

PEACH MATURITY ESTIMATION BY SONIC  
IMPULSE TESTING

By

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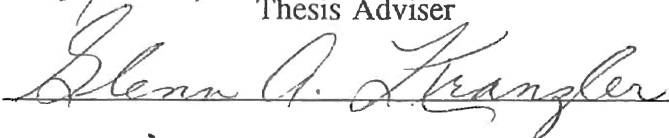
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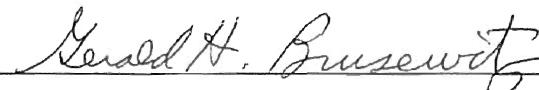
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## NOMENCLATURE

BM80-130	Summation of spectrum magnitudes for the frequency band 80-130 Hz divided by the summation of magnitudes for the complete spectrum, %
BM70-160	Summation of spectrum magnitudes for the frequency band 70-160 Hz divided by the summation of magnitudes for the complete spectrum, %
BM70-220	Summation of spectrum magnitudes for the frequency band 70-220 Hz divided by the summation of magnitudes for the complete spectrum, %
Effegi	Reading of Effegi firmness, N
F2	Second resonance frequency, Hz
P2/T	Attenuation coefficient of the second resonance peak voltage in time domain, v/ms
PRF2-1	Magnitude ratio of the second peak to the first peak in frequency domain, %
PRT2-1	Magnitude ratio of the second peak to the first peak in time domain, %

## CHAPTER I

### INTRODUCTION

Harvesting peaches at the proper stage of maturity is essential for optimum quality and often for the maintenance of this quality after harvest (Mitchell, 1991). Harvest maturity controls the peach's flavor components, physiological deterioration problems, susceptibility to mechanical injuries, resistance to moisture loss, susceptibility to invasion by rot organisms, and ability to ripen.

Peaches that are harvested too soon may fail to ripen properly or may ripen abnormally. Immature fruits typically soften slowly and irregularly, never reaching the desired texture of fully matured fruit. Green color may never fully disappear. Because immature fruit lack a fully developed surface cuticle, they are more susceptible to water loss than properly matured fruit. Immature fruit have lower soluble solids content, higher acids, and higher starch content than properly matured fruit, all of which contribute to inadequate flavor development. Low-maturity fruit are more susceptible to shriveling and to internal breakdown symptoms than properly matured fruit.

Overmature peaches have a shortened postharvest life, primarily because of flesh softening. Flesh softening in these fruit renders them highly susceptible to mechanical injury and microbial invasion. By the time such fruit reach the consumer they may have become overripe, with poor eating quality including off-flavors and

mealy texture.

The current USDA grade standards for peaches specify that peaches of all grades must be mature, but not soft or overripe. No objective measure of maturity is given in the USDA grade standards. Optimum maturity is traditionally a highly subjective determination. Some physical properties like size, color, flavor and texture are commonly used to characterize the maturity stage and many quality factors are evaluated by individual inspection. The criteria are functions of both product and handling conditions. They may vary substantially with different cultivars, the intended use and the constraints of time.

There has been considerable interest in developing indices for objectively estimating fresh fruit maturity. To accomplish the assessment, methods and instruments are needed which are fast, nondestructive, inexpensive and accurate. It is desirable to make measurements on different fruit varieties using a general purpose sensor.

As an objective and nondestructive method, sonic impulse testing has captured researcher's interests with the availability of high-speed data acquisition and digital signal processing technology. The testing is done by applying a mechanical pulse to a specimen and then measuring the resulting vibrations of the specimen. Farabee and Stone (1991) developed a hand-held sensor to determine watermelon maturity using a PZT piezoelectric transducer. Some impulse response parameters were found to have significant correlation with destructively measured sugar content and firmness, but the suitability of the sensor to other fruit needed to be demonstrated.

To help quantify fresh peach maturity and its storage potential using sonic

impulse response, the effective maturity indices and testing method should be determined, and the different parameters obtained from sonic impulse response need to be evaluated.

### Objective

The goal of this research was to find parameters from peach sonic impulse response that indicate maturity. The operational objectives were to:

1. Modify the sensor and develop a test procedure to acquire impulse data from peaches.
2. Search for parameters from peach sonic impulse responses which show progressive change with measured peach maturity indices.
3. Relate the parameters to the effective maturity indicators.
4. Evaluate the parameters with various storage times and cultivars.

## CHAPTER II

### LITERATURE REVIEW

A number of methods for quality evaluation and sorting of agriculture products are based on the detection of various physical and chemical properties which are well correlated with certain quality factors of products (Chen et al., 1991). A series of qualitative, and in some cases quantitative, transformations occur with ripening as fruits near the end of their growth phase. During ripening, fleshy fruits undergo major changes in their chemical and physical state. These changes represent a wide spectrum of synthetic and degradative biochemical processes; many of which occur concurrently or sequentially within the fruit. Those that represent changes in quality attributes of the fruit can be grouped into three general categories: (1) texture, (2) pigmentation, and (3) flavor (Kays, 1991).

Softening is one of the most significant quality alterations consistently associated with the ripening of fleshy fruits. Alterations in texture affect both the edibility of the fruit and the length of time the fruit may be stored. Softening is an essential component in the development of optimum quality. Softening in ripening peaches is attributed to solubilization of protopectin resulting from polygalacturonase activity (Shewfelt et al., 1987). Polygalacturonase is not found in immature peaches, but its activity increases rapidly during the ripening process. Thus, firmness of fruit decreases gradually as they become more mature, and decreases rapidly as they ripen,

therefore, firmness has been used as a criterion for sorting ripening agricultural products.

Primarily, firmness is measured using the resistance to penetration of the tissue by a plunger of a standard shape and size. Several relatively inexpensive pressure testers are commercially available. This destructive method is still commonly used as a basis for comparison with other methods.

Some firmness measurements have been based on force-deformation. Previous studies included applying low-pressure air simultaneously to small areas on opposite sides of peaches to generate a non-bruising maturity-indicating deformation (Perry, 1977). Mehlschau et al. (1981) pressed two steel balls against the pears with a fixed force to measure the deformation.

The response to impact force, generated by dropping fruit on a rigid surface, was found to have fairly good correlation with fruit firmness by several researchers. Tests were conducted on tomatoes (Nahir et al., 1986) and peaches (Delwiche et al., 1987), but the results were not always satisfactory, since impact test measures local firmness rather than average fruit properties. However, Brusewitz et al. (1991) reported several impact parameters and found that they were well correlated with peach firmness.

Acoustic impedance measurements using vibrational characteristic calculated from excitation response has been developed over the past twenty years. In this kind of experiment, the fruit is excited by a vibrator on one side while response is measured by an accelerometer or microphone attached to the opposite side. The early research was focused on correlation between the extent of fruit ripeness and fruit

Young's modulus (Finney, 1967). Young's modulus was calculated according to the resonance frequency of a specimen of the fruit. Abbott et al. (1968) found that the first resonance frequency of forced vibration was not correlated with apple properties, yet, the second resonance was correlated with firmness, although it was mass dependent. Finney (1970) and Yong et al. (1979) obtained similar second resonance frequencies for apples using a different vibration system with the first resonance frequency totally different. An explanation of the large variation in frequency of the first resonance lies in the difference of the excitation methods used by each of the investigators. Finney's arrangement had a large contact area between the fruit and the vibrator, whereas Abbot's small excited area was created by a pin which was stuck into the flesh of the apple. This leads to the conclusion that when vibrating the fruit, the first resonance frequency is not an appropriate measure for fruit properties, since it depends on the area of excitation. This area differs according to the local shape of the fruit and the vibrating device.

Several researchers studied fruit response through mechanical or sonic impulse excitation. Clark (1975) used a modified audio speaker to induce an impulse through watermelon and found a high correlation between the delay time of sound waves crossing watermelons, and their firmness. It was found that sound decay increased with watermelon ripeness. An alternative method for evaluating textural quality via frequency response was suggested by Yamamoto et al. (1980). The fruit was placed on a rigid surface and struck by a pendulum. The acoustic emission was sensed by a microphone, and the signal was analyzed using a FFT algorithm to extract the resonance frequencies of the fruit. Van Woensel et al. (1988) compared resonance

frequencies using forced vibrations by the standard vibrating method and the free vibrations by a small pendulum which hit the fruit that was suspended by its stem. They found that the first resonance measured by the forced vibrations setup was not detected by the free vibration setup, which measured natural frequencies only.

The emerging piezo film technology has opened new possibilities for developing a relatively simple, low-cost, light-weight sensor for nondestructive quality detection of agricultural products. Farabee and Stone (1991) developed a hand-held sensor to determine watermelon maturity using a PZT piezoelectric transducer. They used a solenoid as the impulse generator and PZT piezoelectric crystal as the receiving component. Being independent of fruit mass, average normalized spectrum parameters were calculated from the impulse response. Two spectrum parameters, which were defined as the center frequency of the narrowest 50 percent energy band (CFN50) and energy content of the frequency band from 85 to 160 Hz (EB85-160) were found to have significant correlation with destructively measured sugar content and firmness. Besides PZT material, a new PVDF piezoelectric transducer can be cut or stamped into nearly any shape (Carlisle, 1986), and has shown promise in making multi-sensor transducers (Luan et al., 1989).

Ground color is considered as another effective index of maturity for fresh peaches (Delwiche et al., 1983, 1985). Changes in the coloration of fruits normally involves the loss of chlorophyll and either the synthesis of other pigments such as carotenoids and anthocyanins and/or the unmasking of these pigments formed earlier in the development of the fruit. The timing, rate and extent of change in fruit color vary widely between different species and cultivars of the same species. Changes in

fruit color may or may not coincide with the development of the other quality criteria associated with ripening.

Ground color is generally measured in the field by comparing with standard color chips. The measurements of peach color can be quantified using a tristimulus colorimeter. These instruments provide readings of color in three-dimensional color space by computing weighted integrals of spectral reflectance over the range of visible wavelengths. The "a" value has been widely used in practice, with negative "a" values indicating more relative greenness and positive "a" values indicating more red or less green. Byrne et al. (1991) tested 12 peach genotypes and found mesocarp firmness was correlated with both skin and flesh color and that flesh "a" values within all genotypes and genotypes differed in their ratio of firmness to "a" value. In contrast with this method, Miller (1990) designed an image analysis algorithm to compare peach color with standard peach maturity color by using a computer vision system. So far, firmness and color have been used separately as peach maturity indices.

## CHAPTER III

### INSTRUMENTATION

#### Impulse Testing System

An impulse testing system originally used by Farabee and Stone (1991) was modified for use in this project. The modified system was used to generate a physical impulse and record the resulting response. The impulse energy absorbed by an object under test results in a characteristically attenuated vibration which is specimen dependent. The entire system consists of a personal computer, a 24-volt power supply, a digital oscilloscope, a low-pass filter and a base-supported sensor unit. Figure 1 shows a schematic of the equipment used during the summer of 1992.

The personal computer, which is an Intel 386 based IBM clone, was used to control the system during testing, and to process the data.

An R1288 digital oscilloscope manufactured by Rapid Systems was used to record data. This oscilloscope can sample two channels of analog signals at frequencies up to 1MHZ. An IEEE488 interface is built into the oscilloscope.

The power supply equipped with a solid-state relay was used to power the solenoid, which is a part of sensor unit. The solid-state relay was closed with a high logic signal obtained from the parallel port of the computer.

