Development of a Firmness Tester for Pears

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Abstract

Modifications were made on the experimental hand-held firmness tester and the real-time on-line sorting system. A number of tests were conducted to evaluate the performance of these units. The hand-held sensor correlated quite well with penetrometer readings if it was used only during consistent field conditions. The on-line sorting system performed quite well in sorting fruits into different firmness groups. A commercial-scale prototype is being built by a California company.

Introduction

An experimental hand-held firmness tester and a real-time online sorting system were modified and tested in 2000. Modifications were made on the hand-held tester to make it easier for the operator to aim the tester at the fruit. The on-line sorting system (Figure 1) was modified by adding a second impact sensor to allow the tester to measure firmness in two locations on each fruit. The controller was reprogrammed to record the impact reading of each sensor and the average of the two readings.

Hand-held tester

Tests were made on 50 marked Bartlett pears on two trees at a commercial orchard in Courtland during the 2000 season on the following dates: June 27, July 3 (early morning), 3 (afternoon), 4, 7, 11, 14, 19, 24, 27, and 31. All tests were done between 10 to 11 AM unless noted. The tester was calibrated with the rubber ball to give a firmness reading of 120. On the day of test, firmness readings were first made on the rubber ball to verify the firmness setting, and the readings were recorded for used as a reference. A black circle was marked on each fruit. Impact firmness reading was made on each fruit (within the marked circle) and recorded. At the end of each test period, about twelve fruits were picked randomly from the two trees and brought back to UCD. Ten of these fruits were selected for additional tests to compare the impact readings with a 7.9-mm diameter penetrometer. Each fruit was marked with two circles on opposite sides of the fruit. Firmness measurements were first made at both circled locations with the hand-held impact tester and then by the penetrometer.

The results (Fig. 2) indicate that the average impact firmness reading of the 50 fruits on the trees decreased from about 185 to about 145 with a coefficient of determination (R^2) of 0.90. Similarly, the average impact firmness reading of the ten picked fruits also decreased from about 185 to 145, but with a coefficient of determination (R^2) of 0.89 (Fig. 3). The comparison between the average firmness readings of the ten picked fruits and the average penetrometer readings of the same fruits on each test day is shown in Figure 4.

This year we noticed that the firmness readings of the hand-held tester were influenced by conditions in the orchard. On August 3 we measured higher firmness in the early morning compared with the afternoon testing time, although the penetrometer readings did not differ significantly. The August 4 reading, taken at the normal late morning, time had a value between the values obtained the previous day. On August 7, we observed that the firmness was significantly higher during sprinkler irrigation in early morning. Both of these observations point to the possibility that the hand-held tester is influenced by turgidity of the fruit, which is in turn affected by tree moisture status. In the colder morning and during irrigation the trees had a high water content and the device had a high reading. High turgor results in a high modulus of elasticity of the fruit (the fruit tissue deforms less to a given pressure) and the hand-held unit is very sensitive to changes in elastic modulus. In these same tests however, the penetrometer readings were not significantly different. A penetrometer is sensitive to the ultimate strength of the pear tissue and not very influenced by its elastic modulus. However, there appears to be a correlation between elastic modulus and ultimate strength of the pear tissue. In other words as the fruit mature, its ultimate strength decreases and there is a corresponding reduction in elastic modulus. We believe that if hand-held unit readings are taken under fairly consistent tree water status conditions, these readings will correlate well with penetrometer readings. For example, this means that hand-held firmness readings should be done in the morning at about the same temperature from day-to-day and readings should not be used during irrigation periods or when the trees are under moisture stress. To demonstrate these ideas we eliminated the data taken in the warm afternoon on Aug. 3 and on the two cold mornings of August 3 and 7 (Figure 5). This increased the R^2 value of the correlation between hand-held firmness and penetrometer from 0.89 to 0.95. Similarly, removing these three data points increased the R^2 value of the correlation between hand-held firmness and time for both the on-tree fruits (Figure 6) and picked fruits (Figure 7).

On-line Sorter

A test was made on 40 harvested pears (softer fruits from cold storage) to evaluate the performance of the on-line sorting system. The firmness of each of these fruit was measured by the hand-held tester before sorting test, and by the penetrometer after sorting.

