Fruit Quality - How Do Fruit Get Their Flavor?

In general, fruit quality is defined by three major attributes: color/appearance, texture, and fruit flavor.

Though growers are often paid based on the physical characteristics of their fruit (such as color, size, and lack of defects, texture), it is essential that the flavor of the fruit is considered, as this is the main driver for repeated purchases by consumers.

Why is Fruit Flavor Important?

The flavor of the fruit is very closely linked with the consumer's preference and continued consumption of any given fruit variety and should be strongly considered. Meeting consumer expectations for flavor of specific fruit, not only causes consumers to buy more fruit, but it allows growers to increase their profitability. Consumers are willing to pay a higher price for distinctly flavorful varieties that are going to enhance their experience consuming fresh fruit.

There is nothing more disappointing for consumers than finding the perfect apple from the grocery store — a beautiful red color, no bruises, a firm texture — but when taking the first bite, the flavor is boring, flat, and is overall a disappointment. Once a consumer has purchased a fruit with little or poor flavor, they are inclined to not buy those fruit again and/or move on to a different grower or a different fruit all together. Producing fruit with complex and delicious flavor is extremely important to the consumer's enjoyment of their eating experience.

What is Fruit Flavor?

Flavor is described as the interaction between taste and aroma. Taste relates to the ratios and intensities of non-volatile compounds, specifically sugars, and acids. Sugars and acids are detected by five classes of receptors in the tongue – sweet, sour, salty, bitter, and umami (protein taste, represented by glutamate). Volatile compounds, which create the aromas of fruit, are detected by over 650 types of olfactory nerve endings found in the nose.

The sweetness of a fruit is influenced by the quantity and composition of sugars. Higher contents of sugar in the fruit increases the sweetness of the fruit. Additionally, different forms of sugar affect the sweetness of the fruit. In fruit such as apples, peaches, and plums, the main sugars present are sorbitol, sucrose, fructose, and glucose. Each of these sugars have a different degree of sweetness. Fructose has 1.7 times the sweetness of sucrose, while glucose and sorbitol only have 0.8 and 0.6, respectively. For example, if one apple variety has higher contents of fructose and another variety has higher glucose, the former will taste sweeter.

The acidity of a fruit is influenced by the content and composition of organic acids, and the amount of each type of acid found in each fruit. For example, the dominant acid in apples, peaches, and plums is malic acid.

The balance between the sweetness and acidity of fruit based on the quantity and composition of their sugars and acids is important for developing a complex and interesting taste that will enhance fruit flavor.

Another key component of flavor is aroma. Fruit aroma is influenced by the quantity and composition of volatile compounds. The volatiles that are well-known to affect fruit flavor include esters (fruity aroma), alcohols (fruity or earthy aroma), aldehydes (slightly grassy and bitter aroma), lactones (peach-like aroma), and terpenoids (scented oils aroma). Studies have shown that the flavor intensity of a fruit can be correlated with the quantity and composition of volatiles present. For example, strawberries that presented higher levels of certain key volatiles were perceived as sweeter and highly preferred by consumers, as compared to other strawberry varieties lacking these volatiles.
How is Fruit Flavor Measured?

Fruit flavor can be measured instrumentally as well as through the use of sensory science. Sensory science is a multi-disciplinary field that uses scientific measurements to interpret the human response to the senses of sight, smell, taste, touch, and hearing. This form of science is able to link the product to the person in a direct way.

Instrumentally, sugar content of the fruit is determined by measuring the soluble solid content using a portable refractometer. A refractometer measures how light is bent as it passes through a sample, which is correlated to a specific percentage of sugar in the fruit, and thus is related to fruit sweetness. Titration measures the content of the dominant acid present in the fruit and can also be measured and calculated using portable acidity/pH meters.

Aroma volatiles are challenging to measure with portable instruments. They are quantified by using Gas Chromatography – Mass Spectroscopy (GC-MS), a lab-based technique which helps to separate and identify compounds in their gaseous forms based on their masses.

To correlate these instrumental measurements to consumer perception, two major methods of sensory evaluation are used: consumer testing and descriptive analysis. Consumer testing includes subjective data about the preferences of a large group of untrained tasters (usually more than 100 panelists), while descriptive analysis includes questionnaires for a panel of 8-12 trained tasters who are able to rate specific attributes related to fruit quality.

Portable sugar (refractometer) and acidity meter (left); Gas Chromatography-Mass Spectroscopy (GC-MS) equipment (center); samples for sensory evaluation (right). Photo: Dr. Macarena Farcuh, University of Maryland

What Factors Affect Flavor Development?

Genetics

A key factor for determining fruit flavor lays in the genetic background of the variety that was chosen. When determining which variety to establish, it is important to choose varieties that were bred for flavor as one of its priorities. Additionally, the choice of rootstock, for fruit such as apples, can influence fruit flavor potential. Studies have shown that particular rootstocks can affect the levels of organic acids and sugar content found in the same variety of apple.

Environmental factors

Environmental factors also play a hugely important role in affecting the flavor of the fruit and strongly interact with the genetic background. Although often times these factors cannot be controlled, they must be taken into account when aiming to improve the flavor of the fruit that are being produced. The major environmental factors affecting fruit flavor development include temperature, relative humidity, and sunlight during the growing season.

A good practice before establishing a new orchard is to conduct small variety trials to evaluate which varieties are capable of developing flavor under the specific environmental conditions. As there is strong interaction between varieties and their growing environment, a variety that is successful in one area may not be as successful in another region.

