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POSTHARVEST PEACH WEIGHT LOSS, WATER CONTENT, AND OUTER LAYER FIRMNESS

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A b s t r a c t. Harvesting of a fruit is the beginning of loss in weight and firmness. Measuring changes in weight require maintaining identity of the fruit and current methods used to measure firmness are usually destructive. Alternative methods are needed which can rapidly and nondestructively sense fruit quality. Three cultivars of peaches were measured during 9 days of storage to obtain fruit having varying weight loss and firmness. The average daily whole fruit weight losses were 1.72, 2.19, and 2.22% for 'Garnet', 'Red Haven', and 'Sentinal', respectively. After 9 days of storage, the water content of the outer layers of a peach were less than at the center. Firmness, slope of the force-deformation curve obtained during 1 mm compression, decreased significantly during the first 3 days of storage and continued to decrease but by a smaller amount thereafter. By eliminating the time variable, firmness exponentially decreased with weight loss with an r^2 of 0.79-0.88. Changes in water content and firmness of the outer layers appear to be good predictors of subsequent changes in the whole fruit.

K e y w o r d s: firmness, peach, water content, weight loss

INTRODUCTION

Fresh fruit reach their maximum potential quality at the time of harvest. After being picked, separated from its food supply, the fruit loses weight and firmness. During ripening and storage, changes in whole fruit weight are easy to determine provided measurements are made at harvest and again later on the same fruit. Firmness can be measured at any time by various devices such as puncture resistance (Magness-Taylor), drop impact, sonic impulse, etc. These firmness methods all involve mechanical sensors which are destructive to the fruit and have limited data acquisition time. Optically based sensors could acquire information faster and non-destructively. A simple, low-cost optically-based sensor measures properties of a fruit's surface or outer tissue layers. Are there any properties of the fruit's outer layers which could be optically sensed that are good indicators of whole fruit weight loss or firmness?

Peaches stored at low temperature and high humidity had less reduction in weight and firmness, as measured by impact force parameters [4]. Peach weight loss was highly correlated with the vapor pressure deficit between the fruit's surface and the surrounding air during 20 days of high humidity, cool storage [10]. As peaches lost weight during storage, they also experienced changes in firmness, as indicated by impact force parameters and flesh penetrometer readings. During three days of storage at room temperature, peach firmness was significantly reduced as measured by Effegi firmness, drop impact, and sonic impulse [11]. Fruit turgidity and firmness have been shown to influence impact bruise susceptibility of apples and pears [5].

The force measured by a firmness probe depends on probe geometry and the fruit's compression and shear properties [3]. Abbott *et al.* [1] found that the Magness-Taylor, Effegi, and Instron-held probes produced force values differing more than expected for comparable probes and fruit. Possibly, there is an interaction between the sample's material properties and the geometry of the specific probe. The cheeks of peaches were firmer (higher puncture force) than areas midway between the cheeks and the blossom or stem ends [7]. Cross-sections of peach mesocarp were most firm near the stone and least firm at the outer region of the fruit, particularly for certain peach cultivars [8]. Bourne [2] used puncture measurements to assess the contribution of the skin to flesh firmness.

Since nearly all fruit are stored at vapor pressure deficits (VPD) considerably greater than zero, there is an internal gradient whereby the external surface experiences a lower vapor pressure than the center. This VPD gradient could cause firmness to vary from inner to outer parts of a fruit. The usual measurement of puncture force may thus indicate a firmness value less than the whole fruit average. Thus, using a firmness value less than the average provides a 'factor of safety' in marketing fresh fruit. The objective of this study was to determine the correlation between a peach's whole-fruit weight loss, water content at various layers within a fruit, and small deformation firmness of the outer layer.

MATERIALS AND METHODS

'Garnet Beauty', 'Sentinal', and 'Redhaven' peaches were hand harvested at the Perkins, Oklahoma Fruit Research Station at 8 a.m., each cultivar on a different day in July. Fifteen peaches, of each cultivar, at threshold mature level were visually selected for texture measurements. Fruit firmness was measured using an Instron testing instrument (Instron Corp., Canton, Mass.) with a 50 kg load cell. A 6.35-mm diameter, flat ended probe, mounted in the Instron, was moved into the fruit to measure compression force. The peach was supported on a metal base with the addition of floral clay used to hold the peach in position. Two locations (opposite cheeks) on each peach were tested. The crosshead speed of the Instron was set at 2 mm/min. Each test continued for 30 s, producing a total deformation of 1 mm. Data were plotted on a strip chart recorder and simultaneously digitized by a Keithley System 570 Data Acquisition Workstation (Keithley Instruments, Inc., Cleveland, OH) connected to a personal computer with Soft500 Software System. The data were stored on disk for later processing.