The main parts of the sensor unit shown in Figure 2 are the solenoid, used as

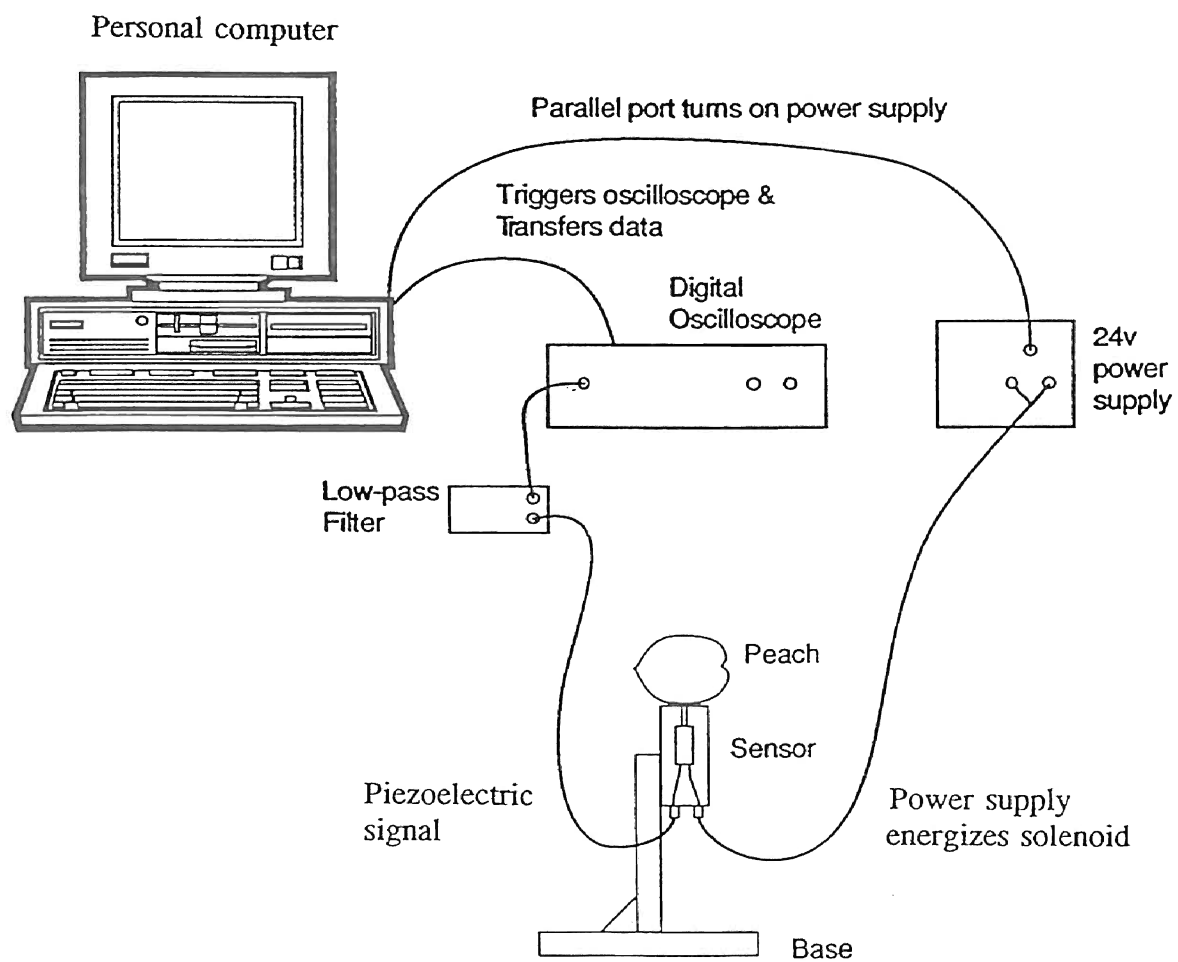
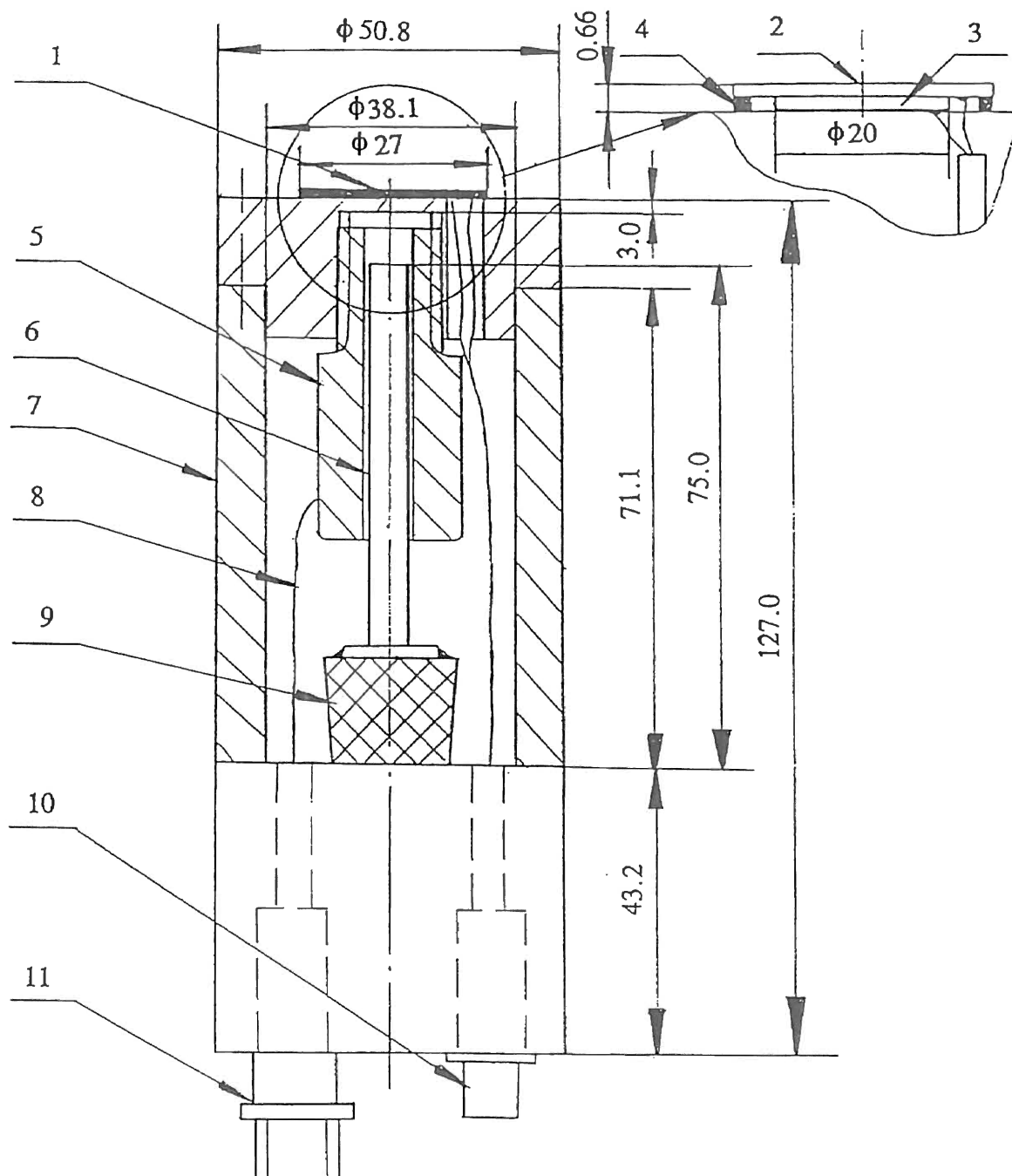


Figure 1. Diagram of Impulse Testing System



1. Piezoelectric audio tone transducer (EC-R200H<sub>2</sub>-27BA, NGK Spark Plug Co.)
2. Brass backing plate 3. Ceramic crystal 4. Adhesive
5. Solenoid (TP8x9-I-24 v DC, Guardian Electric)
6. Plunger 7. Acrylic housing 8. Lead wire 9. Polyethylene foam damper
10. Signal output (BNC male connector, UG-1094/U)
11. 24 v input (AMP free hanging receptacles, 206153-1)

Figure 2. Diagram of Sensor (unit: mm)

generator or excitation source, the foam damper, glued to the end of solenoid plunger to absorb remaining vibration of plunger after each excitation, and the transducer, a layered structure in which the PZT piezoelectric ceramic piece and the brass plate were bonded. The transducer converts mechanical deformation to an electronic signal. Through an amplifier, the maximum signal output in the significant frequency band is approximately 10 volts.

### Color Meter

A CR-300 Minolta Chroma Meter was used to measure reflective color of the peach surfaces. The Chroma Meter consisted of a measuring head and a Data Processor DP-301. The head had an 8-mm diameter measuring area and used diffuse illumination at a 0° viewing angle. A pulsed xenon arc lamp in a mixing chamber provided illumination on the sample surface. Six high-sensitivity silicon photocells, filtered to match the standard observer response, were used to measure both incident and reflected light. Absolute measurements could be displayed in Hunter "L", "a" and "b" coordinates, or XYZ tristimulus values, and data could be converted between color systems. Differences for varied peach maturities occurred primarily in the "a" color coordinate. Each measurement was automatically stored at the time of measurement as both an absolute measurement and a color-difference measurement. Data could also be printed out at the time of measurement.

### Effegi Fruit Tester

Destructively measured firmness was obtained by resistance to puncture using

an Effige fruit tester. Measurements were made using the 11 mm probe. The pressure readings in metric Kg unit were converted to Newtons over the range from 0-125 N.

## CHAPTER IV

### METHODS AND PROCEDURE

Peaches for this study were harvested from the Livesay Orchard at Porter, Oklahoma between middle June and late July in 1992. Seven genotypes were studied. Redhaven, Ranger, Loring, Ruston Red, Cresthaven, Jefferson, and Elberta covered a relatively wide harvest range from early season to mid-season cultivars. Mid-season cultivars are the commercial yellow flesh freestone peaches for fresh market. For each cultivar, ground color chips were used as a reference to aid harvesting of fruit with a variety of maturity stages. One cultivar at a time, peaches were hand-picked from trees, placed no more than three layers deep in boxes and transported 110 miles to the laboratory.

Several peach physical properties; flesh firmness, skin color and fruit mass were originally used as maturity indicators for this study. The test was to determine the correlation between the sonic impulse parameters and the results from the standard destructive and nondestructive methods.

The impulse testing was keyboard controlled in the following manner. The system was checked using a rubber standard object by observing the amplitude of the impulse. Then, the peach was put on the top of the sensor and placed as close as possible to the center of the transducer. Power to the solenoid was controlled by a solid-state relay connected to the parallel port of the computer. When high logic was

applied on the parallel port of the computer, the solenoid was activated and struck the thin layer of acrylic that served as a mount for the piezoelectric transducer. Voltages across the transducer, created by both impulse and the vibration of the peach sample, passed through the 4th order active low-pass filter with a cutoff frequency of 1500 Hz, and were then measured by the digital oscilloscope at a sampling frequency of 5000 Hz. The oscilloscope was connected to the computer by an IEEE 488 interface adapter board. The data were recorded by the oscilloscope, transferred to the computer and stored for later processing. After each impulse excitation, the solenoid plunger returned to its original position by gravity.

Before each day's measurement of skin color, the instrument was standardized with a white tile of known "L", "a", and "b" value. Peaches were brushed but not washed before being measured. Skin color was measured on an area of the peach judged to have the least blush, and only "a" values were recorded. Two or three measurements at different green sites on each peach were taken, and the smallest "a" value was used as a ground color index.

### Preliminary Test

Preliminary testing was essential to specify the standard conditions to be used in the main test. Preliminary testing was done to select a suitable fruit restraint, to determine sampling and analysis method, to evaluate the effect of peach temperature on the sonic impulse response and to verify the nondestructiveness of the sonic impulse testing method. Three cultivars, Redhaven, Ranger and Loring, were used for different purposes. The abbreviations of parameters shown in the results below are

defined in the list of nomenclature and described in detail in Chapter V.

### Fruit Restraint Selection Test

Three types of fruit restraint which are shown in Figure 3 were compared:

- (1) fruit resting directly upon the flat surface of the bonded piezoelectric transducer,
- (2) rubber pads placed between the fruit and the top surface of the acrylic housing,
- and (3) steel wires used to restrain the peach. For the latter two, three rubber pads and fine wires were fixed on the acrylic housing of the sensor unit as a auxiliary peach holder.

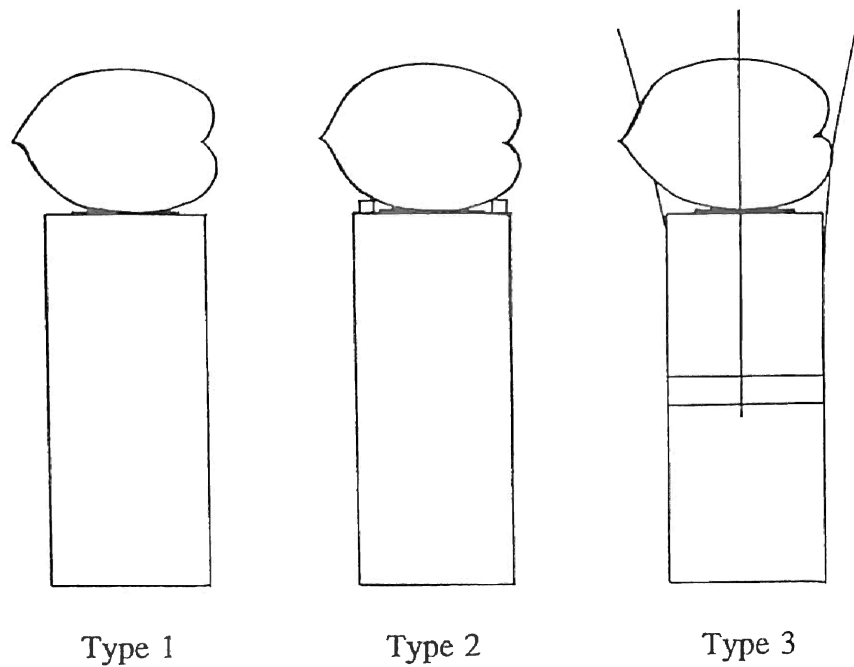


Figure 3. Three Types of Fruit Restraint

The comparison was made by conducting impulse test on 10 marked sites from five peaches, each one had two marked sites, using three types of fruit restraint. Then, the impulse parameter BM80-130 was used, and a statistical Paired T-test was performed on each two sets of dependent data, representing the impulse responses using two types of fruit restraint, to determine if the difference equaled zero. The results are shown in Table 1.

TABLE 1  
PAIRED T-TEST FOR FRUIT RESTRAINT SELECTION ON BM80-130

<u>Mean of differences</u>				
Difference	$d_{\text{mean}}$	$S_d$	T-value	Pr > T
Type 1 - Type 2	1.7020	1.2946	4.1573	0.0025
Type 1 - Type 3	2.1370	3.7560	1.7992	0.1055
Type 2 - Type 3	0.4350	4.2731	0.3219	0.7549

The fruit-restraint of type 1 and type 2, type 1 and type 3 were different at 0.11 significance level. The difference between type 2 and type 3 can be considered zero, but large standard deviation still existed. Since using type 1 fruit restraint obtained the strongest signal magnitude, the selection was then made for the remaining tests.

### Sampling Quality Test

One-time sampling was expected to be the easiest way to obtain the sonic impulse response, and it was demonstrated by a sampling quality test. In this test, 30 fresh peaches of cultivar Ranger were chosen, with each peach having two sampling sites on opposite cheeks. Three impulse responses on each site, named impulse 1, impulse 2 and impulse 3, were recorded in succession under room temperature (24°C) to observe duplication or reproduction. Then all of the impulse responses were grouped according to their impulse numbers with sample size of 60 under each number. Analysis of variance was then performed on the data set to determine if the parameter means under each impulse number were equal. The results of the F-test are listed in Table 2 which convinced us of the reliability of one-time sampling.

TABLE 2  
F-TEST FOR THE HOMOGENEITY OF PARAMETER MEANS  
OF THREE IMPULSES

	Parameter	BM70-220 (%)	PRF2-1 (%)	PRT2-1 (%)	P2/T (v/ms)
Impulse 1	Mean	47.11	47.22	21.42	33.32
Impulse 2	Mean	47.79	48.74	22.21	34.21
Impulse 3	Mean	47.91	49.53	22.48	35.64
F-test	F-value	0.70	0.67	1.04	0.85
	Pr > F	0.50	0.52	0.35	0.43

### Within-fruit Parameter Variation Test

The firmness at any one location may not represent the true average whole fruit firmness if there is significant variation within a fruit (Maness et al., 1992). As a firmness indicator, the sonic impulse parameter was assumed to be site-dependent. To test this hypothesis, 30 fresh peaches of cultivar Loring were used to conduct impulse testing on the two opposite cheeks, followed by Effegi firmness measurement on the same sides. Impulse parameters and Effegi probe readings were correlated using both average values and individual values. The hypothesis was verified by the result in Table 3 which showed the within-fruit parameter variation and suggested that average values be used as whole fruit maturity indicator.

TABLE 3  
PARAMETER VARIATION AND CORRELATION WITH EFFEGI  
FIRMNESS FOR LORING CULTIVAR

Parameter	<u>Mean Variation</u>	<u>Correlation coefficient</u>	
	(%)	Individual	Average
BM80-130	9.00	0.6969	0.8095
PRT2-1	20.92	0.6607	0.7583
Effegi	22.51		

Variation = | (value of side 1 - value of side 2) | / average value of two sides

### Temperature Test

Temperature has a pronounced effect on the respiration rate of stone fruit, since heat alters the physical properties of molecules which in turn may alter their activity and performance within the tissue. To evaluate the effect of peach temperature on the sonic impulse response, about 90 peaches of Redhaven were arbitrarily divided into three groups with each having a wide range of ripeness. Twenty hours after picking, the three groups of peaches were stored at 35°C, 24°C and 2°C for 6 hours and then tested by sonic impulse after storage followed by immediate flesh 24°C ambient temperature.

