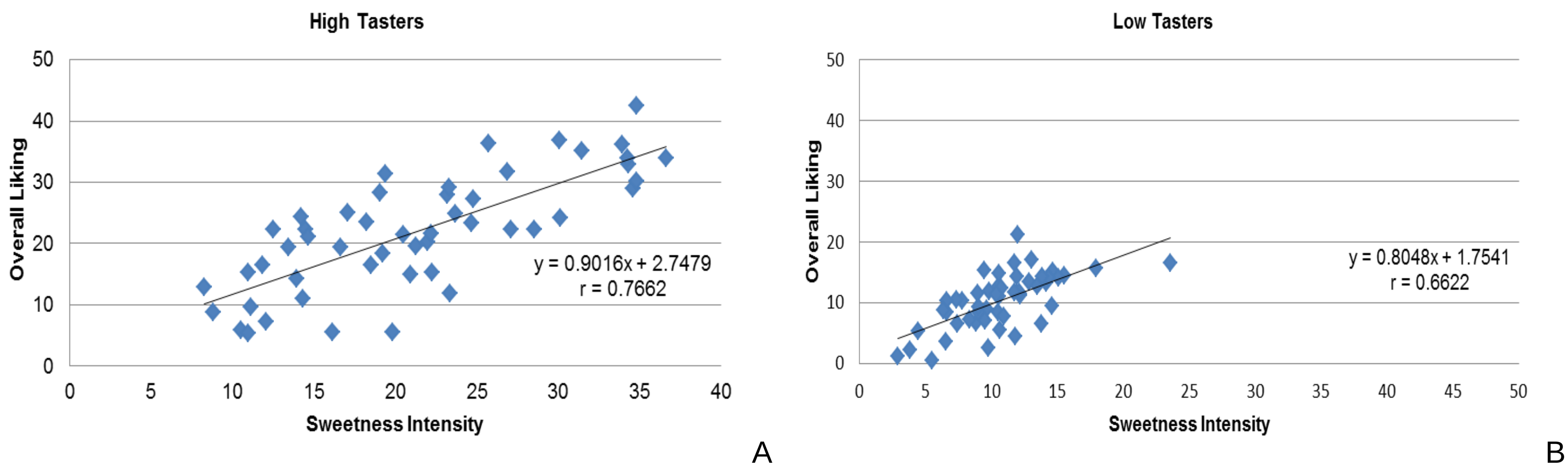


Figure 4-50. Correlation and regression between overall liking and sweetness intensity for A) high tasters and B) low tasters.

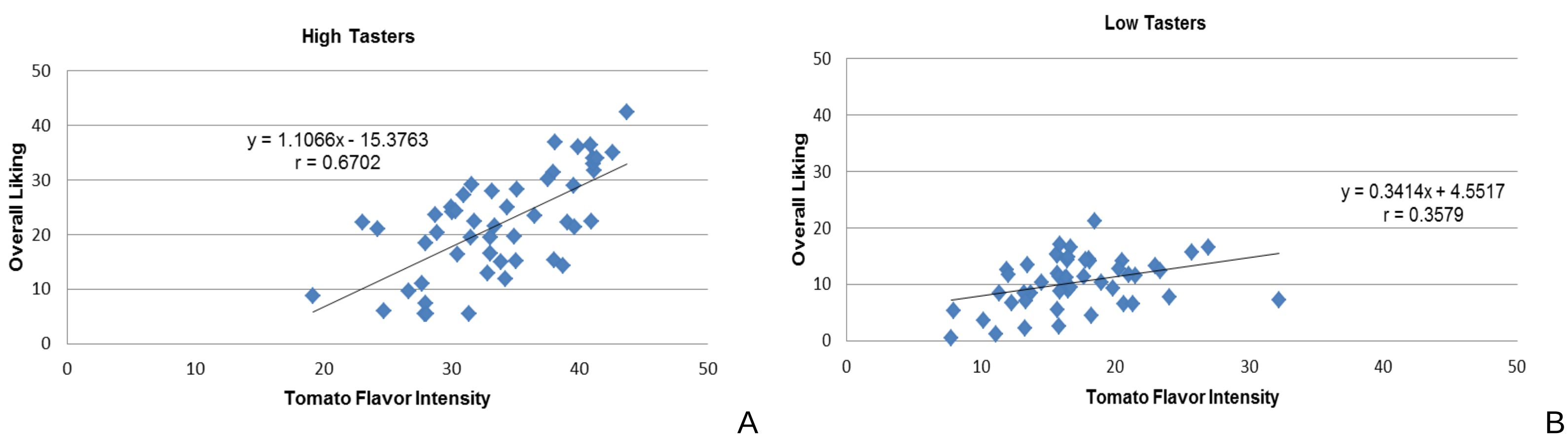


Figure 4-51. Correlation and regression between overall liking and tomato flavor intensity for A) high tasters and B) low tasters.

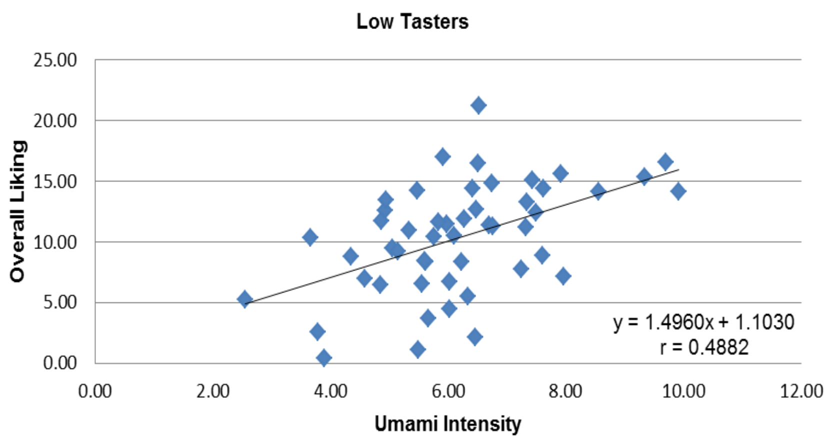
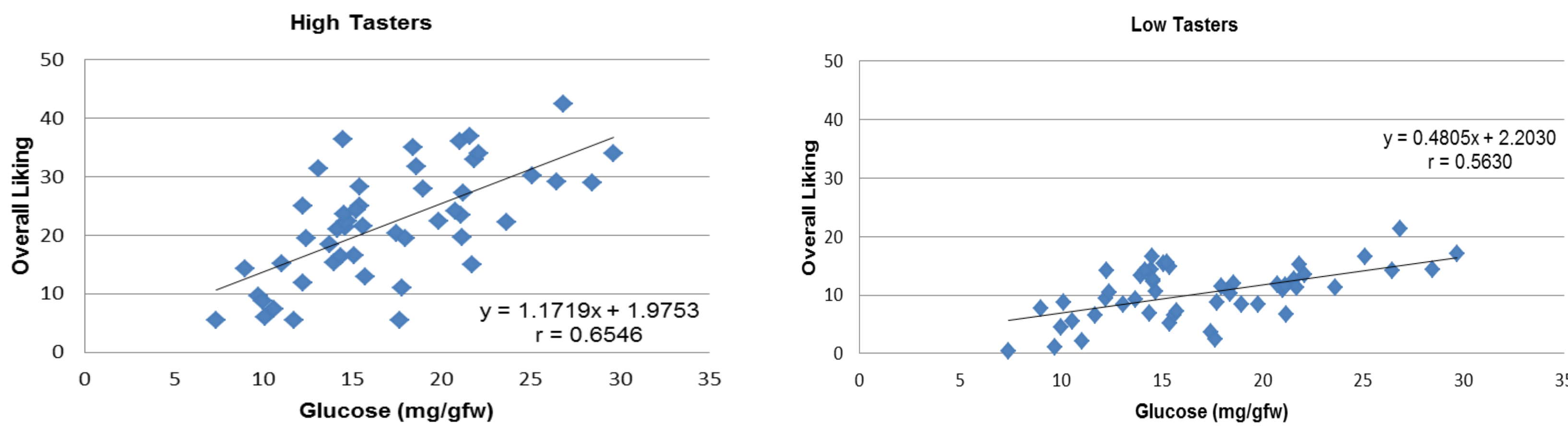


Figure 4-52. Correlation and regression between overall liking and umami intensity for low tasters.



A B

Figure 4-53. Correlation and regression between overall liking and glucose for A) high tasters and B) low tasters.

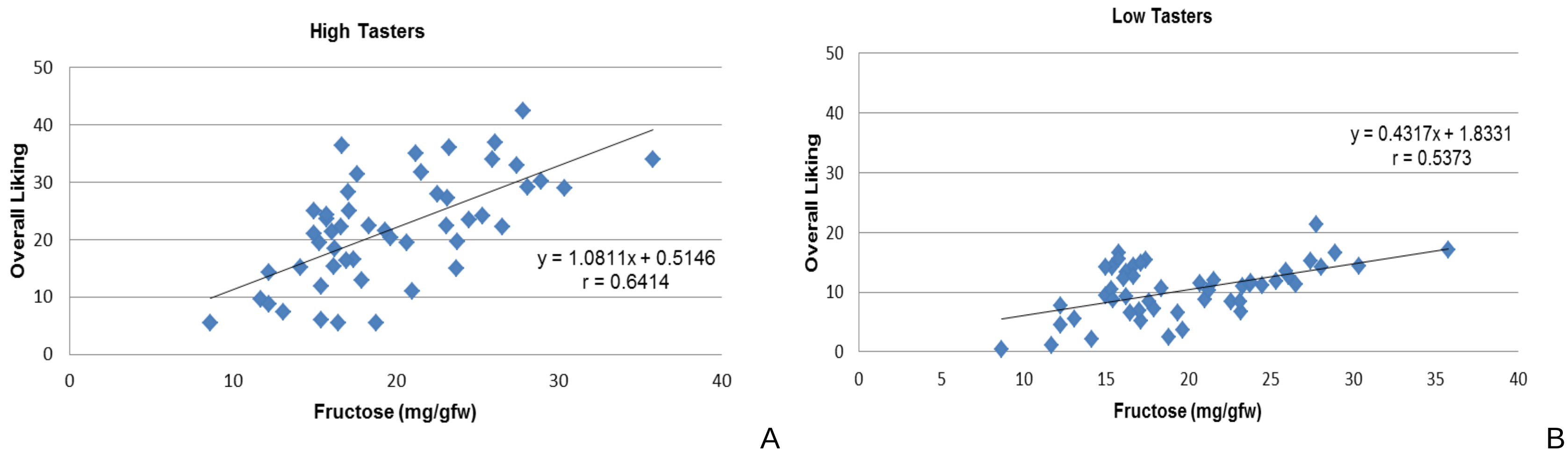


Figure 4-54. Correlation and regression between overall liking and fructose for A) high tasters and B) low tasters.

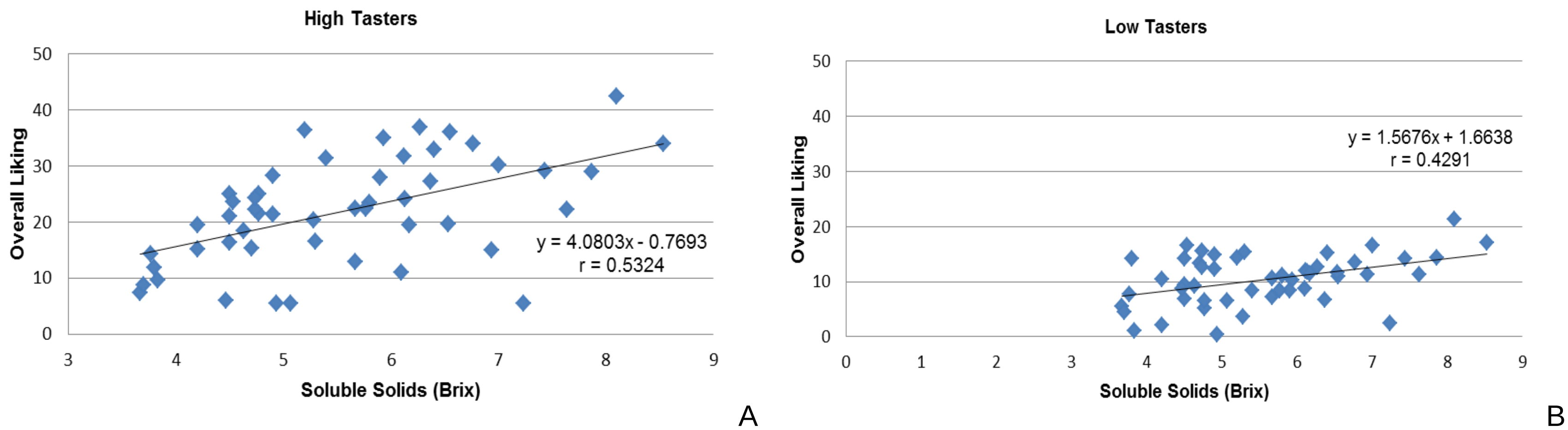


Figure 4-55. Correlation and regression between overall liking and soluble solids for A) high tasters and B) low tasters.

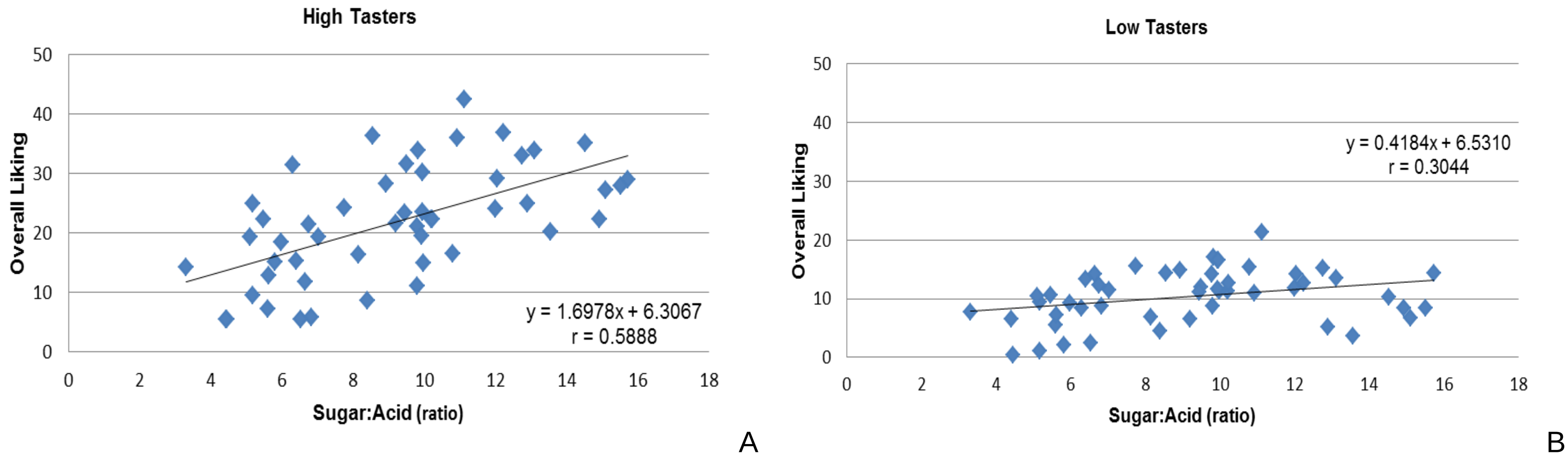


Figure 4-56. Correlation and regression between overall liking and sugar:acid (ratio) for A) high tasters and B) low tasters.

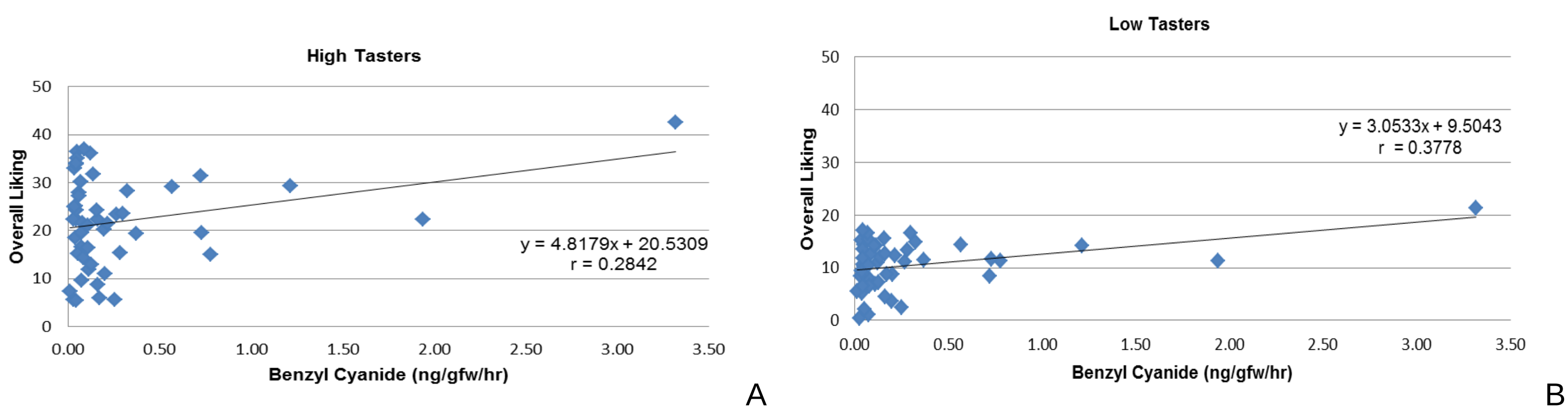


Figure 4-57. Correlation and regression between overall liking and benzyl cyanide A) high tasters and B) low tasters.

