Tomatoes are among the major produce items eliciting greatest consumer dissatisfaction, primarily attributed to flavor. Providing specific consumer segments with items that meet their expectations for flavor acceptability should lead to increased consumer satisfaction. Focus-groups, sensory descriptive analysis, and consumer evaluations were conducted to determine consumer acceptability. Focus-group discussions about fresh tomato flavor revealed distinct segments of tomato flavor acceptance including vine-ripened, sweet, tart, and sweet and tart groups. Consumer evaluation studies found that consumers base their levels of acceptability of tomato flavor on different criteria. Combination of sensory descriptive analysis with consumer testing yielded predictive equations which can be used to identify components of flavor contributing to acceptability of consumer segments. Breeders can then select for these specific characteristics in tomatoes resulting in increased consumer satisfaction in tomato flavor and increased sales of tomatoes; a benefit to both consumers and producers alike.

INDEX WORDS: Tomato flavor, Consumer evaluation, Consumer acceptability, Focus groups, Sensory panel, Acceptance scales.
SEGMENTATION OF TOMATO CONSUMERS BY PREFERENCES IN
FLAVOR ACCEPTABILITY

by

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SEGMENTATION OF TOMATO CONSUMERS BY PREFERENCES IN
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CHAPTER 1
INTRODUCTION AND LITERATURE REVIEW

Tomato Flavor

Flavor is a combination of taste and aroma that is based upon the composition of a food (Shewfelt, 1993). A simple definition like this would suggest that understanding the flavor of fresh tomatoes wouldn’t be complicated. However, tomato flavor is an area where consumer dissatisfaction abounds (Bruhn et al, 1991). Much research is taking place trying to determine the exact compounds responsible for tomato flavor and how to predict the flavor of tomatoes.

Volatile Compounds. Gas chromatography-mass spectrometry has allowed for the identification of over 400 volatile compounds in tomatoes (Petro-Turza, 1987). Of these volatiles, only 30 have odor thresholds over 1 ppb. Odor thresholds are the concentration at which a compound can be detected. By dividing the concentration of a compound by the threshold concentration one can determine the odor unit ($U_o$) of the compound. Buttery and Ling (1993) has determined that of the volatile compounds in tomatoes, less than 20 have odor units great enough to contribute to the flavor (Table 1).

Nonvolatile Compounds. Chemical analyses have allowed for the identification of the chemical compounds in tomatoes that contribute to their flavor. Reducing sugars comprise about 50% of the dry matter of tomatoes and glucose and fructose are the main compounds in this group. Organic acids comprise about 10% of tomato dry matter and the most prevalent of these are citric and malic acids. Free amino acids contribute 2-2.5% of the dry tomato matter. The most abundant of these are glutamic acid, glutamine, gamma-amino-butyric acid, and aspartic acid. The fourth group of compounds is minerals, which comprise 8% of tomato dry matter. Potassium is the major cation with
phosphate the major anion (Petro-Turza, 1987). The interactions of these important
chemical and volatile compounds are responsible for the flavor of fresh tomatoes, but
with so many different compounds it has been difficult to determine exactly which
compounds are responsible for specific flavors.

**TABLE 1.**

**CONCENTRATIONS OF MAJOR VOLATILE FRESH TOMATO COMPONENTS, ODOR THRESHOLDS IN WATER SOLUTION AND LOG ODOR UNITS.**

(Adapted from Buttery and Ling, 1993)

<table>
<thead>
<tr>
<th>Compound</th>
<th>Conc. ppb</th>
<th>Odor Thresh. ppb in H₂O</th>
<th>Log. Odor Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cis-3-hexenal</td>
<td>12000</td>
<td>0.25</td>
<td>4.7</td>
</tr>
<tr>
<td>β-ionone</td>
<td>4</td>
<td>0.007</td>
<td>2.8</td>
</tr>
<tr>
<td>hexanal</td>
<td>3100</td>
<td>4.5</td>
<td>2.8</td>
</tr>
<tr>
<td>1-penten-3-one</td>
<td>520</td>
<td>1</td>
<td>2.7</td>
</tr>
<tr>
<td>3-methylbutanal</td>
<td>27</td>
<td>0.2</td>
<td>2.1</td>
</tr>
<tr>
<td>Trans-2-hexenal</td>
<td>270</td>
<td>17</td>
<td>1.2</td>
</tr>
<tr>
<td>2-isobutylthiazole</td>
<td>36</td>
<td>3.5</td>
<td>1.0</td>
</tr>
<tr>
<td>6-methyl-5-heptne-2-one</td>
<td>130</td>
<td>50</td>
<td>0.4</td>
</tr>
<tr>
<td>Cis-3-hexenol</td>
<td>150</td>
<td>70</td>
<td>0.3</td>
</tr>
<tr>
<td>2-phenylethanol</td>
<td>1900</td>
<td>1000</td>
<td>0.3</td>
</tr>
<tr>
<td>3-methylbutanol</td>
<td>380</td>
<td>250</td>
<td>0.2</td>
</tr>
<tr>
<td>geranylacetone</td>
<td>57</td>
<td>60</td>
<td>-0.02</td>
</tr>
<tr>
<td>hexanol</td>
<td>7</td>
<td>500</td>
<td>-1.9</td>
</tr>
</tbody>
</table>

**Sensory Analysis.** A vast expanse of research has been conducted using sensory
techniques to describe the flavor of tomatoes and determine what causes these flavor
profiles or changes in them. Many forms of sensory analysis exist, but generally a group
of panelists sample a product and score intensities of the flavor attributes of that product.
The use of sensory analysis gives a language for and quantification of the flavor of
tomatoes. This tool allows researchers to compare differences in tomatoes based on their
descriptive attributes to determine the reasons for different flavor profiles. Auerswald et
al. (1999) conducted Qualitative Descriptive Analysis on tomato fruit stored for differing time periods. Using a 0 to 100 point unstructured scale and 10 trained panelists, samples were evaluated and rated for attribute intensities. This study concluded that sensory profiles change with increased storage time, with both favorable and unfavorable attributes increasing. Some of the attributes described and quantified are listed in Table 2.

**TABLE 2.**

RESULTS OF QDA: INTENSITY CHANGES OF SENSORY TOMATO ATTRIBUTES DURING STORAGE PERIODS OF 4 AND 7 DAYS COMPARED TO FRESH FRUITS
(Adapted from Auerswald et al., 1999)

<table>
<thead>
<tr>
<th>Attributes</th>
<th>Storage period (days)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0</td>
</tr>
<tr>
<td>Sour</td>
<td>36.8</td>
</tr>
<tr>
<td>Sweet</td>
<td>24.1</td>
</tr>
<tr>
<td>Tomato-like</td>
<td>18.1</td>
</tr>
<tr>
<td>Mouldy</td>
<td>5.3</td>
</tr>
<tr>
<td>Spoiled sweetish</td>
<td>10.9</td>
</tr>
</tbody>
</table>

Van Lieshout (1993) also analyzed tomato flavor using sensory techniques. Consumers used 5 or 6-point Lickert scales to evaluate 8 organoleptic attributes of different tomato varieties. These attributes were then ‘translated’ into chemical properties. The researchers determined that the sensory attributes vary between cultivars due to differing chemical composition. Based on the sensory analysis they concluded that for optimum fresh tomato flavor sugar levels can be high but there is a maximum level for acids. These sensory analyses provide insight into the possible reasons for differences in tomato flavor and set us closer to understanding its complex nature.

**Chemical/Instrumental Analysis.** Another method of determining the flavor of tomatoes is through chemical/instrumental analysis. Many techniques and instruments can be used to determine the composition of tomatoes, and results may vary depending
on the type of technique employed. Many analyses use GC-MS in determining the volatiles present in tomatoes. One such study compared the volatile composition of tomatoes stored at room temperature and those under refrigeration. First the proper methodology was determined by trying several different techniques until adequate recovery of volatiles was made. Use of Tenax adsorbant trapping and identification of volatiles through Gas liquid chromatography-Mass spectrometry yielded a ten-fold increase in the concentration of trans-3-hexenal in room-temperature stored vine-ripened tomatoes that was not seen in cold stored tomatoes (Buttery et al., 1987). With trans-3-hexenal being one of the 16 volatiles believed to contribute to fresh tomato flavor, these results suggest that cold storage of tomatoes leads to poor flavor. Baldwin et al. (1991) studied sugars, acids and volatiles of six different tomato cultivars, finding that these components vary between cultivars and even between fruits of the same cultivar. Although the 16 volatiles that were quantified and identified by GC headspace analysis were among the important contributors to fresh tomato flavor, the concentrations of each varied among fruits showing the complexity of tomato flavor. Another study using Gas Chromatography to identify volatile compounds important in tomato flavor looked at maturity and volatile profiles. Maul et al. (1998) studied the volatile profiles of tomatoes harvested vine-ripe and those harvested green and ethylene gassed to ripeness. The group found that the fruits harvested green had decreases in concentrations of 6 volatiles, all of which are of the 16 important to fresh tomato flavor. With the reduction of these volatiles that contribute to flavor, the flavor of the tomatoes will surely change also.