The effect of peach temperature on the sonic impulse parameter depends mainly on the temperature characteristics of the piezoelectric transducer. For the transducer used in our test, the temperature characteristics determined by the manufacturer (NTK Technical Ceramics Division) are shown in Figure 4.

The electrostatic capacity of the transducer was directly proportional to the temperature. The resonance resistance and resonance frequency dramatically decreased with the increase of temperature between 0°C and 20°C and changed little between 20°C and 40°C. This responses agreed with the test results in which the detected band magnitude attenuated more quickly at a peach temperature of 2°C, but showed reduced attenuation 24°C and 35°C (Figure 5).

Since a temperature gradient existed between the tested specimen and bonded piezoelectric transducer and contact temperature was not a constant during the test, an expected fluctuation was observed in impulse response parameter. The result strongly recommended that both peach and sensor unit be allowed to come to equilibrium at

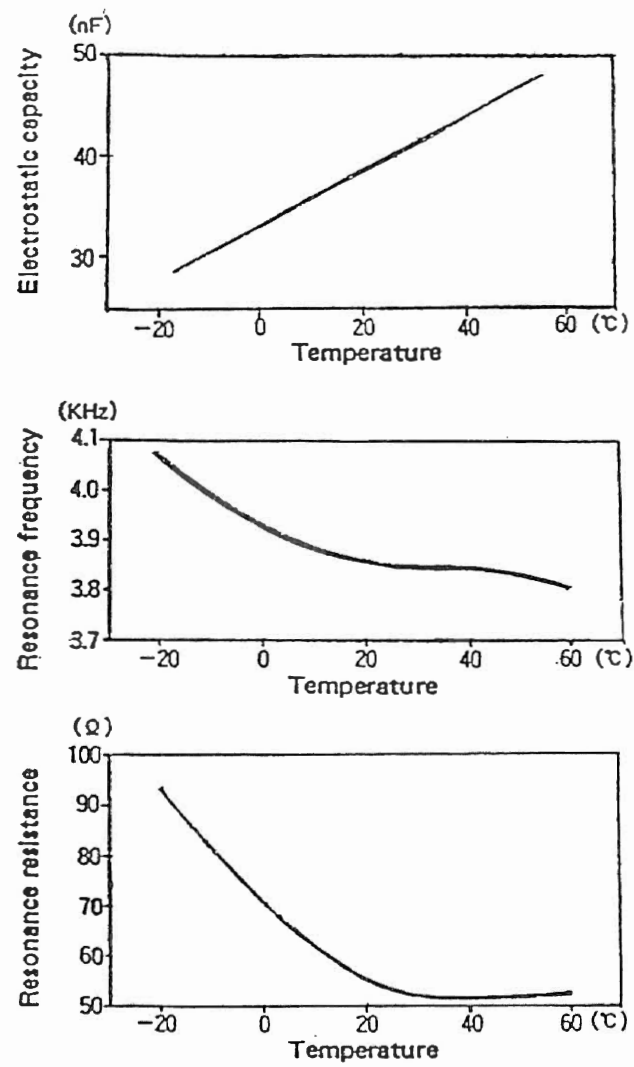


Figure 4. Temperature Characteristics of the Piezoelectric Transducer

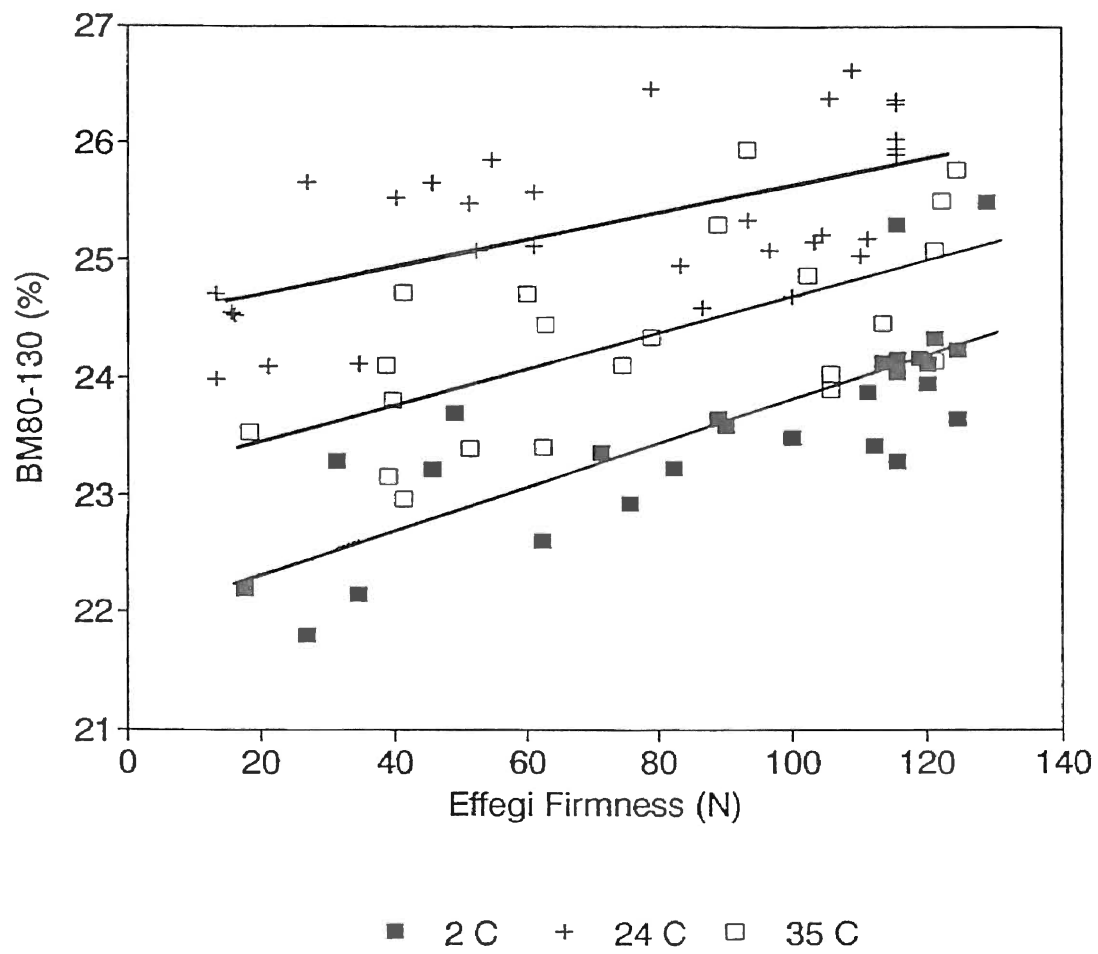


Figure 5. BM80-130 vs Effegi Firmness for Redhaven Cultivar

room temperature or the testing temperature before testing.

#### Nondestructiveness Test

To verify the nondestructiveness of impulse testing, we used 30 peaches of each cultivar (Redhaven, Ranger, Loring) which covered a wide maturity range, randomly divided them into two groups and exposed one of them to the impulse five times and another three times in succession on two cheeks of each peach. The peaches were then stored for two days at 24°C. No external indication of bruising on the marked impulse sites was observed.

The entire top and bottom impulse areas were cut from the peach (ie., parallel to the impulse surface). Each piece was then cut perpendicularly to the approximate center of the impulse site and observed for discoloration of the mesocarp. Although peaches of three cultivars softened differently, with Ranger having the highest fruit ripening rate, no localized bruising was observed.

#### Main Test

This test was designed to find the correlation between the sonic impulse parameters and other maturity indicators for fresh peaches and to evaluate the changes of parameters with storage time.

Thirty peaches of each cultivar, Loring, Ruston Red, Cresthaven, Jefferson and Elberta, were wiped, weighed and marked with an ID number using a permanent ink felt pen. After completing the color measurement, the impulse testing was conducted on the two opposite cheeks of peach followed by an Effegi firmness test described

above.

Peaches of the same cultivars were stored for the first, second and third day's handling. The peaches were covered with plastic film to retain moisture and held in an air-conditioned room. Handholes and vents were cut in the plastic film to provide ventilation of product respiration.

The following condition and methods were used in the main test based on the preliminary test:

1. Fruit was placed on the center of the sensor and was in direct contact with the piezoelectric transducer without any other restraint.
2. Both fruit and sensor unit were allowed to come to equilibrium with the room temperature (about 24°C) before testing.
3. The average parameter of two cheeks obtained by one-time sampling was used as the whole fruit maturity indicator.

## CHAPTER V

### SIGNAL ANALYSIS AND DATA PROCESSING

This chapter includes selection and development of an analysis method and software for signal processing. Each of the response parameters that was selected to indicate peach maturity is described. Finally, the methods used to determine the efficiency of the parameters in predicting maturity are discussed.

#### Sonic Impulse Response

Figure 6 presents a typical time domain impulse response signal of a peach. The sample signal is made up of three regions. The initial flat region shows the steady-state signal from the transducer before excitation with the peach in place. The impulse generation region starts from the point when the solenoid is activated, and the acceleration of the plunger causes the signal to decrease to a negative voltage. The voltage signal then rises rapidly when the plunger strikes the back of the transducer. The final vibration region consists of a combination of the peach vibration as a solid mass, the tissue vibration, and the deceleration of the plunger.

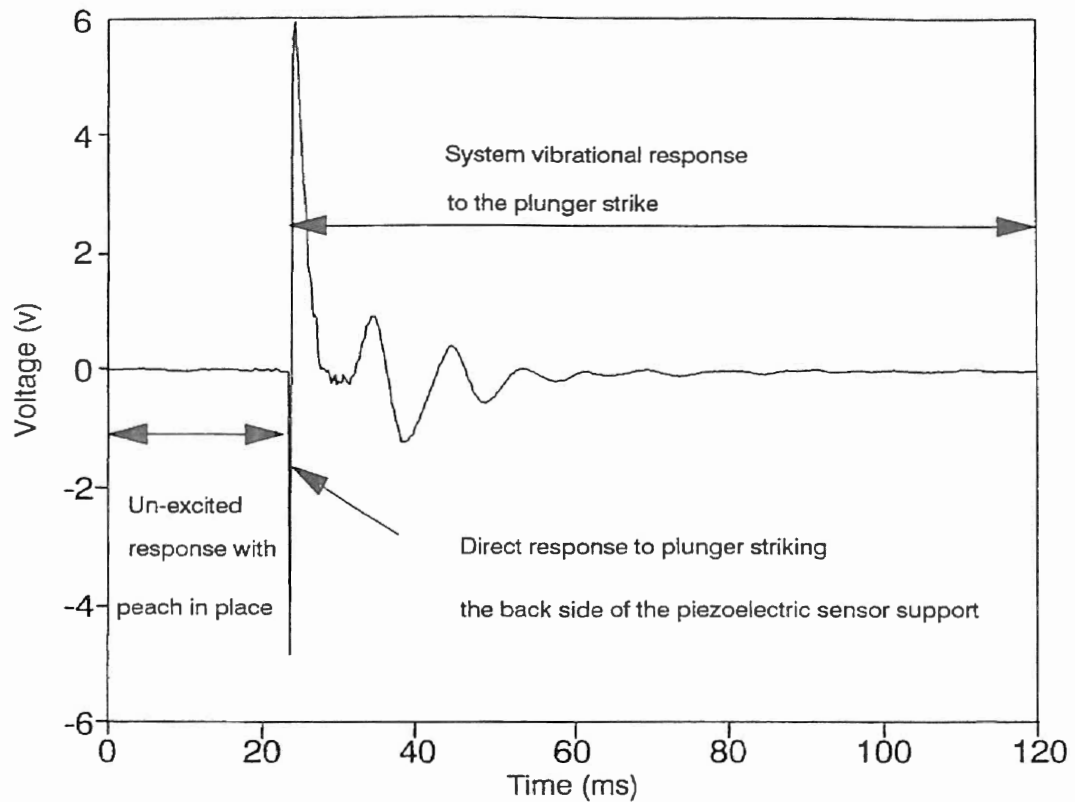


Figure 6. Typical Impulse Response Signal in Time Domain

Figure 7 shows the frequency spectrum for the impulse signal contained in Figure 6. A 2048 point FFT was computed using 1000 points of data in the time domain. The time domain sampling frequency was 5000 Hz. This spectrum contains magnitude only and consists of 206 individual points. The digital frequency step between individual points is 2.441 Hz ( $5000 \text{ Hz}/2048$ ), therefore, the spectrum covers a frequency range from 0-500 Hz. The frequency components higher than 1500 Hz are cut off by using a lowpass filter. The high-order resonance frequencies between 500 and 1500 Hz are still detectable, but their magnitudes are very small and were not

analyzed. The first resonant peak (about 30 Hz) was not related to the tested peach, but was contributed by the low-frequency components of the dead load of the testing system through forced vibration. This was proven by detecting the frequency spectrum of a generated impulse without presence of the specimen. The other resonance induced by impulse excitation was contributed by the natural vibration frequency of the peach. Although the first resonance frequency location was neglected, its magnitude differences still existed for each forced vibration excitation and therefore influenced the response vibration.