Sorting test was made by running these fruits through the on-line sorter (with two sensors) to separate them into 3 three firmness groups. The on-line sensors were calibrated with the rubber ball to give a firmness reading of 150. Sorting of these same fruits were repeated 6 times to evaluate the repeatability of the system. The majority of the fruits stayed in the same firmness groups with the exception of about 5 to 6 fruits that moved between two firmness groups. Figure 8 shows how the fruits were sorted according to the hand-held impact reading, and Figure 9 compares the sorting result with the penetrometer readings. The impact firmness readings from the two sensors on the on-line sorter were also recorded for 20 of these fruits. Figure 10 shows the relationship between the average on-line impact readings and penetrometer readings.

The results show that the on-line sorter was effective in segregating pears into three distinct firmness categories. Average penetrometer firmness of the categories differed by about 5 to 6 pounds. The unit can operate at speeds of 6 fruit per second and is nondestructive. A company in California is developing a commercial-scale on-line sorting system based on this technology.

Future work

It appears that the hand-held sensor readings could be made more consistent by incorporating a temperature sensor into the device. This and the effect of more direct measurements of tree moisture status should be studied.

Acknowledgement: We would like to thank Greene and Hemly, Inc. for providing the trees and fruits for our tests.

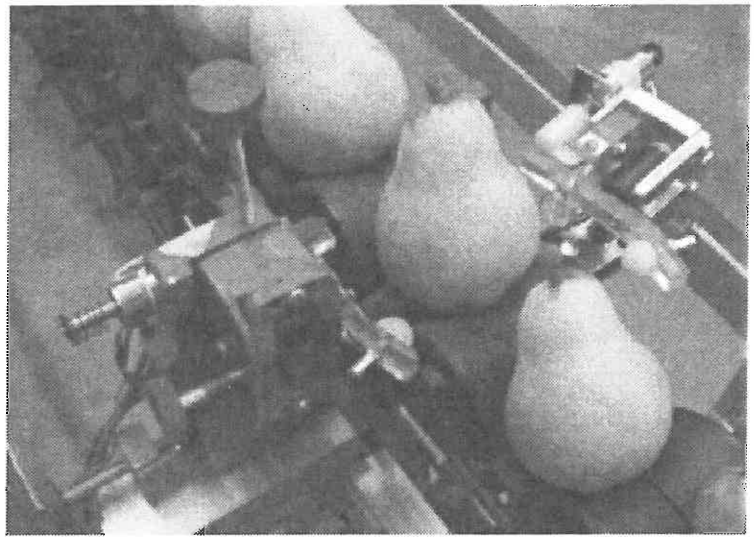

Figure 1. On-line sorting system with dual impact firmness sensors.

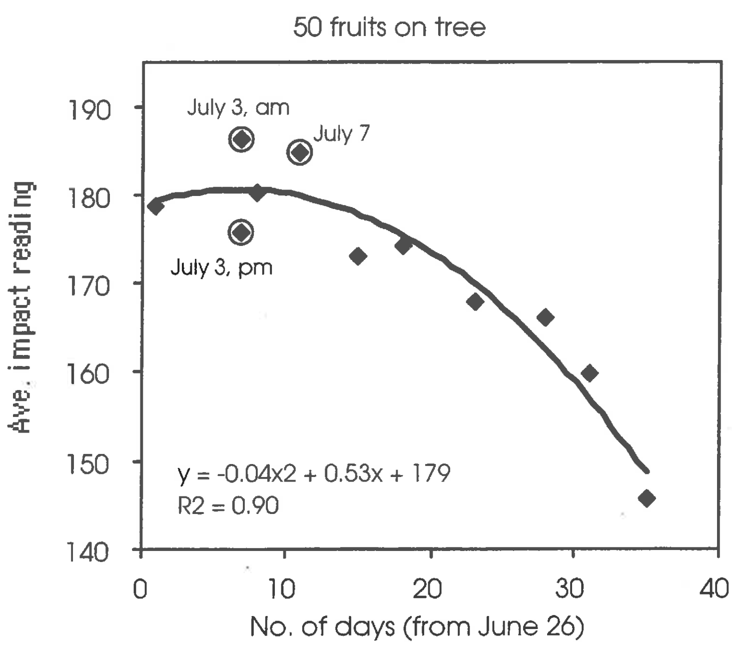

Figure 2. Results of in-field firmness measurement of pears in Courtland. Each point represents the average impact firmness reading of all 50 fruits on each test day.