Preharvest Factors, Orchard Management, and Cultural Practices

Fruit flavor can be affected by different orchard management practices, such as planting density, tree structure, irrigation regime, light manipulation, crop load, nutrition, and pest control methods.

Practices that increase the amount of sunlight reaching the fruit, such as pruning or the use of reflective groundcovers, have been shown to increase flavor development as well as color.

Crop load management is another important factor affecting fruit flavor development. In a study done on apples, trees with lower crop loads were found to have fruit with increased flavor development. This was mainly due to higher levels of aroma volatiles and sugars in the apple fruit with lower crop load. Many times, trying to aim for the highest yield will play against flavor development.

Irrigation management can also have an effect on fruit flavor. It is important to maintain balanced irrigation levels in the orchards. Excess irrigation will decrease the overall flavor produced during the fruit growth. Irrigating in intervals to avoid inducing stress on the tree is good practice and will positively impact fruit flavor development.
Concerning nutrition, excessive levels of nitrogen will decrease the "fruity" aromas that are developed in the fruit, while increasing the "green" and "grassy" aromas. Many studies have shown that moderate nitrogen supply for the tree increased fruit flavor, but an excessive amount actually deteriorates fruit flavor.

**Fruit Maturity at Harvest**

Harvesting practices and the maturity of the fruit at harvest is an often-forgotten key factor in maintaining fruit flavor. Fruit produced for wholesale distribution typically tends to be harvested before fully ripe in order to ensure that the fruit can be transported easily without being damaged. Unfortunately, in this case the fruit's flavor is likely not completely developed. On the other hand, if fruit are harvested over-mature, there is an increase in the "fermented" flavor, which is disliked by consumers. Thus, in the Mid-Atlantic when harvest is delayed waiting for red skin color development in apples, fruit flavor is directly affected. Harvesting over-mature apples is harmful for 'Honeycrisp' apples, respectively, to avoid the development of physiological disorders that will induce flavor loss.

Harvesting at the correct time is a 'balancing act' between great flavor, overall quality, and shelf-life capacity. Favoring one of these factors over others may affect the marketability of the fruit, so it is of key importance to harvest fruit at the correct time.

**Postharvest Factors**

Once the fruit is harvested, flavor can be maintained or lost, which is why improving postharvest factors is critical to ensure flavor maintenance. These factors are mainly a balance of storage temperature, relative humidity levels, oxygen (O\(_2\)) and carbon dioxide (CO\(_2\)) balance, and ethylene levels.

The combination of storage temperature and length of storage can cause loss of flavor and development of physiological disorders that will affect fruit marketability. Storage temperatures vary with each fruit and each variety to ensure the best possible maintenance of flavors. Practices such as fruit conditioning, e.g., storing fruit at 68°F for 24-48 hours or at 50°F for 7 days before cold storage, are used in peaches and 'Honeycrisp' apples, respectively, to avoid the development of unwanted "off-flavors".

In terms of relative humidity, the target is to achieve ranges between 85-95%. If the humidity levels are too low, the water content of the fruit can decrease which leads to fruit shriveling, weight loss, and consequent changes in flavor profiles. In humidity levels over 95%, condensation on the fruit may lead to mold growth.

The balance between O\(_2\) and CO\(_2\) concentration during storage can also directly affect fruit flavor. Storing fruit with a low O\(_2\) supply can cause the fruit to begin undergoing anaerobic respiration which leads to a quick break down in internal sugars, essential to the overall flavor of the fruit. A high level of CO\(_2\) negatively influences the respiration of the fruit in storage, affecting the acidity levels of the fruit. Lower levels of O\(_2\) and high levels of CO\(_2\) can lead to fermentation, which results in the formation of an 'off-flavor' which is disliked by consumers. Controlling the atmosphere of apples in storage allows the fruit to maintain their flavor and not develop these unwanted "off-flavors".

Ethylene, a gaseous plant hormone that enhances fruit ripening and can be produced by the fruit itself, plays an important role in fruit flavor development during postharvest. High ethylene levels during storage enhance the development of aroma volatiles, but make fruit become soft and last less in storage. Low ethylene levels during storage, often achieved by using commercial products such as SmartFresh (1-MCP), which blocks the perception of ethylene by the fruit, maintains high fruit firmness, but inhibit the production of aroma volatiles. Therefore, maintaining adequate ethylene levels during storage is a key factor for maintaining fruit flavor.

**Summary**

As discussed throughout this article, taking the flavor of the fruit into account in every step of the production process is essential. Although it may be complex and difficult to evaluate, fruit flavor is one of the main factors that keeps consumers enjoying eating fresh fruit and pursuing repeated purchases. Therefore, a great fruit flavor development consequently increases the marketability and subsequent profitability of fresh fruit.

**Authors**

**Macarena Farcuh, Ph.D.**
Assistant Professor and Extension Specialist
University of Maryland
mfarcuh@umd.edu

**Erin McCaughey**
Candidate for B.S. in Chemistry
University of Maryland
emccaugh@terpmail.umd.edu

---

© The Pennsylvania State University 2024

**Penn State College of Agricultural Sciences research and extension programs are funded in part by Pennsylvania counties, the Commonwealth of Pennsylvania, and the U.S. Department of Agriculture.**

Where trade names appear, no discrimination is intended, and no endorsement by Penn State Extension is implied.

This publication is available in alternative media on request.

Penn State is an equal opportunity, affirmative action employer, and is committed to providing employment opportunities to all qualified applicants without regard to race, color, religion, age, sex, sexual orientation, gender identity, national origin, disability, or protected veteran status.

© The Pennsylvania State University 2024
Code: ART-6396