Nondestructive Maturity Assessment in Mangos

The Big Picture:
Delivering a ripe, succulent mango to consumers involves many steps, but perhaps the most important part of the process starts with harvesting a mature piece of fruit.
Judging a mango's maturity without harming the fruit can be a challenge. While several methods are available for evaluating maturity, some of these techniques are destructive and cause injury to the fruit in the process.

To maximize efficiencies and reduce shrink, the National Mango Board commissioned a research study to determine what options the industry has for nondestructive testing – evaluating a mango's maturity without harming it. The goal of assessing mango maturity at harvest is to determine which fruit are mature and ready for harvest, and which fruit should be left on the tree longer. A nondestructive maturity sensor would also allow processors to separate partially mature fruit from fully mature fruit, making for more uniform lots at the destination point. Additionally, creating lots that are uniform in maturity can allow for their correct handling and the optimum marketing of each load.

Dr. David Slaughter of the University of California-Davis conducted a review of nondestructive testing methods with regard to maturity of mangos and determined which options the mango industry could explore in order to boost its production of high-quality fruit. While Slaughter's findings show several viable options, mangos tested were not always varieties that are currently available in the U.S. Further testing on the five common cultivars imported in the U.S. would need to be conducted to ensure published findings are appropriate. Additionally, it should be noted that currently no standard objective method for measuring mango maturity has been adopted. Establishing such guidelines would offer a baseline from which all processors could operate, Slaughter said.

Overall findings:

- **Developing an objective mango flesh color standard is the first step to determining mango maturity. Establishing a given location and depth on the mango from which to accurately measure color will be key.**

  Initially, Slaughter says, establishing this standard will require destructive testing. He recommends using a colorimeter (which requires cutting the skin to expose a small amount of flesh) to test mangos in the orchards. For instance, a supervisor in the field might sample a few sections of fruit using the colorimeter.

  Using a mango with desirable flesh color, he would then determine the external qualities of the fruit that would likely be an indicator of maturity (shape of the fruit's shoulders, color of the skin on a certain side of the tree, etc.). Pickers could then be trained to look for these indicators to determine mature fruit, so a colorimeter would not have to be used all the time.

  Because the yellow interior color of mangos appears first in the center of the fruit and proceeds outward as it matures, researchers say the industry needs to determine what specific location on the mango and at what depth flesh can be measured to provide uniform results over all five mango varieties marketed in the U.S.

- **Developing a nondestructive method of measuring flesh color using optical measurements can provide additional clues into a mango's maturity.**

  Scientifically, nondestructive testing of mango flesh color should be possible using instruments like a spectrophotometer (which measures light visible to the human eye).

  Researchers say it's possible that a method could be developed to help predict compounds such as carotenoid content (a source of vitamin A) in mangos upon evaluation of their flesh color. Currently, the only nondestructive method developed to predict flesh color uses near infrared technology (which measures light just outside the range of human vision).

  This indirect method measures the soluble solids content, starch content and water content of the fruit. A number of commercial automated online color machine vision sorting systems also available for nondestructive measurement of skin color, researchers say, but none are currently available for nondestructive measurements of flesh color.

- **Developing a nondestructive way to evaluate internal composition in mangos, like using near infrared (NIR) methods to analyze starch and sugar content of both immature and mature fruit, could be another solution.**

  Both NIR and magnetic resonance imaging offer ways to test mangos nondestructively to evaluate internal composition. The industry would need to determine how variety, growing location, season and fruit temperature would affect the NIR calibrations, Slaughter said. The method would also have to be evaluated for all five major mango varieties in the U.S. market.

  - **Near Infrared (NIR) Spectroscopy uses measurements of light not visible by the human eye (light just outside the range of color humans can see) to evaluate internal composition of fruit.**

    Two kinds of NIR methods have been tested on mangos to evaluate maturity.

    - **Interactance measurements** use a fiber optic probe that is pressed against the fruit to see how much light is absorbed through a portion of the flesh, typically at depths of about 1 cm.

    - **Reflective measurements** use light reflected onto the surface of the fruit without touching it so measurements are typically more shallow than interactance measurements. For reflectance measurements to accurately predict fruit maturity, the flesh just below the skin would have to be well correlated to the composition of the whole fruit.

  Both methods have been used by researchers to track mangos' internal quality by judging internal composition like the amount of soluble solids content and dry matter in a mango. Not only do these measurements evaluate a mango's maturity, but through various calibration models they can be used to predict the soluble solids content a fruit will have when it ripens. However, studies show that calibrations for dry matter, for instance, do not remain the same over all cultivars.

- **Magnetic resonance (MR) and magnetic resonance imaging (MRI) use electromagnetic radiation to evaluate internal composition in fruit.**

  MR and MRI can "see inside" a piece of fruit by picking up areas of increased water or voids in the internal tissue. These discrepancies in the internal tissue highlight defects such as bruising, chilling injury and insect damage, researchers found. For instance, damage from heat treatment can appear as "air filled cavities," while increased water in the fruit from the center to the skin's surface indicated gradual ripening, studies showed.

  MRI has been used to evaluate damage and ripeness in fruits like apples and pineapple, but further work is necessary to determine how MRI technology could track maturation and ripening in mangos, researchers said.

- **Developing a handheld electronic nose, or enose, could be used to determine mango maturity by aroma on the tree before harvest.**

  By placing fruit in a sealed container for several minutes, researchers can identify volatiles in the fruit based on the aroma it emits. Such enose techniques have already been used for fruits like apples, bananas, blueberries, grapes, peaches, mandarins and tomatoes. In addition to testing for ripeness, the enose can also detect defects in fruits, like freeze damage or mechanical damage, researchers found. Previous studies show that the enose has already been effective in distinguishing one mango variety from another, as well as being able to differentiate between different-sized green mangos. Further research with regard to measuring maturity in U.S. cultivars would be necessary, but this nondestructive method of testing shows promise.

- **Developing a handheld device to assess firmness would provide a way to monitor ripening in mango.**

  Destructive firmness tests (like conducting a pressure test using a pentrometer or performing a compression test by squeezing a piece of fruit until it cracks or breaks apart) have long been the norm for measuring fruit firmness. However, several nondestructive methods are available that measure the elasticity of fruit. While these methods show promise, there are no commercially available handheld versions of these products, so they cannot be purchased at this time.

  - One measure of firmness involves the **acceleration response** in which fruits are gently tapped as they travel along the packing line to see how firm they are (measured by how quickly an instrument bounces off the fruit). Research shows that an average impact firmness score using the acceleration response was well correlated with scores from a compression test.

  - Another measure of firmness involves the **ultrasound acoustic wave attenuation** to determine firmness. Research has shown that the ability of fruit tissue to transmit ultrasound is affected by the fruit firmness. One research study of this method in Tommy Atkins mangos showed the firmness of the fruit was correlated with the average traditional destructive penetrometer measurement.

Looking ahead:
Nondestructive testing of mangos certainly warrants further evaluation because such testing methods would help to ensure that only mature mangos are picked at harvest, which is critical in providing consumers with high quality fruit. The most significant part of this research, however, is Slaughter's initial recommendation to develop an objective mango flesh color

standard to use in judging mango maturity. Nondestructive testing without such a standard would prove counterproductive.

Once such a standard is put into place, research shows that current technology offers several testing methods that could help to streamline the process of picking and ripening mangos. Picking the fruit at a correct maturity (as judged by nondestructive testing methods) would help to reduce shrink, enable processors to correctly sort and ripen loads, and aid in marketing efforts throughout the process. NMB will evaluate the existing technologies available to sorting mangos according to different maturity levels to define the next steps in this area.