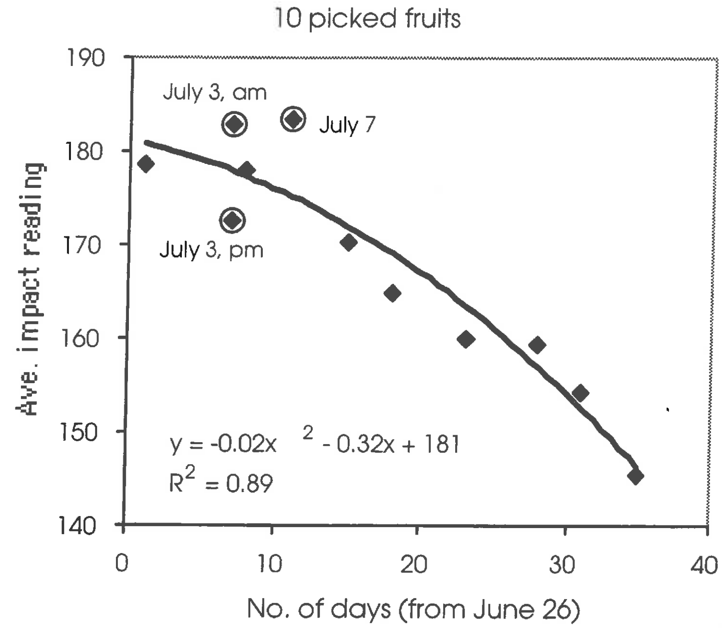

Figure 3. Average impact firmness readings of the ten picked fruits on each test day.

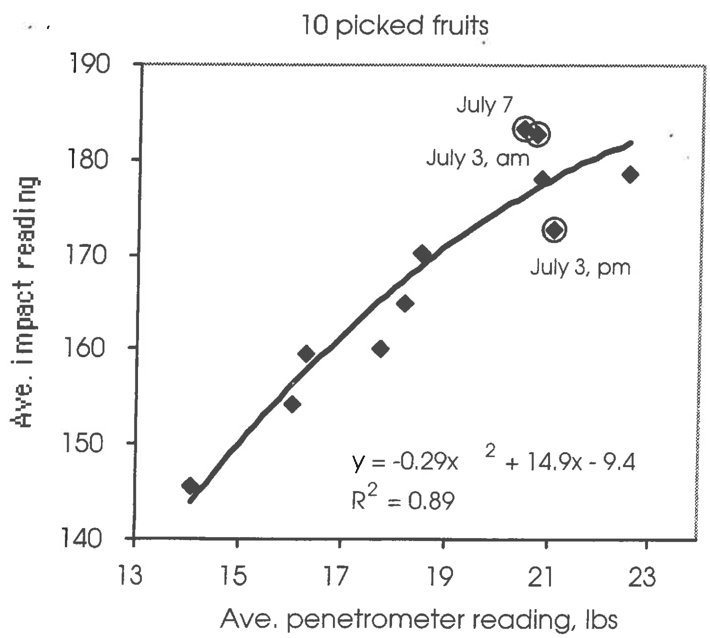

Figure 4. Comparison between firmness measured with the hand-held tester and that measured with the penetrometer.