In addition to GC and GC-MS analysis, the electronic nose is an instrument also used to measure tomato flavor. Although no lists of volatiles are produced, this instrument can detect volatiles using an array of sensors. Interest in electronic nose applications have increased due to valuable data, some of which has shown this instrument can distinguish different stages of tomato maturity due to different volatile profiles (Maul et al., 1998).
Other findings. In volatile and chemical/instrumental analyses, some modifications may be made but there are standard methods used. However, some recent research has incorporated different methods into identification and quantification of tomato flavor constituents. Tandon (2000) used sensory, chemical, and volatile analyses in determining flavor differences of several tomato cultivars. He found mathematical relationships using the data from these analyses and was able to develop prediction models for tomato flavor.

Abegaz (2000) also incorporated mathematical relationships into his research, as well as a technique called partitioning, which allows for better panelist distinction between volatiles and non-volatiles in sensory analysis. This technique employed nose clips to be used while evaluating taste descriptors of tomato samples and removing the clips to evaluate the aromatic descriptors. Analyses of the data and prediction models have shown that there are more significant relationships between the partitioned data and chemical composition than that of the non-partitioned data. The use of mathematical relationships for the data collected and partitioning in sensory analysis shows there are new ways of approaching the tomato flavor issue and possibilities for understanding its complexity.

Integrated Approaches. The previously discussed methods for identifying composition and amounts of compounds affecting tomato flavor have used either sensory or chemical/instrumental techniques as the main identification and quantification method. Using these methods of analysis are indeed beneficial because of the knowledge they have provided, but integrating these techniques can allow for a deeper understanding of the factors leading to fresh tomato flavor. By connecting data from sensory analysis and chemical/instrumental analysis, significant correlations and relationships have been identified between taste descriptor intensities and volatile concentrations. Baldwin et al. (1998) has suggested that the combination of Sucrose Equivalents/Titratable Acidity and Sucrose Equivalents are useful in predicting sweetness as well as tomato-like flavor. Maul et al. (1998) integrated techniques to show that as ripening changes chemical and
volatile compounds, these changes induce significant sensory perception differences. Auerswald et al. (1999) used integration of approaches to show that changing the nutrient solution electro-conductivity (EC) of tomatoes in turn changes the composition of the tomato and these changes also affect the intensity of sensory attributes. Taste (sweet and sour) attributes have been shown to be affected by sugar and acid levels, and that there is a optimum level of acids that can be exceeded and result in unfavorable tomato flavor (Malundo et al., 1995).

The development of sensory, chemical, and volatile analysis, partitioning, mathematical relationships, and integration techniques has allowed researchers different ways of studying the tomato flavor issue. It is obvious that further research using each of these techniques is important to attaining the goal of understanding tomato flavor. Most studies focus on the product (e.g. tomato) and relate the information to the consumer. There appears to be a need for studies that focus on the consumer and relate the information to the consumer. True understanding of tomato flavor will come by integrating knowledge about the consumer to other methods of tomato flavor analysis.

**Consumer Acceptance of Tomato Flavor**

The main purpose for conducting studies on tomato flavor is to increase consumer satisfaction. Yet very few studies have been conducted identifying factors contributing to consumer acceptance of tomato flavor, and of these studies, less than 15 actually had consumers taste tomatoes at the time of the study. Sensory attributes, volatile profiles, soluble solids, and titratable acidities are all important aspects of tomato flavor, but have little relevance to improved quality if not linked to consumer preference. Instead of general information, knowledge of what tomato buyers prefer or find acceptable/ unacceptable allows researchers to look at more specifics of sensory and chemical compositions of tomatoes. Much debate has occurred over use of consumers in these studies. Some researchers believe consumers can’t express what they like/dislike and are
too variable to be useful to this research. Data supporting this idea has shown that consumer tastes are not as sensitive as trained panelists and therefore cannot detect some flavor differences that the trained panels detect (Auerswald et al., 1999). Yet other studies have shown through paired comparison tests including duplicate samples that consumers score the same samples accurately (Eytan, 1990). Such studies show the difference in sensitivity levels of consumers and trained panelists, but also show consumer knowledge. Consumers cannot detect small differences in flavor because they have not been trained to do so, but they can conclude what they like or dislike, which is all that matters from a marketing point of view (Conner, 1994).

Eytan (1990) conducted several consumer tests on tomato flavor. One cultivar was found most acceptable in all testing methods, and when compared to ideal tomato flavor attributes, the tomato found most acceptable was closest to these scores. The consumers were able to show the tomato found most acceptable was closest in sensory attribute scores to those of an ‘ideal’ tomato. Another consumer study using a triangle test showed consumers can distinguish between different cultivars and determine which cultivars are the same (Hobson et al., 1990). Additional studies have evaluated different nutrient levels during growth and asked consumers select a preferred sample based on flavor, showing many factors can be manipulated to affect consumer preference.

Malundo (1995) developed models to predict consumer response of flavor acceptance as a function of sugar and acid concentrations of tomatoes. They found an optimum level of acidity relating to high consumer acceptance with levels above the optimum negatively affecting acceptability. Van Lieshout (1993) also reported that sugar and acid concentrations were important in determining consumer acceptance and tried to find those optimum levels. He found that sugar levels greater than 1.6% were found to be of better quality by 68% of consumers and sugar levels less than 1.1% were found to be of worse quality by 69% of consumers. No levels for acidity could be determined but it was concluded that to improve taste and acceptance of flavor higher sugar levels are needed and acidity has an optimum level. There has also been data generated to suggest that
there is a correlation between tomato appearance and flavor (van Lieshout, 1993).
    Consumer testing showed that a tomato looking well from the inside also had a typically
good tomato taste which includes tasteful, not tart, and aromatic.

    Vesseur (1990) concluded through consumer studies of tomato flavor that
acceptance of flavor is affected by production method and the country of origin. Von
Alvensleben and Meier (1990) found that consumers assess tomato flavor quality by
labels. Consumers were presented identical samples with different labels and different
responses were given for these samples. However, the researchers stated this was only
one segment of tomato consumers that use labeling to assess flavor rather than the actual
flavor. Wolters and von Gemert (1990) determined consumers prefer tomatoes with
sweeter, spicier flavor and a more full flavored, smoky odor while disliking a hospital-like
odor and bitter taste. Once again we find the presence of consumer preference toward
sweet flavor, which could be related to the idea of an optimum acidity level (Malundo et
al., 1995). Auerswald et al. (1999) concluded that consumers preferred the flavor of fresh
tomatoes to those that had been stored for 4 or 7 days. This study also concluded that
texture and flavor are related, as consumer scores for one attribute increases the other
attribute score will also increase. Correlating consumer acceptance to sensory descriptive
attribute values, Abegaz (2000) noted that consumer acceptance of tomato flavor was
positively influenced by sweet, sour, and salty sensory notes. Prediction of consumer
acceptance by sensory descriptive values was found to be inconclusive, but it was found
that the different consumer levels of acceptance were influenced by different sensory
attributes.