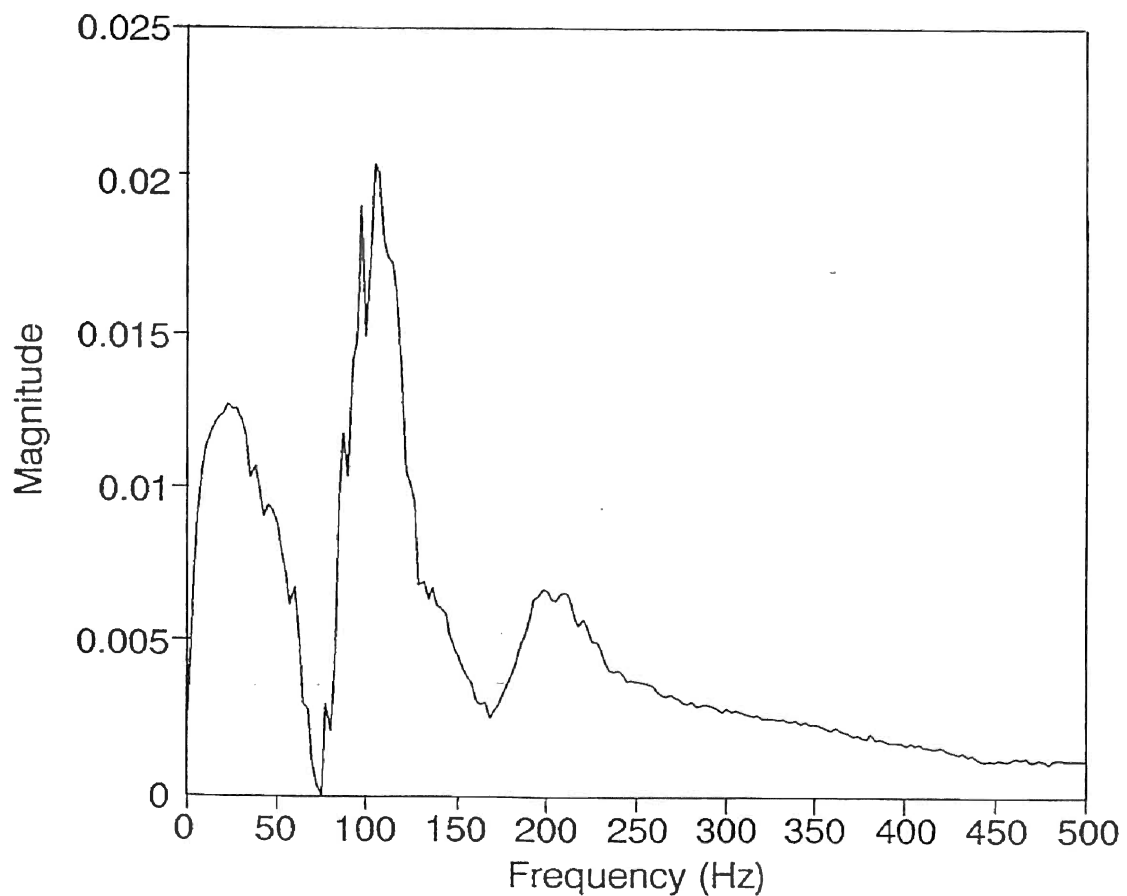


Figure 7. Typical Impulse Frequency Response Spectrum

### Impulse Response Parameter

Determination of resonance frequency through forced vibration excitation and sonic or mechanical impulse excitation is a well documented method for evaluating average elastic properties of whole fruit. There is other evidence that the decay time and attenuation rate of sonic vibration waves may also be used for quality detection in some fruit. For spectrum parameters, the magnitude of the resonance frequency is significant, but excitation source-dependent. The combination of natural frequency and spectrum energy content may create a parameter that is dependent only upon the maturity properties (Farabee, 1991).

In this study, the sonic impulse response signals such as attenuation ratio, decay rate, spectrum band magnitude and resonance frequency were examined for their ability to detect physical properties. The following parameters were computed and studied for all of the peaches tested.

#### Magnitude Ratio PRT2-1

As shown in Figure 8, magnitude ratio of the second peak to the first peak in the time domain (PRT2-1) is a relative measure of the response intensity to impulse intensity. Figure 9 presents the difference between a firm peach and a soft peach. Since the magnitude of signal voltage is strongly related to deformation of the crystal, the factors that influence the deformation of the transducer play a major role in measurement precision. These factors include the impulse intensity contributed by the distance between the plunger and crystal and the activation time of the solenoid, the original load condition of the transducer resulting from the way in which the crystal

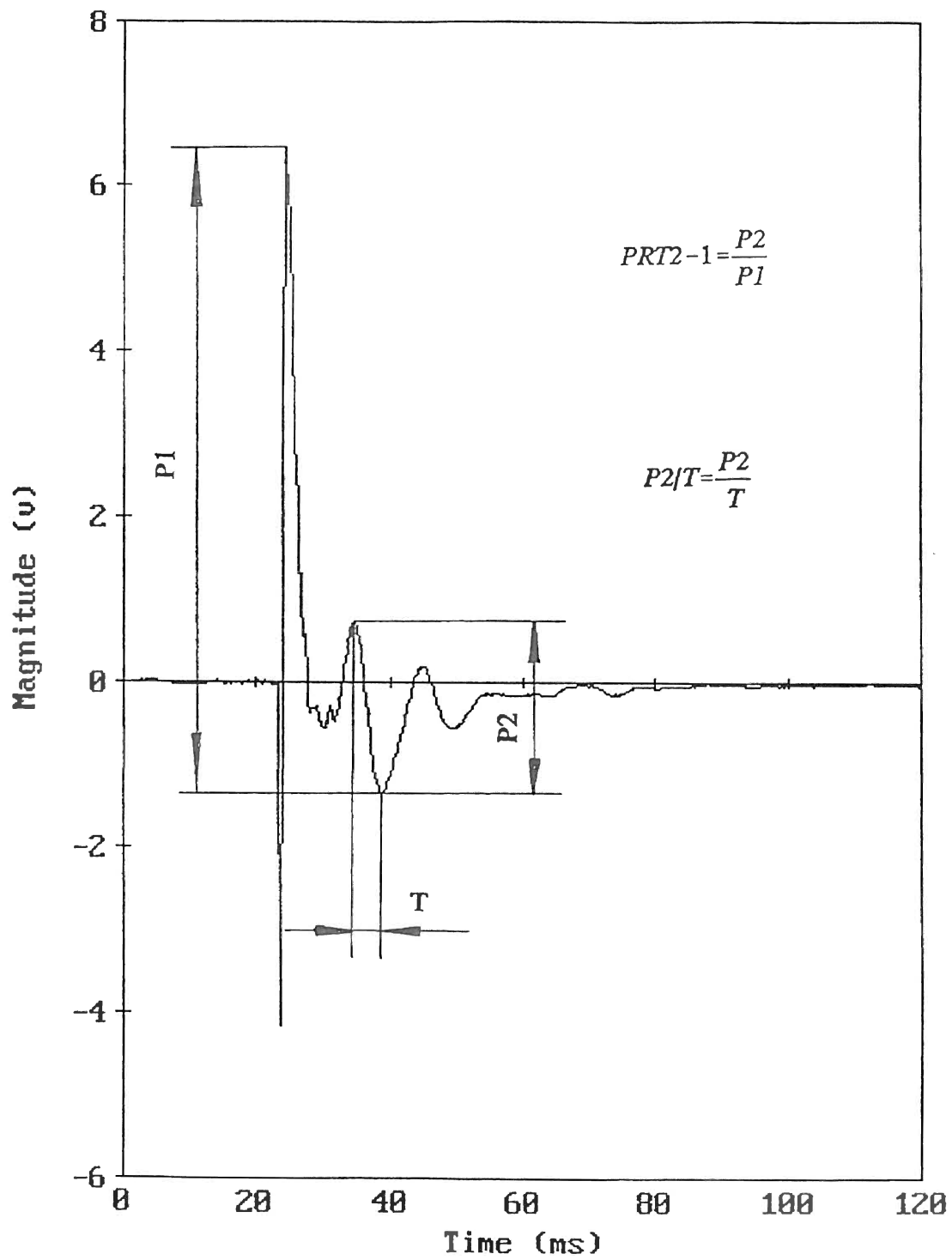


Figure 8. Impulse Parameters in Time Domain

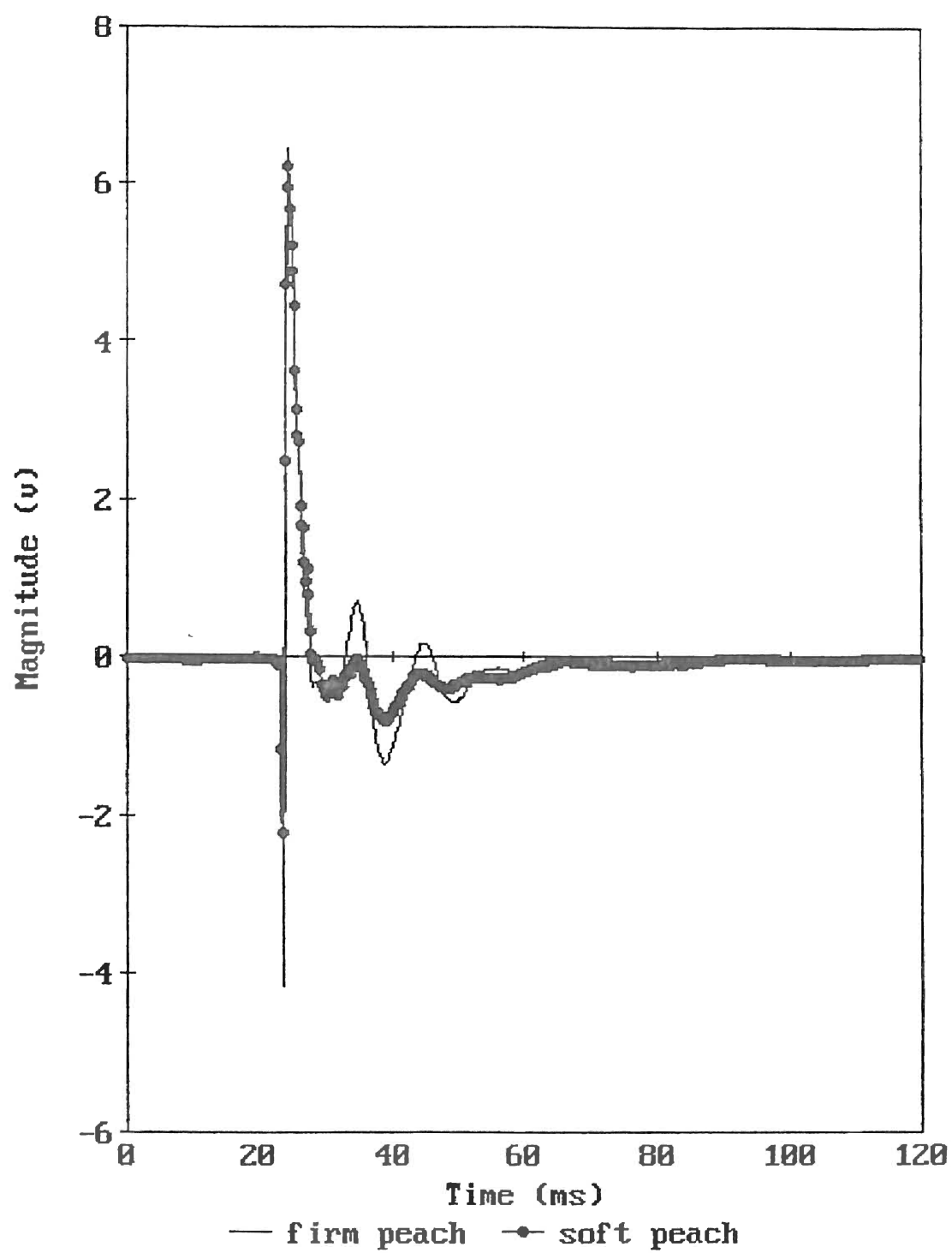


Figure 9. Time Domain Signals of a Firm and a Soft Peach

was glued to the sensor, the location of peach on the transducer and the contact area between specimen and transducer. Although some factors change or fluctuate during the testing and may affect the single peak magnitude, the precision can be improved by using the ratio of the two peak magnitudes. The instrument variables that generally influence both impulse intensity and the response intensity in the same way can be removed using this technique.

#### Attenuation Coefficient $P2/T$

$P2/T$  is a gradient in time domain using the second resonance peak voltage as numerator and the time interval as denominator over which the response peak signal first reaches its lowest point. Assuming the sensor unit to be an equivalent electric circuit, the attenuation coefficient of the response signal is dependent on the circuit component. Short duration of total response vibration results from the large equivalent resistance and occurs on the more mature peaches accompanied by the loss of moisture, decrease of acidity and increase in softness.  $P2/T$  in this case is small and indicates less potential to maintain the further vibration. Less mature peaches displayed larger  $P2/T$  because there are increases in the numerator and decreases in the denominator. This property is also less influenced by instrument variables, because the change in numerator and denominator caused by instrument factors is different from the change caused by the physical properties of the peach tissue. When instrument factors increase the voltage magnitude, decay time is usually proportionally increased, and the error is offset by using the gradient.

### Band Magnitude BM

As shown in Figure 10, band magnitude (BM) is the value obtained from the summation of spectrum magnitudes for a frequency band, divided by the summation of magnitudes for the complete spectrum.

$$BM = \frac{\sum_{n=a}^b P_n}{\sum_{n=0}^{\infty} P_n} \quad (1)$$

$P_n$  is the magnitude obtained from the FFT. The BM value for the specific frequency band is a approximation of energy content in the form of a dimensionless percentage in that band.

The band magnitude from 70 to 220 Hz (BM70-220) includes the second and the third dominance frequencies which are assumed to be the natural vibration frequency of peaches. Figure 11 presents the normalized frequency spectrum of a firm peach and a soft peach. As a maturity indicator, BM70-220 showed good correlation with Effegi firmness and color for fresh peaches. The band magnitude of other frequency bands were also investigated in this study, including BM80-130 and BM70-160. The correlation coefficient and sensitivity to the measured maturity indices were considered in selecting the most effective band magnitude as parameter.