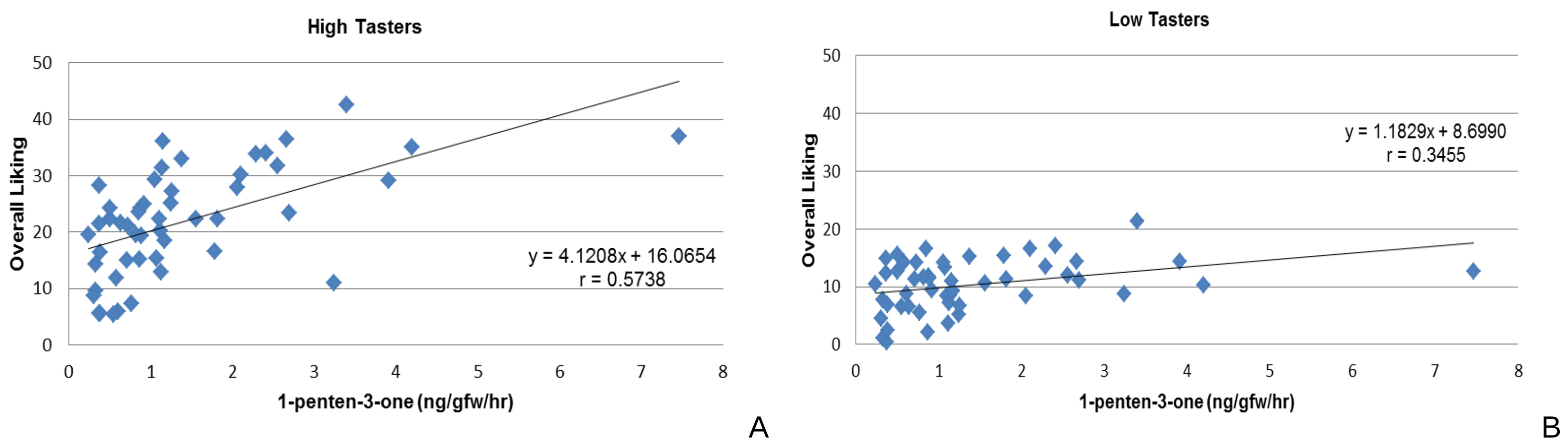


Figure 4-58. Correlation and regression between overall liking and 1-penten-3-one A) high tasters and B) low tasters.

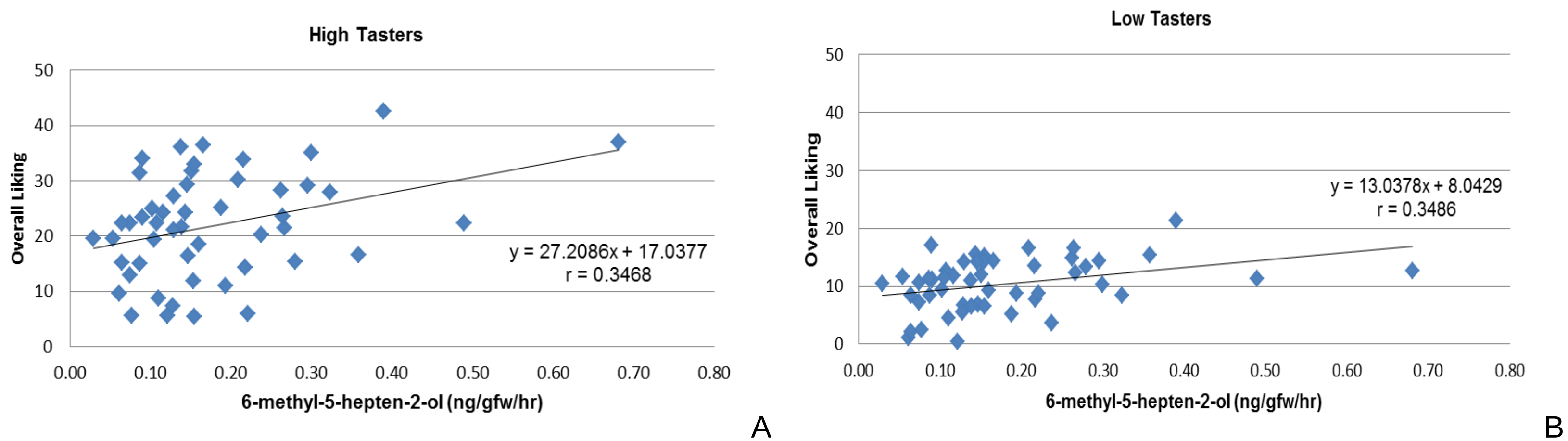


Figure 4-59. Correlation and regression between overall liking and 6-methyl-5-hepten-2-ol for A) high tasters and B) low tasters.

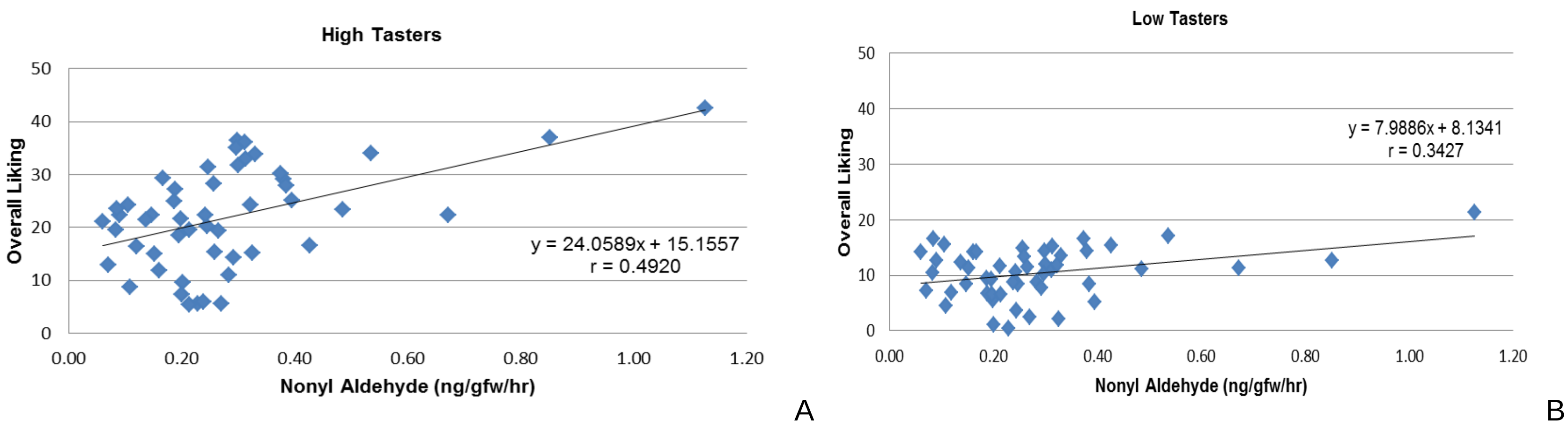


Figure 4-60. Correlation and regression between overall liking and nonyl aldehyde for A) high tasters and B) low tasters.

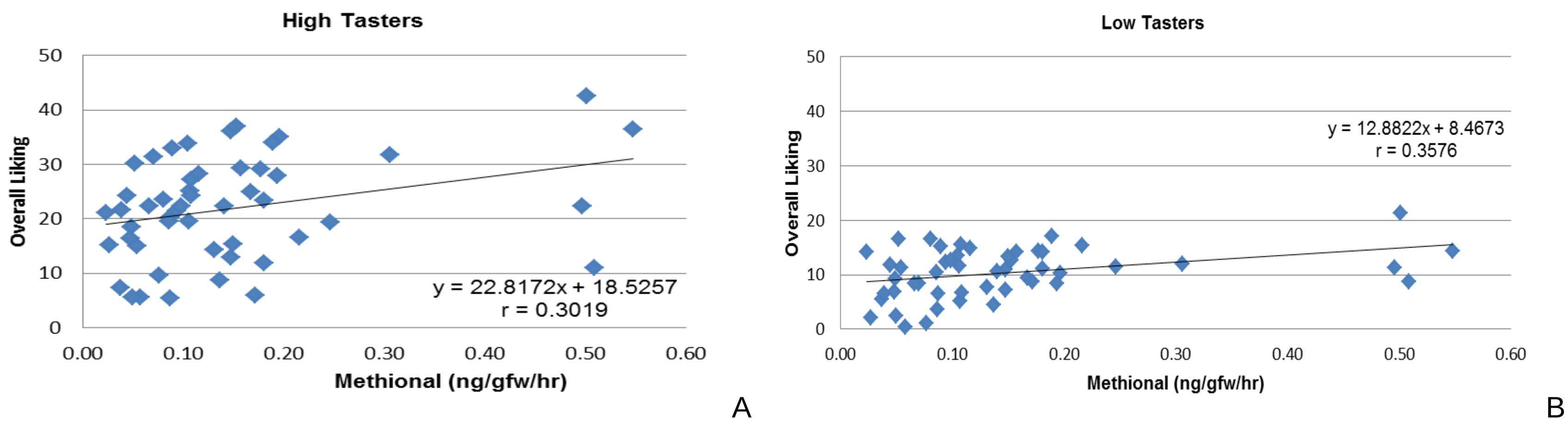
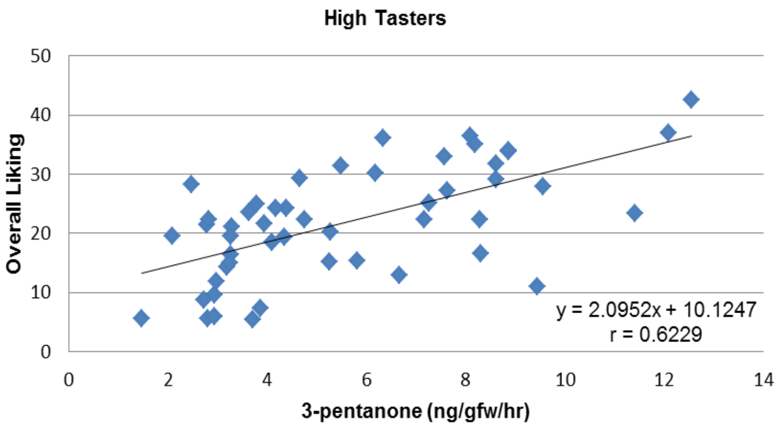
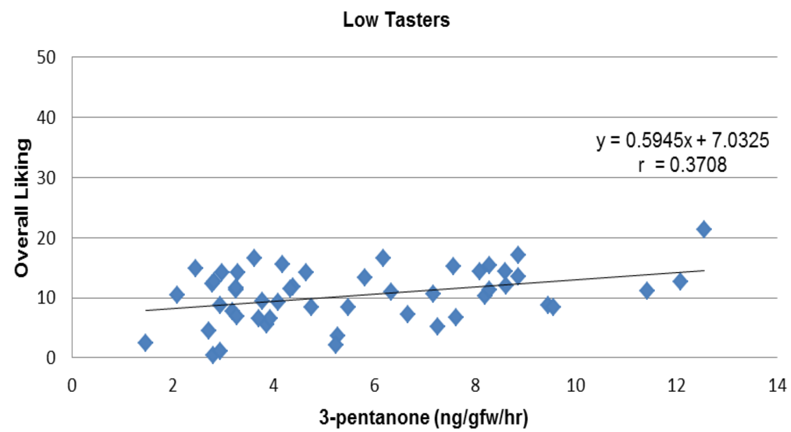


Figure 4-61. Correlation and regression between overall liking and methional for A) high tasters and B) low tasters



A



B

Figure 4-62. Correlation and regression between overall liking and 3-pentanone for A) high tasters and B) low tasters

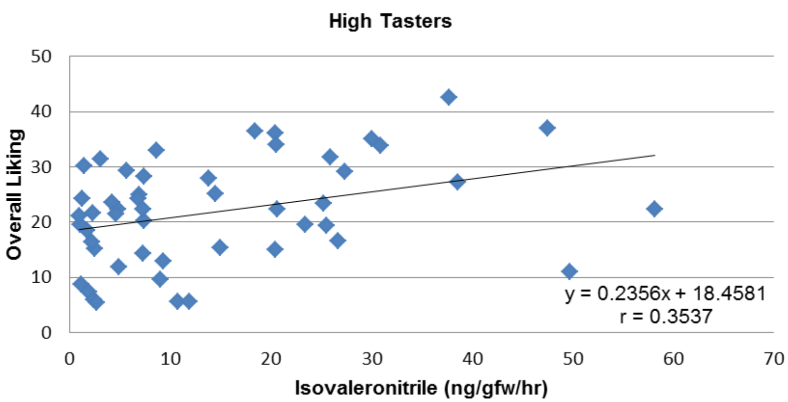
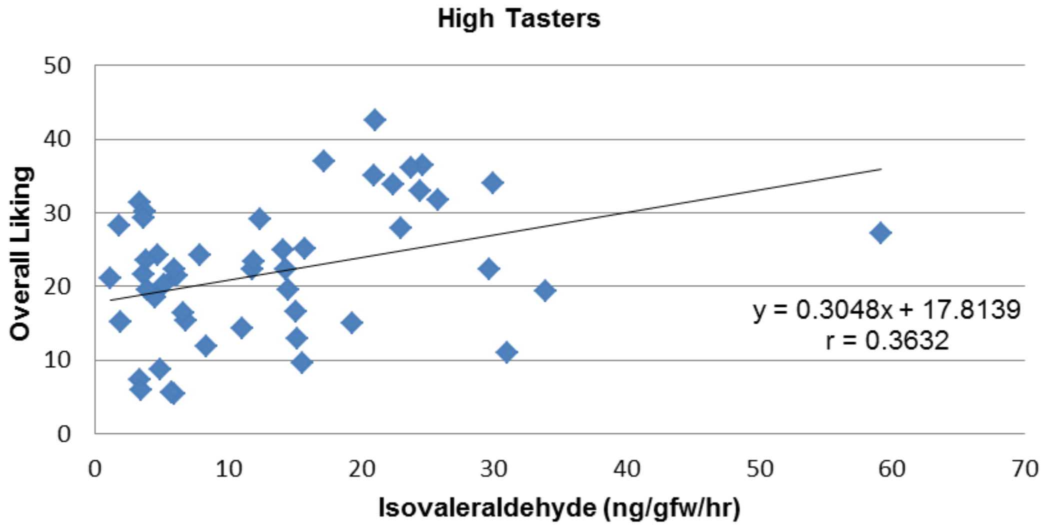
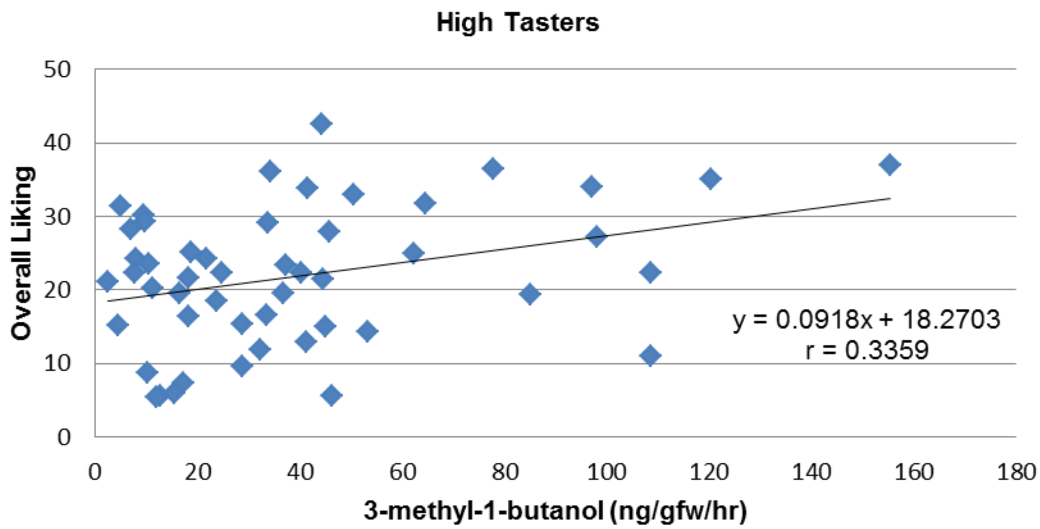


Figure 4-63. Correlation and regression between overall liking and isovaleronitrile for high tasters.



A



B

Figure 4-64. Correlation and regression for high tasters between overall liking and A) isovaleraldehyde B) 3-methyl-1-butanol.