    Methodology. For consumer testing, there is no one method that is regarded as
best in gaining the most accurate and precise results. In the previously discussed
consumer testing, a wide range of testing was incorporated including 5 and 9-point
hedonic scales (Peryam and Pilgrim, 1957; von Alvensleben and Meier, 1990; Malundo
et al., 1995), 6-point Likert scales (van Lieshout, 1993), pair comparison, ranking order,
100-point unstructured scales (Wolters and Gemert, 1990; Auerswald et al., 1999), and 3-
point acceptability scales (Kopeliovitch, 1982; Brumfield et al., 1993; Abegaz, 2000). Although the goal of these methods is to determine consumer acceptability, the differing methodology could cause different results. Of the studies using hedonic scaling methods, differing results may have been influenced by the terminology used to score the tomato flavor. Three studies had consumers score based on acceptance or preference (Hobson, 1990; von Alvensleben and Meier, 1990; Malundo, 1995) while another study used overall quality (van Lieshout et al., 1990). Preference or acceptance of tomato flavor is different from overall quality, which includes characteristics like texture and appearance. Results from one study concluded that consumer acceptance of tomato flavor was influenced by labeling (von Alvensleben and Meier, 1990) with results “different” for each sample using a 5-point hedonic scale, and of the possible zero to five scoring range. The samples ranged from 2.5 and 3.2, indicating that different methodology affected the results obtained. Paired-comparison and rank-order tests have the consumer rate samples or select the better sample. The acceptance ratings from these methods are not based on the sample alone, but use comparison with another sample(s) to determine acceptance (Eytan, 1990; Vesseur, 1990). Unstructured 100-point scales (Wolters and Gemert, 1990; Auerswald et al., 1999) give panelists a wide range of possible responses for the same fruit resulting in inconsistencies. It is difficult to compare results from consumer studies because of the testing method, language used, the number of panelists, and the form of the tomato tasted (whole, sliced, diced, puree) can all affect results and conclusions.

Consumer acceptance testing can include many different methods and techniques to achieve the same goal, but these differences can also cause inconsistent results. However, one result that has seemed to prevail throughout the methods and techniques is that of preferred sweetness and optimum acid levels. With this conclusion prevailing through many objectives and methods, it seems to stress its importance in understanding tomato flavor acceptance.
Developing an Ideal Scale for Acceptance

Food companies as well as other product producing businesses have placed an increasing focus on moving from product-oriented quality to consumer-oriented quality (Shewfelt et al., 1997). Since the quality of the product affects its acceptance and purchase and that the consumer is the fundamental assessor of quality, it is important to understand and predict consumer acceptance of products. Acceptability has been defined in many ways, but the most appropriate definition is defined by Land (1988) as a “level of continued purchase or consumption by a specified population.” To predict consumer acceptability, one must first select a method to measure consumer acceptability, of which several methods and modifications of methods exist.

Internal vs. External Validity. Internal validity is defined as “the extent to which variation in sensory evaluation can be traced back to variations in product composition” whereas external validity is defined as “the extent to which the variation in sensory evaluation contributes to explanation and prediction of actual food choice behavior in the market” (van Trijp and Schifferstein, 1995). The methods available in assessing consumer acceptability tend to be high in either internal or external validity, but not both. Only the incorporation of the two will result in information relevant to systematic improvement of tomato flavor (van Trijp and Schifferstein, 1995; Shewfelt et al., 1997).

Requirements of testing methods to achieve internal validity is opposite from those to achieve external validity. Internally valid studies focus on the product, using either analytical methods or sensory panels to generate measurable characteristics (i.e. level of sugar, intensity of green notes, etc.). Analytical methods such as soluble solids and titratable acidity are used while sensory panels score levels of attributes of the product. These panels are limited in size (10 to 20 subjects), are trained in specialized and consistent terminology, highly sensitive to the attributes being measured, are tested in controlled environments and are given detailed tasting instructions. Changing the focus from product to consumer increases external validity. To change this focus, more
subjects must be enlisted, these subjects should be naïve without specific training or previous experience in the study, the consumers selected should represent target segments of the consuming population, the terminology should be adapted from the consumer, and the testing environment should be less controlled or more typical of eating conditions (van Trijp and Schifferstein, 1995).

Both internal and external validity are important to the final conclusions of consumer acceptability of a product. Creating a scale with both internal and external validity has proven difficult, but using a consumer acceptance method incorporating levels of both types would yield very useful data, it would have meaning for both product and consumer.

*Methods of Acceptance Measurements.* There are three general types of consumer acceptance tests including paired preference tests, ranking tests, and category scaling tests (Meilgaard et al., 1987; Lawless, 1998; Resurreccion, 1998). The objective of the first two types of testing is to determine preference and not acceptability. Paired preference testing presents panelists with two samples and the subject selects one sample over the other, while ranking tests present panelists with three or more samples and the subject ranks the samples in order of most preferred to least preferred or vice versa. Preference of a sample does not mean the panelist found the preferred sample acceptable or the other sample unacceptable. Category scaling simply uses categories to rate acceptance and the objective, language, and the numbers of categories vary vastly between studies and researchers.

The most often used method of category scaling is the hedonic scale with variations from 5 to 11 points but usually the 9-point scale is most often employed. This scale was developed in the late 1940’s by the U.S. Army Food and Container Institute (Lawless, 1998). The scale consists of levels with each level marked by a category term. The scale typically ranges from dislike extremely to like extremely. Best results are found when the steps on the scale are of equal size and have a balanced number of categories (Meilgaard et al., 1987). Consumers are presented a sample(s) and select a
level or degree of acceptability of the sample from those listed on the scale. The levels chosen are then transformed to numbers based on the number of points, and statistical analysis is usually conducted to determine the level of consumer acceptance for the product(s). The 9-point hedonic scale is often used in tandem with other sensory or instrumental methods. Resurreccion (1998) uses this scale as an extension of sensory evaluation and relates the results to sensory descriptive attribute scores. Andani and Macfie (2000) use preference mapping to match consumer preference and descriptive attributes to identify consumer segments and market products to these segments.

Another frequently used method to determine consumer acceptability is Willingness-to-Purchase or Purchase-Intent scaling. Consumers score the level of their willingness to purchase the product based on its quality, price, and other attributes (Stone and Sidel, 1993) typically using a 5-point scale. From the categories scored (definitely would purchase, probably would purchase, might or might not purchase, probably would not purchase, definitely would not purchase) the top two categories are judged as willingness (Moskowitz, 1993). Although this is not a direct measure of acceptance, acceptability can be inferred from the purchase intent scores. The level of purchase intent directly relates to the level of acceptability (Reed, 1998; Brewer and McKeith, 1999).

The just-right scale measures acceptance by measuring desirability of a specific attribute of a product (Lawless, 1998). The scale again is similar to the 9-point hedonic and the willingness to purchase in that it uses a specific number of levels with category terms or phrases detailing degrees of desirability. A company trying to decide if a candy bar is at the right level of sweetness would use the just right scale based on the attribute sweet to find consumers acceptance of the sweetness. If the scores are significantly scored “just right” then the product is interpreted as being acceptable, but if the scores are significantly “too sweet” or “not sweet enough” the product sweetness is interpreted as being unacceptable.
The 3-point acceptability scale (tastes great, acceptable, and unacceptable) was designed to model consumer response to a single food when it is in the mouth. The use of this scale assumes that most consumers have additional things on their mind when eating and are not solely focused on evaluating flavor. It further assumes that most consumers, under ordinary circumstances, do not differentiate most foods beyond meeting or exceeding expectations. The most likely response is labeled in the scale as “acceptable”, since most food is acceptable or meets expectations of the consumer, failing to evoke a conscious response. On the other hand, conscious responses are noted when a product (unacceptable) does not meet expectations or exceeds expectations (tastes great). The consumer is surprised, either pleasantly or not, and a mental note is made that this food flavor is different from the normal acceptable flavor that could affect future purchase behavior and modify expectations of that individual consumer.

The 3-point acceptability scale expresses acceptability “as a probability distribution of a percentage of a population finding the product acceptable” (Shewfelt and Tijskens, 2000). The rationale for this expression is that the 3 categories are discrete and not continuous. The scale is subjective because acceptability is subjective and individualized because standards for individuals vary widely.

*Strengths and Weaknesses of Acceptance Methods.* Although all of the aforementioned methods of consumer acceptance are useful, some are more helpful than others. While the main goal of using the 9-point hedonic method is to determine acceptability and ultimately probability of purchase by the consumer, this scale measures degrees of liking and not actual acceptability. An inference must be made as to the acceptability of the product based on the liking scores, which are simply means or averages of the responses. This scale has been said to have ruler-like properties (Lawless, 1998) and has been shown to be just as reliable and accurate as other acceptance measuring methods (O’Mahony and Odbert., 1988). Yet the scale is not interval data or equally-spaced (Lawless, 1998) and so no measurement can be made as to the value between categories of liking. Comparing a score of 3 and a score of 6 on the
scale does not mean that the score of 6 has twice the acceptance of the score of 3 (Meiselman, 1988; O’Mahony, 1991). Thus, no value measurements can be made of different degrees (Meilgaard et al., 1987). Another weakness of this method is that although 9 points are used for increased discrimination (Meilgaard et al., 1987; Stone and Sidel, 1993), the full range is not used. Most consumers only use the middle of the scale points 5, 6, and 7 (O’Mahony, 1991) due in part to “end-effects” (consumer reluctance to use the extreme ends of the scale), consumer unwillingness to discriminate among the small degrees of difference and experimenter reluctance to serve unacceptable product. Although many believe 9 points in a hedonic scale are ideal, O’Mahony (1991) states that panelists may confuse some adjacent points and use them interchangeably. Also, the language used is not as specified as sensory descriptive, but the degrees of the category titles are relative to each consumer’s definition. Thus, the language does not seem to be directed toward the consumer, decreasing external validity.