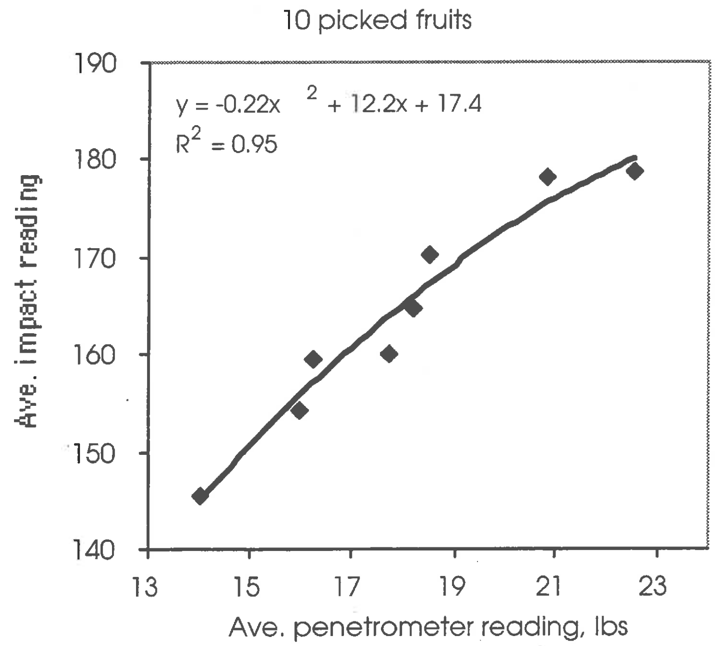

Figure 5. Comparison between firmness measured with the hand-held tester and that measured with the penetrometer, excluding the data on the two cold mornings and warm afternoon.

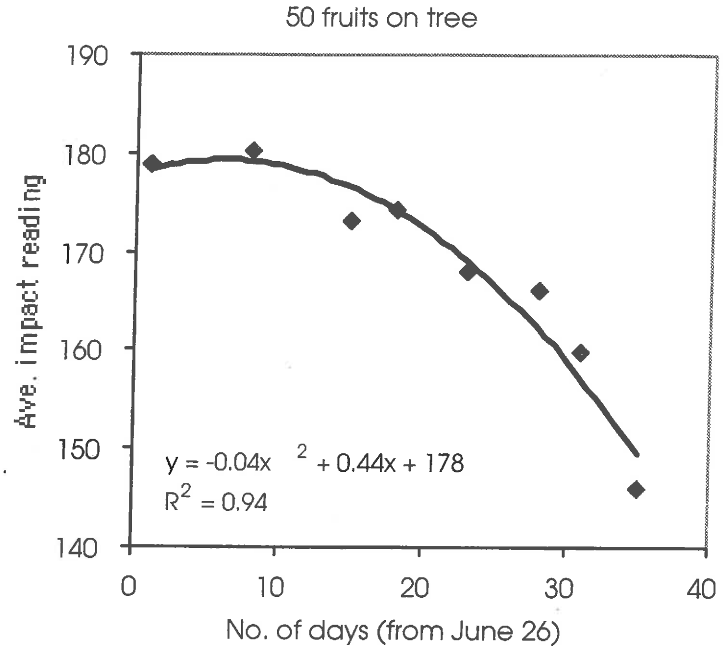

Figure 6. Results of in-field firmness measurement of pears in Courtland, excluding the data on the two cold mornings and warm afternoon.

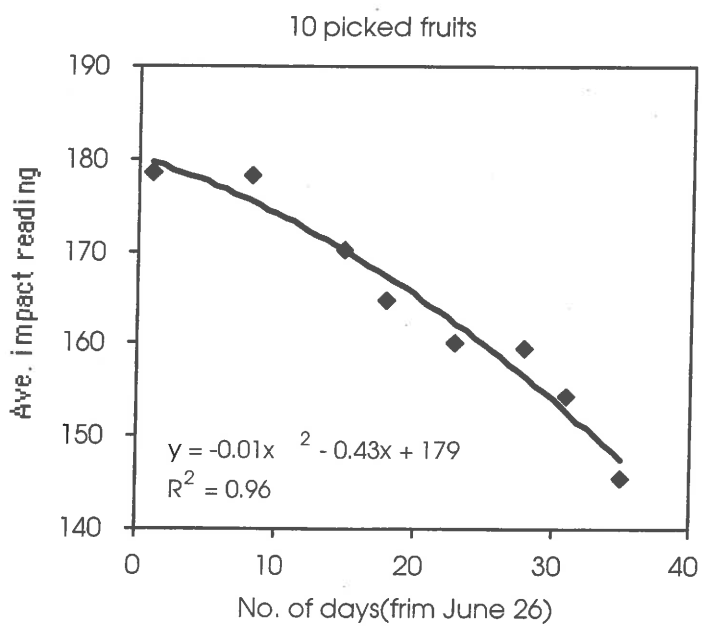

Figure 7. Average impact firmness readings of the ten picked fruits on each test day, excluding the data on the two cold mornings and warm afternoon.