Each peach was tested five times; initially when peaches were brought from the orchard and at four times spread over nine days of storage (eight days for Sentinal). Peaches were stored in a controlled temperature-humidity chamber at 5 °C and 70% RH. This less-than-optimum storage condition was used to accelerate weight loss and accentuate the desired, unfavorable condition. Peaches were numbered and weighed before the first test. For later tests, peaches were taken out of the environmental chamber to warm up to room temperature (23°C) for 2 h before testing. Just before the firmness test, individual peach weight was measured and weight loss was calculated using the formula: % weight loss = ((initial weight - current weight) / initial weight) x 100. Firmness was then measured on the cheek at a location at least 3 cm away from any previous probe site.

The water content of peach samples was measured before the first and after the final Instron firmness test. From two cheeks of each peach, 4 x 10 x 10-mm samples were cut with a knife at three depths. The outer sample was taken just underneath the skin, the inner sample was taken close to the stone and the middle sample was taken midway between the other two samples. Before the first firmness test, five peaches (replicates) were randomly selected for water content measurement, and thus not used for firmness testing. After all the firmness tests, another five peaches, from the firmness test group, were selected for final water content measurement from the lowest, intermediate, and the highest weight loss peaches. Each sample had an initial weight of about 20 g. Aluminum dishes were used as sample containers for drying. Samples were dried in a forced convection air oven for 24 h at 70°C. The drying time was selected because longer drying did not further reduce the sample weight. Sample weight was measured before and after drying. Water content was computed and reported on a percentage, dry basis.

The plotted force-deformation curves were viewed to select the best method for analysis, i.e., what unique features to use as firmness parameters. For the compression test, force increased slowly with deformation at the beginning because the contacting surfaces of peach and probe were not flat. When full contact was achieved between the probe's tip and the fruit, the force-deformation curve became nearly linear. The slope of the linear part of the force-deformation curve was defined as firmness and denoted as F.

RESULTS

Weight loss

Weight losses for each of the three peach cultivars and various storage times are given in Table 1. Regression analysis showed that the average weight loss for each cultivar increased linearly with storage time with r^2 greater than 0.98. The results were consistent with the previous studies [6,9,10]. There were greater than expected variations between individual peaches and the variation increased with storage time. The final weight loss ranges were from 13.1 to 23.3 % for Garnet, 14.4 to 22.7 % for Redhaven, and 14.8 to 20.6 % for Sentinal. The average daily weight losses were 1.72, 2.19, and 2.22 % for Garnet, Redhaven, and Sentinal, respectively.

Water content

The measured water content data for all three peach cultivars before and after nine days storage (eight days for Sentinal) are shown in Table 2. The water content of Garnet and Redhaven peaches dropped 30 % and 31 %, respectively after 9 days in storage, and Sentinal dropped 18 % after 8 days in storage. Garnet had higher overall water content than the other two cultivars both before and after storage.

The water content distribution within a peach was cultivar dependent. For Garnet, the water content was initially evenly distributed within a peach. Nine days later, the outer layer had lost more water than the inner layer. The difference in water content between these two layers was statistically significant while the differences between adjacent layers were not significant. Redhaven peaches had higher water content at the inner layer than at the outer layer at harvest time, but the water content in the middle layer was not statistically different from either the inner or outer layer. After nine days in storage, the outer layer had

Table 1. Average* weight loss (WL in %) and firmness (F in N/mm) of three peach cultivars after storage