The willingness-to-purchase scale is quite beneficial in that data on purchase and acceptability can be garnered from one test and the category levels have symmetry. However, this scale poses some of the same shortcomings as the 9-point hedonic. The scale is not equal interval, so no measurements of degrees of values can be made. Also, the use of this as an indicator for acceptability is only by inference. Different attributes are included in the decision of acceptability and willingness to purchase. While price may be a factor in acceptability, it is not as motivating a factor as with purchase intent; a consumer may find a product acceptable but not be willing to purchase the item. This objection can be neutralized by inserting “at a reasonable price” in evaluation instructions. One item of note with this scale is the means of analyzing the data obtained. While other scales use means and averages, analysis of willingness-to-purchase data frequently considers only the top two categories (definitely would purchase, probably would purchase) and expresses acceptability as a probability distribution (Oliver, 1997).

Just-right scales measure levels of specific attributes of a product. Sensory descriptive panelists perform this task only with extensive training, so naïve consumers
can’t be expected to perform as well as the descriptive panels. This lack of training of the consumer also limits the attributes to be measured due to a lack of understanding of many attributes by consumers (Lawless, 1998). A major weakness of this scale is the presence of consumer segmentation. In testing a very sweet peach a segment of consumers may like very sweet peaches and would score the sample just right, suggesting that analyzing means can be misleading and would omit consumer segments (Lawless, 1998).

The first weakness noted of the 3-point scale is that it is not symmetrical or balanced with regards to the categories and there is no neutral middle. The scale is not equal interval; a score of tastes great is not twice as acceptable as a score of acceptable. This scale is not looking to measure the degrees between the categories, it is to determine if a consumer finds a product acceptable. The top category is termed “tastes great” which may seem inappropriate terminology, but was developed to mirror the consumer’s terminology. The label can be replaced by the phrase exceeds expectations, but the use of consumer language increases the external validity (van Trijp and Schifferstein, 1995). Another difficulty with this scale is that it is not parallel (e.g. acceptable and unacceptable are parallel, but tastes great is not parallel). The three-point scale, as described above, has been successfully used in studies on bananas (Shewfelt and Tijskens, 2000), mangos (Malundo, 1996), peaches, romaine lettuce, and tomatoes (Abegaz, 2000). Attempts have been made recently to modify the scale to “does not meet expectations”, “meets expectations”, “exceeds expectations” confused consumers and did not yield useful data (Shewfelt, personal communication).

As previously stated, this scale does not use averages or means, but rather a probability distribution of a percentage of the population. This scale is the only scale described that measures acceptability, rather than determining acceptability by inference. Use of only 3 categories forces consumers to make a choice. End effects do not appear to be a problem as previous studies have shown that 36% (Shewfelt and Tijskens, 2000) and 51% (Abegaz, 2000) of the responses were either unacceptable or tastes great. The direct relation to consumers provides this scale with greater external validity than the other
scales mentioned. The lack of internal validity for this scale can be overcome by expressing acceptability as a function of sensory descriptors obtained on the same treatments using logistic regression (Malundo, 1996; Reed, 1998; Malundo et al., 1999).

References


CHAPTER 2
SEGMENTATION OF CONSUMER ACCEPTABILITY OF TOMATO FLAVOR
BY FOCUS GROUPS AND CONSUMER EVALUATION

ABSTRACT

Segmentation of consumers’ acceptance of tomato flavor has been suggested as a means to change the current overwhelming consumer dissatisfaction with tomato flavor. Focus-group sessions comprised of regular tomato consumers were conducted to determine segments based on flavor as well as other important data concerning tomato purchase and storage. Further supermarket consumer evaluations were then conducted based on the data collected from the focus group sessions. Segments based on acceptability of tomato flavor, sweet, tart, and vine-ripened were supported by the consumer evaluations, but the segment sweet and sour was also found to be important. Consumer testing also suggested that although flavor is important to tomato acceptance, there are other attributes that also influence a consumer’s decision of acceptance. Price and level of firmness have been found to affect tomato acceptability. Too firm or too soft results in unacceptable tomato quality, while a high price for a less than premium quality tomato is also unacceptable. Consumers vary widely in variety selection, place of purchase, storage conditions, and preparation of tomatoes, yet there is a general consensus that more work should be done to improve the flavor of tomatoes available at the supermarket.
Any attempt to improve flavor of an agricultural crop or food product must involve an understanding of consumer desires. Unfortunately recent efforts to improve flavor of fresh tomatoes have ignored consumers’ opinions and attitudes, relying solely on breeder estimates. Tomatoes are among the major produce items eliciting greatest consumer dissatisfaction, primarily attributed to flavor (Bruhn et al., 1991). Marketers and researchers are trying to identify current problems with tomato flavor and methods of improvement. One suggested method is segmentation of consumers by their acceptability of tomato flavor (Moskowitz, 1993; Shewfelt, 2000); by knowing the different flavor segments of consumers and further research, it may be possible to provide these flavor segments at the supermarket level.

One way to identify consumer segments is through focus group sessions. Focus groups help identify a range of consumer attitudes (Krueger, 1988). Focus groups have been conducted on a wide range of issues. They have been used to develop instruments to assess women’s health beliefs during pregnancy (Tiedje et al., 1992) and to understand patient delay in seeking care for heart attack symptoms (Finnegan et al., 2000). Focus groups helped identify priority foods of ethnic backgrounds (Samuda et al., 1998), develop school lunch planners for specific ethnic groups (Price, 1978), and to determine effect of nutritional labeling on consumer behavior (Anderson and Calingaert, 1994). Previous consumer issues described by focus groups included consumer evaluation of beef quality (Grunert, 1997), consumer acceptability of cheddar-type cheeses (Bogue et al., 1999) and acceptability of peaches and mangoes (Malundo, 1996). Product development departments of food companies have used focus groups to aid in new product development of products like dark chicken meat (Elsner et al., 1998). Focus groups are also used in quality assurance of dairy products (Payne et al., 1999). We know of no published reports to date using focus groups to better understand tomato flavor.
The objectives of this study are to identify potential market segments for fresh tomatoes based on flavor perception, determine the range of consumer purchase and home storage techniques, and to test the validity of the segments in actual consumer evaluation tests.

**MATERIALS AND METHODS**

**Experimental Materials**

All tomatoes were grown under standard agricultural practices (Hochmuth et al., 1988) at the Gulf Coast Research and Education Center, University of Florida in Bradenton, Florida. The breeder and an assistant harvested 9 breeding lines based on specific flavor attributes. Tomatoes were transported back to the University of Georgia campus on the day of harvest. Tomatoes were stored at 10C until the evaluation period. All tomato samples were served to panelists at room temperature.

**Focus Groups**

Three focus-group sessions were conducted at the University of Georgia Food Processing and Research Development Laboratory, in Athens, Georgia. All sessions contained between nine and twelve panelists. Panelists were recruited based on the regularity of their tomato consumption. For each focus group discussion, steps were taken to control environmental conditions so as not to detract from the discussion (Krueger, 1988). As panelists arrived, they were given nametags to be worn during the session and were encouraged to talk to other panelists. The moderator, based upon personalities found during the introductory meeting, seated the panelists around a rectangular table. While the moderator sat at the head of the table, more outspoken panelists were seated to the left or right while less talkative panelists were seated within eye contact range of the moderator to aid in eliciting discussion. Two tape recorders were placed at either end of the table to record the discussion of the panelists. The
moderator asked questions based on a previously outlined set of questions, but did not follow a script. Each panelist was given an opportunity to respond to each question. If the moderator found responses needed further explanation, additional discussion probed panelists for further details. Panelists were encouraged to discuss topics, not just to simply answer the questions. Panelists were compensated for their time with either a meal or a gift certificate.