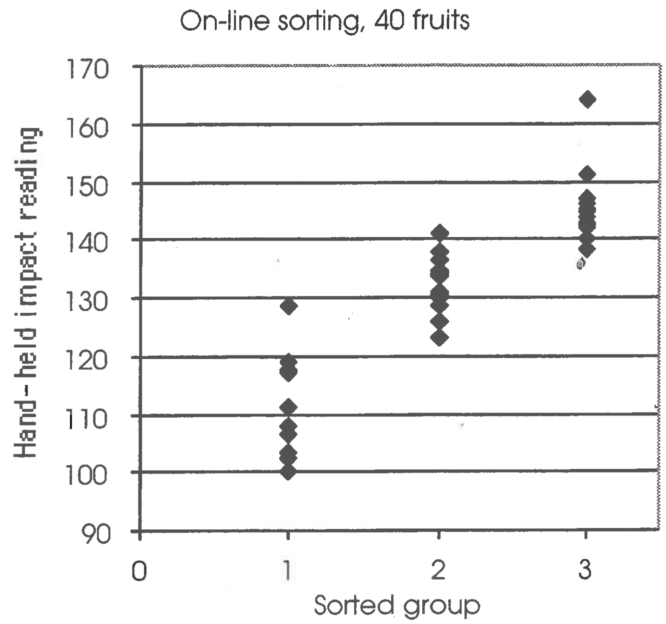

Figure 8. Result of the sorting made with the on-line sorting system, compared with fruit firmness measured by the hand-held firmness tester.

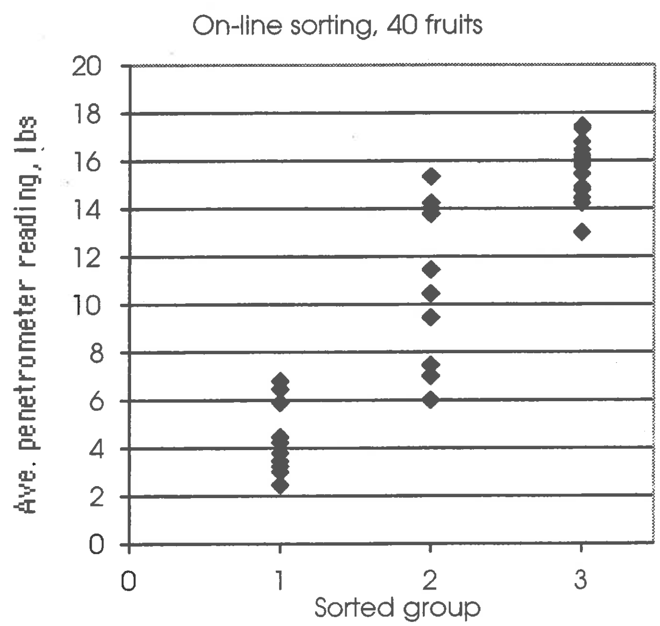

Figure 9. Result of sorting made with the on-line sorting system, compared with fruit firmness measured by penetrometer.

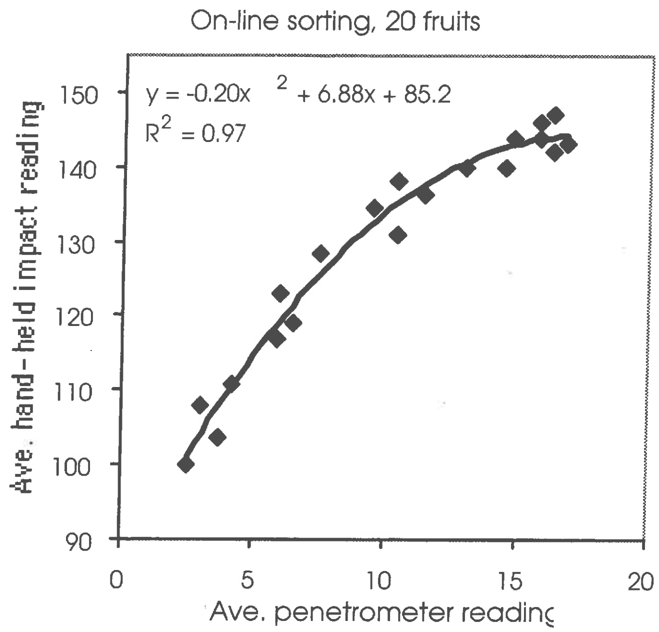

Figure 10. Comparison between firmness measured with the on-line impact sensors and that measured with the penetrometer.