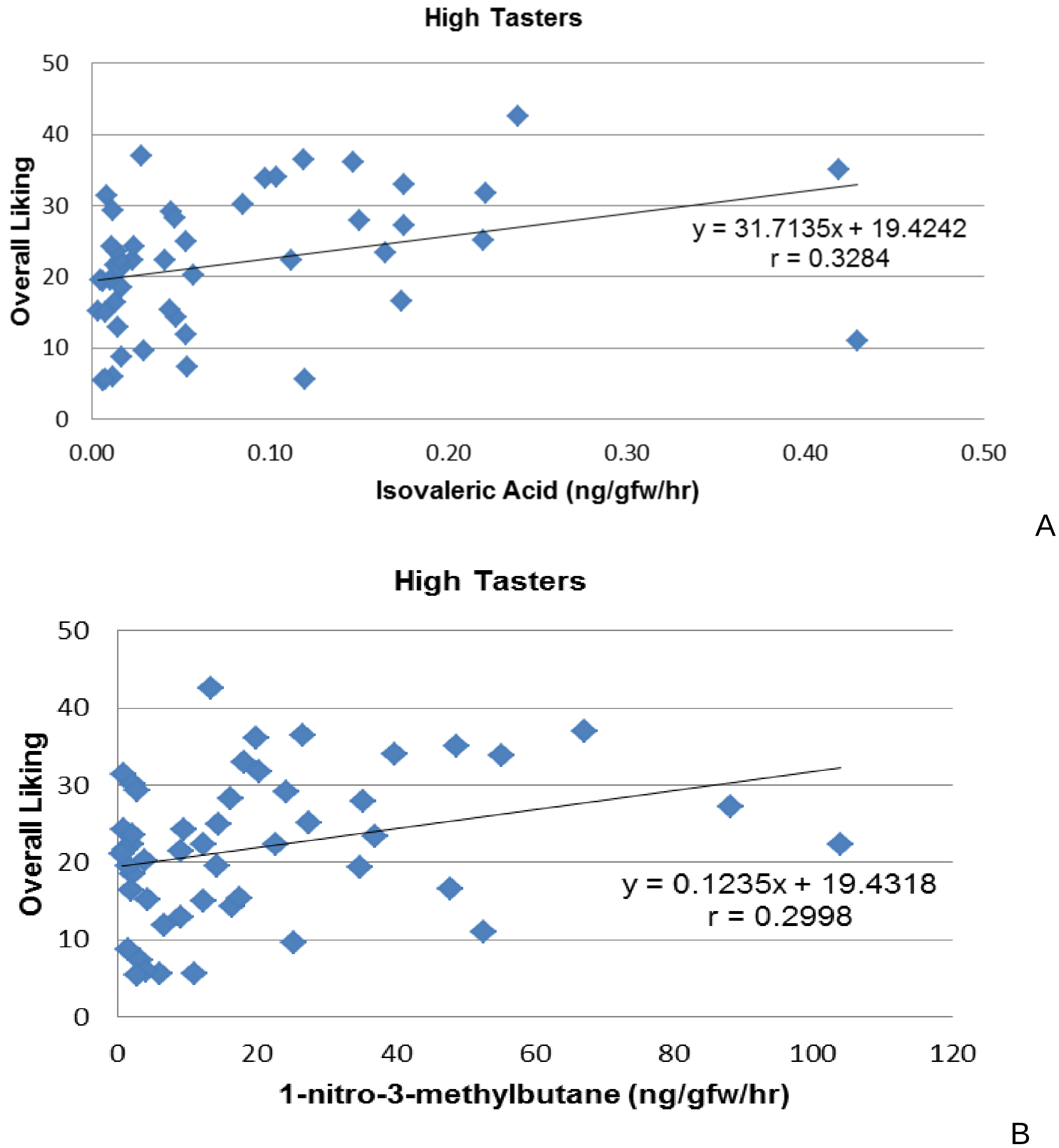
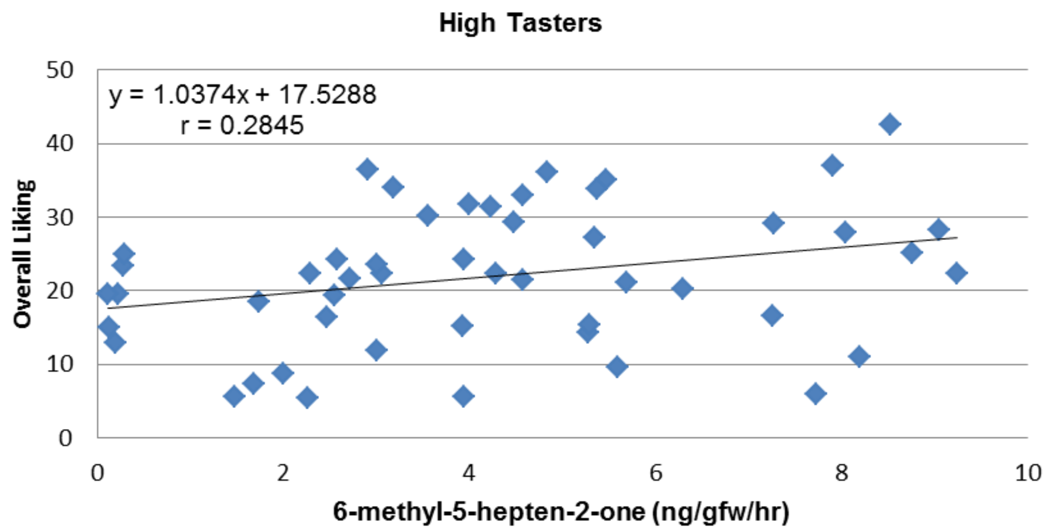
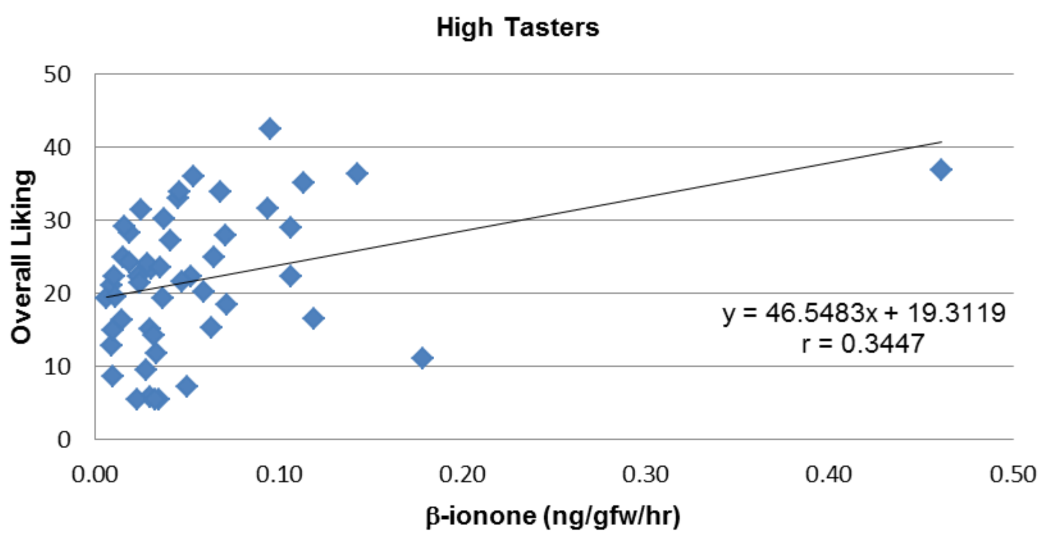


Figure 4-65. Correlation and regression for high tasters between overall liking and A) isovaleric Acid B) 1-nitro-3-methylbutane.

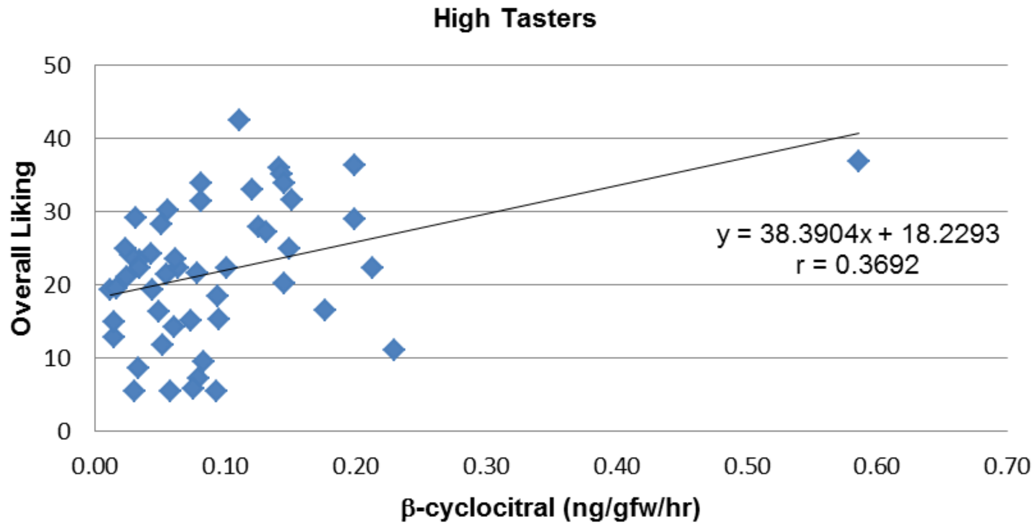


A

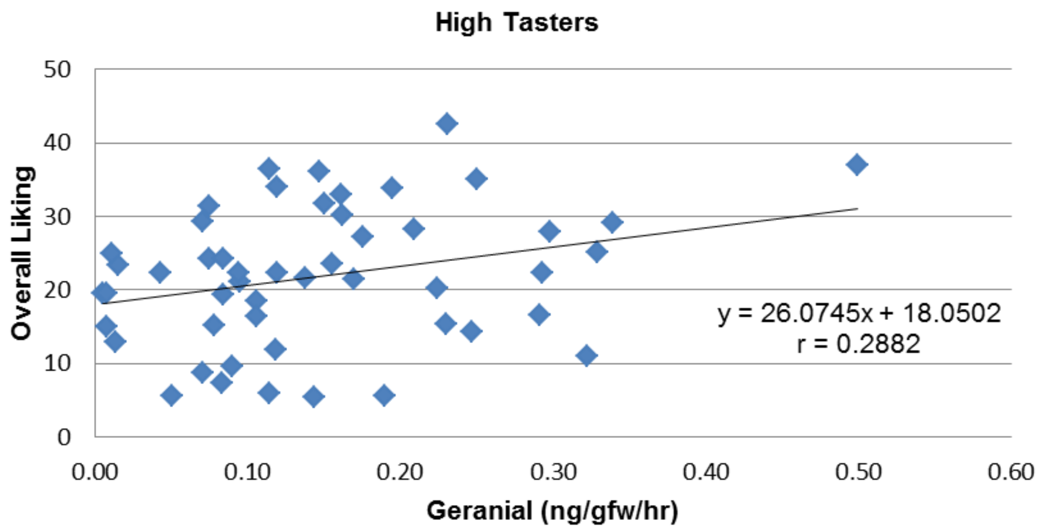


B

Figure 4-66. Correlation and regression for high tasters between overall liking and A) 6-methyl-5-hepten-2-one B) β-ionone.

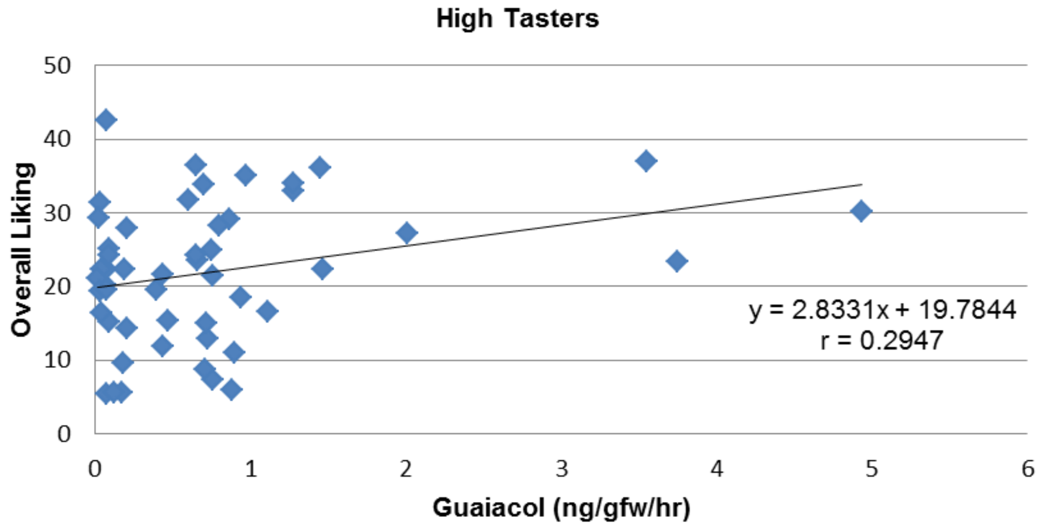


A

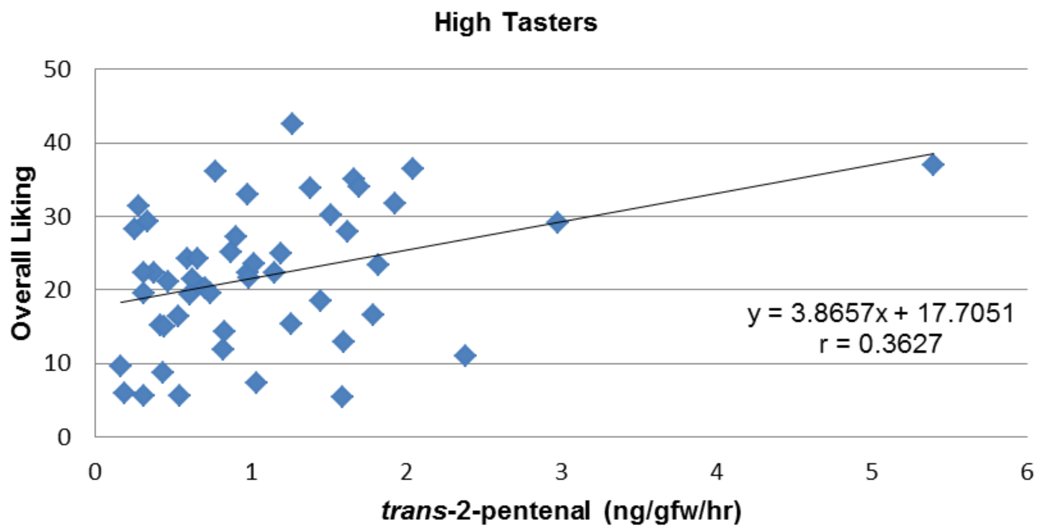


B

Figure 4-67. Correlation and regression for high tasters between overall liking and A) β-cyclocitral B) geranial.

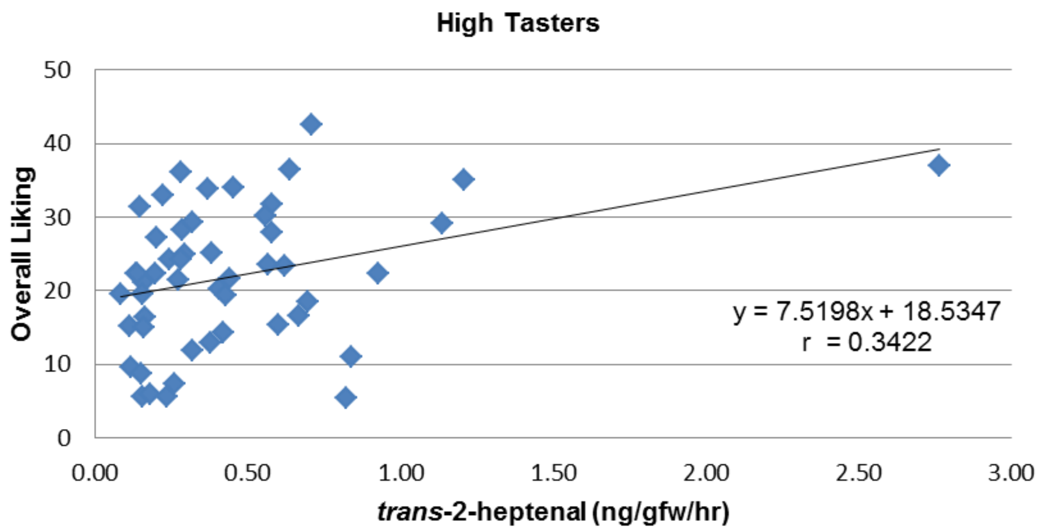


A

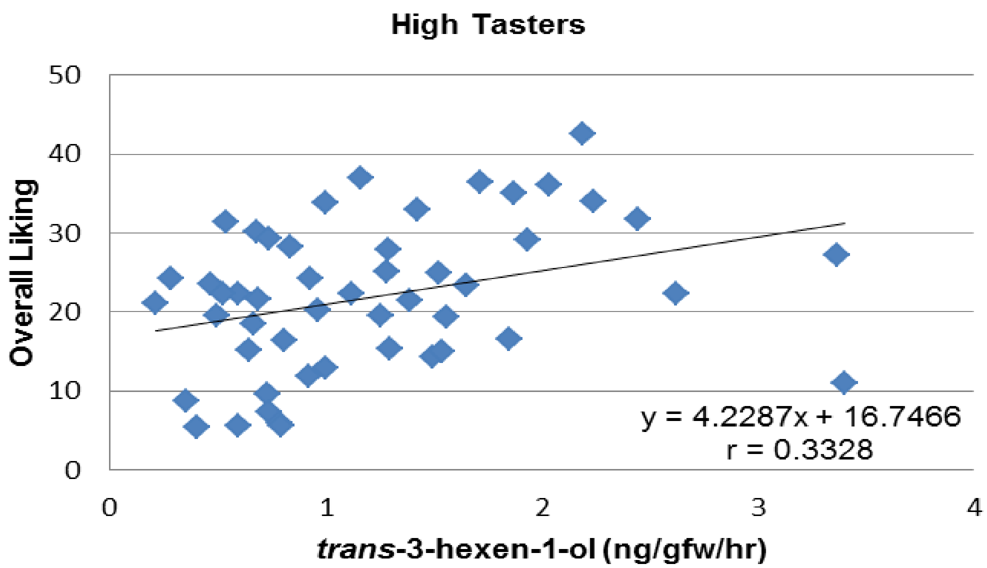


B

Figure 4-68. Correlation and regression for high tasters between overall liking and A) guaiacol B) *trans*-2-pentenal.