**Consumer Evaluation**

All consumer evaluation testing was performed at a local supermarket. Tables were setup next to the tomato display, one for recruitment and another for the tomato evaluation. Consumers were recruited based on tomato consumption. As consumers were recruited, one assistant explained the evaluation process and sent consumers over to the evaluation table. A questionnaire consisting of three sections was followed as conductors marked consumers’ responses. In the first section, consumers were monadically served three tomato samples labeled with 3-digit random codes and to select the one they most prefer. In the second section, consumers were again monadically served three tomato samples labeled with 3-digit random codes with different levels of flavor based on the first section selection, and asked to evaluate each sample’s flavor using a 3-point acceptability scale (tastes great, acceptable, and unacceptable). In the third section, consumers responded to questions about their selection and storage of tomatoes. Each panelist was given a small treat for his/her participation.

**Statistical Analysis**

For the second section of the consumer evaluation significant differences were tested among samples. Means separation was done using Duncan’s procedure at p< 0.05 with SAS v.6.12 software package.
RESULTS AND DISCUSSION

Focus-group discussions about fresh tomato flavor revealed that consumers were clear in their likes and dislikes. Some probing by the moderator was necessary to understand preferences and the rationale for them, but the consumer still knew what they liked even if they could not always verbalize it (Conner, 1994).

Consumers participating in this study varied widely in their purchase, storage, and consumption of fresh tomatoes. Attributes used to decide purchase are quite different from those used to decide consumption (Table 1). External characteristics are used to determine purchase acceptability while external as well as internal characteristics are used to determine consumption acceptability. Purchase frequency varied from daily to monthly to special meals only. Place of purchase included locations like grocery stores,

<table>
<thead>
<tr>
<th>Critical Purchase Attributes</th>
<th>Critical Consumption Attributes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Color</td>
<td>Flavor</td>
</tr>
<tr>
<td>Firmness</td>
<td>Color</td>
</tr>
<tr>
<td>Variety</td>
<td>Juiciness</td>
</tr>
<tr>
<td>Price</td>
<td>Texture</td>
</tr>
<tr>
<td>Season</td>
<td>Odor</td>
</tr>
</tbody>
</table>

flea markets, home gardens, and roadside stands. Color choice was based upon intended time of use; tomatoes to be used soon are selected bright red while those to be used later
are selected with some green color remaining. All consumers agreed that tomatoes should be firm and at an inexpensive price. The number of tomatoes purchased depended on the season. During the summer, most consumers liked the flavor of tomatoes available and some preferred to select tomatoes from gardens and roadside stands to grocery stores as described earlier by Gallons et al. (1997). However, due to lack of availability during the winter, consumers must use grocery stores if they want tomatoes, and previous data have shown there is a general dislike of tomato flavor during the winter (Puig and Casado, 1983). Dissatisfaction with winter fruit may stem from shorter day-length leading to lower synthesis of carotenoids, which contribute to tomato flavor (Petro-Turza, 1987). Varieties are chosen based on the intended method of preparation and consumption (Table 2). Smaller varieties such as grape, cherry, and roma are used for salads while larger varieties are used for sandwiches and dishes.

Characteristics for consumption acceptability were quite different from those for purchase acceptability with the inclusion of internal characteristics. Most consumers purchase tomatoes prior to the red-ripe stage to extend home storage life (Shewfelt et al.,

<table>
<thead>
<tr>
<th>Variety</th>
<th>Method of Preparation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cherry</td>
<td>Salad</td>
</tr>
<tr>
<td>Grape</td>
<td>Salad</td>
</tr>
<tr>
<td>Roma</td>
<td>Salad</td>
</tr>
<tr>
<td>Big Boys</td>
<td>Sandwich, Meal (tacos, fajitas, pasta, etc.)</td>
</tr>
<tr>
<td>Better Boys</td>
<td>Sandwich, Meal</td>
</tr>
<tr>
<td>Medium/Big</td>
<td>Sandwich, Meal</td>
</tr>
</tbody>
</table>
2000), but they wanted them completely red for consumption. Juiciness was a critical consumption attribute for all participants but the degree of juiciness varied within the groups. A segment of consumers want a minimal amount, to maintain the integrity of the slice, segment or dice while others want it so juicy that “it soaks into the bread and mayonnaise.” Odor was described as being tomato-like, while flavor was divided into several categories including sweet, sour, vine-ripened, and sweet and sour. Consumers agreed that the texture should be firm but not mealy or too fibrous. Although consumers have specific signals that they use to purchase and consume tomatoes, it would seem that purchase signals used to indicate an enjoyable tomato upon consumption are not always correct (Shewfelt, 2000). In fact, the inconsistency of purchase characteristics in relation to consumption characteristics has led to consumer dissatisfaction with tomato flavor (Bruhn et al., 1991).

Participants agreed that a tomato was unacceptable for consumption if bruises, mold, cracks, or indentations were visible. The lack of firm internal appearance classified as “mushy” or lack of juiciness classified as “mealy” were uniform indicators of unacceptable texture. The primary indicator of unacceptable flavor was a lack of flavor. Although other off-flavors were described as medicine-like or “like a green watermelon”, the main complaint was no flavor. If a tomato met all other criteria but had no flavor, it was still found to be unacceptable. This displays the importance of flavor to acceptance, but flavor alone is not the key to acceptance. Participants also indicated that poor appearance or texture, regardless of flavor, could render a fresh tomato unacceptable. Thus, although flavor is an important factor in acceptability, it is not the only factor considered by the consumer.

Focus-group participants could be divided into several segments of flavor acceptability. The main segments were found to be vine-ripened, sweet, tart/sour, and not bland. The range and number of differences in these segments suggests that segmentation should be considered in marketing and merchandising of fresh tomatoes. Marketing a tart tomato will only find acceptance with a certain percent of the
population, while the rest will find it unacceptable. Market segmentation of tomatoes based on flavor should lead to greater consumer satisfaction and more tomatoes sold (Shewfelt, 2000).

An in-store evaluation and survey was conducted to validate and quantify focus-group data. Sweet, vine-ripened, and tart were the main segments, but a sweet and sour segment was also found to be important (Table 3). This segment preferred sweet with a little sour/acid/tart flavor as well. This finding supports previous reports (van Lieshout, 1993; Malundo et al., 1995) that acceptability increases with sweetness, but there is an optimum acid level above which the flavor becomes unacceptable. When comparing consumer self-selected segments to the segments they preferred upon flavor evaluation, more of the sweet segment preferred the sweet flavor, more of the vine-ripened segment preferred tart flavor and more of the sweet/sour segment preferred almost equally sweet and tart flavors while more of the tart segment preferred a sweet flavor (Table 3). This observation shows that although many consumers know what flavor they prefer, focus-groups need to be followed up by consumer evaluation to

<table>
<thead>
<tr>
<th>Self–identified Segment</th>
<th>% Total Consumers</th>
<th>% Prefer Sweet Segment</th>
<th>% Prefer Tart Segment</th>
<th>% Prefer Floral/Fruity Segment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sweet</td>
<td>39</td>
<td>46</td>
<td>27</td>
<td>27</td>
</tr>
<tr>
<td>Vine-ripened</td>
<td>24</td>
<td>31</td>
<td>38</td>
<td>31</td>
</tr>
<tr>
<td>Tart</td>
<td>18</td>
<td>44</td>
<td>36</td>
<td>20</td>
</tr>
<tr>
<td>Sweet/sour</td>
<td>15</td>
<td>40</td>
<td>35</td>
<td>25</td>
</tr>
<tr>
<td>Other</td>
<td>4</td>
<td>26</td>
<td>37</td>
<td>37</td>
</tr>
<tr>
<td>Total</td>
<td>100</td>
<td>40</td>
<td>33</td>
<td>27</td>
</tr>
</tbody>
</table>
validate that consumers actually select the same flavor segment as they identify themselves a part.

Age and gender of the panelists did not appear to influence the segments as there was a fairly even number of panelists from each segment (Table 4). Most participants were the home purchasing agent (Shewfelt and Tijskens, 2000) for the family, which accounts for the age and gender distribution of the sample.