Parameter	Day 0	Day 3	Day 5	Day 6	Day 7	Day 8	Day 9
Garnet							
WL	0.0(00.0)	6.0(10.7)	9.3(11.9)		12.7(13.7)		15.5(15.4)
F	5.95(42.9)	2.49(28.5)	1.36(25.4)		1.07(16.1)		0.90(22.3)
Redhaven							
WL	0.0(00.0)	8.3(20.0)	12.6(17.9)		16.5(13.9)		19.8(11.2)
F	6.36(39.8)	2.34(28.9)	1.31(27.6)		0.81(26.2)		0.64(39.3)
Sentinal							
WL	0.0(00.0)	4.6(17.2)	10.3(10.3)	13.2(9.7)		17.2(9.2)	
F	6.54(19.0)	4.02(17.6)	1.90(13.3)	1.89(19.8)		1.19(17.3)	

Note: Values in parentheses are coefficients of variation, i.e., (standard deviation/mean) x 100. *N=30 for 2 sides of 15 peaches

Table 2. Average* water content (%) at three locations within a peach before storage and after 8 days for Sentinal and 9 days for Redhaven and Garnet

	Location in peach**	Garnet	Redhaven	Sentinal
Before storage	Inner	9.11a	7.33a	7.43a
	Middle	9.35a	7.11a,b	7.57a
	Outer	9.35a	6.17b	6.45
After storage	Inner	7.28b	5.00c	6.44b
	Middle	6.45b,c	4.87c	5.78b
	Outer	5.68c	4.31d	5.45b

a,b,c,d - values in the same column with different letters are statistically different (P0.05) by 1sd multiple comparison test for the same storage time. * N = 10 for 2 sides of 5 peaches. **Outer=just beneath skin, middle=intermediate or mid-way between skin and stone, inner=near stone.

lost more water which made the difference significant between the middle and outer layers. For Sentinal peaches, the water contents among the three layers were not statistically different either when fresh or after eight days in storage. After storage, the water content at the outer layer was the lowest, although not statistically different from the other layers. As expected, peaches after storage had less water content near the outside of the fruit than at the center.

Firmness

Firmness as a function of weight loss is plotted in Fig. 1 for Garnet where each data point is the average of two sides of a peach. Plots for Redhaven and Sentinal (not shown) were similar to that of Garnet. Firmness decreased exponentially with weight. The regression equation constants, A and B, and r^2 are given in Table 3 for all three cultivars.

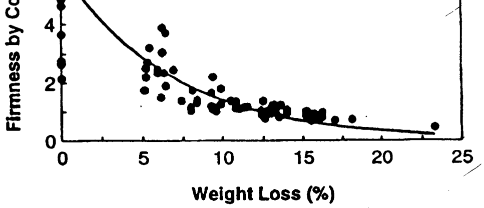

Fig. 1. Firmness (F) as a function of weight loss (WL) for Garnet. Regression equation is F = 5.91 exp (-0.144 WL) with r^2 of 0.83.

Table 3. Parameters for firmness F=A exp (-B WL) where F is firmness (n/mm) and WL is weight loss (%) for n= 30

	Garnet	Redhaven	Sentinal
A	5.91	6.28	6.45
B	0.144	0.126	0.103
r^2	0.828	0.792	0.884

When a peach loses more than 10-12 % of its initial fresh weight, its quality has become unacceptable for marketing [10]. From the given model parameters in Table 3, the firmness corresponding to 10% weight loss was 1.4, 1.8 and 2.3 N/mm for Garnet, Redhaven, and Sentinal, respectively. Using a specific value of firmness equal to 1.5 N/mm to estimate a maximum allowable weight loss of all cultivars, the respective weight losses would be 9.5, 11.4, and 14.1 % for Garnet, Redhaven, and Sentinal. These values correspond to 5-6 days storage, by interpolating the data in Table 1.

The variation in firmness at each day was cultivar dependent (Table 1). The firmness of freshly picked Garnet and Redhaven (zero weight loss) varied over a wide range. As the peaches lost water, the firmness range narrowed and the variation became smaller. The variation for Sentinal peaches was smaller than the other two cultivars, especially at the fresh stage.

CONCLUSIONS

Peach firmness (slope of the force-deformation curve) exponentially decreased with weight loss and was cultivar dependent. Firmness is particularly sensitive to initial changes in fruit weight loss because moisture commonly comes first from the outer portion where firmness is measured. During storage, a peach loses more water from its outer region than from its center region with whole fruit weight loss being an intermediate amount. This moisture gradient could be another cause for the large changes in firmness found in a peach's outer layers during postharvest storage.

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