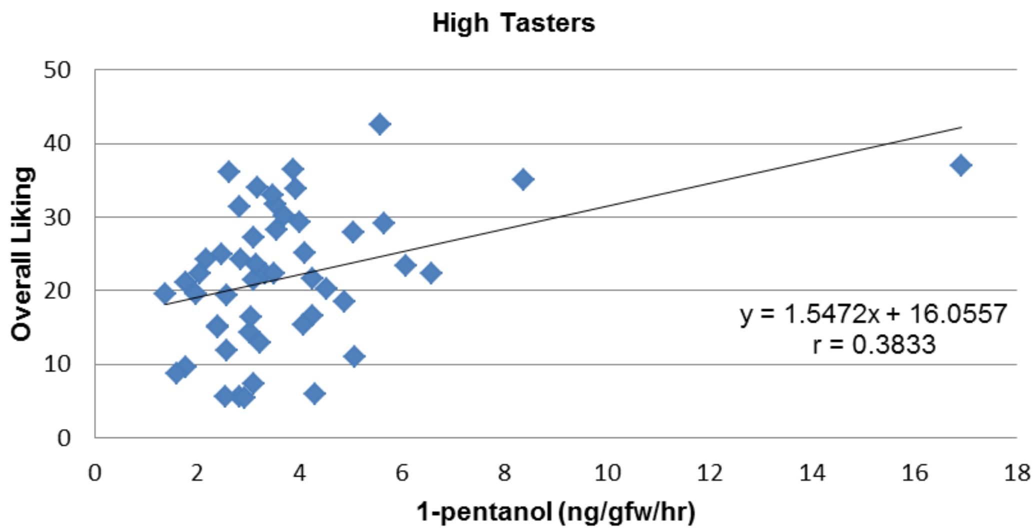


A

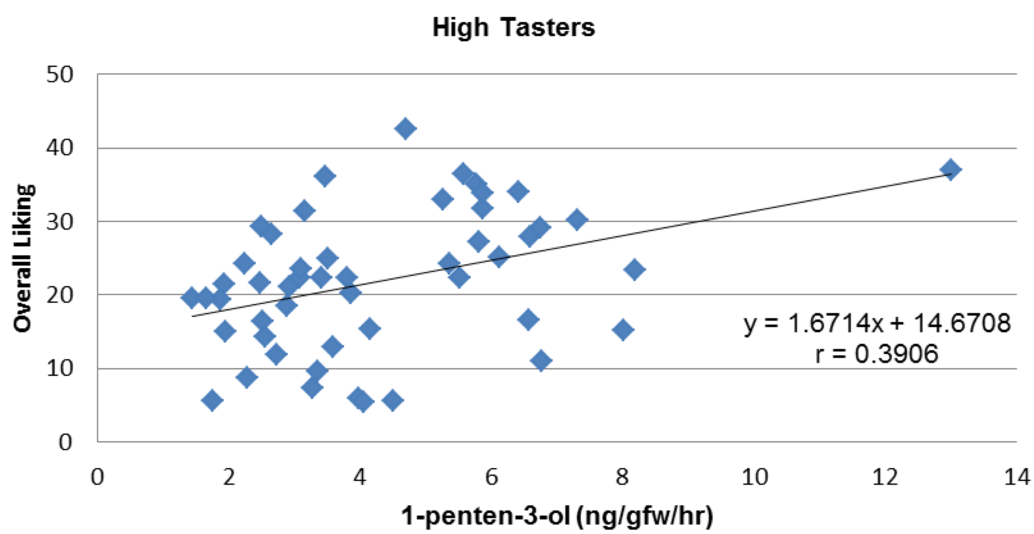


B

Figure 4-69. Correlation and regression for high tasters between overall liking and A) *trans*-2-heptenal B) *trans*-3-hexen-1-ol.

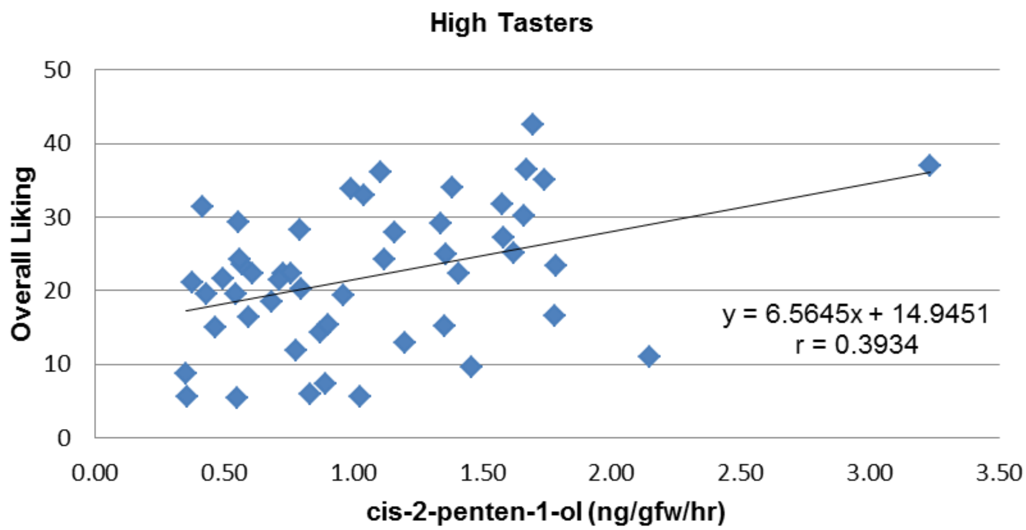


A

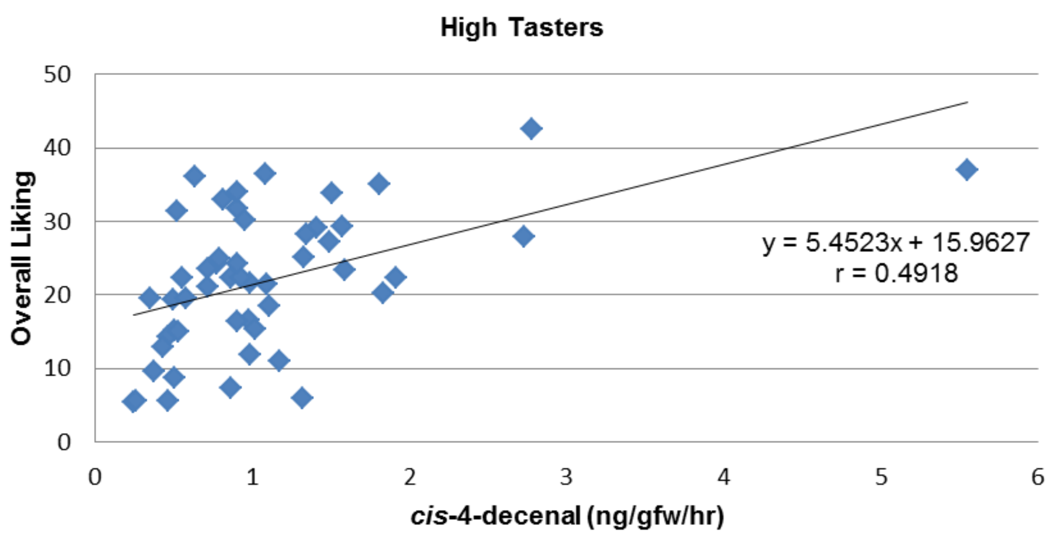


B

Figure 4-70. Correlation and regression for high tasters between overall liking and A) 1-pentanol B) 1-penten-3-ol.

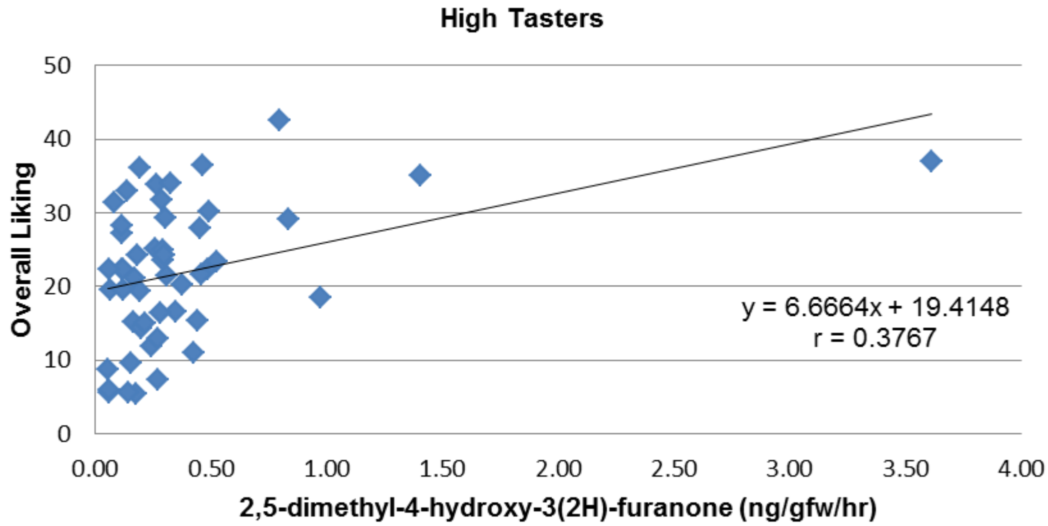


A

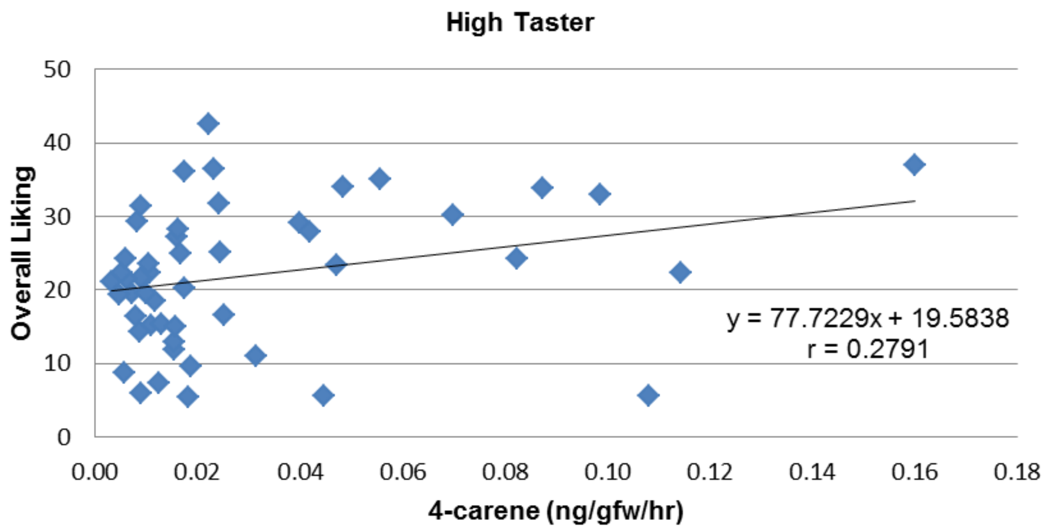


B

Figure 4-71. Correlation and regression for high tasters between overall liking and A) *cis*-2-penten-1-ol B) *cis*-4-decenal.

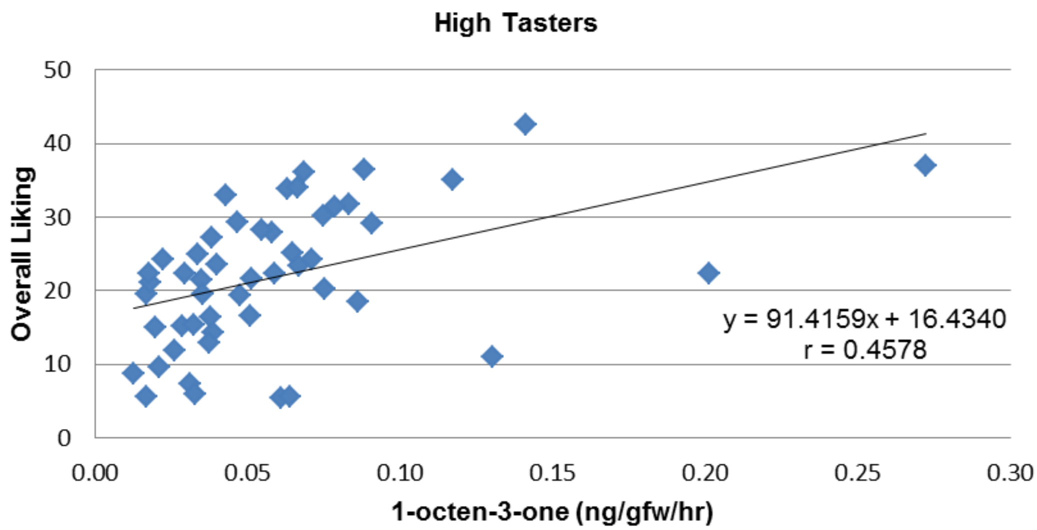


A

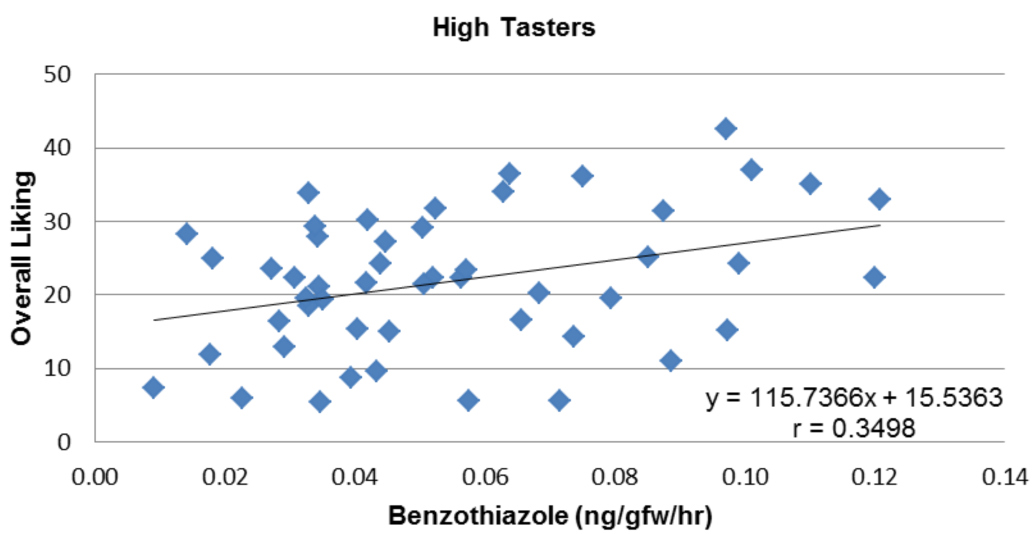


B

Figure 4-72. Correlation and regression for high tasters between overall liking and A) 2,5-dimethyl-4-hydroxy-3(2H)-furanone B) 4-carene.

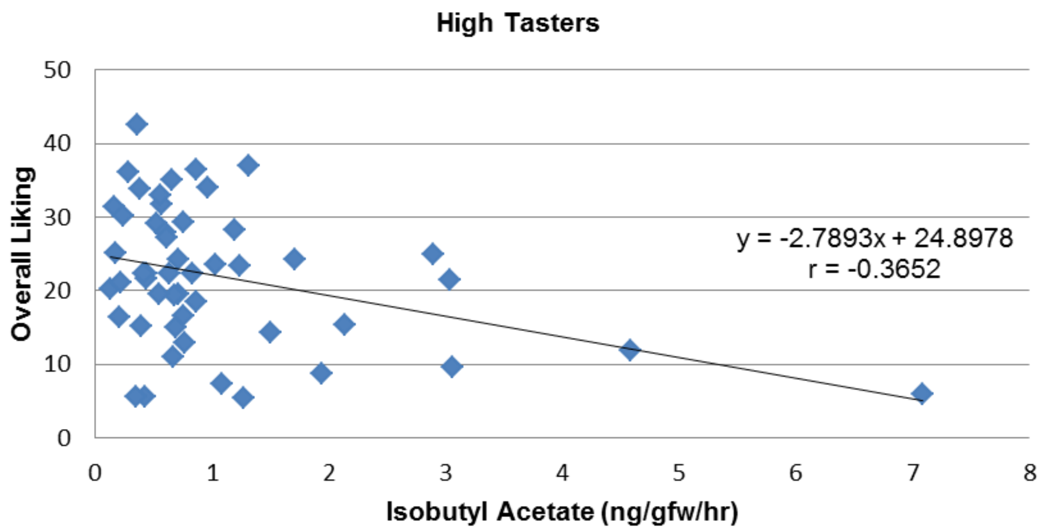


A

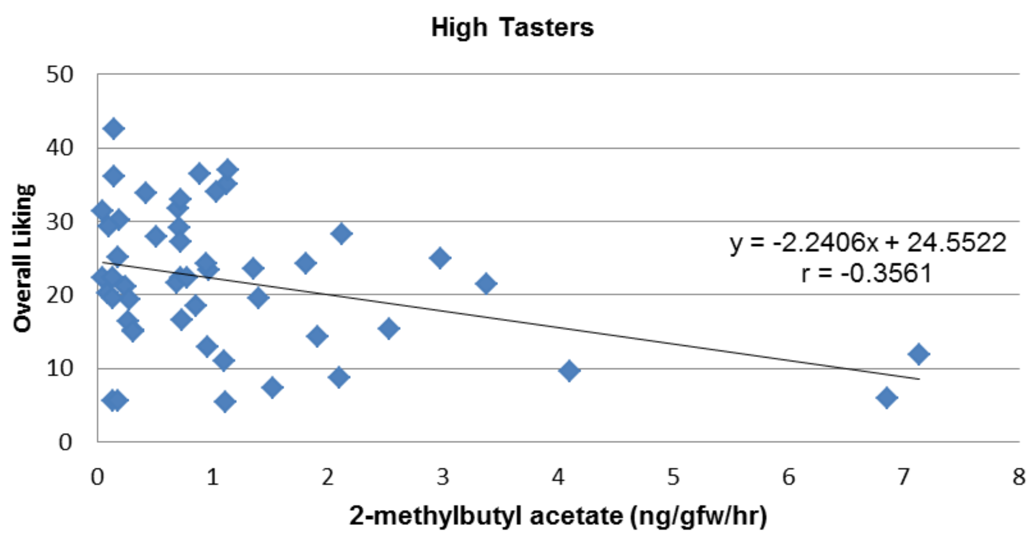


B

Figure 4-73. Correlation and regression for high tasters between overall liking and A) 1-octen-3-one B) benzothiazole.