**TABLE 4.**
SUPERMARKET CONSUMERS’ AGE AND GENDER

<table>
<thead>
<tr>
<th>Age</th>
<th>Range</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>18 &amp; under</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>19-24</td>
<td>21</td>
<td></td>
</tr>
<tr>
<td>25-34</td>
<td>18</td>
<td></td>
</tr>
<tr>
<td>35-44</td>
<td>23</td>
<td></td>
</tr>
<tr>
<td>45-54</td>
<td>15</td>
<td></td>
</tr>
<tr>
<td>55 &amp; above</td>
<td>22</td>
<td></td>
</tr>
<tr>
<td>Gender</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>29</td>
<td></td>
</tr>
<tr>
<td>Female</td>
<td>71</td>
<td></td>
</tr>
</tbody>
</table>

Other factors identified by the focus groups that were explored by the supermarket panels were variety purchased, seasonal purchase, and storage conditions. Table 5 shows that single/big, roma, and homegrown tomatoes are the fruit types and locations most selected by consumers. Frequency of tomato use was slightly greater in summer than winter but not as pronounced as expected from the focus-group comments (Table 6). Consumers are most likely to use the refrigerator, followed by out on the counter, and then the window sill (Table 7). This data supported comments from focus-group sessions. One item of note is the large number of consumers using the refrigerator to store fresh tomatoes. It has shown that refrigeration is known to reduce fresh tomato flavor (Buttery et al., 1987; Shewfelt, 1990) which could account for some of the dissatisfaction of tomato flavor. Consumers that selected tomatoes from fresh sources
(gardens, roadside stands, farmer’s market, etc.) were satisfied with the flavor of those tomatoes, but rarely satisfied with the flavor of supermarket tomatoes. Another possible source of poor tomato flavor is the early harvest and treatment with ethylene, which may prevent the full flavor potential from developing (Kader et al., 1978; Baldwin et al., 1998).

**TABLE 5.**

**VARIETIES OF TOMATOES SELECTED**

<table>
<thead>
<tr>
<th>Variety</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cherry</td>
<td>7</td>
</tr>
<tr>
<td>Roma</td>
<td>21</td>
</tr>
<tr>
<td>Grape</td>
<td>7</td>
</tr>
<tr>
<td>Cluster</td>
<td>10</td>
</tr>
<tr>
<td>Single/Big</td>
<td>29</td>
</tr>
<tr>
<td>Homegrown</td>
<td>16</td>
</tr>
<tr>
<td>Roadside</td>
<td>5</td>
</tr>
<tr>
<td>Farmer’s market</td>
<td>3</td>
</tr>
<tr>
<td>Organic</td>
<td>1</td>
</tr>
<tr>
<td>Cheapest</td>
<td>1</td>
</tr>
</tbody>
</table>

**TABLE 6.**

**SEASONAL FREQUENCY OF TOMATO SELECTION**

<table>
<thead>
<tr>
<th>Frequency</th>
<th>Summer (%)</th>
<th>Winter (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weekly or more</td>
<td>61</td>
<td>55</td>
</tr>
<tr>
<td>Every 2-3 weeks</td>
<td>21</td>
<td>24</td>
</tr>
<tr>
<td>Monthly or less</td>
<td>18</td>
<td>21</td>
</tr>
</tbody>
</table>
TABLE 7.

STORAGE CONDITIONS EMPLOYED
IN CONSUMER HOMES

<table>
<thead>
<tr>
<th>Storage condition</th>
<th>No. per condition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Refrigerator</td>
<td>50</td>
</tr>
<tr>
<td>Windowsill</td>
<td>11</td>
</tr>
<tr>
<td>Counter</td>
<td>34</td>
</tr>
<tr>
<td>Other</td>
<td>5</td>
</tr>
</tbody>
</table>

In the second section of supermarket consumer evaluations, consumers were given three samples with varying levels of the flavor they selected as best from the first section. The sweet segment consumers’ scores for the sweet sample were found to be significantly different from the slightly sweet and not sweet samples (Figure 1.a). Of those consumers among the tart segment, the tart sample was rated highest for tastes great and acceptable, yet no significant differences were found among the scores of the three samples (Figure 1.b). Consumers selecting the floral sample as the best were given samples floral, musty, and “worst”. In this segment, consumers’ scores for the floral sample were significantly different from those samples labeled musty and worst (Figure 1.b).

Data collected from focus groups followed up by supermarket consumer panels show definite segments of consumer acceptability of tomato flavor. They also suggest that consumers use more than flavor to determine tomato acceptability. The results of these panels support the idea that tomato acceptability is determined by more characteristics than flavor. Further research is needed to better understand the complex relationships of flavor acceptability.
FIGURE 1.a. PERCENT ACCEPTABILITY OF SWEET SEGMENT

FIGURE 1.b. PERCENT ACCEPTABILITY OF TART SEGMENT

FIGURE 1.c. PERCENT ACCEPTABILITY OF FLORAL SEGMENT

Acknowledgement

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CHAPTER 3
CONSUMER ACCEPTABILITY OF TOMATO FLAVOR AS VIEWED
BY THE BREEDER AND CONSUMER

ABSTRACT

Tomatoes are one of the most often cited items with respect to consumer dissatisfaction. Segmentation of consumer acceptability of tomato flavor has been offered as a means to improve acceptability. Consumer panels were performed to establish consumer segments. Flavor acceptability of different tomato lines was evaluated using a three-point scale. Consumer judgments were compared with that of the tomato breeder and assessment by a sensory descriptive panel. Consumer evaluation showed different characteristics contributed to superior flavor (tastes great) than to acceptable flavor. The descriptor tomato-like was negatively correlated to a score of tastes great while an acceptable rating was correlated positively to sour and negatively to bite. A comparison of the breeder's evaluation of the cultivars showed general agreement with the consumer’s evaluation, but there were some important differences. One such difference was line 307 being rated “bad” by the breeder and rated higher than average acceptability by the consumer panel. A mathematical relationship was developed for consumer acceptability as a function of specific flavor characteristics. The results emphasize the need to select for different characteristics for premium tomatoes than those for the mass market.
INTRODUCTION

Increasing health-consciousness among consumers is leading to an increased purchase of fresh fruits and vegetables. Flavor is an important consideration in the specific choices consumers make, and many consumers are dissatisfied with the flavor of tomatoes purchased at the supermarket (Bruhn et al., 1991). Previous consumer studies (Bruhn et al., 1991; Auerswald et al., 1999; Beattie et al., 1983; van Lieshout, 1993), show that purchasing can be used to divide consumers into segments based on characteristic preferences. Segmentation by flavor can be grouped into consumers preferring sweet, tart, vine-ripened, or sweet and sour flavor. Consumer segments can also be divided by purchase price based on quality, because some consumers are willing to pay more for premium quality produce. Providing specific consumer segments with items that meet their expectations for flavor acceptability should lead to increased consumer satisfaction (Moskowitz, 1993; Shewfelt, 2000).

To determine these segments, the consumer, descriptive and chemical languages of tomato flavor must be translated into a predictive model. This model will allow scientists and breeders to predict consumer acceptance of tomatoes based on the chemical properties and sensory attributes present. Breeders can then select for these specific characteristics in tomatoes resulting in increased consumer satisfaction in tomato flavor and increased sales of tomatoes; a benefit to both consumers and producers alike.

In determining these segments, some genetic research on tomato flavor has been pursued. Bucheli et al. (1999) attempted to enhance tomato flavor by determining biochemical markers for tomato flavor. Understanding these biochemical markers will allow breeders to select for specific varieties with specific flavor characteristics, thus fulfilling consumer segmentation needs. The objective of this study is to determine some preliminary segments that consumers can be divided into based on their acceptability of tomato flavor. Also, the goal of this study is to determine a relationship between specific flavor characteristics and consumer acceptability of tomatoes.
MATERIALS AND METHODS

Experimental Materials

All tomatoes were grown under standard agricultural practices at the Gulf Coast Research and Education Center, University of Florida in Bradenton, Florida. The breeder and an assistant harvested six breeding lines based on specific flavor attributes, with two stages of maturity per line, red-ripe and breaker (USDA, 1975). Tomatoes were transported back to the University of Georgia campus on the day of harvest. Red-ripe tomatoes were stored at 10°C until the evaluation period while breaker tomatoes were ripened at 20°C to red-ripe. All tomato samples were served to panelists at room temperature.

Consumer Testing

All consumer testing was performed at the University of Georgia. Sets of three samples were labeled with 3-digit random numbers and monadically served in random order to panelists in their workplace. Panelists completed questionnaires consisting of two sections; (1) evaluation of each sample’s flavor using a 3-point acceptability scale (tastes great, acceptable, and unacceptable) (Reed, 1998), and (2) preferences of tomato flavor into one of five segments (vine-ripened, sweet, tart, not bland, and other). The panelists were provided unsalted crackers and water to cleanse the palate between samples.

June 1999. Six tomato breeding lines were harvested at red-ripe and breaker stages. Red-ripe tomatoes were harvested red and evaluated within 4 days of harvest. Breaker tomatoes were harvested at the breaker stage, allowed to ripen off-vine and evaluated within 12 days of harvest. One hundred naïve panelists participated in the consumer test and each of the six breeding lines was evaluated by at least 50 panelists. Consumer panel evaluations of the red-ripe samples were conducted on the same days as...
the sensory panels evaluations. Consumer panel evaluations of the breaker samples were begun on the second day of the sensory panel evaluations.