### Magnitude Ratio PRF2-1

The magnitude ratio of the second peak over the first peak in the frequency

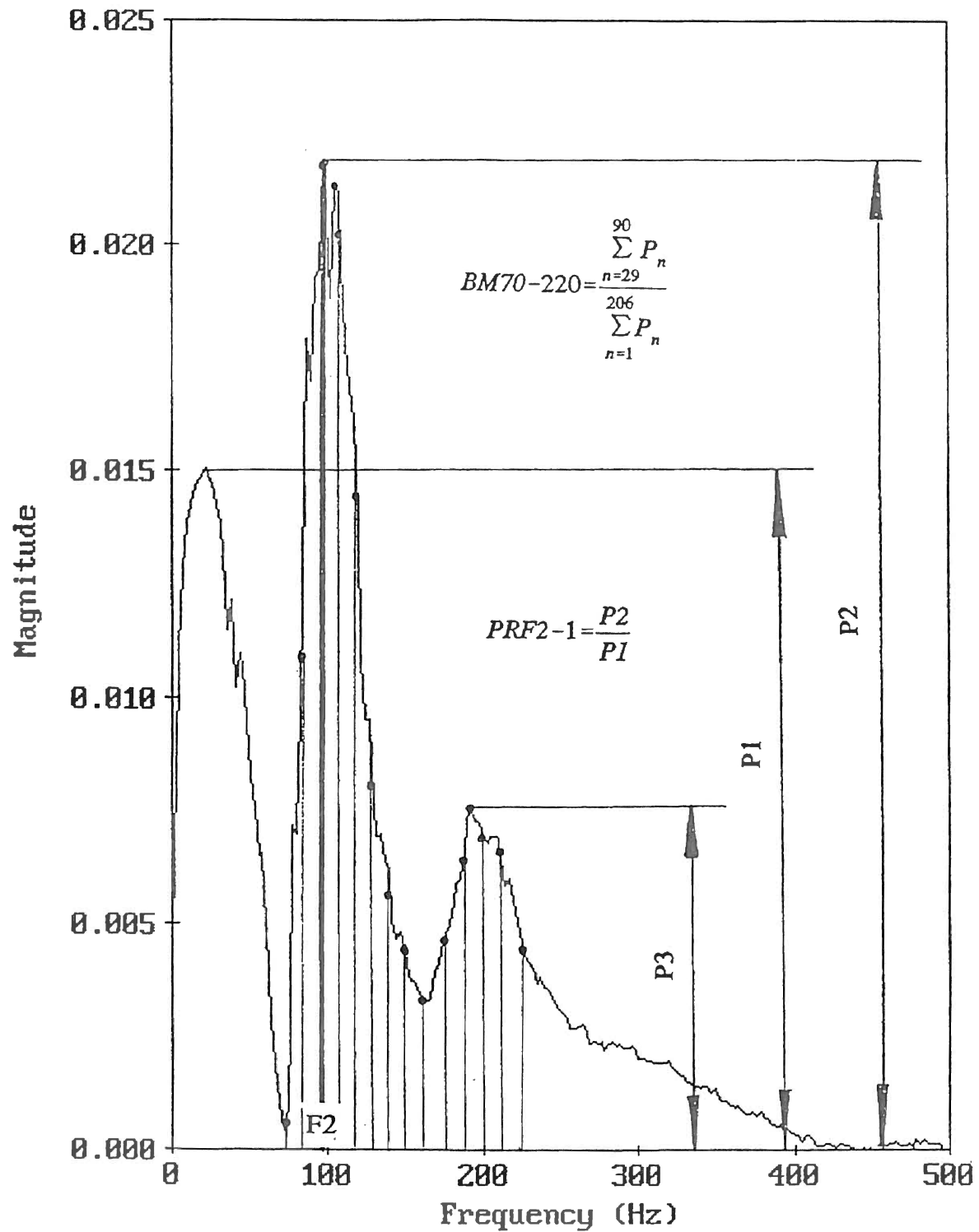


Figure 10. Impulse Parameters in Frequency Domain

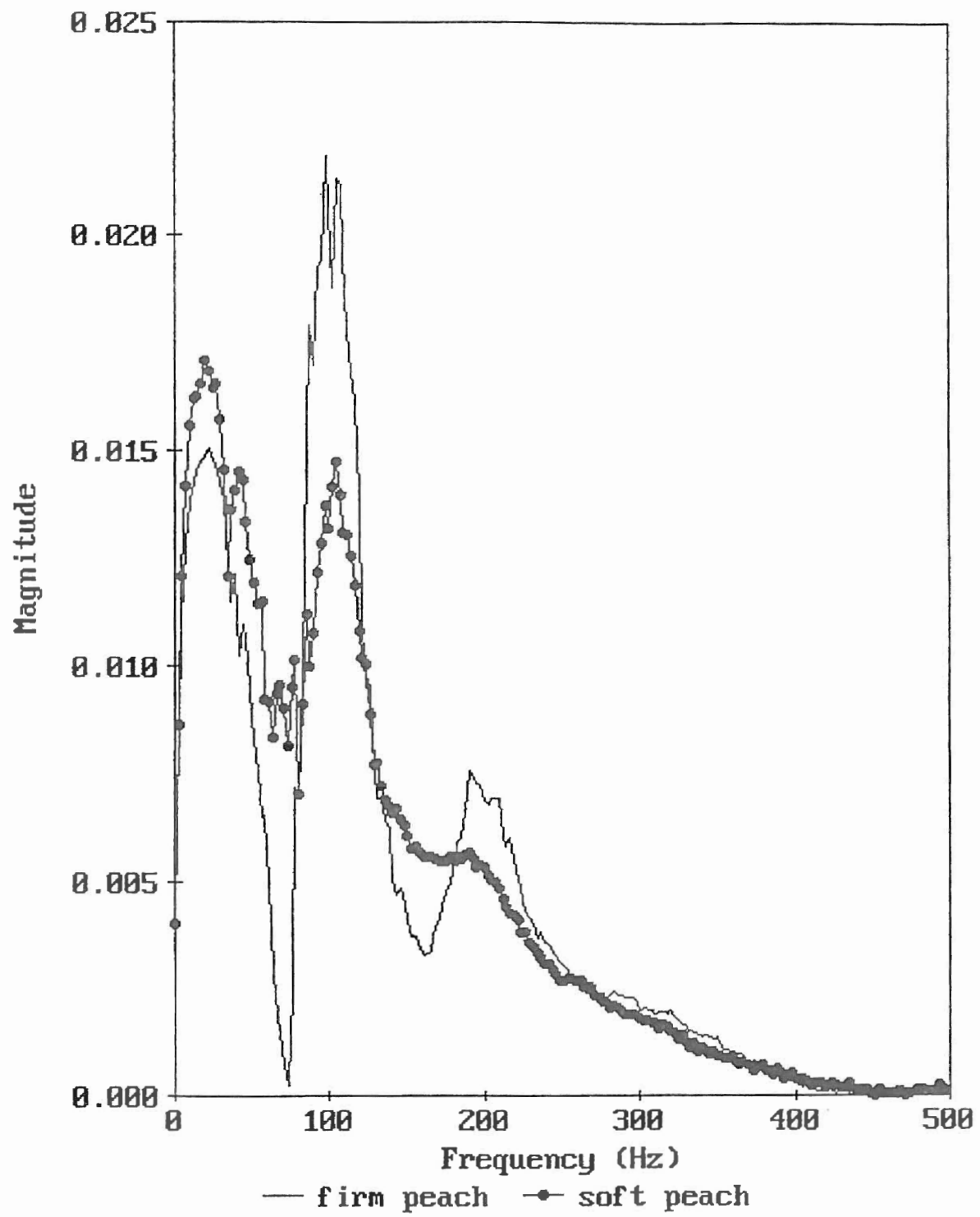


Figure 11. Frequency Spectrum of a Firm and a Soft Peach

domain (PRF2-1) can be considered as the adjusted magnitude of the principal resonance frequency of peach vibration. The magnitude of principal resonance is important in spectrum analysis. It is a multiple function of tissue properties, impulse intensity and original load condition of the transducer. For the reason mentioned above, the magnitude ratio of the second peak (principal resonance frequency of peach vibration) to the first peak (dead load frequency) was used to minimize the fluctuation induced by the instrument factors. The ratio was found to be inversely proportional to peach maturity. The ratios of the principal resonance to the double-frequency magnitude and to the triple-frequency magnitude were also calculated in searching for correlation with peach maturity in my study, but no significant result was found.

#### Resonance Frequency F2

The second resonance frequency (F2) varied from 80 to 120 Hz for most peaches tested. As suggested by many researchers, the first resonance frequency is not an appropriate measure for fruit properties and does not appear in free vibration. This observation was confirmed in my study by choosing different starting points for the FFT. When the starting point was within the impulse generation region, the first resonance frequency was detected as reported in forced vibration models, while with a starting point at the first zero-crossing after the impulse, similar to the free vibration model, the original first resonance frequency disappeared. The third resonance was around 200 Hz for fresh peaches, but it was not always detectable for the peaches tested on the second and the third day, therefore only F2 correlated with peach

maturity properties.

### Data Processing and Analysis

The data resulting from impulse testing were recorded by the oscilloscope, then transformed to the computer and stored for later processing. For each peach, the data from two impulse sites were saved in two different files. All of the data files were then divided into several groups according to the cultivars and storage time. Data processing was conducted for the group. A computer program was developed to read in data from each file, to perform the FFT, to normalize the data, to search for parameters and to compute the average normalized values.

The data were normalized in the following way. For both the time-domain signal and the frequency-domain spectrum, the smallest magnitude was subtracted from each data point, shifting the magnitude of the signal. Then, ratio parameters, such as PRT2-1 and PRF2-1 were calculated. If all data magnitudes were expected to be defined into a dimensionless range from 0-100, the following formula was used:

$$normalized = \frac{(actual - minimum)}{(maximum - minimum)} \times 100 \quad (2)$$

with minimum and maximum being determined from the whole data set concerned.

The ratio parameter using normalized values from the above formula was the same as just after magnitude shifting. This result was still true when further normalization was applied to the energy spectrum with the sum of magnitudes in the total significant frequency band (0-500 Hz) being denoted as unity. In this case, the normalized

magnitude for each discrete frequency was equal to its magnitude after shifting divided by the sum of the shifted magnitude. The average normalized parameter for each peach was the mean value of the two individual normalized parameters from each impulse site.

The statistical analysis of data was performed using ANOVA, GLM, REG and STEPWISE procedure, which are available in SAS software (SAS Institute Inc., 1988). The ANOVA procedure is used for analysis of variance of a balanced data set. The effect of cultivar on the fresh peach parameters was evaluated with this procedure. The GLM procedure is used for unbalanced data analysis. Because the number of peaches tested on each day was different, the ANOVA procedure lost its validity in evaluating the storage time effect on the parameters of each cultivar, whereas GLM was suitable to this case. The REG procedure was applied for both linear regression and multiple regression analysis. The general type of regression model with three explanatory variables is:

$$Y=a+b_1X_1+b_2X_2+b_3X_3 \quad (3)$$

where

Y is the dependent variable

$X_1$ ,  $X_2$ ,  $X_3$  are independent variables

a is the intercept of Y

$b_1$ ,  $b_2$ ,  $b_3$  are partial slopes of independent variables

The STEPWISE procedure begins by finding the variable that produces the optimum one-variable model. In the second step, the procedure finds the variable

that, when added to the already chosen variable, results in the largest increase in  $R^2$  (coefficient of determination). The third step finds the variable that, when added to the two already chosen, gives the maximum  $R^2$ . After a variable has been added to the model, the resulting equation is examined to see if any coefficient has a sufficiently large probability to suggest that a variable should be dropped.

## CHAPTER VI

### RESULTS AND DISCUSSION

The correlation of the sonic impulse response parameters with the measured peach maturity indicators are presented and evaluated in this chapter. The suitability and limitation of impulse parameters as firmness and color predictors are discussed mainly for fresh peaches. Storage time was involved in the regression equation because of its significance to the ripening process. Besides the time variable, the firmness was found to be the only other explanatory variable for the combined data of each cultivar.

#### Fresh Peaches

The investigation of sonic impulse parameters for fresh peaches is very important in determining the optimum harvest time and for grading and sorting peaches in the later postharvest handling process. The parameters were expected to be not only maturity related, but also cultivar related due to the different cultural practices and varied tissue composition.

#### Cultivar Effect

The evaluation of the cultivar effect was based on the variance analysis of parameters obtained from both standard methods and impulse testing.

Regarding the cultivar tested, Table 4 lists the mean of each parameter, the F-value and the observed significance level ( $Pr > F$ ). For each parameter, the evidence was sufficient to reject the hypothesis that all cultivars had the same mean, with PRF2-1 and BM70-220 having a largest difference and P2/T having the smallest one. Since the cultivar effect was obvious, the correlations among the dependent and independent variables were investigated separately by cultivar using multiple correlation.

TABLE 4  
F-TEST FOR HOMOGENEITY IN PARAMETER MEANS  
OF FIVE CULTIVARS

	LR	RR	CH	JF	EB	F	Pr > F
BM70-220 (%)	47.23	40.69	39.20	34.75	39.24	61.24	0.0001
PRF2-1 (%)	44.03	37.14	23.30	19.14	25.10	86.60	0.0001
PRT2-1 (%)	21.72	17.38	18.71	15.75	19.64	19.01	0.0001
P2/T (v/ms)	34.33	34.10	36.93	28.39	35.52	5.08	0.0007
F2 (Hz)	99.81	84.88	89.56	92.89	98.88	26.46	0.0001
EFFEGI (N)	82.28	100.95	108.03	86.16	91.07	6.11	0.0001
COLOR (a)	-5.97	0.87	-2.72	-3.00	-4.37	14.93	0.0001

LR = Loring

RR = Ruston Red

CH = Cresthaven

JF = Jefferson

EB = Elberta

### Multiple Correlation

Effegi firmness, color and mass were first taken as the input explanatory variables to correlate with impulse parameters using the Stepwise Procedure. The number of independent variables in the model was dependent on the significance level employed in the procedure. The results are shown in Table 5.

Correlated with parameter F2, mass was the first variable to enter the procedure at the 0.05 significant level for Cresthaven, Ruston Red, Elberta and Jefferson, having a correlation coefficient (R value) from the -0.57 to -0.73 with Cresthaven the highest. F2 varied from 70 to 110 Hz and was also found second-best correlated with firmness at the 0.15 level for Cresthaven and Elberta with an improvement of  $R^2$  up to 12%. Since the mass is not the most effective maturity indicator for peaches and the correlation between firmness and F2 is not dominant, the feasibility for peach maturity prediction using F2 is limited.

Firmness was shown to produce the "best" one-variable model for Loring, Ruston Red, Cresthaven and Jefferson. The variables involved in the "best" two or "best" three-variable model were different from cultivar to cultivar, and from parameter to parameter. Table 5 gives the explanatory variables entered in order at 0.1 significance level, the partial  $R^2$  associated with the variable first entered and the total  $R^2$  of the output model. The mass effect observed from Loring was partially caused by the extremely large size of the tested peaches, which were one-third heavier than the other cultivars on average.

TABLE 5  
MULTIPLE CORRELATION OF IMPULSE PARAMETERS  
WITH EXPLANATORY VARIABLES  
FOR FRESH CULTIVARS

Cultivar	Parameter	BM70-220	PRF2-1	PRT2-1	P2/T	F2
Loring	Expl.	F M	F M	F M	F M	F M
	$R_1^2$	0.6312	0.4521	0.5750	0.5355	0.1110
	$R_t^2$	0.7350	0.5426	0.6887	0.5900	0.1967
Ruston Red	Expl.	F	F C M	F	F	M
	$R_1^2$	0.3859	0.3217	0.3036	0.2535	0.4875
	$R_t^2$	0.3859	0.5098	0.3036	0.2336	0.4875
Cresthaven	Expl.	F	F	F	F	M F
	$R_1^2$	0.5669	0.4900	0.5964	0.5718	0.5503
	$R_t^2$	0.5669	0.4900	0.5964	0.5718	0.5959
Jefferson	Expl.	F	F	F C	F C	M
	$R_1^2$	0.7217	0.5794	0.6327	0.6354	0.3317
	$R_t^2$	0.7217	0.5794	0.6744	0.6713	0.3317
Elberta	Expl.	C F	C	C	C M	M F
	$R_1^2$	0.5679	0.5023	0.4915	0.3185	0.3865
	$R_t^2$	0.5951	0.5023	0.4915	0.4498	0.4333

Expl. = Explanatory variables

F = Firmness

C = Color

M = Mass

$R_1^2$  = Partial  $R^2$  associated with the variable first entered

$R_t^2$  = Total  $R^2$

Although adding variables to the multiple regression model improved the total  $R^2$ , the partial  $R^2$  for the first entered variable accounted for 92.9% of the overall coefficient of determination on average, therefore, the most appropriate model appears to be a single-variable model.

### Linear Correlation

Because firmness and color are two effective maturity indicators for peaches, the correlation between each of them and the sonic impulse parameters were investigated respectively (Table 6). In our study, the firmness was more effective than color as an explanatory variable for most of the cultivars tested.