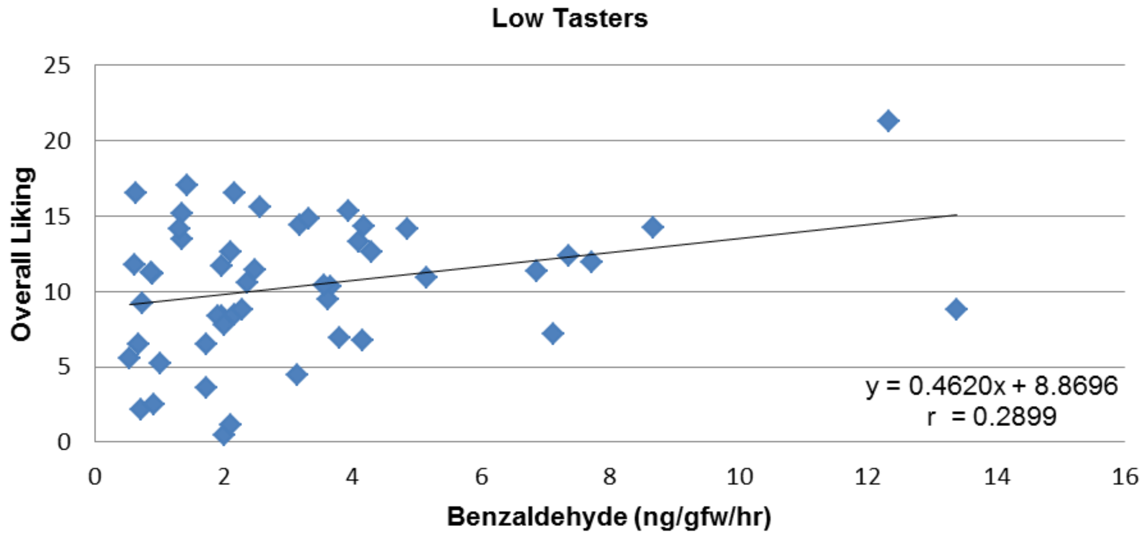


A

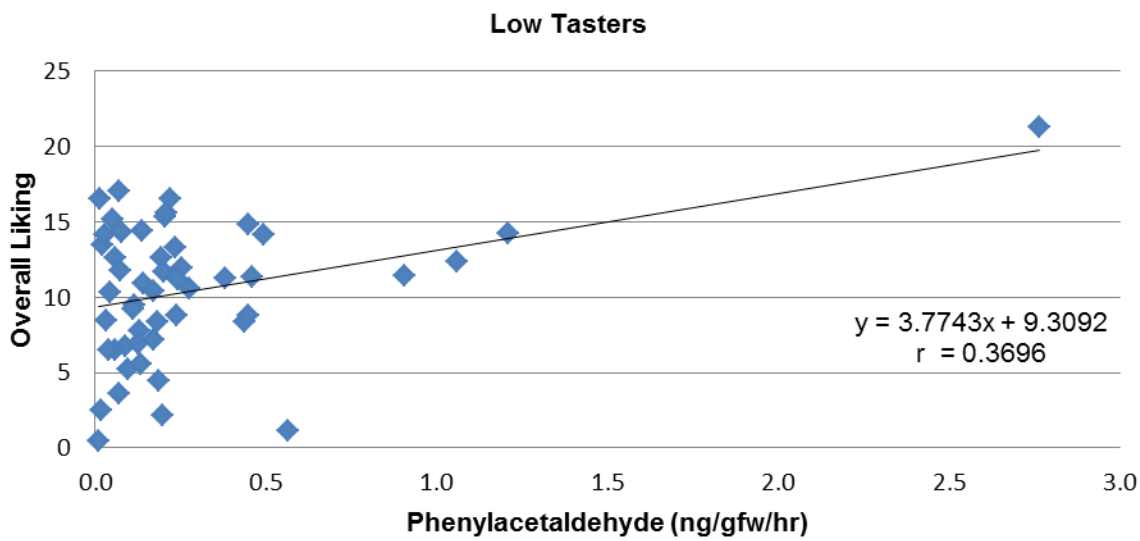


B

Figure 4-74. Correlation and regression for high tasters between overall liking and A) isobutyl Acetate B) 2-methylbutyl acetate.

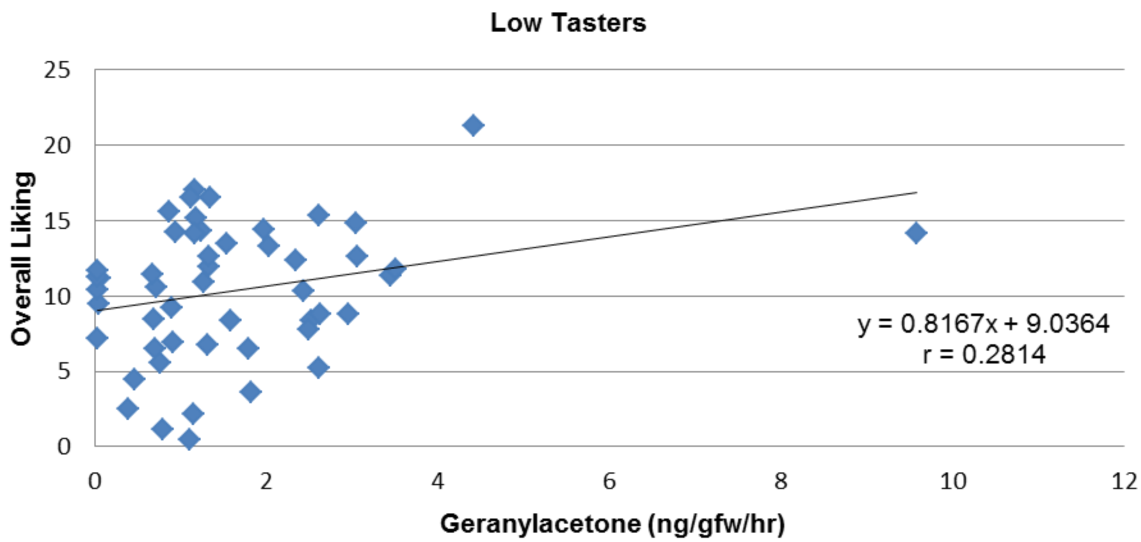


A

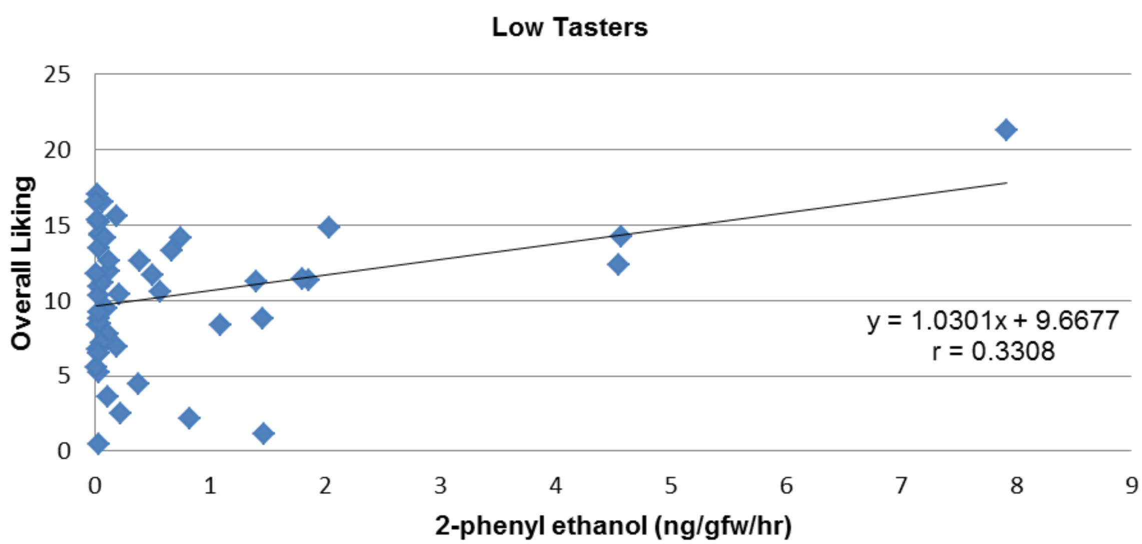


B

Figure 4-75. Correlation and regression for low tasters between overall liking and A) benzaldehyde B) phenylacetaldehyde.



A



B

Figure 4-76. Correlation and regression for low tasters between overall liking and A) geranylacetone B) 2-phenyl ethanol.

CHAPTER 5
CONCLUSIONS

The information collected with all panelists reflected that liking of tomatoes is influenced by the liking of the texture, sweetness intensity, and tomato flavor intensity. A relationship between overall liking and umami was also found, however, it was weaker than the correlations with the other variables. A positive correlation between saltiness and umami, and a lack of correlation between glutamic acid and overall liking, led us to believe that panelists were not distinguishing between saltiness and umami. These data suggest that increments in acceptability of tomatoes could be obtained by improving texture, and increasing the intensity of sweetness, and tomato flavor. On the other hand, increments in bitterness cause decreases in acceptability, which is shown by the negative correlation between liking of tomatoes and bitterness intensity.

From the non-volatile components analyzed during this study, only glucose, fructose, soluble solids, and the ratio of sugars to acids were positively correlated with overall liking. Acids were not a factor of influence in acceptability. Although it is tempting to assume that an increase in sugars by itself could improve liking of tomatoes, it is also necessary to account for the role played by volatile compounds. Increases in sugar content of tomatoes can be done only to a certain point without affecting yield, but there is a bigger chance of changing volatile content without sacrificing production.

From 62 volatiles studied, 25 were positively correlated with overall liking. When grouped according to their precursors, five come from amino acids, five from carotenoids, eight from lipids, one phenylpropanoid, and six from unknown pathways.

Only six of the seventeen previously reported as being important for tomato flavor were correlated with liking of tomatoes. This indicates that there is a need to reevaluate the threshold technique, by which the volatiles that were supposed to be important for tomato flavor were determined in the past. Threshold methods provide a limited view of the capacities of our senses and also fail to describe suprathreshold sensitivity. A good example for this situation is *cis*-3-hexenal. This volatile was believed to be an important contributor to for tomato flavor based on its threshold but in this study no significant relationship was found between this compound and acceptability of tomatoes. On the other hand, the volatiles that were correlated with overall liking are not necessarily present in high concentrations in tomato fruit. For instance, nonyl aldehyde is found even in quantities as small as 0.20 ng/gfw/hr and it presented a positive influence in acceptability.

The list of volatiles important to tomato flavor changes depending on the consumer groups. In the case of “Tomato Lovers” and “Non-tomato Lovers”, they presented a shared list of volatiles, but also some unique correlations. For the shared list, “Tomato Lovers” always showed a higher Pearson correlation coefficient (r), which may indicate that the presence of these volatiles in tomato fruit is more important for this group than for “Non-tomato Lovers”. Also, “Tomato Lovers” showed a higher number of correlations between overall liking and volatiles, as well as negative correlations between isobutyl acetate, 2-methylbutate acetate, and also benzyl alcohol. “Non-tomato Lovers” did not show any negative correlation.

In the case of “High tasters” and “Low Tasters”, the first group showed greater correlations between liking and volatiles. “High tasters” showed a total of 27 correlations, while “Low tasters” only showed 11 correlations. “High Tasters” also showed negative correlations between overall liking and Isobutyl acetate and 2-

methylbutyl acetate, which was not the case for “Low tasters”. This difference in the amount of volatiles correlated with overall liking in each group suggests that there is a different level of sensitivity to this set of volatiles between these groups.

This project has focused on the study of linear relationships between acceptability and sensory variables, volatiles and non-volatiles, but the complex interactions between volatiles require an experimental design such that the role of every compound is studied when present or absent in the fruit matrix. However, this study provides new insight of the complexity of tomato flavor and most importantly, offers a roadmap to obtain a great tasting tomato. Those volatiles that are correlated with overall liking and are found in small quantities can be increased, and those that are negatively correlated need to be excluded or reduced. If a tomato is developed for different consumer groups, such as “High tasters” or “Low tasters” different parameters need to be adjusted for each group. Researchers and breeders have the alternative of creating a tomato that meets these characteristics or improving one of the tomatoes that is closest to these parameters.

APPENDIX A

QUESTIONNAIRE

Question # 1.

Please indicate your gender.

- ❍ Male
- ❍ Female

Question # 2.

Please enter your age.

Mage ___________

Question # 3 - Sample <<Sample1>>

Please enter your age.

Fage ___________

Question # 4 - Sample <<Sample1>>

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

Height ___________

Question # 5.

Please enter your weight in pounds.

Weight ___________

Question # 6.

What is your ethnic background?

- ❍ Hispanic
- ❍ Non-Hispanic

Question # 7.

Which of the following best describes you?

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

Question # 8.

How often do you eat raw tomatoes?

- ❍ Once a day
- ❍ 2-3 times a week
- ❍ Once a week
- ❍ 2-3 times a month
- ❍ Once a month
- ❍ Twice a year
- ❍ Once a year
- ❍ Never

Question #9.

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, please take a few minutes to identify the strongest **LIKING** (i.e., pleasure) of any kind that you have ever experienced. Once you have identified your strongest **LIKING** experienced, please write it down on the paper provided and type it in on the next screen.

Please remember to use the strongest liking that you've identified, and written down as the top of your scale (100).

Please click on the 'Continue' button below.

Question # 8.

Please type the strongest **LIKING** in the space below and remember that this sensation will be 100 on your scale.

___

___

___

1.

Now, please take a few minutes to identify the strongest **<u>DISLIKING</u>** (i.e., displeasure) of any kind that you have ever experienced. Once you have identified your strongest **<u>DISLIKING</u>** experienced, please write it down on the paper provided and type it in on the next screen.

<u>Please remember to strongest disliking that you've identified, and written down as the bottom of your scale (-100).</u>

Please click on the 'Continue' button below.

Question # 9.

Please type the strongest **<u>DISLIKING</u>** in the space below and remember that this sensation will be -100 on your scale.

____

____

____

Now you will be answering questions about the Overall Liking and Disliking from memory using a line scale.
Please click on the 'Continue' button below.

On the line scale, 100 indicates the most intense liking (i.e., pleasure) you have ever experienced (no matter what the source). Similarly, -100 indicates the opposite: the most intense disliking you have ever experienced. Neutral is indicated by 0.

<u>Please use your 100 and -100 (written on the paper provided) to answer the following questions.</u>

Please click the 'Continue' button below.

Question # 1 - Sample <<Sample1>>

Please rate the experience of listening to your **Favorite music**.

Strongest Dislike **Neutral** **Strongest Like**

-100 0 100

Question # 2 - Sample <<Sample1>>

Please rate the experience of spending time with your **loved ones**.

Strongest Dislike **Neutral** **Strongest Like**

-100 0 100

Question # 3 - Sample <<Sample1>>

Please rate the most **Annoyance** you have ever experienced.

Strongest Dislike **Neutral** **Strongest Like**

-100 0 100

Question # 4 - Sample <<Sample1>>

Please rate the most intense **Anger** you have ever experienced.

Strongest Dislike **Neutral** **Strongest Like**

-100 0 100

Question # 5 - Sample <<Sample1>>

Please rate the experience of eating your **Favorite Food**.

Strongest Dislike	**Neutral**	**Strongest Like**
-100	0	100

Question # 6 - Sample <<Sample1>>

Please rate the experience of eating your **Least Favorite Food**.

Strongest Dislike	**Neutral**	**Strongest Like**
-100	0	100

Question # 7 - Sample <<Sample1>>

Please rate the **Proudest** you have ever been of accomplishing a specific goal.

Strongest Dislike	**Neutral**	**Strongest Like**
-100	0	100

Question # 8 - Sample <<Sample1>>

Please rate the most **Enthusiastic** you have ever been about a hobby.

Strongest Dislike	**Neutral**	**Strongest Like**
-100	0	100

Question # 9 - Sample <<Sample1>>

Please rate the **Shyest** you have ever been.

Strongest Dislike **Neutral** **Strongest Like**

-100 0 100

Question # 10 - Sample <<Sample1>>

Please rate the most **Amused** you have ever been by an anecdote.

Strongest Dislike **Neutral** **Strongest Like**

-100 0 100

Question # 11 - Sample <<Sample1>>

Please rate the most **Inspired** you have ever been by a lecture.

Strongest Dislike **Neutral** **Strongest Like**

-100 0 100

Question # 12 - Sample <<Sample1>>

Please rate the most **Disgusted** you have ever been by a specific food.

Strongest Dislike **Neutral** **Strongest Like**

-100 0 100

Question # 13 - Sample <<Sample1>>

Please rate the experience of **The Best Tomato You Have Ever Tasted**.

Strongest Dislike	**Neutral**	**Strongest Like**

-100 0 100

Question # 14 - Sample <<Sample1>>

Please rate the experience of **The Worst Tomato You Have Ever Tasted**.

Strongest Dislike	**Neutral**	**Strongest Like**

-100 0 100

PLEASE LIFT THE WINDOW TO RECEIVE YOUR TASTING SAMPLES

PLEASE CLICK ON THE 'CONTINUE' BUTTON BELOW

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 on the 'Continue' button below.

Question # 1 - Sample <<Sample1>>

Please rate **Sample <<Sample1>> for each of the attributes below. (Asked for each sample individually, 6 samples total)**

OVERALL LIKING

Strongest Dislike	**Neutral**	**Strongest Like**
-100	0	100

TEXTURE

Strongest Dislike	**Neutral**	**Strongest Like**
-100	0	100

<u>PLEASE LIFT THE WINDOW TO RECEIVE SAMPLES</u>

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 intesity 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 10% 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.

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

Please click on the 'Continue' button below.

Question # 1.

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

____

____

____

Question # 2.

Please enter a number from zero (no sensation) to 100 (strongest imaginable sensation of any kind) that best describes the experience 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	__________

Many individuals have not tasted monosodium glutamate (MSG), a common food additive. MSG tastes salty but many individuals also perceive another sensation called umami. When you taste the tomatoes in the next part of this experiment, we want you to rate the umami taste.

Please click the 'Continue' button below.

Question # 3 - Sample <<Sample1>>

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

MSG __________

Saltiness __________

Now please taste the same samples and rate the intensity of the attributes listed.