December 1999. Six tomato breeding lines were harvested at red-ripe and breaker stages. Red-ripe tomatoes were evaluated within 3 days of harvest.; breaker tomatoes, ripened and evaluated within 10 days of harvest. One hundred and eight naïve panelists participated in the consumer test and each of the six breeding lines was evaluated by at least 50 panelists. The consumer panel evaluations were conducted on the same days as the sensory panel evaluations.

**Sensory Evaluation**

All sensory training and evaluation were conducted in partitioned booths at the Food Research and Development Lab in the Food Science Department of the University of Georgia. The panels were introduced to flavor attributes of tomatoes by sampling locally purchased tomatoes. Panelists selected eleven sensory descriptors from a list of ones used previously for tomato flavor (Meilgaard et al., 1991; Civille and Lyon, 1996). The panels were trained using a modified Spectrum™ technique for descriptive analysis (Meilgaard et al., 1991) and calibrated using reference standards (Galvez and Resurreccion, 1990; Abdullah et al., 1993; Malundo et al., 1994; Abegaz, 2000). Panelists scored each of the eleven attributes for each tomato using 150mm unstructured line scales.

**June 1999.** Ten panelists participated in eight 60-minute training sessions. The panelists evaluated the red-ripe samples over a three-day period with two sessions per day. A week later the breaker tomatoes were evaluated over a three-day period with two sessions per day.

**December 1999.** Nine panelists participated in six 60-minute training sessions. Seven of the nine panelists had also participated in the June 1999 panels. The panelists evaluated the red-ripe samples over a three-day period with two sessions per day.
week later the breaker tomatoes were evaluated over a three-day period with two sessions per day.

**Statistical Analysis**

Acceptability scores from consumer tests and attribute scores from sensory analysis were tested for correlations. Predictive models from this data were obtained using Proc Corr and Proc Reg (backward elimination) using the SAS v.6.12 software package.

**RESULTS**

Regression equations were developed for consumer acceptability as a function of sensory descriptors for the tomatoes (Table 1). The only descriptor that was significant in the regression model ($R^2=0.73$) for fruit rated as “Tastes Great” was “tomato-like” (defined as “combines the characteristics normally associated with tomatoes” by Tandon, 2000). Unexpectedly the sign of the tomato-like parameter was negative suggesting that presence of the “tomato-like” note detracts from tomatoes rated by consumers as having superior flavor. The regression model ($R^2=0.61$) for fruit rated “Acceptable” or “Tastes Great” was positively related to the sour notes while negatively related to bite.

<table>
<thead>
<tr>
<th>Score</th>
<th>Intercept</th>
<th>Parameter</th>
<th>P-value</th>
<th>Corr.Coeff.</th>
<th>$R^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>TG</td>
<td>Bo</td>
<td>0.83</td>
<td>0.0001</td>
<td>-0.855</td>
<td>0.73</td>
</tr>
<tr>
<td></td>
<td>Tomato-like</td>
<td>-0.016</td>
<td>0.0004</td>
<td>-0.347</td>
<td>0.61</td>
</tr>
<tr>
<td>ACC</td>
<td>Bo</td>
<td>-0.93</td>
<td>0.0001</td>
<td>0.606</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Sour</td>
<td>0.003</td>
<td>0.0421</td>
<td>0.347</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Bite</td>
<td>-0.013</td>
<td>0.0084</td>
<td>-0.606</td>
<td></td>
</tr>
</tbody>
</table>

Bo: Parameter estimate. TG: Tastes Great. ACC: Acceptable and Tastes Great
Consumer acceptability scores for each of the lines evaluated is shown in Table 2. In general tomatoes harvested and evaluated at the red-ripe stage of maturity had higher “Tastes Great” scores than those harvested breaker and evaluated red-ripe. There was no significant difference for “Acceptable” fruit (includes those rated “Tastes Great” and “Acceptable” by consumers). In general the consumers tended to support the evaluation of the breeder, with the best lines (337, 301, 308 and 341) rated good and very good by the breeder and scoring above average for “Tastes Great” when harvested red-ripe. Some of the poorer lines (201, 212) tended to rate below average by consumers while being assessed by the breeder as bitter/sour terrible and bland respectively. The primary exception was line 307 which was rated “bad” by the breeder but rated higher than average acceptability by the consumer panel.

<table>
<thead>
<tr>
<th>Line #</th>
<th>Breeder Assessment</th>
<th>RED</th>
<th>BREAKER</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>TG</td>
<td>ACC</td>
<td>TG</td>
</tr>
<tr>
<td>207</td>
<td>Sweet, moderately acid</td>
<td>30</td>
<td>85</td>
</tr>
<tr>
<td>215</td>
<td>Balanced</td>
<td>26</td>
<td>82</td>
</tr>
<tr>
<td>216</td>
<td>Sweet, low acid</td>
<td>32</td>
<td>85</td>
</tr>
<tr>
<td>217</td>
<td>Industry standard</td>
<td>33</td>
<td>94</td>
</tr>
<tr>
<td>201</td>
<td>Bitter/sour terrible</td>
<td>24</td>
<td>74</td>
</tr>
<tr>
<td>212</td>
<td>Bland</td>
<td>39</td>
<td>80</td>
</tr>
<tr>
<td>337</td>
<td>Very good, bal. alcohol</td>
<td>49</td>
<td>86</td>
</tr>
<tr>
<td>307</td>
<td>Bad</td>
<td>41</td>
<td>90</td>
</tr>
<tr>
<td>301</td>
<td>Good</td>
<td>60</td>
<td>96</td>
</tr>
<tr>
<td>305</td>
<td></td>
<td>48</td>
<td>100</td>
</tr>
<tr>
<td>308</td>
<td>Good</td>
<td></td>
<td>88</td>
</tr>
<tr>
<td>341</td>
<td>Very good</td>
<td>56</td>
<td>72</td>
</tr>
<tr>
<td>TOTAL</td>
<td>40</td>
<td>86</td>
<td>33</td>
</tr>
</tbody>
</table>

Five consumer segments were developed based on previous consumer studies (Bruhn et al., 1991; Auerswald et al., 1999; Beattie et al., 1983; van Lieshout, 1993) and focus groups (data not shown). In the consumer panel for the present study almost half of the sample identified themselves as preferring “vine-ripened” tomatoes (see Fig. 1). More than a quarter of the sample prefer their tomatoes “sweet”, and fewer consumers described their flavor preferences as “tart and tangy” or “not bland”. Consumer acceptability models for the two largest segments are shown in Tables 3 and 4. The model for "Tastes Great" is similar for the vine-ripened segment (Table 3) and the entire dataset. The models for "Tastes Great" and "Acceptable" are similar (Table 4) to each other for the sweet segment. Although this segment indicates a preference for sweetness, the "sweet" note was not significant for "Tastes Great" and was negatively related to "Acceptable" flavor. Most of the results (Table 1, Table 3, and Table 4) show a negative correlation with the tomato-like descriptor. The relationship between “Tastes Great” as evaluated by the consumer and the tomato-like descriptor is shown in Figure 2.

TABLE 3.

PREDICTIVE EQUATIONS FOR CONSUMER ACCEPTABILITY AS A FUNCTION OF SENSORY DESCRIPTORS: VINE-RIPENED SEGMENT

<table>
<thead>
<tr>
<th>Score</th>
<th>Intercept</th>
<th>Parameter</th>
<th>P-value</th>
<th>Corr. Coef</th>
<th>R²</th>
</tr>
</thead>
<tbody>
<tr>
<td>TG</td>
<td>Bo</td>
<td>0.872</td>
<td>0.0001</td>
<td>-0.752</td>
<td>0.565</td>
</tr>
<tr>
<td></td>
<td>Tomato-like</td>
<td>-0.018</td>
<td>0.0048</td>
<td>-0.752</td>
<td></td>
</tr>
<tr>
<td>ACC</td>
<td>Bo</td>
<td>0.996</td>
<td>0.001</td>
<td>-0.253</td>
<td>0.764</td>
</tr>
<tr>
<td></td>
<td>Green</td>
<td>0.004</td>
<td>0.033</td>
<td>-0.773</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Astringent</td>
<td>-0.014</td>
<td>0.0006</td>
<td>-0.773</td>
<td></td>
</tr>
</tbody>
</table>

TG: Tastes Great. ACC: Acceptable and Tastes Great
TABLE 4.

