Evaluation of Non-Destructive Firmness Detectors for Bartlett Pears

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Dec 7, 2005

Abstact

Three new methods of pear firmness were compared with the industry standard penetrometer firmness measurement. Two of the techniques are non-destructive, and the third is significantly less destructive than the traditional penetrometer method. A hand-held, inexpensive durometer measurement correlated well with a penetrometer, does not require cutting the pear to remove the skin, and would be useful for orchard determination of when to harvest fruit and for monitoring fruit during ripening. A non-destructive bench top device from the Sinclair Systems International correlated well with penetrometer firmness at penetrometer firmness great than 14 pounds. The non-destrucitve firmness device from the Aweta-Autoline company, while well correlated with the Sinclair measurement ($r^2 = 0.81$), was not as well correlated with penetrometer firmness.

Background

Pears firmness is used as an indicator of when to harvest the fruit and to track ripening of the fruit in wholesale and retail operations. It is measured with a penetrometer that measures the force required to push an 8mm diameter convex probe into the flesh of the fruit. The industry would like to use a nondestructive instrument that could replace the penetrometer. Two companies now manufacture bench-top devices (in addition to on-line versions of the technology) for measuring fruit firmness, during the 2005 harvest they were each leased for $2000 per season. Sinclair Systems International makes a device that taps the fruit and measures the deceleration of the impactor as it hits the fruit. The Aweta-Autoline company manufactures a similar device that measures impactor deceleration and acoustic transmission of the flesh. These units require 110-volt electricity and usually require that fruit be brought to the laboratory for measurement. For many years the ‘hardness’ of materials such as plastic and rubber foams, has been measured with device called a durometer (ASTM D2240, additional information may be found the American Society for Testing and Materials Annual Book of ASTM Standards), Fig. 1. It measures the relative distance a spring-loaded (maximum force = 1.8 lbs.) probe can be pushed into a soft material. The deflection of the probe is quite small (0.1 inches) so it usually does not cause noticeable damage to the flesh of firm fruit. The device requires no power, is operated by hand, and can be taken to the orchard to measure firmness of fruit on the tree. It costs about $500.

Figure 1. Photo of a durometer in a lever-operated drill stand. The unit can be operated without the stand.

Goal

Determine the correlation between three non-destructive firmness sensors and a standard penetrometer.

Procedure

Bartlett pears selected for this study did not contain any fruit that was cut, contained imbedded foreign material or that had conspicuous discoloration, rot or mildew near the equator. Fruit was allowed to equilibrate to room temperature before testing. Each fruit was labeled at one point on its equator using a permanent marker. The letter 'A' was placed at this location and letters 'B', 'C', and 'D' were placed in alphabetical order in a clockwise direction approximately 90 degrees apart. Non-destructive firmness was measured using the pneumatically actuated impact firmness tester, 2005 model iQ firmness tester, Sinclair Systems International, Fresno, CA and with an electronic impact firmness sensor, model AFS with impact, Aweta-Autoline, Reedley, CA. The firmness was measured at the four equatorial locations on each fruit and the readings were recorded. The height of the fruit support was adjusted for each fruit so that the tip of the impacter was about 25 mm above the top of the fruit when using the Sinclair system. The Aweta system automatically controls for fruit size by weighing the fruit and by tapping from the bottom of a fruit shaped cup. Durometer firmness (called hardness) was measured using a digital multi-scale DD-3 unit with a standard 'E' tip, Rex Gauge Co., Buffalo Grove IL, The durometer was placed in a lever-operated drill press for improved consistency. Finally penetrometer firmness was determined. A knife was used to remove a 160-mm^2 section of skin from the four equatorial locations. An automated penetrometer (Fruit Texture Analyzer, Model GS-14) equipped with a standard 7.9 mm diameter Magnus-Taylor tip and was programmed to insert the probe into the fruit flesh at speed of 5 mm/second. The firmness was measured at each of the four equatorial positions. Firmness of each fruit was reported as the median value of the four readings.

Results

The durometer correlated well with penetrometer firmness, but relationship was not linear, Fig. 2. A logarithmic fit of the data had a coefficient of determination of $r^2 = 0.90$. At penetrometer firmnesses between 10 to 22 lbs there was linear relationship between the methods and penetrometer firmness equaled durometer firmness minus 71 units. Ripening operations are interested in firmnesses below 10 lbs and would need a calibration table to correlate measurements with a penetrometer. Although a better approach would be to convert ripening instructions directly into durometer numbers and eliminate the use of penetrometer terminology. Actually the durometer provides better resolution at low fruit firmnesses and would be more useful than the penetrometer in tracking firmness changes of ripe fruit. It causes no damage to firm fruit, but may cause a small circular bruise to ripe fruit. As with a penetrometer, repeatability would likely be better when the durometer is used in a lever-operated press, as we did in our testing. The durometer is compact, easy to use and costs about the same as a good penetrometer. It is a good alternative to a penetrometer for use in the field and for managing ripening.

Firmness measured by the Sinclair unit correlated well with penetrometer firmness at penetrometer firmnesses greater than 14 lbs. At lower firmness the Sinclair unit had very poor resolution and would not be suitable for measuring fruit firmness of ripening or ripe fruit. The unit is not particularly convenient for measuring firmness in the orchard because it is too large to take to the field. Fruit would need to be picked in the orchard and brought to the lab.