Question # 1 - Sample <<Sample1>> (Asked for each sample individualli, a total of 6 samples).

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

Sweetness __________

Sourness __________

Salty __________

Bitter __________

Umami __________

Overall Tomato Flavor Intenstity __________

How typical is this tomato flavor? __________ (0%=not like a tomato at all, 100%=just like a tomato)

<u>PLEASE LIFT THE WINDOW TO RECEIVE YOUR LAST SET OF SAMPLES</u>

Please enter a number from zero (no sensation) to 100 (strongest sensation of any kind) that best describes the bitterness of **SOLUTION 1-4**.

Sweet __________

Sour __________

Salty __________

Bitter __________

APPENDIX B
BIOCHEMICAL COMPOSITION OF FIFTY VARIETIES OF TOMATOES

Table B-1.1. Biochemical composition of fifty varieties of tomatoes. Part 1.

Variety	Glucose mg/gfw	Fructose mg/gfw	Soluble Solids Brix	malic acid mg/gfw	Citric acid mg/gfw	citric:malic ratio	sugar:acid ratio	1-penten-3-one ng/gfw/hr
Standard Deviation	5.25	5.58	1.23	0.29	1.11	6.27	3.26	1.31
Ailsa Craig 1	14.51	16.69	5.20	0.64	3.00	4.68	8.56	2.66
Ailsa Craig 2	21.59	26.09	6.27	0.66	3.24	4.91	12.24	7.46
Ailsa Craig 3	13.72	16.24	4.63	1.08	3.95	3.67	5.96	1.17
Amish Salad	14.38	17.00	4.50	0.86	3.00	3.49	8.14	0.39
Aunt Ruby's German Green	21.07	24.51	5.80	0.36	4.47	12.32	9.44	2.70
Bloody Butcher 1	21.86	27.41	6.40	0.59	3.28	5.56	12.75	1.37
Bloody Butcher 2	22.09	25.91	6.77	0.58	3.08	5.29	13.11	2.29
Bloody Butcher 3	15.61	19.35	4.77	0.89	2.90	3.25	9.21	0.64
Brandywine	25.12	28.90	7.00	0.40	5.03	12.59	9.94	2.11
Chadwick Cherry	28.44	30.36	7.87	0.35	3.38	9.58	15.74	3.91
Cherry Roma	26.84	27.80	8.10	0.21	4.70	22.76	11.13	3.40
Clear Pink Slicer	12.25	15.40	3.80	0.40	3.75	9.28	6.65	0.58
Dixie Golden Giant	20.77	25.32	6.13	0.38	3.45	9.00	12.01	0.88
Garden Peach	12.40	15.32	4.20	0.57	4.86	8.49	5.10	0.24
Giant Belgium	18.98	22.58	5.90	0.24	2.43	10.01	15.52	2.06
Green Zebra	15.73	17.93	5.67	0.56	5.43	9.78	5.62	1.12

Table B-1-1. Continued.

Variety	Glucose mg/gfw	Fructose mg/gfw	Soluble Solids Brix	malic acid mg/gfw	Citric acid mg/gfw	citric:malic ratio	sugar:acid ratio	1-penten-3-one ng/gfw/hr
Gulf State Market	14.57	16.09	4.90	0.56	3.98	7.11	6.75	0.37
Kentucky Beefsteak	14.18	14.98	4.50	0.32	2.66	8.28	9.79	0.73
LA1482	11.71	16.46	5.07	0.28	6.11	21.94	4.41	0.55
Large Red Cherry	17.76	21.00	6.10	0.46	3.50	7.62	9.80	3.25
Lemon Drop	21.72	23.73	6.93	0.25	4.30	16.98	9.98	0.71
Marmande VFA	7.39	8.64	4.93	1.01	2.59	2.57	4.45	0.38
Matina	18.40	21.24	5.93	0.44	2.28	5.14	14.53	4.20
Matt's Wild Cherry	17.65	18.81	7.23	0.18	5.40	29.25	6.53	0.38
Mexico Midget	17.95	20.71	6.17	0.23	5.27	22.78	7.02	0.89
Peacevine Cherry	23.65	26.55	7.63	0.33	4.59	13.80	10.20	1.82
Porter	17.46	19.68	5.28	0.47	2.27	4.79	13.56	1.12
Store B3	15.40	17.11	4.90	0.44	3.20	7.21	8.92	0.37
Store B4	10.11	15.43	4.47	0.59	3.16	5.39	6.82	0.61
Store B5	14.57	16.66	4.73	0.52	2.53	4.90	10.23	0.51
Store B6	26.45	28.09	7.43	0.74	3.79	5.12	12.05	1.05
Store B1	9.71	11.70	3.83	0.79	3.35	4.26	5.17	0.32
Store B2	11.05	14.14	4.20	0.50	3.83	7.60	5.81	0.87
Red Calabash	29.66	35.78	8.53	0.83	5.83	7.05	9.83	2.41
Red Pear	21.01	23.30	6.55	0.62	3.44	5.56	10.93	1.15
Skorospelka Red	8.98	12.22	3.77	0.55	5.88	10.75	3.30	0.32

Table B-1.1. Continued.

Variety	Glucose mg/gfw	Fructose mg/gfw	Soluble Solids Brix	malic acid mg/gfw	Citric acid mg/gfw	citric:malic ratio	sugar:acid ratio	1-penten-3-one ng/gfw/hr
St. Pierre	14.53	15.76	4.53	0.83	2.21	2.67	9.95	0.85
Stupice	15.11	17.40	5.30	0.64	2.38	3.74	10.79	1.79
Super Sioux	15.26	15.78	4.73	0.45	3.56	7.89	7.74	0.50
Thai Pink Cherry	15.39	17.14	4.77	0.19	2.33	12.35	12.89	1.25
Thessaloniki 1	21.20	23.19	6.37	0.45	2.49	5.55	15.11	1.26
Thessaloniki 2	19.82	23.12	5.77	0.38	2.50	6.58	14.93	1.10
Three Sisters	13.97	16.20	4.70	0.92	3.80	4.12	6.39	1.08
Tigerella Orange	10.59	13.08	3.67	1.15	3.08	2.67	5.60	0.77
Tommy Toe	18.58	21.55	6.12	0.61	3.61	5.87	9.50	2.56
Store A1	13.10	17.61	5.40	0.33	4.55	13.93	6.29	1.14
Store A2	14.70	18.39	5.67	0.30	5.75	19.34	5.47	1.56
Yellow Jelly Bean	21.14	23.77	6.53	0.21	4.31	20.28	9.93	0.82
Yellow Perfection	12.22	15.00	4.50	1.64	3.62	2.20	5.18	0.92
Zapotec	10.00	12.22	3.70	1.03	1.62	1.58	8.40	0.31

Table B-1.2. Biochemical composition of fifty varieties of tomatoes. Part 2.

Variety	isovaleronitrile ng/gfw/hr	*trans*-2-pentenal ng/gfw/hr	*trans*-2-heptenal ng/gfw/hr	*trans*-3-hexen-1-ol ng/gfw/hr	6-methyl-5-hepten-2-ol ng/gfw/hr	nonyl aldehyde ng/gfw/hr	*cis*-4-decenal ng/gfw/hr	isovaleraldehyde ng/gfw/hr
Standard Deviation	14.12	0.88	0.43	0.74	0.12	0.19	0.85	11.20
Ailsa Craig 1	18.44	2.04	0.64	1.71	0.17	0.30	1.09	24.62
Ailsa Craig 2	47.53	5.40	2.76	1.16	0.68	0.85	5.55	17.26
Ailsa Craig 3	1.76	1.45	0.69	0.67	0.16	0.20	1.11	4.50
Amish Salad	2.15	0.54	0.16	0.81	0.15	0.12	0.90	6.60
Aunt Ruby's German Green	25.24	1.83	0.62	1.65	0.09	0.48	1.59	11.89
Bloody Butcher 1	8.64	0.98	0.22	1.42	0.15	0.31	0.82	24.49
Bloody Butcher 2	30.89	1.39	0.37	1.00	0.22	0.33	1.50	22.42
Bloody Butcher 3	2.29	0.99	0.44	0.69	0.14	0.20	0.98	3.61
Brandywine	1.44	1.51	0.56	0.68	0.21	0.37	0.95	3.71
Chadwick Cherry	27.30	2.98	1.14	1.93	0.30	0.38	1.41	12.45
Cherry Roma	37.73	1.27	0.71	2.19	0.39	1.13	2.78	21.12
Clear Pink Slicer	4.87	0.83	0.32	0.92	0.15	0.16	0.98	8.35
Dixie Golden Giant	1.18	0.59	0.24	0.28	0.12	0.32	0.77	4.72
Garden Peach	1.08	0.31	0.08	0.50	0.03	0.08	0.35	3.93
Giant Belgium	13.78	1.63	0.58	1.29	0.32	0.38	2.73	23.02
Green Zebra	9.29	1.60	0.38	1.00	0.07	0.07	0.43	15.20
Gulf State Market	4.63	0.63	0.27	1.39	0.27	0.14	1.09	6.14
Kentucky Beefsteak	0.89	0.47	0.16	0.21	0.13	0.06	0.72	1.09
LA1482	2.66	1.59	0.82	0.40	0.15	0.21	0.24	5.99

Table B-1.2. Continued.

Variety	isovaleronitrile ng/gfw/hr	*trans*-2-pentenal ng/gfw/hr	*trans*-2-heptenal ng/gfw/hr	*trans*-3-hexen-1-ol ng/gfw/hr	6-methyl-5-hepten-2-ol ng/gfw/hr	nonyl aldehyde ng/gfw/hr	*cis*-4-decenal ng/gfw/hr	isovaleraldehyde ng/gfw/hr
Marmande VFA	10.73	0.54	0.15	0.59	0.12	0.23	0.46	5.73
Matina	30.03	1.66	1.21	1.87	0.30	0.30	1.81	21.01
Matt's Wild Cherry	11.92	0.31	0.23	0.79	0.08	0.27	0.26	5.75
Mexico Midget	25.50	0.61	0.43	1.56	0.11	0.27	0.50	33.93
Peacevine Cherry	20.64	0.98	0.93	1.12	0.49	0.67	1.92	11.82
Porter	7.34	0.70	0.41	0.96	0.24	0.24	1.83	5.17
Store B3	7.42	0.26	0.28	0.83	0.26	0.26	1.34	1.81
Store B4	2.40	0.19	0.18	0.79	0.22	0.24	1.32	3.46
Store B5	7.24	0.31	0.14	0.52	0.11	0.09	0.93	6.00
Store B6	5.68	0.34	0.32	0.74	0.15	0.17	1.57	3.63
Store B1	8.98	0.16	0.12	0.73	0.06	0.20	0.38	15.62
Store B2	2.45	0.42	0.11	0.64	0.06	0.33	0.51	1.95
Red Calabash	20.52	1.70	0.45	2.24	0.09	0.54	0.90	29.96
Red Pear	20.47	0.77	0.28	2.03	0.14	0.31	0.63	23.81
Skorospelka Red	7.31	0.83	0.42	1.49	0.22	0.29	0.46	11.09
St. Pierre	4.20	1.02	0.57	0.47	0.26	0.08	0.72	3.84
Stupice	26.64	1.79	0.67	1.85	0.36	0.43	0.98	15.14
Super Sioux	6.80	0.66	0.28	0.93	0.14	0.10	0.90	7.85
Thai Pink Cherry	14.52	0.87	0.38	1.28	0.19	0.40	1.33	15.76
Thessaloniki 1	38.59	0.91	0.20	3.37	0.13	0.19	1.49	59.18

Table B-1.2. Continued.

Variety	isovaleronitrile ng/gfw/hr	*trans*-2-pentenal ng/gfw/hr	*trans*-2-heptenal ng/gfw/hr	*trans*-3-hexen-1-ol ng/gfw/hr	6-methyl-5-hepten-2-ol ng/gfw/hr	nonyl aldehyde ng/gfw/hr	*cis*-4-decenal ng/gfw/hr	isovaleraldehyde ng/gfw/hr
Tigerella Orange	1.92	1.04	0.26	0.74	0.13	0.20	0.86	3.38
Tommy Toe	25.90	1.93	0.58	2.45	0.15	0.30	0.90	25.86
Store A1	3.04	0.28	0.15	0.53	0.09	0.25	0.52	3.38
Store A2	4.81	0.37	0.13	0.60	0.07	0.24	0.55	14.31
Yellow Jelly Bean	23.42	0.74	0.16	1.25	0.05	0.21	0.58	14.57
Yellow Perfection	6.89	1.20	0.29	1.52	0.10	0.19	0.79	14.19
Zapotec	1.13	0.44	0.15	0.35	0.11	0.11	0.50	4.91

Table B-1.3. Biochemical composition of fifty varieties of tomatoes. Part 3.

Variety	3-methyl-1-butanol ng/gfw/hr	methional ng/gfw/hr	2,5-dimethyl-4-hydroxy-3(2H)-furanone ng/gfw/hr	3-pentanone ng/gfw/hr	1-pentanol ng/gfw/hr	benzyl cyanide ng/gfw/hr	isovaleric acid ng/gfw/hr	2-isobutylthiazole ng/gfw/hr
Standard Deviation	34.44	0.12	0.53	2.80	2.33	0.55	0.10	4.95
Ailsa Craig 1	77.77	0.55	0.47	8.09	3.86	0.05	0.12	5.87
Ailsa Craig 2	155.28	0.15	3.61	12.09	16.93	0.09	0.03	24.78
Ailsa Craig 3	23.77	0.05	0.97	4.10	4.87	0.04	0.02	2.74
Amish Salad	18.20	0.05	0.28	3.27	3.06	0.11	0.01	2.45
Aunt Ruby's German Green	37.23	0.18	0.53	11.42	6.08	0.27	0.16	8.02
Bloody Butcher 1	50.45	0.09	0.14	7.58	3.46	0.03	0.17	4.83
Bloody Butcher 2	41.50	0.10	0.26	8.87	3.91	0.04	0.10	8.28
Bloody Butcher 3	18.25	0.04	0.46	3.93	4.24	0.08	0.01	3.39
Brandywine	9.52	0.05	0.49	6.18	3.71	0.07	0.08	2.73
Chadwick Cherry	33.81	0.18	0.84	8.61	5.66	0.57	0.04	10.48
Cherry Roma	44.34	0.50	0.79	12.56	5.58	3.32	0.24	17.42
Clear Pink Slicer	32.32	0.18	0.24	2.97	2.58	0.11	0.05	6.99
Dixie Golden Giant	7.89	0.04	0.18	4.39	2.18	0.04	0.02	1.93
Garden Peach	16.48	0.09	0.07	2.08	1.38	0.07	0.01	2.14
Giant Belgium	45.82	0.19	0.46	9.56	5.04	0.06	0.15	5.63
Green Zebra	41.34	0.15	0.27	6.67	3.23	0.13	0.01	9.40
Gulf State Market	44.38	0.09	0.31	2.78	3.09	0.21	0.02	7.18
Kentucky Beefsteak	2.51	0.02	0.17	3.29	1.77	0.11	0.02	0.89
LA1482	12.03	0.09	0.18	3.71	2.92	0.04	0.01	7.32

Table B-1.3. Continued

Variety	3-methyl-1-butanol ng/gfw/hr	methional ng/gfw/hr	2,5-dimethyl-4-hydroxy-3(2H)-furanone ng/gfw/hr	3-pentanone ng/gfw/hr	1-pentanol ng/gfw/hr	benzyl cyanide ng/gfw/hr	isovaleric acid ng/gfw/hr	2-isobutylthiazole ng/gfw/hr
Marmande VFA	12.81	0.06	0.06	2.80	2.82	0.03	0.12	4.52
Matina	120.42	0.20	1.40	8.20	8.38	0.05	0.42	9.27
Matt's Wild Cherry	46.13	0.05	0.14	1.46	2.55	0.25	0.01	13.77
Mexico Midget	84.99	0.25	0.19	4.34	2.57	0.37	0.01	11.82
Peacevine Cherry	40.35	0.50	0.49	8.29	6.57	1.94	0.04	14.16
Porter	11.15	0.09	0.38	5.27	4.52	0.20	0.06	1.73
Store B3	7.00	0.12	0.12	2.46	3.54	0.32	0.05	3.99
Store B4	15.40	0.17	0.06	2.93	4.30	0.17	0.01	4.67
Store B5	7.75	0.10	0.06	2.81	2.04	0.16	0.02	2.89
Store B6	9.66	0.16	0.30	4.65	4.00	1.21	0.01	0.74
Store B1	28.81	0.08	0.15	2.94	1.77	0.07	0.03	2.75
Store B2	4.51	0.03	0.17	5.25	2.40	0.05	0.00	1.03
Red Calabash	97.05	0.19	0.33	8.87	3.18	0.04	0.10	6.61
Red Pear	34.12	0.15	0.19	6.34	2.62	0.12	0.15	4.62
Skorospelka Red	53.17	0.13	0.20	3.19	3.02	0.08	0.05	7.92
St. Pierre	10.55	0.08	0.29	3.62	3.15	0.30	0.01	5.60
Stupice	33.54	0.22	0.35	8.30	4.24	0.07	0.17	7.63
Super Sioux	21.85	0.11	0.30	4.18	2.84	0.16	0.01	5.61
Thai Pink Cherry	18.67	0.11	0.26	7.26	4.10	0.04	0.22	5.67

Table B-1.3. Continued.

