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Fruit Texture and the Science Behind It

When harvesting your fruit crop, it is vital to keep consumer needs in mind. What do they look for when purchasing fruit? Is it only color or something else? In fact, while consumers generally cite flavor as the most important quality in fruit, textural defects and the interaction between flavor and texture are most likely to cause consumers to reject a fresh fruit.

Why is Texture Important?

Texture and consumer preferences are key qualities influencing consumer acceptability of fruit. Texture is usually perceived with the sense of touch and the sensation experienced when eating the fruit. Most consumers want a crisp, crunchy apple and a juicy peach with a melting texture (that softens to a smooth buttery consistency) that isn't mushy when eating. Meeting these texture standards can increase fruit marketability.

Fruit texture, and particularly flesh firmness, is an important maturity index, in combination with other fruit quality parameters. Late harvests will lead to softer fruits with low storability potential and increased disease susceptibility, while early harvests lead to firmer but bland fruits. The texture of the fruit at harvest is also highly related to the target market of the fruit. For wholesale, fruit are harvested with a firmer texture which allows for easier handling and longer storability, as firm fruit is less likely to bruise and be damaged. For example, apples stored longer than 3 months should be harvested with a firmness of at least 15 lbs,, meaning they can withstand 15 lbs. or more of pressure when measured with a penetrometer (described below). When the fruit will be stored for 1 month or sold immediately, apples should have a firmness of around 13-17 lbs, depending on the cultivar.

What is Fruit Texture? How do Fruit Develop Their Texture Characteristics?

Most fruits soften at different rates as the fruit ripens. During the ripening process, fruit like apples develop their crispness and peaches, their melting texture. Some factors contributing to changes in texture during the ripening process include cell wall modifications, turgor pressure, and cuticle composition.

Cell wall modification **–** Cell walls are tough yet flexible barriers that surround plant cells and help keep the important parts of a cell in one place and protect it from unwanted outside pressures. During ripening, the cell wall structure deteriorates leading to weakening of the structure. This brings about textural changes such as fruit softening, decreasing the storability potential of the fruits.

Turgor pressure – Most fruits are 80-90% water. For example, apples and peaches are 85% and 89% water, respectively. The water in fruits is stored in vacuoles in the cells. Vacuoles are like a pouch of water that presses against the cell wall. More water in the vacuole creates stronger pressure. In biology, turgor pressure is defined as the pressure created by the water in a cell that pushes against the cell wall. When there is enough water to maintain high turgor pressure, the texture is crisp. However, as fruits lose water pre- or post-harvest, the turgor pressure can decrease and lead to changes in texture such as fruit softening. Too much water can cause the turgor pressure inside the cell to exert greater force on the cell wall, resulting in cracking or splitting.

Cuticle composition **–** The cuticle covers the outside of fruit and is made up of various fatty acids. The cuticle is important for protecting fruit from damage as well as

attacks from pests or pathogens. It also plays an important role in fruit texture. The cuticle acts as a barrier against water loss which helps prevent decreased turgor pressure, leading to fruit softening.

Measuring Fruit Texture

To accurately measure the texture of fruit, growers perform instrumental tests or use human sensory evaluation (Figure 1).

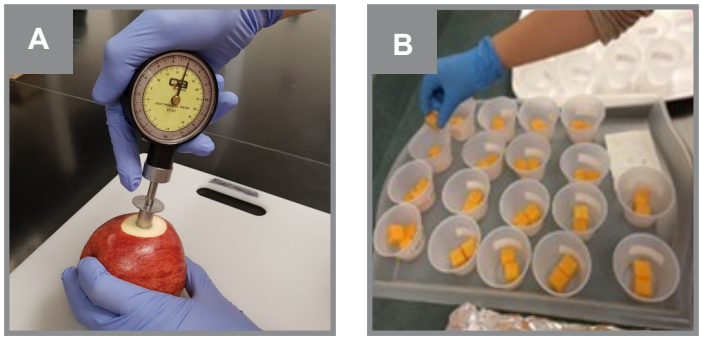

Figure 1. (A) *An Effegi firmness tester/penetrometer with a 7/16-inch diameter plunger,* ***(B)*** *Sample preparation for a sensory panel evaluation. Photos: Dr. Macarena Farcuh, University of Maryland.*

Instrumental tests – Growers can assess fruit texture using a puncture test done with a handheld penetrometer or a firmness tester. A penetrometer works by measuring the force required to puncture fruit to the point of irreversible damage. Common brands include Effegi firmness tester and Magness-Taylor pressure tester. These pressure testers have a 7/16-inch diameter plunger for apples and a 5/16-inch plunger for peaches. To test fruit:

- remove a patch of skin the size of a quarter;
- hold fruit against a hard surface and force the plunger into the skin up to the scribed line on the plunger (7.9 mm);
- take a sample from both sides of the fruit, compressing the plunger at a consistent speed to get accurate readings.