The nature of the cultivar at harvest time had some effect on the R-value of impulse parameters associated with firmness and color. Table 7 gives the mean and standard deviation on Effegi firmness for five cultivars. In Loring and Jefferson cultivars, firmness was well correlated with impulse parameters. These cultivars are quick-softening cultivars and cover a relatively wide firmness range when harvested, while Ruston Red had high firmness, on the average, and had small standard deviation for Effegi readings resulting in poor correlation. Unlike the other cultivars which had a relative consistent mesocarp firmness from the part beneath the skin to the part close to the stone, Ruston Red had a hard periphery and a soft internal portion. Effegi readings were uncertain because smooth insertion of the probe was not possible.

The correlation coefficients related to the impulse parameters and firmness were also limited by the resolution of the sensor and the imprecision of the Effegi penetrometer. The variation of measures using the sensor was reasonable and

TABLE 6  
CORRELATION COEFFICIENTS FOR IMPULSE PARAMETERS  
WITH EFFEGI FIRMNESS AND COLOR

Cultivar	Variable	BM70-220	PRF2-1	PRT2-1	P2/T
Loring	Firmness	0.7945	0.6724	0.7583	0.7318
	Color(-)	0.7580	0.6348	0.7181	0.6975
Ruston Red	Firmness	0.6140	0.5672	0.5509	0.5035
	Color(-)	0.0930	0.0270	0.0280	0.1260
Cresthaven	Firmness	0.7529	0.6956	0.7723	0.7562
	Color(-)	0.4524	0.4576	0.5265	0.5674
Jefferson	Firmness	0.8495	0.7611	0.7954	0.7971
	Color(-)	0.6727	0.5969	0.7076	0.6980
Elberta	Firmness	0.7196	0.6702	0.6730	0.5131
	Color(-)	0.7536	0.7088	0.7010	0.5644

TABLE 7  
MEAN AND STANDARD DEVIATION OF EFFEGI FIRMNESS  
FOR FIVE CULTIVARS

	LR	RR	CH	JF	EB
Mean (N)	82.28	100.95	108.03	86.16	91.07
Std.	26.41	11.05	20.41	19.80	33.90

allowable for biological material because of its irregular shape , inconsistent tissue and varied contact with the sensor. The Effegi resistant force range for high-firmness cultivars was close to, or exceeded, the maximum scale for fresh peaches causing some problems and reading error. Like any other elastic transducers, which utilize one or another form of spring as their sensitive element, higher relative precision of the Effegi penetrometer can be obtained when it is used at about two thirds of full-scale. There was a conflict between consistent measurement and the optimum range, because our test lasted three days, leading to a wide maturity range of peaches. This effect was characterized by an Effegi resistant force from lower than 20 N after two days storage to higher than 140 N on fresh peaches using an 11 mm diameter probe. A method to transform the data while using different sized probes is needed. This change would improve the precision of the firmness tester as a standard reference method over a wider range.

The relationship between the firmness and color were also cultivar-dependent. Although Ruston Red was firmer than Loring, Jefferson and Elberta, the color meter "a" readings were mostly positive. Conversely, although Loring was the softest of all the cultivars tested, its ground color had a more negative value. According to the test results, the correlation of firmness and color was higher for softer cultivars than for the firmer cultivars (Table 8). It was still true for the correlation among the impulse parameters and color, which made the R-value range from lower than 0.1 in Ruston Red to higher than 0.75 in Loring (Table 6).

TABLE 8  
CORRELATION COEFFICIENTS FOR EFFEGI  
FIRMNESS WITH COLOR

Cultivar	Loring	Ruston Red	Cresthaven	Jefferson	Elbter
R-value	-0.8964	-0.5108	-0.5790	-0.7078	-0.7858

### Linear Regression

The linear regression constants and correlation coefficients for four impulse parameters of five cultivars regressed on Effegi firmness are summarized in Table 9. Figure 12 presents BM20-220 vs average firmness for Jefferson cultivar with highest R-value.

The parameter BM70-220 had the highest R-value among the four parameters. The nature of the sum of magnitudes for the selected frequency band stabilized the variation of this parameter and contributed to its high correlation with Effegi firmness. The comparison of BM70-220 with band magnitude of other frequency range, from 80 to 130 Hz and from 70 to 160 Hz, is also listed in Table 10.

The R-values among the three frequency bands were similar for Loring, Jefferson and Elberta, but quite different for the other two cultivars. The slope of each linear regression equation, ie., the sensitivity of the parameter to the firmness change for each cultivar, was directly proportional to the listed frequency range. BM70-220 had higher energy content with slope value being 1.5 - 2 times as high as

TABLE 9

LINEAR REGRESSION CONSTANTS AND CORRELATION COEFFICIENTS  
FOR IMPULSE PARAMETERS REGRESSED ON  
EFFEGI FIRMNESS

Cultivar	Parameter	BM70-220	PRF2-1	PRT2-1	P2/T
Loring	a	37.15	21.30	12.08	15.52
	b	0.1792	0.2763	0.1172	0.2285
	R	0.7945	0.6724	0.7583	0.7318
Ruston Red	a	30.73	12.42	8.27	11.09
	b	0.1650	0.2449	0.0903	0.2338
	R	0.6140	0.5672	0.5509	0.5035
Cresthaven	a	29.47	8.63	7.88	-5.16
	b	0.1453	0.1358	0.1002	0.3896
	R	0.7529	0.6956	0.7723	0.7562
Jefferson	a	24.75	5.46	6.84	7.77
	b	0.1822	0.1588	0.1034	0.2393
	R	0.8495	0.7611	0.7954	0.7971
Elberta	a	38.52	18.20	14.95	23.60
	b	0.0790	0.0757	0.0514	0.1309
	R	0.7196	0.6702	0.6730	0.5131

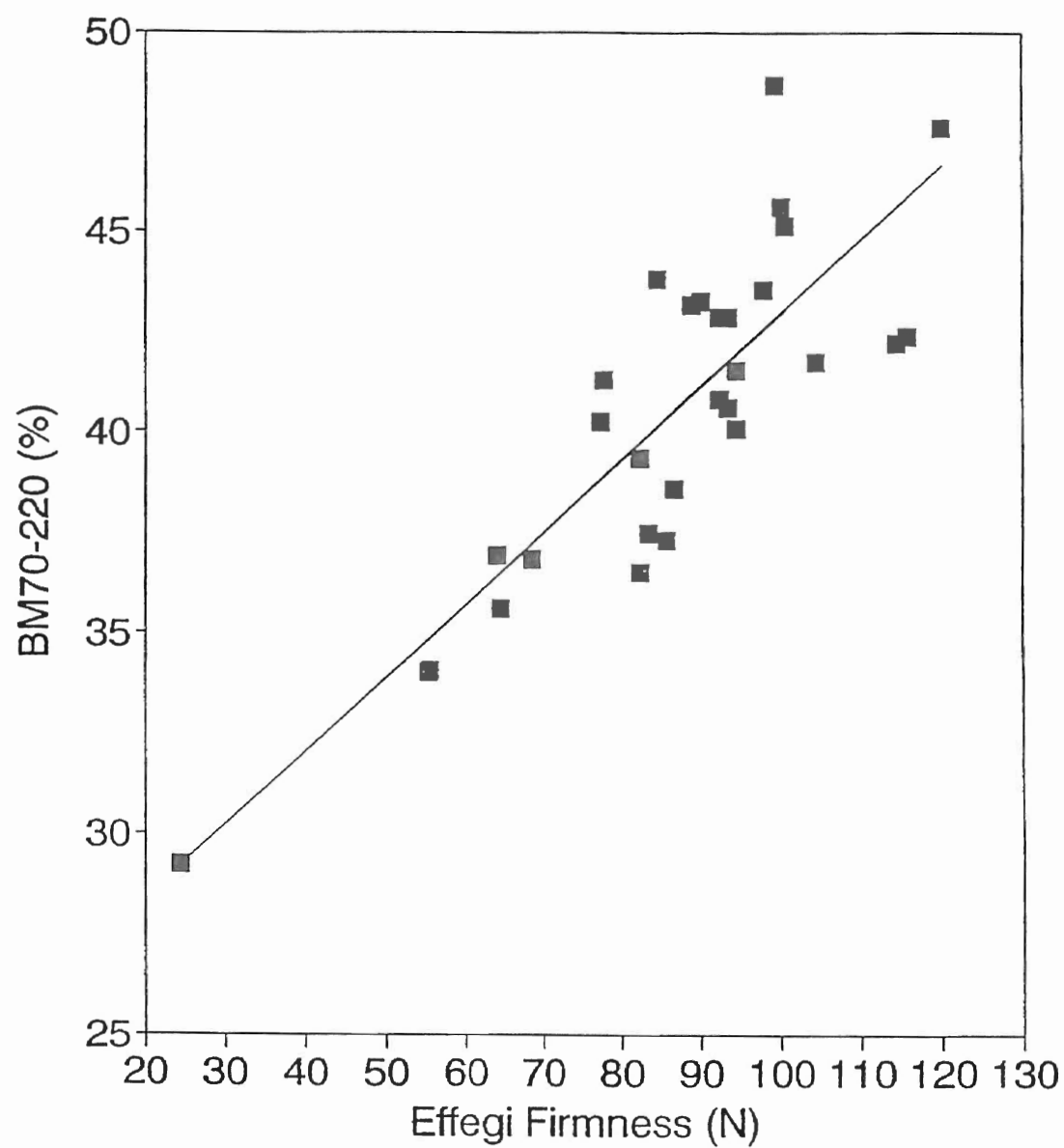


Figure 12. BM70-220 vs Effegi Firmness for Jefferson Peaches

TABLE 10

LINEAR REGRESSION CONSTANTS AND CORRELATION COEFFICIENTS  
FOR THREE BAND MAGNITUDES REGRESSED  
ON EFFEGI FIRMNESS

Cultivar	Parameter	BM80-130	BM70-160	BM70-220
Loring	a	27.20	35.29	37.15
	b	0.1002	0.1451	0.1792
	R	0.8095	0.8305	0.7945
Ruston Red	a	18.73	30.00	30.73
	b	0.1030	0.1058	0.1650
	R	0.6525	0.5983	0.6140
Cresthaven	a	19.07	31.07	29.47
	b	0.0716	0.0753	0.1453
	R	0.7143	0.6365	0.7529
Jefferson	a	13.76	21.62	24.75
	b	0.1137	0.1524	0.1822
	R	0.8334	0.8325	0.8495
Elberta	a	23.30	34.50	38.52
	b	0.0415	0.0520	0.0790
	R	0.7585	0.7435	0.7196

that of BM80-130. The band magnitude between the 160 and 220 Hz frequency range, where the third resonance peak was observed, is very important for its sensitivity to the firmness, especially for Ruston Red, Cresthaven and Elberta.

PRT2-1 had relatively high R-value, but had the lowest sensitivity to firmness change. P2/T was the most firmness-sensitive parameter, but had relatively large variation. The PRF2-1 was the most cultivar-dependent. For each unit increase of Effegi reading, the increase of PRF2-1 for Loring was about four times as high as that for Elberta. In general, BM70-220 was the best parameter as a firmness predictor for fresh peaches with the highest correlation coefficient and second-highest sensitivity.

Although color was less well correlated with impulse parameters than firmness, the negative linear correlations were still significant at the 0.05 confidence level for most cultivars. Table 11 gives the regression constants and R-value to show the relationship between color and each of four impulse parameters. Figure 13 presents a example, BM70-220 vs color for Loring cultivar, with relatively high correlation. Although color and firmness are two different maturity indicators, both can be predicted by using impulse parameters.

### Stored Peaches

Peaches lose their quality very quickly after harvest under the room temperature. Numerous physical and chemical changes take place during storage. During ripening, changes occur in cell structure, color, carbohydrates, organic acids and aroma volatiles. Loss of firmness and loss of green color are the two most and visual changes. As the integrated reflection of the tissue property changes during

TABLE 11  
 LINEAR REGRESSION CONSTANTS AND CORRELATION COEFFICIENTS  
 FOR IMPULSE PARAMETERS REGRESSED  
 ON COLOR

Cultivar	Parameter	BM70-220	PRF2-1	PRT2-1	P2/T
Loring	a	38.85	23.32	12.90	17.03
	b	-2.1840	-3.4673	-1.4758	-2.8959
	R	-0.7282	-0.6348	-0.7181	-0.6975
Ruston Red	a	40.72	37.11	17.48	34.83
	b	-0.0397	-0.0283	-0.1104	-0.1472
	R	-0.0934	-0.0273	-0.2785	-0.1267
Cresthaven	a	43.75	22.07	17.76	32.88
	b	-0.5199	-0.4549	-0.3479	-1.4890
	R	-0.5289	-0.4576	-0.5265	-0.5674
Jefferson	a	37.44	16.54	13.83	24.01
	b	-1.0035	-0.8656	-0.6392	-1.4570
	R	-0.6731	-0.5969	-0.7076	-0.6980
Elberta	a	42.69	22.10	17.63	30.12
	b	-0.6933	-0.6854	-0.4590	-1.2353
	R	-0.7375	-0.7091	-0.7010	-0.5644