Variety	3-methyl-1-butanol ng/gfw/hr	methional ng/gfw/hr	2,5-dimethyl-4-hydroxy-3(2H)-furanone ng/gfw/hr	3-pentanone ng/gfw/hr	1-pentanol ng/gfw/hr	benzyl cyanide ng/gfw/hr	isovaleric acid ng/gfw/hr	2-isobutylthiazole ng/gfw/hr
Three Sisters	28.83	0.15	0.44	5.82	4.06	0.28	0.04	9.02
Tigerella Orange	17.13	0.04	0.27	3.87	3.10	0.01	0.05	1.35
Tommy Toe	64.61	0.31	0.29	8.62	3.51	0.14	0.22	3.70
Store A1	5.06	0.07	0.08	5.49	2.82	0.72	0.01	1.09
Store A2	24.75	0.14	0.11	7.18	3.32	0.04	0.02	0.80
Yellow Jelly Bean	36.66	0.11	0.12	3.26	1.98	0.73	0.00	17.53
Yellow Perfection	62.38	0.17	0.29	3.78	2.46	0.03	0.05	6.18
Zapotec	10.22	0.14	0.05	2.72	1.60	0.16	0.02	2.58

Table B-1.4. Biochemical composition of fifty varieties of tomatoes. Part 4.

Variety	1-nitro-3-methylbutane ng/gfw/hr	benzaldehyde ng/gfw/hr	6-methyl-5-hepten-2-one ng/gfw/hr	β-ionone ng/gfw/hr	β-cyclocitral ng/gfw/hr	geranial ng/gfw/hr	phenylacetaldehyde ng/gfw/hr	eugenol ng/gfw/hr
Standard Deviation	22.83	2.81	2.58	0.07	0.09	0.10	0.44	0.51
Ailsa Craig 1	26.60	4.18	2.91	0.14	0.20	0.11	0.08	1.27
Ailsa Craig 2	67.16	4.29	7.91	0.46	0.59	0.50	0.06	1.91
Ailsa Craig 3	2.20	0.73	1.74	0.07	0.09	0.11	0.11	0.94
Amish Salad	2.00	3.79	2.47	0.01	0.05	0.11	0.12	0.01
Aunt Ruby's German Green	36.92	0.89	0.28	0.03	0.03	0.02	0.24	0.28
Bloody Butcher 1	18.15	1.35	4.58	0.05	0.12	0.16	0.05	0.18
Bloody Butcher 2	55.18	1.35	5.37	0.07	0.14	0.19	0.02	0.09
Bloody Butcher 3	1.06	1.73	2.72	0.05	0.08	0.14	0.06	0.27
Brandywine	2.21	0.63	3.55	0.04	0.06	0.16	0.22	0.21
Chadwick Cherry	24.27	3.18	7.27	0.11	0.20	0.34	0.14	0.46
Cherry Roma	13.29	12.33	8.53	0.10	0.11	0.23	2.77	0.00
Clear Pink Slicer	6.63	4.85	3.01	0.03	0.05	0.12	0.50	1.65
Dixie Golden Giant	0.92	0.61	3.94	0.03	0.03	0.07	0.07	0.01
Garden Peach	1.53	3.56	0.23	0.01	0.01	0.00	0.17	0.75
Giant Belgium	35.30	1.90	8.05	0.07	0.13	0.30	0.18	0.01
Green Zebra	9.04	7.12	0.20	0.01	0.01	0.01	0.17	0.57
Gulf State Market	9.16	7.35	4.57	0.02	0.05	0.17	1.06	0.95

Table B-1.4. Continued.

Variety	1-nitro-3-methylbutane ng/gfw/hr	benzaldehyde ng/gfw/hr	6-methyl-5-hepten-2-one ng/gfw/hr	β-ionone ng/gfw/hr	β-cyclocitral ng/gfw/hr	geranial ng/gfw/hr	phenylacetaldehyde ng/gfw/hr	eugenol ng/gfw/hr
Large Red Cherry	52.54	13.39	8.20	0.18	0.23	0.32	0.45	0.50
Lemon Drop	12.36	0.87	0.13	0.01	0.01	0.01	0.38	0.01
Marmande VFA	6.13	2.00	3.94	0.04	0.09	0.19	0.01	0.01
Matina	48.78	3.66	5.47	0.11	0.14	0.25	0.04	0.31
Matt's Wild Cherry	10.91	0.92	1.48	0.03	0.03	0.05	0.02	0.00
Mexico Midget	34.82	2.48	2.55	0.04	0.04	0.08	0.91	0.00
Peacevine Cherry	22.74	6.87	9.25	0.11	0.21	0.29	0.46	0.02
Porter	3.96	1.73	6.30	0.06	0.14	0.22	0.07	0.01
Store B3	16.31	3.33	9.05	0.02	0.05	0.21	0.45	0.42
Store B4	4.06	2.29	7.73	0.03	0.07	0.11	0.24	0.28
Store B5	12.32	2.10	4.29	0.01	0.03	0.09	0.19	0.15
Store B6	2.69	8.67	4.48	0.02	0.03	0.07	1.21	0.00
Store B1	25.40	2.11	5.59	0.03	0.08	0.09	0.57	0.25
Store B2	4.40	0.71	3.93	0.03	0.07	0.08	0.20	0.19
Red Calabash	39.76	1.43	3.18	0.05	0.08	0.12	0.07	0.47
Red Pear	19.96	5.15	4.84	0.05	0.14	0.15	0.14	0.34
Skorospelka Red	16.39	2.00	5.27	0.03	0.06	0.25	0.13	0.02

Table B-1.4. Continued.

Variety	1-nitro-3-methylbutane ng/gfw/hr	benzaldehyde ng/gfw/hr	6-methyl-5-hepten-2-one ng/gfw/hr	β-ionone ng/gfw/hr	β-cyclocitral ng/gfw/hr	geranial ng/gfw/hr	phenylacetaldehyde ng/gfw/hr	eugenol ng/gfw/hr
Super Sioux	9.45	2.56	2.59	0.02	0.04	0.08	0.21	0.10
Thai Pink Cherry	27.43	1.00	8.77	0.06	0.15	0.33	0.10	0.02
Thessaloniki 1	88.06	4.15	5.35	0.04	0.13	0.17	0.09	0.84
Thessaloniki 2	103.97	2.16	3.06	0.05	0.10	0.12	0.03	0.80
Three Sisters	17.59	4.10	5.29	0.06	0.10	0.23	0.24	0.35
Tigerella Orange	3.12	0.54	1.68	0.05	0.08	0.08	0.14	1.73
Tommy Toe	20.34	7.72	4.00	0.09	0.15	0.15	0.25	0.31
Store A1	0.75	1.97	4.23	0.02	0.08	0.07	0.44	0.01
Store A2	1.93	2.37	2.30	0.02	0.06	0.04	0.28	0.01
Yellow Jelly Bean	14.24	1.96	0.12	0.01	0.02	0.01	0.20	0.08
Yellow Perfection	14.58	3.61	0.29	0.01	0.02	0.01	0.12	1.96
Zapotec	1.51	3.14	2.00	0.01	0.03	0.07	0.19	0.36

Table B-1.5. Biochemical composition of fifty varieties of tomatoes. Part 5.

Variety	geranylacetone ng/gfw/hr	2-phenyl ethanol ng/gfw/hr	neral ng/gfw/hr	salicylaldehyde ng/gfw/hr	isobutyl acetate ng/gfw/hr	butyl acetate ng/gfw/hr	*cis*-3-hexen-1-ol ng/gfw/hr	1-nitro-2-phenylethane ng/gfw/hr
Standard Deviation	1.54	1.44	0.06	0.45	1.23	0.11	27.47	1.02
Ailsa Craig 1	1.24	0.04	0.24	0.41	0.86	0.13	47.06	0.08
Ailsa Craig 2	3.06	0.12	0.40	1.71	1.31	0.11	196.96	0.17
Ailsa Craig 3	0.89	0.03	0.21	1.45	0.86	0.21	56.68	0.36
Amish Salad	0.90	0.18	0.18	0.68	0.21	0.14	24.30	0.41
Aunt Ruby's German Green	0.06	0.06	0.19	0.42	1.24	0.13	59.85	1.66
Bloody Butcher 1	1.17	0.03	0.17	0.55	0.56	0.16	47.09	0.18
Bloody Butcher 2	1.53	0.03	0.12	0.28	0.38	0.10	40.15	0.29
Bloody Butcher 3	1.78	0.03	0.19	0.53	0.43	0.16	34.83	0.47
Brandywine	1.33	0.06	0.11	0.60	0.24	0.15	45.87	0.15
Chadwick Cherry	1.97	0.04	0.18	0.36	0.53	0.09	103.87	1.07
Cherry Roma	4.41	7.92	0.30	0.02	0.36	0.00	34.74	3.14
Clear Pink Slicer	1.16	0.74	0.19	0.90	4.58	0.32	49.81	0.57
Dixie Golden Giant	3.50	0.01	0.15	0.05	0.71	0.68	19.22	0.06
Garden Peach	0.03	0.21	0.13	0.91	0.71	0.11	11.08	0.43
Giant Belgium	2.52	0.02	0.22	0.12	0.60	0.11	48.53	0.83
Green Zebra	0.03	0.05	0.11	0.82	0.76	0.17	35.39	0.26
Gulf State Market	2.35	4.54	0.19	0.65	3.04	0.16	24.66	1.74
Kentucky Beefsteak	9.58	0.08	0.11	0.06	0.22	0.04	17.75	0.48
LA1482	0.69	0.04	0.16	0.19	1.27	0.13	35.83	0.13

Table B-1.5. Continued.

Variety	geranylacetone	2-phenyl ethanol	neral	salicylaldehyde	isobutyl acetate	butyl acetate	*cis*-3-hexen-1-ol	1-nitro-2-phenylethane
	ng/gfw/hr	ng/gfw/hr	ng/gfw/hr	ng/gfw/hr	ng/gfw/hr	ng/gfw/hr	ng/gfw/hr	ng/gfw/hr
Marmande VFA	1.10	0.03	0.31	0.39	0.42	0.04	33.02	0.09
Matina	2.43	0.03	0.20	0.77	0.65	0.13	46.11	0.15
Matt's Wild Cherry	0.39	0.22	0.16	0.05	0.35	0.04	27.35	0.87
Mexico Midget	0.67	1.80	0.11	0.03	0.68	0.02	20.87	4.03
Peacevine Cherry	3.45	1.85	0.20	0.04	0.63	0.07	30.72	4.16
Porter	1.82	0.11	0.14	0.03	0.13	0.05	42.19	0.35
Store B3	3.04	2.03	0.27	0.52	1.19	0.20	42.45	2.17
Store B4	2.63	1.45	0.21	0.82	7.09	0.41	40.28	1.43
Store B5	1.32	0.38	0.10	0.13	0.42	0.09	25.40	0.88
Store B6	0.94	4.57	0.11	0.15	0.75	0.01	23.94	3.97
Store B1	0.78	1.46	0.15	0.12	3.06	0.12	28.09	1.04
Store B2	1.14	0.82	0.11	0.11	0.40	0.06	36.48	0.33
Red Calabash	1.17	0.02	0.15	0.31	0.96	0.19	49.44	0.10
Red Pear	1.26	0.03	0.16	0.84	0.29	0.05	26.96	0.37
Skorospelka Red	2.49	0.11	0.20	0.10	1.50	0.21	52.41	0.46
St. Pierre	1.11	0.00	0.11	1.14	1.03	0.12	35.07	0.41
Stupice	2.61	0.02	0.18	0.74	0.75	0.10	40.61	0.56
Super Sioux	0.86	0.18	0.15	0.69	1.71	0.17	29.10	0.90
Thai Pink Cherry	2.60	0.03	0.20	0.05	0.17	0.05	36.09	0.35
Thessaloniki 1	1.31	0.02	0.16	0.87	0.61	0.09	30.05	0.57

Table B-1.5. Continued.

Variety	geranylacetone ng/gfw/hr	2-phenyl ethanol ng/gfw/hr	neral ng/gfw/hr	salicylaldehyde ng/gfw/hr	isobutyl acetate ng/gfw/hr	butyl acetate ng/gfw/hr	*cis*-3-hexen-1-ol ng/gfw/hr	1-nitro-2-phenylethane ng/gfw/hr
Tigerella Orange	0.76	0.01	0.13	2.00	1.09	0.24	62.93	0.03
Tommy Toe	1.32	0.13	0.18	0.41	0.57	0.08	42.78	0.33
Store A1	1.58	1.09	0.09	0.06	0.17	0.00	23.37	0.34
Store A2	0.71	0.57	0.06	0.17	0.84	0.01	28.32	0.20
Yellow Jelly Bean	0.02	0.50	0.09	0.35	0.55	0.01	28.50	1.24
Yellow Perfection	0.05	0.10	0.19	1.02	2.90	0.24	42.54	0.16
Zapotec	0.46	0.38	0.12	0.41	1.94	0.11	19.98	0.80

Table B-1.6. Biochemical composition of fifty varieties of tomatoes. Part 6.

Variety	1-penten-3-ol ng/gfw/hr	2-methylbutyl acetate ng/gfw/hr	heptaldehyde ng/gfw/hr	*trans,trans*-2,4-decadienal ng/gfw/hr	2-methylbuteraldehyde ng/gfw/hr	4-carene ng/gfw/hr	hexyl alcohol ng/gfw/hr	guaiacol ng/gfw/hr
Standard Deviation	2.20	1.49	5.60	0.02	1.44	0.03	25.57	0.98
Ailsa Craig 1	5.58	0.89	4.56	0.01	3.99	0.02	19.14	0.65
Ailsa Craig 2	13.00	1.14	8.93	0.13	1.68	0.16	176.48	3.55
Ailsa Craig 3	2.88	0.86	1.00	0.06	2.49	0.01	34.43	0.94
Amish Salad	2.53	0.27	0.71	0.00	3.09	0.01	10.30	0.04
Aunt Ruby's German Green	8.20	0.96	7.15	0.00	3.85	0.05	25.14	3.75
Bloody Butcher 1	5.26	0.73	4.19	0.00	2.64	0.10	16.95	1.27
Bloody Butcher 2	5.87	0.43	7.04	0.01	2.15	0.09	29.71	0.70
Bloody Butcher 3	2.48	0.69	1.11	0.04	2.09	0.01	27.83	0.43
Brandywine	7.31	0.19	1.13	0.00	1.18	0.07	17.27	4.94
Chadwick Cherry	6.75	0.71	5.30	0.01	1.99	0.04	69.30	0.87
Cherry Roma	4.71	0.15	3.55	0.02	5.45	0.02	8.95	0.07
Clear Pink Slicer	2.74	7.14	1.39	0.01	4.30	0.02	25.85	0.44
Dixie Golden Giant	5.37	0.94	0.63	0.00	1.90	0.08	5.71	0.09
Garden Peach	1.45	1.40	0.42	0.00	3.45	0.01	2.99	0.39
Giant Belgium	6.60	0.52	7.01	0.01	3.43	0.04	48.83	0.21
Green Zebra	3.59	0.95	1.97	0.01	3.96	0.02	11.29	0.72
Gulf State Market	1.94	3.38	2.02	0.01	2.62	0.01	9.16	0.75
Kentucky Beefsteak	2.94	0.24	0.31	0.01	3.06	0.00	5.60	0.01
LA1482	4.06	1.11	1.93	0.00	4.56	0.02	39.12	0.07

Table B-1.6. Continued.

Variety	1-penten-3-ol ng/gfw/hr	2-methylbutyl acetate ng/gfw/hr	heptaldehyde ng/gfw/hr	*trans,trans*-2,4-decadienal ng/gfw/hr	2-methylbuteraldehyde ng/gfw/hr	4-carene ng/gfw/hr	hexyl alcohol ng/gfw/hr	guaiacol ng/gfw/hr
Marmande VFA	4.51	0.14	1.03	0.01	1.15	0.11	19.04	0.17
Matina	5.78	1.13	9.50	0.07	2.66	0.06	34.88	0.97
Matt's Wild Cherry	1.76	0.18	1.58	0.02	3.18	0.04	21.07	0.12
Mexico Midget	1.88	0.28	8.73	0.00	6.39	0.00	14.33	0.03
Peacevine Cherry	3.81	0.73	3.72	0.01	6.55	0.11	13.72	0.08
Porter	3.87	0.09	1.49	0.00	1.38	0.02	31.12	0.06
Store B3	2.67	2.12	1.55	0.00	3.25	0.02	49.77	0.80
Store B4	3.99	6.86	1.17	0.01	5.15	0.01	37.70	0.88
Store B5	3.08	0.78	2.53	0.00	4.40	0.01	18.74	0.19
Store B6	2.50	0.11	1.51	0.00	6.02	0.01	13.48	0.02
Store B1	3.36	4.10	2.41	0.01	4.51	0.02	17.33	0.18
Store B2	8.02	0.31	0.85	0.00	1.23	0.01	15.60	0.09
Red Calabash	6.42	1.04	4.39	0.00	2.40	0.05	9.17	1.28
Red Pear	3.48	0.14	2.58	0.00	2.70	0.02	11.60	1.45
Skorospelka Red	2.56	1.91	2.48	0.01	3.47	0.01	35.22	0.20
St. Pierre	3.10	1.35	0.97	0.01	3.33	0.01	28.72	0.66
Stupice	6.58	0.74	10.14	0.01	3.06	0.03	22.57	1.11
Super Sioux	2.25	1.81	1.83	0.01	4.51	0.01	15.23	0.65
Thai Pink Cherry	6.12	0.19	3.45	0.00	2.38	0.02	17.64	0.09

Table B-1.6. Continued.

Variety	1-penten-3-ol ng/gfw/hr	2-methylbutyl acetate ng/gfw/hr	heptaldehyde ng/gfw/hr	*trans,trans*-2,4-decadienal ng/gfw/hr	2-methylbuteraldehyde ng/gfw/hr	4-carene ng/gfw/hr	hexyl alcohol ng/gfw/hr	guaiacol ng/gfw/hr
Three Sisters	4.16	2.54	2.85	0.02	5.17	0.01	32.87	0.46
Tigerella Orange	3.27	1.52	0.87	0.01	3.08	0.01	22.59	0.76
Tommy Toe	5.88	0.70	3.48	0.00	3.34	0.02	12.43	0.60
Store A1	3.16	0.04	1.04	0.00	2.14	0.01	11.60	0.03
Store A2	3.41	0.05	0.77	0.00	6.35	0.01	7.79	0.04
Yellow Jelly Bean	1.66	0.13	3.99	0.00	3.89	0.01	9.94	0.07
Yellow Perfection	3.52	2.98	2.39	0.01	5.20	0.02	8.78	0.75
Zapotec	2.28	2.11	0.69	0.00	5.66	0.01	12.46	0.71

Table B-1.7. Biochemical composition of fifty varieties of tomatoes. Part 7.