PREDICTIVE EQUATIONS FOR CONSUMER ACCEPTABILITY 
AS A FUNCTION OF SENSORY DESCRIPTORS:
SWEET SEGMENT

<table>
<thead>
<tr>
<th>Score</th>
<th>Intercept</th>
<th>Parameter</th>
<th>P-value</th>
<th>Corr. Coef</th>
<th>R^2</th>
</tr>
</thead>
<tbody>
<tr>
<td>TG</td>
<td>Bo</td>
<td>2.04</td>
<td>0.0001</td>
<td>-0.712</td>
<td>0.937</td>
</tr>
<tr>
<td></td>
<td>Tomato-like</td>
<td>-0.036</td>
<td>0.0017</td>
<td>-0.525</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Sour</td>
<td>0.011</td>
<td>0.04</td>
<td>0.05</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Salty</td>
<td>-0.052</td>
<td>0.0019</td>
<td>-0.511</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Bitter</td>
<td>0.065</td>
<td>0.0067</td>
<td>-0.461</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Bite</td>
<td>-0.035</td>
<td>0.0621</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ACC</td>
<td>Bo</td>
<td>0.927</td>
<td>0.0002</td>
<td>-0.161</td>
<td>0.818</td>
</tr>
<tr>
<td></td>
<td>Tomato-like</td>
<td>0.012</td>
<td>0.0214</td>
<td>-0.35</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Sweet</td>
<td>-0.009</td>
<td>0.0505</td>
<td>-0.33</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Sour</td>
<td>0.008</td>
<td>0.0129</td>
<td>0.333</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Salty</td>
<td>-0.017</td>
<td>0.0281</td>
<td>-0.122</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Fruity</td>
<td>0.012</td>
<td>0.0676</td>
<td>-0.289</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Bite</td>
<td>-0.032</td>
<td>0.0115</td>
<td>-0.206</td>
<td></td>
</tr>
</tbody>
</table>


FIGURE 1. DISTRIBUTION OF CONSUMER SEGMENTS
DISCUSSION

Most consumer testing provides information on preferences of an “average consumer”, but pursuit of an average consumer is of little use in the marketability of a product (van Tripp and Schifferstein, 1995; Shewfelt, 2000). More useful information can be obtained by segmenting the market (Land, 1988; Moskowitz, 1993; Shewfelt, 2000). The “vine-ripe” segment predominated, but it is not clear if this segment is different from the “not bland” segment. There appear to be other distinct segments who prefer either a sweeter tomato or a more acid one.

A common assumption in flavor acceptability research holds that acceptability proceeds from acceptable to superior simply by increasing similar characteristics. Data presented in Tables 1 and 3 suggest that the characteristics describing superior and acceptable tomato flavor are different for the entire dataset and one segment. This observation indicates that consumers base their levels of acceptability of tomato flavor on...
different criteria. Segmentation data show that different characteristics are important to
distinct segments. Thus, selection of new lines for an average consumer may be
counterproductive.

While there was general agreement between the breeder and the consumer,
the breeder appeared to have a more acute sense of flavor that the consumer. Frequently
it is the breeder that makes the decision whether a line should be released. These data
suggest that the breeder’s assessment needs to be tempered with an appreciation for
consumer preferences. In addition, breeders tend to evaluate flavor of tomatoes only
when harvested red-ripe, but most of the fruit available commercially has been harvested
mature green or breaker. Line 216 recorded much higher ratings for “Tastes Great” when
harvested breaker than when harvested red-ripe suggesting a potential for commercial
distribution. Line 301, with the highest score for “Tastes Great” when harvested red-ripe
but a much lower score well when harvested breaker would not be a good candidate for
commercial distribution.

Sensory descriptive notes represent the fundamental units of flavor quality.
Unlike trained panelists, consumers do not identify these notes when consuming a food.
Rather, they integrate all sensory input to form a general impression, usually restricted to
superior (delights the consumer or exceeds expectations), acceptable (fit for use or meets
expectations) or unacceptable (not fit for use or does not meet expectations). A
combination of descriptive analysis with consumer testing permits an identification of the
components of flavor that contribute to acceptability with consumer segments. It has
been well-established that green/ grassy, salty and fruity (Meilgaard et al., 1991; Civille
and Lyon, 1996) contribute to characteristic tomato flavor. The presence of bitter in the
regression model is unexplained, but it apparently is at a threshold in these lines below its
detection as an unacceptable trait to consumers. The importance of the “sour” note
(Table 4) to the “sweet” segment supports the importance of acid as well as sugar in
tomato flavor perception (Jones and Scott, 1984). Too much acid can lead to decreased
acceptability (Malundo et al., 1995). The unexpected negative correlation of the sensory
attribute tomato-like to acceptance (illustrated in Figure 2) provides a cautionary note about extrapolating sensory data to acceptance without actual consumer evaluation.

**SUMMARY AND CONCLUSIONS**

Overall, the red-ripe tomatoes received higher “Tastes Great” scores than those for breaker tomatoes. An interesting note is the similarity in scores for the two harvest maturities in “Acceptable” scores in tomatoes evaluated red-ripe. Although consumer evaluation of tomato flavor generally supported the breeder’s assessment, there a need for consumer input in the selection of tomatoes introduced to the commercial market. Consumer evaluation studies were able to identify distinct segments of tomato flavor acceptance including vine-ripened, sweet and acid groups. The models generated from the data show similarities between the vine-ripened segment “Tastes Great” model and the overall “Tastes Great” and “Acceptable” models, while the sweet segment “Tastes Great” and “Acceptable” models were similar. These findings indicate that just increasing the characteristics present in a tomato will not necessarily increase acceptability; rather each consumer segment has specific characteristics contributing to the level of acceptance of tomato flavor. Understanding the preferences of each of these segments provides the breeder and producers with critical information needed to deliver more acceptable tomatoes to the tomato consumer.

**Acknowledgement**

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REFERENCES


REED, C.A. 1998. Sensory techniques to enhance flavor acceptability of a citrus flavored beverage using the quality enhancement (QE) model. MS Thesis, Univ. of Georgia, Athens, pp. 76.


CHAPTER 4
SUMMARY AND CONCLUSION
Tomatoes are an important produce item, so understanding the relation of tomato flavor and consumer acceptability is crucial to consumer satisfaction. In a time where more consumers are looking to items like tomatoes to maintain a healthy diet, premium quality tomatoes must be available. To achieve these goals, researchers should consider employing sensory and consumer tests to determine consumer segments and provide tomato cultivars to meet the needs of each of these segments.

In Chapter 2 it was found that consumers are clear about their likes and dislikes, permitting a classification of consumer segments. Segments based on acceptability of tomato flavor were (1) sweet, (2) tart, (3) vine-ripened, and (4) sweet and sour. Further validation of these segments with consumer testing found that most consumers select tomatoes as acceptable from the segment they chose. Consumer testing also suggested that although a consumer may know the flavor they find acceptable, they may not be able to distinguish between varying levels of this flavor.

In Chapter 3, some previous assumptions about consumers and their acceptance of tomato flavor have been questioned. The assumption is that there is an average consumer. Attempts to improve tomato quality focused only at this average does not appear valid. These data suggest that there are several segments of consumer acceptability of tomato flavor. To meet consumer needs, research should consider each segment. It has also been suggested that when characteristics for an acceptable tomato are known, increasing those characteristics leads to superior flavor. Data in this chapter show that characteristics like bite and sour influence an acceptable score while the characteristic tomato-like was found to influence a score of tastes great (superior). Thus, characteristics influencing acceptable and superior tomatoes are different. It was also found that the refined sense of taste of the breeder is not a reliable predictor of consumer acceptability. Although breeder and consumer assessment were consistent for many selections, some assessments were exactly opposite. A clearer appreciation of factors affecting consumer acceptability should be a useful guide for research to improve tomato flavor.
Although much research has been conducted on tomato flavor, there is still much not understood. Tomato flavor has been found to be complex and requiring much more detailed work to fully understand influences on flavor. Present research has shown the direction that future research must go to achieve this goal. More consumer testing must be conducted to understand consumer preferences and attitudes. Knowledge and understanding of consumer segments will allow for specification to each segment thereby increasing consumer satisfaction of tomato flavor. Combination of sensory descriptive analysis and consumer testing provides a powerful technique in identifying components of flavor contributing to acceptability of consumer segments. Research integration is key to satisfying consumer desires in tomato flavor.