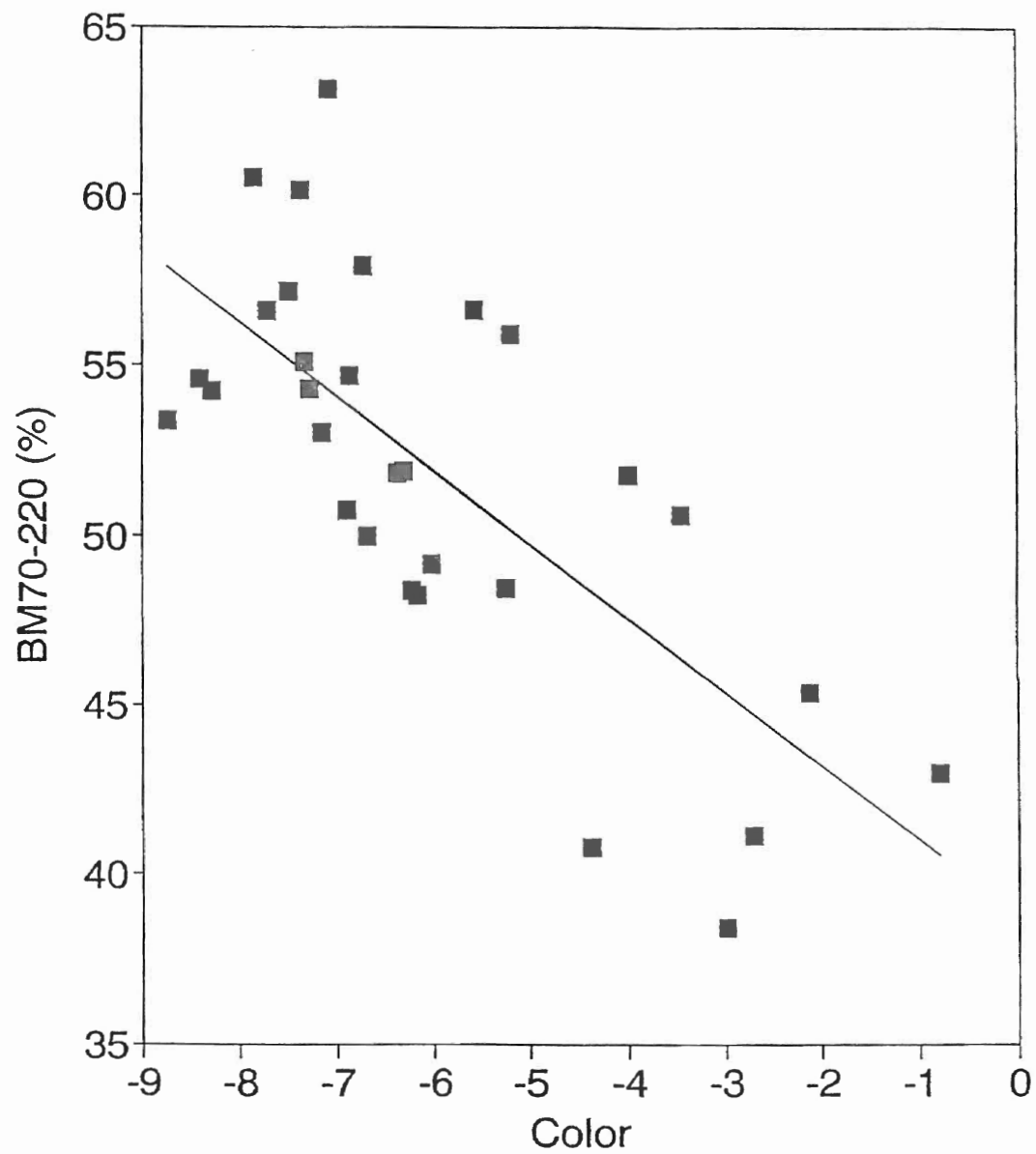


Figure 13. BM70-220 vs Color a-value for Loring Peaches

ripening, the impulse response parameters may, or may not, be well correlated with each single indicator. To interpret the change of the impulse parameters as the result of a certain continuous ripening process, a new independent variable is needed to quantitatively measure ripeness which is not well explained by other variables involved.

### Storage Time Effect

The storage time effect on the measured parameters for each cultivar was evaluated by testing the homogeneity of the parameter means over three days. The results of analysis of variance using GLM procedure are listed in Table 12.

It is obvious that the impulse parameters and Effegi firmness changed significantly with storage time as indicated by the large F-values and the decrease of the mean value. Although the differences were significant for Loring and Jefferson, color generally changed little during three days, suggesting that no good correlation exists between color and impulse parameters under these conditions. The rates of change of impulse parameters over time were cultivar dependent, with Loring and Ruston Red being the highest. Since the F-values for some impulse parameters were much larger than the F-value for Effegi firmness, the changes of these parameters can not be explained simply by the change of firmness. BM70-160 vs Effegi firmness with different storage time for Cresthaven is illustrated in Figure 14. Within the same firmness range, BM70-160 from different days did not overlap, indicating something other than firmness changes impulse parameters (Figure 15). It was unknown how many factors affected the change of BM70-160, but it is certain that the changes were

TABLE 12  
F-TEST FOR DIFFERENCE IN PARAMETER MEANS  
OF THREE DAYS

Cultivar	Parameter	day1	day2	day3	F	Pr > F
Loring	BM70-160	47.23	36.75	29.08	169.02	0.0001
	PRF2-1	44.03	22.40	14.38	137.75	0.0001
	PRT2-1	21.72	14.56	11.00	109.76	0.0001
	P2/T	34.33	24.69	19.41	49.32	0.0001
	Effegi	82.28	80.83	25.56	54.93	0.0001
	Color	-5.97	-6.47	-5.04	5.06	0.0084
Ruston Red	BM70-160	40.58	34.76	24.96	129.02	0.0001
	PRF2-1	36.89	23.49	13.36	156.74	0.0001
	PRT2-1	17.35	13.59	8.62	120.04	0.0001
	P2/T	34.42	22.72	13.53	121.28	0.0001
	Effegi	100.09	79.79	47.92	49.72	0.0001
	Color	0.78	0.97	0.24	0.25	0.7790
Cresthaven	BM70-160	38.86	34.78	31.09	69.73	0.0001
	PRF2-1	22.66	19.08	16.87	34.22	0.0001
	PRT2-1	18.58	14.78	12.06	77.52	0.0001
	P2/T	36.68	24.72	18.40	59.37	0.0001
	Effegi	110.69	96.54	67.66	18.42	0.0001
	Color	-3.44	-2.73	-2.00	1.20	0.3061

TABLE 12 (Continued)

Cultivar	Parameter	day1	day2	day3	F	Pr > F
Elberta	BM70-160	39.22	34.27	29.04	118.86	0.0001
	PRF2-1	24.87	20.44	13.56	110.51	0.0001
	PRT2-1	19.75	15.80	12.44	99.94	0.0001
	P2/T	35.38	25.06	18.88	65.22	0.0001
	Effegi	91.21	62.11	23.18	70.95	0.0001
	Color	-4.21	-4.12	-4.06	0.01	0.9853
Jefferson	BM70-160	35.33	29.70	30.03	58.02	0.0001
	PRF2-1	19.53	14.67	15.08	38.83	0.0001
	PRT2-1	16.34	12.10	12.64	60.73	0.0001
	P2/T	29.99	20.74	24.58	70.43	0.0001
	Effegi	90.69	70.88	24.58	104.45	0.0001
	Color	-3.68	-2.29	-1.69	6.38	0.0024

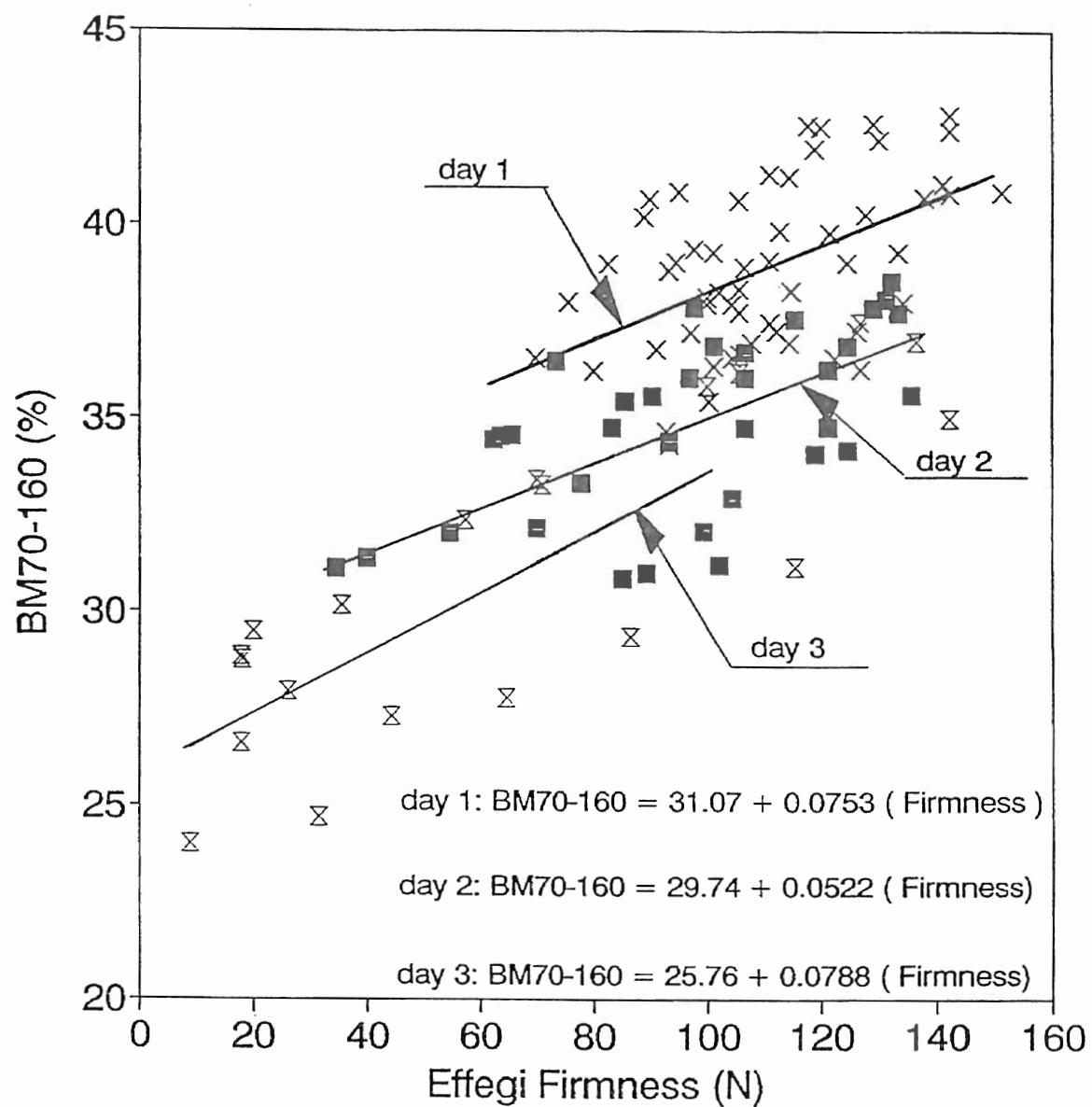


Figure 14. BM70-160 vs Effegi Firmness for Three Days' Cresthaven Peaches

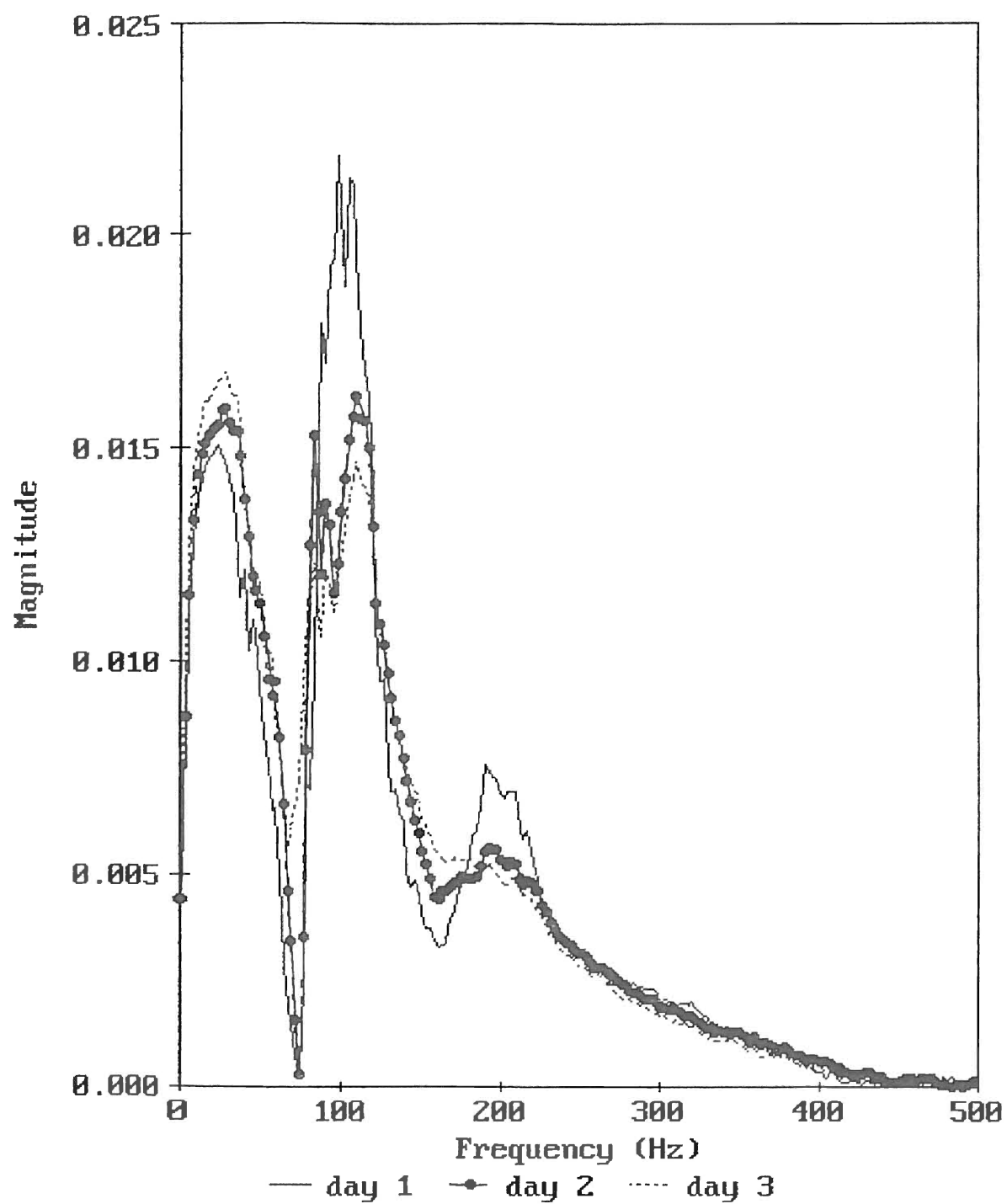


Figure 15. Frequency Spectrum of Peaches with Similar Firmness

time-dependent, therefore, adding a time variable to the regression model might improve the correlation.

The reason for using BM70-160 instead of BM70-220 here was based on the comparison of the result of linear correlation and regression among the different band magnitude with firmness on the second (Table 13) and the third day (Table 14). Although the firmness sensitivity of BM70-220 was still higher than that of BM70-160 after a period of storage time, the partial improvement was offset by the decrease of R-value. Therefore, BM70-160 was more acceptable when considering both slope and correlation coefficient.

#### Multiple Regression And Correlation

The impulse response parameters were regressed on Effegi firmness, color and storage time using the STEPWISE procedure for the combined data set from three days of each cultivar. Time and firmness were the only variables to enter the procedure for all cultivars, except Jefferson. The partial  $R^2$  correlated impulse parameters with firmness, and the total  $R^2$  included time in the regression are shown in Table 15.

The impulse parameters were well correlated with Effegi firmness and storage time, especially for BM70-160 and PRT2-1. The increase in  $R^2$  by adding the time variable was from 20% to 63% on Loring, Ruston Red and Cresthaven and from 5% to 8% on Elberta. A nonlinear regression model or a high-order polynomial, may improve the fit of the Elberta data (Figure 16), but we still prefer the simpler model for its consistency, convenience and acceptable precision.