Variety	propyl acetate	hexanal	*cis*-2-penten-1-ol	glutamatic acid	*2*-butylacetate	1-octen-3-one	*cis*-3-hexenal	methylsalicylate
	ng/gfw/hr	ng/gfw/hr	ng/gfw/hr	mg/gfw	ng/gfw/hr	ng/gfw/hr	ng/gfw/hr	ng/gfw/hr
Standard Deviation	0.22	62.66	0.56	1.36	0.22	0.05	48.90	0.64
Ailsa Craig 1	0.36	164.00	1.67	1.40	0.04	0.09	168.52	0.28
Ailsa Craig 2	0.41	202.28	3.23	1.25	0.01	0.27	64.45	0.22
Ailsa Craig 3	0.33	65.54	0.68	1.32	0.06	0.09	33.63	0.40
Amish Salad	0.14	47.11	0.59	1.76	0.16	0.04	27.19	0.01
Aunt Ruby's German Green	0.18	162.76	1.78	1.16	0.01	0.07	131.33	2.06
Bloody Butcher 1	0.23	93.94	1.04	0.90	0.02	0.04	60.98	0.18
Bloody Butcher 2	0.22	116.54	0.99	1.57	0.01	0.06	49.01	0.14
Bloody Butcher 3	0.18	44.75	0.49	1.26	0.09	0.05	19.56	0.13
Brandywine	0.16	143.18	1.66	1.17	0.04	0.07	161.32	2.28
Chadwick Cherry	0.17	173.87	1.34	2.58	0.00	0.09	112.85	1.18
Cherry Roma	0.08	68.39	1.69	3.53	0.01	0.14	52.68	0.01
Clear Pink Slicer	0.58	132.11	0.78	0.69	0.36	0.03	84.45	0.41
Dixie Golden Giant	0.40	82.28	1.12	0.57	0.06	0.07	79.24	0.09
Garden Peach	0.15	22.12	0.55	1.10	0.23	0.02	21.44	0.32
Giant Belgium	0.29	306.77	1.16	1.36	0.00	0.06	36.79	0.02
Green Zebra	0.12	136.00	1.20	2.20	0.67	0.04	122.97	0.71
Gulf State Market	0.33	52.21	0.71	1.64	0.86	0.03	34.45	0.88
Kentucky Beefsteak	0.16	21.92	0.38	1.28	0.29	0.02	15.96	0.02
LA1482	0.34	200.77	0.55	1.38	0.02	0.06	64.16	1.06

Table B-1.7. Continued.

Variety	propyl acetate ng/gfw/hr	hexanal ng/gfw/hr	*cis*-2-penten-1-ol ng/gfw/hr	glutamatic acid mg/gfw	*2*-butylacetate ng/gfw/hr	1-octen-3-one ng/gfw/hr	*cis*-3-hexenal ng/gfw/hr	methylsalicylate ng/gfw/hr
Marmande VFA	0.07	164.65	1.03	0.67	0.01	0.02	81.83	0.02
Matina	0.94	107.77	1.74	2.15	0.01	0.12	42.78	0.29
Matt's Wild Cherry	0.25	18.65	0.36	2.95	0.01	0.06	6.87	0.02
Mexico Midget	0.06	196.76	0.96	5.24	0.01	0.05	102.57	0.00
Peacevine Cherry	0.35	76.15	0.73	1.66	0.06	0.20	34.73	0.01
Porter	0.19	95.45	0.80	1.59	0.01	0.08	39.58	0.01
Store B3	0.26	105.96	0.79	2.61	0.04	0.05	22.28	0.81
Store B4	1.04	41.88	0.83	1.95	0.08	0.03	14.90	0.74
Store B5	0.18	132.87	0.61	2.14	0.02	0.02	43.00	0.50
Store B6	0.04	45.51	0.55	2.71	0.00	0.05	23.29	0.01
Store B1	0.72	147.30	1.46	2.05	0.06	0.02	69.68	0.21
Store B2	0.11	68.08	1.35	1.63	0.53	0.03	44.21	0.15
Red Calabash	0.28	131.25	1.38	1.26	0.06	0.07	175.07	1.02
Red Pear	0.10	127.50	1.10	2.60	0.01	0.07	81.69	0.70
Skorospelka Red	0.33	135.81	0.87	1.43	0.66	0.04	68.99	0.01
St. Pierre	0.18	225.94	0.57	1.10	0.77	0.04	61.74	2.47
Stupice	0.31	208.78	1.78	2.47	0.04	0.05	143.68	0.28
Super Sioux	0.23	93.58	0.56	1.36	0.42	0.02	43.14	1.68
Thai Pink Cherry	0.21	144.84	1.62	2.06	0.03	0.06	70.78	0.04
Thessaloniki 1	0.14	138.32	1.58	9.01	0.03	0.04	61.95	0.36

Table B-1.7. Continued.

Variety	propyl acetate ng/gfw/hr	hexanal ng/gfw/hr	*cis*-2-penten-1-ol ng/gfw/hr	glutamatic acid mg/gfw	*2*-butylacetate ng/gfw/hr	1-octen-3-one ng/gfw/hr	*cis*-3-hexenal ng/gfw/hr	methylsalicylate ng/gfw/hr
Tigerella Orange	0.41	86.12	0.89	0.70	0.13	0.03	88.72	0.38
Tommy Toe	0.18	128.81	1.58	2.63	0.06	0.08	157.39	1.46
Store A1	0.03	49.59	0.41	3.09	0.02	0.08	29.09	0.01
Store A2	0.03	34.94	0.76	1.69	0.01	0.06	32.84	0.03
Yellow Jelly Bean	0.04	41.70	0.43	2.03	0.02	0.04	31.82	0.11
Yellow Perfection	0.34	96.66	1.36	1.35	0.49	0.03	158.23	0.24
Zapotec	0.22	91.85	0.35	0.95	0.27	0.01	32.72	0.35

Table B-1.8. Biochemical composition of fifty varieties of tomatoes. Part 8.

Variety	*trans*-2-hexenal ng/gfw/hr	b-damascenone ng/gfw/hr	2-methyl-1-butanol ng/gfw/hr	2-methyl-2-butenal ng/gfw/hr	prenyl acetate ng/gfw/hr	hexyl acetate ng/gfw/hr	3-methyl-1-pentanol ng/gfw/hr	2-ethylfuran ng/gfw/hr
Standard Deviation	5.99	0.00	11.07	5.13	0.03	0.39	0.46	0.05
Ailsa Craig 1	9.91	0.00	27.09	9.89	0.02	0.22	1.20	0.19
Ailsa Craig 2	30.31	0.01	25.25	7.81	0.05	1.45	0.97	0.15
Ailsa Craig 3	9.92	0.00	5.69	3.97	0.01	0.69	0.21	0.08
Amish Salad	1.29	0.00	2.66	2.97	0.01	0.17	0.27	0.04
Aunt Ruby's German Green	7.25	0.00	28.44	13.41	0.02	0.38	0.20	0.13
Bloody Butcher 1	1.88	0.00	6.46	2.13	0.01	0.47	0.74	0.09
Bloody Butcher 2	2.89	0.01	5.43	2.48	0.03	0.50	0.62	0.09
Bloody Butcher 3	6.37	0.00	3.76	2.00	0.01	0.66	0.34	0.04
Brandywine	6.70	0.00	3.75	4.30	0.02	0.66	0.30	0.12
Chadwick Cherry	12.29	0.00	8.78	3.14	0.03	1.03	0.24	0.08
Cherry Roma	1.68	0.01	21.28	14.42	0.02	0.16	1.37	0.11
Clear Pink Slicer	3.71	0.01	42.81	19.79	0.01	0.68	0.26	0.13
Dixie Golden Giant	5.30	0.01	3.37	6.72	0.01	0.80	0.32	0.09
Garden Peach	0.82	0.00	16.53	5.94	0.00	0.07	0.41	0.02
Giant Belgium	9.92	0.01	18.14	7.78	0.03	0.53	0.36	0.25
Green Zebra	9.29	0.00	14.42	5.18	0.00	0.20	0.74	0.14
Gulf State Market	2.53	0.00	34.40	15.62	0.01	0.26	0.74	0.09
Kentucky Beefsteak	0.38	0.00	2.12	1.45	0.00	0.10	0.11	0.03
LA1482	27.47	0.00	7.33	5.52	0.01	0.85	0.02	0.13

Table B-1.8. Continued.

Variety	*trans*-2-hexenal ng/gfw/hr	b-damascenone ng/gfw/hr	2-methyl-1-butanol ng/gfw/hr	2-methyl-2-butenal ng/gfw/hr	prenyl acetate ng/gfw/hr	hexyl acetate ng/gfw/hr	3-methyl-1-pentanol ng/gfw/hr	2-ethylfuran ng/gfw/hr
Marmande VFA	1.88	0.01	5.18	3.56	0.01	0.99	0.38	0.14
Matina	5.67	0.01	23.30	6.39	0.04	0.43	1.48	0.06
Matt's Wild Cherry	0.53	0.00	8.90	1.95	0.00	0.11	0.18	0.01
Mexico Midget	3.42	0.00	24.66	8.86	0.00	0.13	0.52	0.09
Peacevine Cherry	0.88	0.00	40.81	9.34	0.02	0.45	0.25	0.12
Porter	1.41	0.00	2.92	2.36	0.01	0.13	0.42	0.05
Store B3	2.75	0.00	15.59	7.52	0.01	1.15	0.76	0.07
Store B4	9.58	0.00	28.00	15.79	0.19	2.03	0.55	0.03
Store B5	0.73	0.00	6.38	6.15	0.01	0.41	0.17	0.08
Store B6	0.29	0.00	21.15	11.60	0.01	0.04	0.17	0.02
Store B1	1.11	0.01	33.35	18.99	0.00	0.53	2.27	0.11
Store B2	0.72	0.00	5.74	4.93	0.01	0.19	0.29	0.12
Red Calabash	11.40	0.00	21.39	10.23	0.02	0.32	0.30	0.10
Red Pear	3.04	0.00	7.28	4.41	0.01	0.15	0.64	0.07
Skorospelka Red	2.67	0.00	21.33	14.50	0.02	0.55	0.52	0.14
St. Pierre	2.39	0.00	9.57	3.50	0.01	0.74	0.10	0.10
Stupice	7.55	0.00	16.51	7.10	0.03	0.34	0.88	0.20
Super Sioux	1.39	0.00	22.80	8.36	0.00	0.25	0.24	0.06
Thai Pink Cherry	2.50	0.00	5.92	3.10	0.02	0.16	1.56	0.21
Thessaloniki 1	2.37	0.00	15.11	5.91	0.01	0.22	1.32	0.15

Table B-1.8. Continued.

Variety	*trans*-2-hexenal ng/gfw/hr	b-damascenone ng/gfw/hr	2-methyl-1-butanol ng/gfw/hr	2-methyl-2-butenal ng/gfw/hr	prenyl acetate ng/gfw/hr	hexyl acetate ng/gfw/hr	3-methyl-1-pentanol ng/gfw/hr	2-ethylfuran ng/gfw/hr
Tigerella Orange	6.71	0.00	9.53	7.99	0.01	0.49	0.19	0.22
Tommy Toe	6.13	0.00	18.30	6.53	0.02	0.24	0.77	0.09
Store A1	0.38	0.00	6.84	5.28	0.01	0.01	0.19	0.06
Store A2	0.81	0.00	31.49	19.03	0.01	0.02	0.47	0.10
Yellow Jelly Bean	0.91	0.00	8.39	4.53	0.00	0.08	0.20	0.02
Yellow Perfection	4.83	0.01	24.86	13.23	0.01	0.18	0.64	0.14
Zapotec	1.30	0.00	19.88	12.32	0.01	0.26	0.10	0.14

Table B-1.9. Biochemical composition of fifty varieties of tomatoes. Part 9.

Variety	isopentyl acetate ng/gfw/hr	*cis*-3-hexenyl acetate ng/gfw/hr	benzothiazole ng/gfw/hr	benzyl alcohol ng/gfw/hr	3-methyl-2-butenal ng/gfw/hr	*p*-anisaldehyde ng/gfw/hr
Standard Deviation	0.29	0.78	0.03	0.49	0.33	0.01
Ailsa Craig 1	0.33	1.34	0.06	0.39	0.49	0.01
Ailsa Craig 2	1.31	4.38	0.10	0.73	0.61	0.05
Ailsa Craig 3	0.52	2.46	0.03	0.24	0.20	0.01
Amish Salad	0.12	1.31	0.03	0.30	0.23	0.01
Aunt Ruby's German Green	0.13	1.52	0.06	0.54	0.31	0.00
Bloody Butcher 1	0.69	1.68	0.12	0.22	0.42	0.00
Bloody Butcher 2	0.47	1.67	0.03	0.16	0.35	0.01
Bloody Butcher 3	0.48	2.03	0.04	0.39	0.17	0.01
Brandywine	0.02	1.59	0.04	0.26	0.34	0.00
Chadwick Cherry	0.45	2.26	0.05	0.50	0.51	0.02
Cherry Roma	0.00	2.37	0.10	0.61	0.34	0.00
Clear Pink Slicer	0.68	2.15	0.02	0.73	0.29	0.01
Dixie Golden Giant	0.17	1.87	0.10	0.31	0.31	0.01
Garden Peach	0.09	0.59	0.08	0.38	0.17	0.00
Giant Belgium	0.10	2.56	0.03	0.19	0.93	0.01
Green Zebra	0.16	1.08	0.03	1.08	0.25	0.00
Gulf State Market	0.54	1.42	0.05	1.47	0.36	0.02
Kentucky Beefsteak	0.01	0.75	0.03	0.10	0.13	0.00
LA1482	0.12	1.62	0.03	0.97	0.09	0.01
Large Red Cherry	0.47	1.59	0.09	0.37	0.58	0.01
Lemon Drop	0.24	0.75	0.05	1.38	0.26	0.00

Table B-1.9. Continued.

Variety	isopentyl acetate ng/gfw/hr	*cis*-3-hexenyl acetate ng/gfw/hr	benzothiazole ng/gfw/hr	benzyl alcohol ng/gfw/hr	3-methyl-2-butenal ng/gfw/hr	*p*-anisaldehyde ng/gfw/hr
Matt's Wild Cherry	0.03	0.53	0.06	1.46	0.75	0.01
Mexico Midget	0.03	0.89	0.04	1.69	0.14	0.00
Peacevine Cherry	0.04	2.26	0.12	0.60	0.33	0.00
Porter	0.01	1.54	0.07	0.10	0.22	0.00
Store B3	0.07	2.03	0.01	0.51	0.15	0.01
Store B4	0.41	4.17	0.02	0.79	2.25	0.00
Store B5	0.07	1.21	0.03	0.18	0.07	0.00
Store B6	0.00	1.21	0.03	0.19	0.17	0.00
Store B1	0.39	1.05	0.04	0.15	0.22	0.01
Store B2	0.01	0.82	0.10	0.04	0.16	0.00
Red Calabash	0.69	1.36	0.06	0.24	0.58	0.00
Red Pear	0.02	0.85	0.08	0.33	0.41	0.00
Skorospelka Red	0.56	1.51	0.07	0.61	0.38	0.02
St. Pierre	0.08	1.51	0.03	0.30	0.11	0.01
Stupice	0.16	1.66	0.07	0.32	0.38	0.01
Super Sioux	0.08	1.19	0.04	0.50	0.20	0.00
Thai Pink Cherry	0.02	1.39	0.09	0.13	0.32	0.01
Thessaloniki 1	0.55	1.65	0.04	0.34	0.56	0.00
Thessaloniki 2	0.07	0.84	0.05	0.21	0.53	0.00
Three Sisters	0.25	1.89	0.04	1.04	0.79	0.02
Tigerella Orange	0.39	2.47	0.01	0.12	0.20	0.01

Table B-1.9. Continued.

Variety	isopentyl acetate ng/gfw/hr	*cis*-3-hexenyl acetate ng/gfw/hr	benzothiazole ng/gfw/hr	benzyl alcohol ng/gfw/hr	3-methyl-2-butenal ng/gfw/hr	*p*-anisaldehyde ng/gfw/hr
Store A2	0.03	0.73	0.06	0.03	0.24	0.00
Yellow Jelly Bean	0.02	0.66	0.03	2.55	0.08	0.00
Yellow Perfection	0.76	1.73	0.02	0.45	0.26	0.00
Zapotec	0.04	0.84	0.04	0.28	0.11	0.03

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BIOGRAPHICAL SKETCH

Adilia was born in Jinotega, Nicaragua in August of 1987. Since she was little she learned that success requires effort and responsibility. After graduating with high honors from high school she decided to continue her studies at EARTH University in Costa Rica, where she was awarded with a full scholarship. During her college years, she had the opportunity to take several food science-related classes, which made her realize that it was the perfect complement for her career goals. She believed that Central America needed more professionals who understand how to handle food products from the field up to the consumer’s table. For this reason, after graduating in 2008 with a Bachelor of Science in agricultural engineering, she moved to Gainesville, Florida to work at the Sensory Laboratory in the University of Florida. She spent six months working on sensory analysis and in the fall of 2009 she enrolled in the master’s program in the Food Science and Human Nutrition Department at UF. This program gave her the opportunity to learn about food and research skills but most importantly, to develop a sense of perseverance and commitment with self. Her thesis involved sensory and chemical analysis of heirloom tomatoes and although it represented a big challenge, it was crucial for Adilia’s professional development. She graduated in August 2011 with a master’s degree in food science from the University of Florida and is very excited about future challenges and learning opportunities in the food science discipline.