Sensory techniques – Sensory techniques involve the use of human subjects to evaluate a product's quality for specific traits, such as texture. Trained tasters identify different textural attributes used to describe the product. Alternatively, around 100 or more untrained panelists can provide input on consumer preferences for fruit textual characteristics. Generally, the objective is to determine instrumental measurements that correspond to sensory data results.

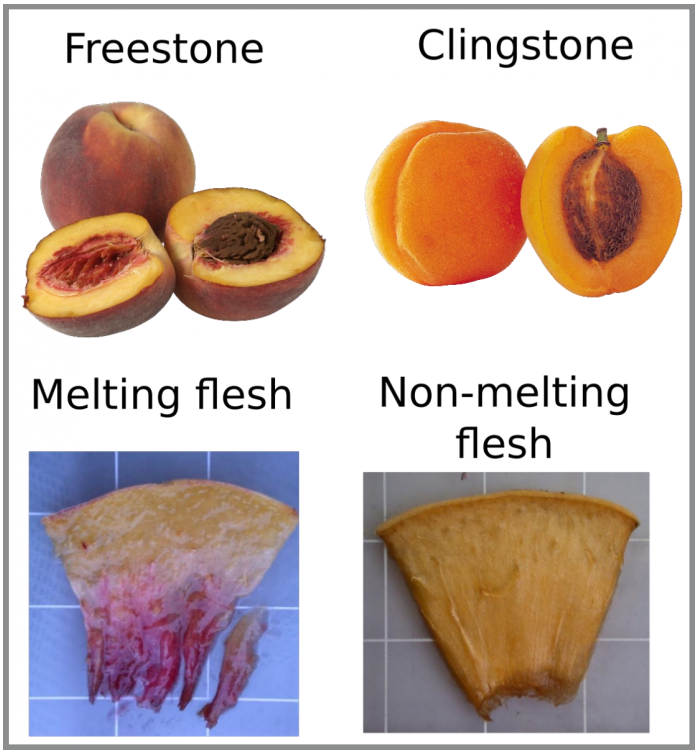

Figure 2. Genetic background and their differences in peach texture characteristics. Photo: RosBREED (Link: https://www.rosbreed.org/sites/default/files/peach%20texture.png).

Which Factors Affect Fruit Texture?

Genetic background – There are big differences in the texture of non-melting and melting peaches and stony-hard classes (Figure 2). Non-melting type peaches retain their firmness and soften slowly so they are best for canning; melting-type peaches soften fast as they ripen and are grown for eating fresh. Stony-hard types soften even less than non-melting type and have a crisp texture. Stony-hard peaches are used for eating fresh as well as cooking or baking.

Apple textures also vary. Fuji apples have a soft, crisp texture. Honeycrisp apples are crisp, crunchy, and juicy.

Orchard management factors –

Irrigation management: A crop experiencing drought from lack of rain or due to irrigation mismanagement may have fruit with low turgor pressure which can lead to a premature softening. A crop watered excessively either from irrigation or rain may end up cracking as cells burst.

Crop load management: Thinning and pruning influence fruit texture by affecting size and sunlight exposure. Thinning also improves texture characteristics

at harvest, as crop load can have a large effect on firmness. In a study of Royal Gala apples, fruit firmness was positively correlated with fruit size; meaning larger fruits were slightly firmer at harvest. Pruning is also key for fruit texture characteristics. Correct pruning practices help optimize light distribution to all fruit on the tree. Incorrect pruning can result in fruit shading, leading to smaller under ripe fruit with a hard, grainy, undesirable texture.

Nutritional management*:* Avoiding nutrient imbalances is crucial for maintaining optimal fruit texture. For example, fruit from trees that are nitrogen deficient will usually be smaller with firmer texture. Excess nitrogen leads to fruit that lose firmness faster, decreasing its storability. Inadequate calcium can lead to premature softening. Supplementing fruit with calcium sprays is recommended for a high-quality texture and longer storage potential. Potassium deficiency also leads to texture changes as the trees will produce small, poorly colored fruit that may not ripen, leaving fruit hard and inedible. Lack of boron can result in fruit with a mealy texture.