The Aweta unit measured firmness with an impactor and with an acoustic sensor. The Aweta impact firmness score was well correlated with the Sinclair impact firmness score (r2 = 0.81), however the Aweta impact score showed more variability with penetrometer firmness than the Sinclair impact firmness score. The Aweta acoustic firmness score was also correlated with Sinclair impact firmness, but not as well as the two impact scores ($r^2 = 0.69$).

Fruit firmness is influenced by flesh temperature and moisture status of the fruit. Future work is needed to determine if either of these factors influence the correlation between penetrometer firmness and the alternative methods.

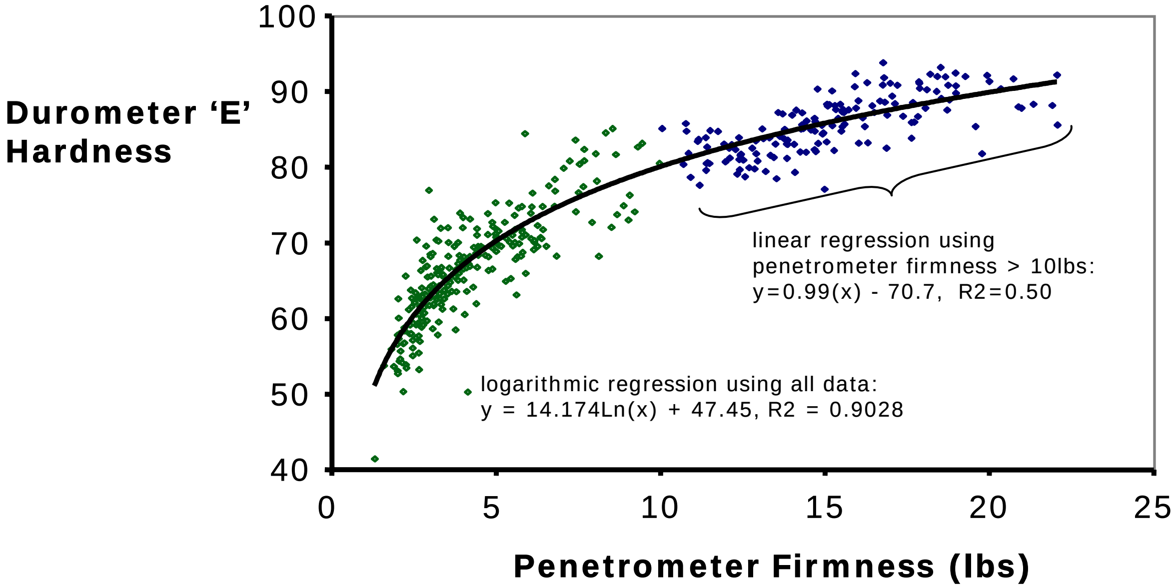

Figure 2. Correlation between firmness measured by penetrometer and durometer with a standard 'E' tip

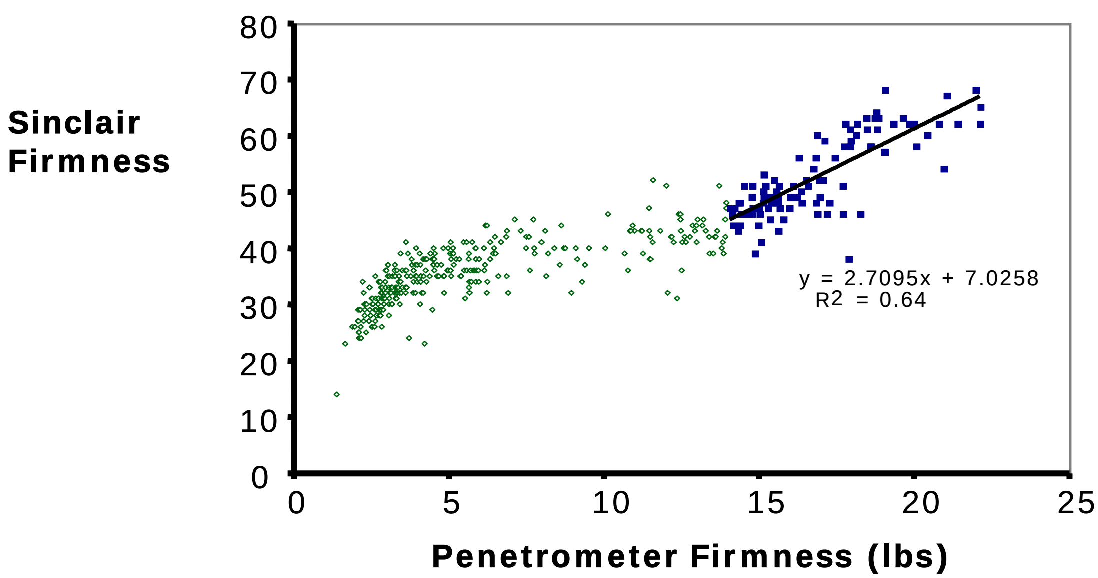

Figure 3. Correlation between firmness measured with a penetrometer and Sinclair unit