Environmental factors –

Light is a critical factor for optimal fruit quality so pruning and training are important practices. The desired texture will be achieved when all fruit on a tree receive sufficient, uniform sunlight.

Temperature during fruit development plays an important role. Hotter than average temperatures in spring increase fruit growth rate early in development. The trees are unable to keep up with this increased rate and ultimately end up with smaller, firmer fruit that will not soften. A similar occurrence happens when apple orchards experience hot spring temperatures. Hotter than average temperatures in summer and fall advance maturity, which can lead to a premature softening of the apples after harvest.

Rainfall and humidity are also important factors. In the Mid-Atlantic fruit growing region, significant rainfall during the growing and ripening season can lead to fruit splitting or cracking (Figure 3). In contrast, fruit experiencing drought stress undergo chemical and physical changes to cells that can result in decreased fruit firmness.

Figure 3. *Gala fruit with cracks due to excessive rainfall and increased turgor pressure during the growing season. Photo: Dr. Macarena Farcuh, University of Maryland.*

Preharvest fruit maturity management –

Plant hormones such as ethylene regulate ripening. As ethylene production increases, the fruit becomes softer. This can increase fruit drop from the tree, as well as make fruit more susceptible to handling (bruises, injuries, disease exposure) and decrease storability.

Preharvest plant growth regulators are available for controlling ripening. Application of these products will also impact fruit textural characteristics. Ethephon (Ethrel®, Bayer Crop Science; Motivate™, Fine Americas; Ethephon 2, Arysta LifeScience North America, LLC), which is an ethylene-releasing chemical, promotes fruit ripening and advances maturity, accelerating fruit abscission and softening and negatively impact fruit storability. ReTain® (active ingredient: Aminoethoxyvinylglycine (AVG), Valent USA) will inhibit ethylene production, delaying fruit ripening, while Harvista® (active ingredient: 1-Methylcyclopropene (1-MCP), AgroFresh), will bind to ethylene receptors in the fruit, blocking its perception, preventing fruit response to ethylene and delaying ripening. ReTain® and Harvista™ keep fruit on the tree longer, preventing fruit drop and maintaining a firmer texture.

Figure 4. (A) Peaches and (B) apples with chilling injury symptoms after postharvest storage. Photo: Dr. Macarena Farcuh, University of Maryland.

Postharvest factors –

A combination of temperature and storage length can have significant impact on fruit in postharvest. Storage at improper temperatures can lead to premature fruit softening, development of physiological disorders and decrease in shelf life. Storing peaches at 68°F for 24-48 hours or some apple cultivars at 50°F for 7 days before transferring to cold storage can greatly increase the length of time the fruit retains a firm texture and reduce development of chilling injury (characterized by mealy and brownish texture, Figure 4). Honeycrisp apples, for example, are prone to chilling injury when stored below 36°F, while most other cultivars can be stored between 32°F and 33°F. Chilling injury on peaches occurs when storage temperatures are 36°F to 46°F and the longer the peaches are stored at this temperature (> 2 weeks), the higher the susceptibility to develop chilling injury.

The ideal range for storage humidity is between 85-95%. When humidity levels are low, water evaporates from the fruit and is not replenished. This reduces turgor pressure which can cause fruit to soften and shrivel, decreasing textural properties. Humidity levels over 95% will cause condensation on the fruit which may lead to mold growth.

It is also important to regulate ethylene levels during postharvest storage because fruit will continue to release ethylene gas causing them to ripen and soften. Damaged fruit produce more ethylene. Those fruit should be removed from storage so the remaining fruit are not exposed to high ethylene levels and possible pathogen infections. Products such as SmartFresh™ (active ingredient: 1-MCP, AgroFresh) block the perception of ethylene by the fruit in storage, and maintain high flesh firmness.

Controlled atmosphere (CA) storage can ensure fruit maintains proper texture longer, particularly in fruit such as apples. By regulating the humidity, temperature, CO_2 and O_2 levels in the storage rooms, the apple ripening process is delayed, keeping the fruit texture firm longer.

Summary

Attaining the optimal fruit texture is a challenge all growers must face in order to maximize consumer acceptability. Fruit texture, and particularly flesh firmness, is an important maturity index, in combination with other quality parameters. Learning how to measure fruit texture is an integral part of orchard management. It is also crucial to understand what are the factors that affect fruit textural characteristics, from pre harvest practices to environmental factors and postharvest storage. If these factors are controlled, the desired fruit texture can be enhanced, increasing consumer satisfaction and crop profitability.

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