TABLE 13

LINEAR REGRESSION CONSTANTS AND CORRELATION COEFFICIENTS  
FOR THREE BAND MAGNITUDES REGRESSED  
ON EFFEGI FIRMNESS (DAY 2)

Cultivar	Parameter	BM80-130	BM70-160	BM70-220
Loring	a	20.73	30.12	33.39
	b	0.0602	0.0821	0.0853
	R	0.7009	0.6913	0.6897
Ruston Red	a	18.28	25.97	28.55
	b	0.0758	0.1103	0.1215
	R	0.5263	0.5607	0.5255
Cresthaven	a	19.89	29.74	33.21
	b	0.0370	0.0522	0.0570
	R	0.5835	0.6135	0.5553
Jefferson	a	16.03	24.94	28.96
	b	0.0513	0.0672	0.0748
	R	0.7536	0.7463	0.7201
Elberta	a	19.45	28.44	32.19
	b	0.0675	0.0940	0.1151
	R	0.7352	0.7669	0.7627

TABLE 14

LINEAR REGRESSION CONSTANTS AND CORRELATION COEFFICIENTS  
FOR THREE BAND MAGNITUDES REGRESSED  
ON EFFEGI FIRMNESS (DAY 3)

Cultivar	Parameter	BM80-130	BM70-160	BM70-220
Loring	a	16.61	24.95	28.88
	b	0.1203	0.1616	0.1700
	R	0.5203	0.5221	0.4968
Ruston Red	a	12.58	19.94	22.80
	b	0.0755	0.1046	0.1153
	R	0.6007	0.5756	0.5717
Cresthaven	a	16.50	25.76	28.52
	b	0.0604	0.0788	0.0860
	R	0.8566	0.8452	0.8455
Jefferson	a	17.44	26.14	29.11
	b	0.1253	0.1583	0.1887
	R	0.7261	0.7084	0.6867
Elberta	a	17.00	25.17	28.91
	b	0.1189	0.1671	0.1884
	R	0.7578	0.7980	0.7727

TABLE 15  
PARTIAL AND TOTAL  $R^2$  FOR IMPULSE PARAMETERS  
REGRESSED ON EFFEGI FIRMNESS  
AND STORAGE TIME

Cultivar	Parameter	BM70-160	PRF2-1	PRT2-1	P2/T
Loring	$R^2_p$	0.5917	0.4531	0.5269	0.5101
	$R^2_t$	0.8508	0.7381	0.7484	0.6214
Ruston Red	$R^2_p$	0.6972	0.6464	0.6724	0.6257
	$R^2_t$	0.8339	0.8381	0.8172	0.7974
Cresthaven	$R^2_p$	0.5776	0.4121	0.5685	0.4409
	$R^2_t$	0.7641	0.5314	0.7721	0.6483
Jefferson	$R^2_p$	0.4981	0.4265	0.4198	0.5161
	$R^2_t$	0.5023	0.4268	0.4333	0.5527
Elberta	$R^2_p$	0.7726	0.7674	0.7709	0.6496
	$R^2_t$	0.8365	0.8214	0.8180	0.6848

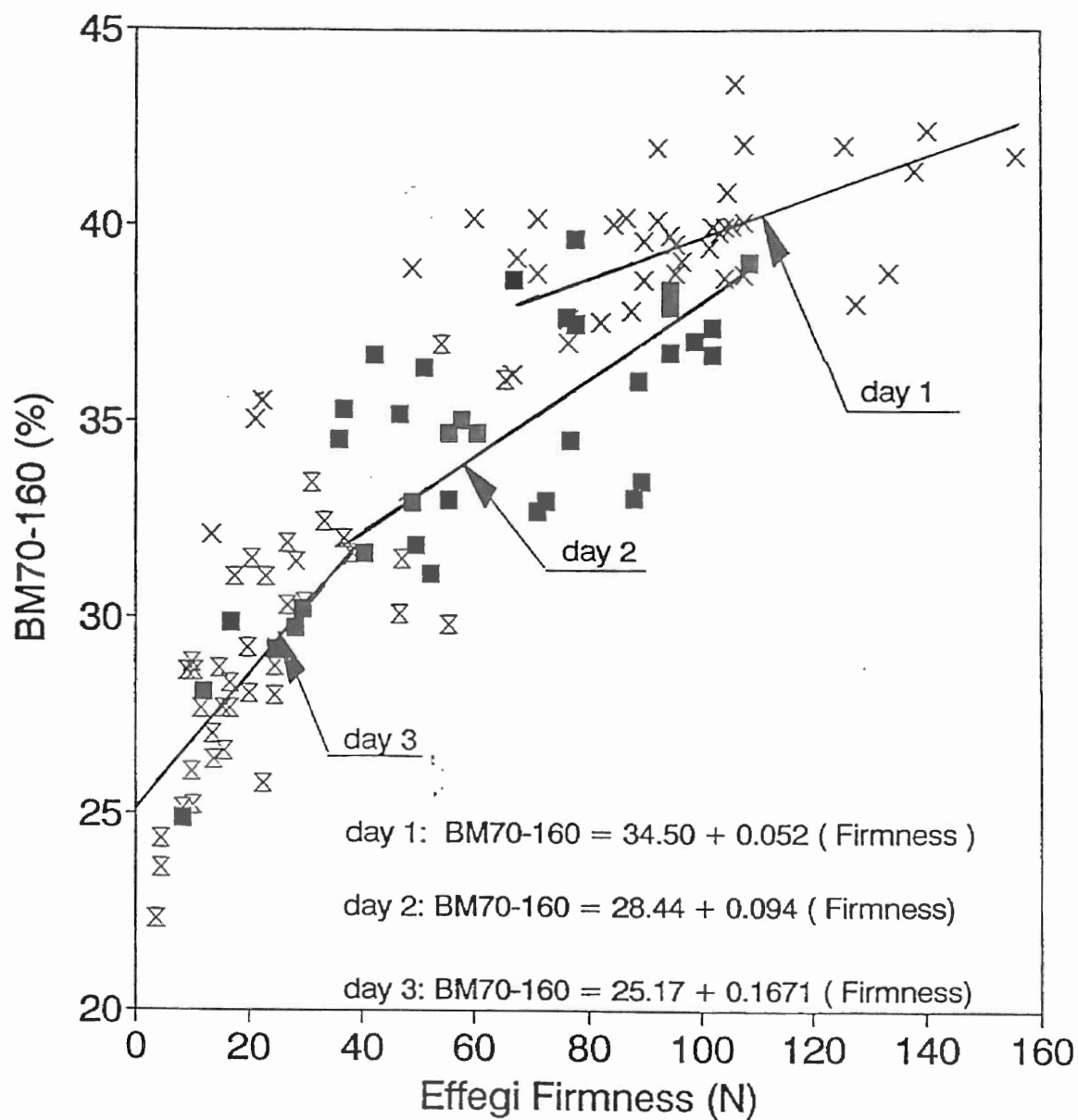


Figure 16. BM70-160 vs Effegi Firmness for Three Days' Elberta Peaches

The constants of the regression equations are given in Table 16, where  $a$  is the intercept of dependent variable,  $b_1$  is the partial slope of Effegi firmness (in units of N),  $b_2$  is the partial slope of storage time (in units of days after harvest). All  $b_1$  had a positive sign indicating the impulse parameters and the peach firmness were positively linear correlated, while the negative  $b_2$  meant the impulse parameters decreased with storage time. The value of  $b_2$  also quantitatively explained the rate of change of the dependent variable with time, when firmness was given. For instance, PRF2-1 for Loring and Ruston Red had highest time sensitivity followed by P2/T for all listed cultivars and PRT2-1 which was the least sensitive to firmness and time.

A storage time effect was not obvious in the multiple regression model for the combined Jefferson data set. The impulse parameters for Jefferson from the third day had an unexplained increase leading to the irregular data sequence. The problem probably was caused by the fluctuation of the variables in the testing system and no other conclusions can be drawn.

TABLE 16

MULTIPLE REGRESSION CONSTANTS FOR IMPULSE  
PARAMETERS REGRESSED ON EFFEGI  
FIRMNESS AND STORAGE TIME

Cultivar	Parameter	BM70-160	PRF2-1	PRT2-1	P2/T
Loring	a	39.83	34.23	16.90	24.43
	b1	0.0763	0.0834	0.0464	0.101
	b2	-6.9367	-12.4837	-4.0162	-4.6031
Ruston Red	a	29.83	24.08	11.61	22.35
	b1	0.1105	0.1227	0.0580	0.1163
	b2	-4.9158	-8.5897	-2.8466	-7.4336
Cresthaven	a	31.49	16.60	12.52	21.05
	b1	0.0653	0.0528	0.0531	0.1343
	b2	-2.5881	-1.9359	-2.2712	-6.8728
Jefferson	a	28.11	12.58	12.02	20.04
	b1	0.0677	0.0658	0.0388	0.0934
	b2	-0.4954	-0.1247	-0.6357	-2.6983
Elberta	a	31.81	16.53	13.77	20.99
	b1	0.0805	0.0939	0.0636	0.1485
	b2	-2.3576	-2.4513	-1.4992	-3.2315

## CHAPTER VII

### CONCLUSIONS AND RECOMMENDATIONS

#### Conclusions

The following conclusions may be drawn from this study:

1. The ability to detect physical properties of peach through sonic impulse responses such as attenuation ratio, decay rate, spectrum band magnitude and magnitude ratio was proved.
2. The method utilizing impulse testing to evaluate peach maturity was firmness-sensitive and nondestructive.
3. Four impulse parameters were well correlated ( $0.45 < R^2 < 0.72$ ) with Effegi firmness of fresh Loring, Jefferson and Cresthaven peaches which had a relatively wide firmness range.
4. Impulse parameter BM70-220 or BM70-160 was the best maturity prediction parameter for its consistently high correlation with firmness.
5. Impulse parameters were negatively linear correlated ( $0.28 < R^2 < 0.58$ ) with color for fresh Loring, Jefferson and Elberta cultivars. Color was less effective than firmness to be predicted by impulse parameters.
6. In three days' storage test, Effegi firmness and storage time were the variables best correlated ( $0.53 < R^2 < 0.85$ ) with the impulse parameters for Loring,

Ruston Red, Cresthaven and Elberta cultivars.  $R^2$  was tremendously improved by adding the time variable to Effegi firmness in the multiple regression model.

7. The changes of color did not coincide with the changes of impulse parameters during the observed ripening process. Color changes were very cultivar-dependent. Correlations were low between color and impulse indices for the data set of each cultivar obtained from all three days' test.

8. A linear regression model for fresh peaches, and a multiple regression model for stored peaches were developed to help sorting and grading peaches using impulse parameters.

9. Firmness sensitivity and storage time sensitivity for each impulse parameter were cultivar-dependent. The attenuation coefficient  $P2/T$  had the highest sensitivity to both firmness and storage time in general.

10. The modified sensor unit and developed test procedure were appropriate to this study.

### Recommendations for Further Study

1. The preliminary testing in this study showed that the averaged impulse parameters were better correlated with the averaged Effegi firmness than the individual impulse parameter to the local firmness reading. As a whole fruit maturity prediction method, the comparison of two impulse sites with more impulse sites should be done to determine the influences of local properties and the most suitable impulse site number, and location.

2. The time interval after harvest under normal storage conditions has a strong

effect on peach quality and impulse response parameters. Instead of studying storage time effect using different groups of peaches for each storage treatment, further research based on the impulse testing data obtained from same group of peaches over a period of storage time may be necessary to develop a fruit grading and sorting method.

3. The change of natural frequency of fruit was expected to be less related to impulse excitation sources and much more related to tissue properties. A new filter with wide-pass band should be studied to detect response in the high-frequency range.

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## APPENDICES

## APPENDIX A

### FRESH PEACH TESTING DATA

Appendix A contains the data for fresh peach impulse testing obtained during the summer 1992. The data of Loring, Ruston Red, Cresthaven, Jefferson and Elberta cultivars are presented from Table 17 to Table 21. Under each peach number, the value of each impulse parameter and Effegi firmness is averaged from two impulse sites.

TABLE 17

## PEACH IMPULSE TESTING DATA FOR LORING CULTIVAR (FRESH)

No.	BM70-220	PRF2-1	PRT2-1	P2/T	F2	Effegi	Color	Mass
	(%)	(%)	(%)	(v/ms)	(Hz)	(N)	(a)	(g)
1	50.0	38.1	20.2	35.9	101.3	89.0	-6.7	332.5
2	54.7	46.9	24.1	45.1	102.5	102.3	-6.9	346.3
3	40.8	29.5	14.4	21.9	102.5	58.9	-4.4	324.6
4	48.2	41.0	18.5	27.2	102.5	85.6	-6.2	350.4
5	55.1	45.7	23.2	38.0	101.3	111.2	-7.3	306.8
6	51.8	42.4	21.9	40.2	96.4	67.4	-4.0	306.9
7	54.2	43.8	23.1	37.7	103.8	92.3	-8.3	306.5
8	55.9	57.1	23.7	40.7	96.4	92.3	-5.2	307.5
9	51.9	42.5	22.2	34.8	106.2	90.1	-6.3	330.6
10	53.4	46.4	22.2	39.1	95.2	90.1	-8.7	334.1
11	54.3	49.1	23.7	35.1	106.2	110.1	-7.3	341.8
12	43.0	30.3	16.3	22.6	106.2	28.2	-0.8	294.0
13	56.6	50.0	24.6	38.8	101.3	107.6	-7.7	272.3
14	38.4	23.7	13.1	20.8	106.2	33.1	-3.0	291.2
15	56.6	39.2	21.7	31.6	98.9	91.9	-5.6	291.5
16	60.5	59.9	28.7	51.4	95.2	106.5	-7.9	253.3
17	49.1	40.1	20.1	28.7	102.5	75.0	-6.0	277.8
18	50.6	43.3	20.8	27.7	96.4	49.2	-3.5	268.8
19	41.1	27.5	14.9	20.7	106.2	8.9	-2.7	265.0
20	53.0	43.5	22.1	33.7	105.0	103.9	-7.2	296.4
21	48.4	33.9	18.7	29.1	105.0	71.2	-5.2	263.6
22	48.4	35.0	19.5	30.3	107.4	80.1	-6.2	320.9
23	51.8	39.3	21.5	39.3	92.8	100.1	-6.4	307.8
24	60.2	63.1	27.6	37.8	79.3	99.0	-7.4	310.3
25	54.6	48.0	23.5	36.6	96.4	105.6	-8.4	259.8
26	57.2	57.2	27.0	44.0	95.2	97.2	-7.5	284.7
27	45.3	33.5	17.0	22.7	102.5	43.4	-2.1	290.0
28	50.7	44.7	21.0	27.2	102.5	99.2	-6.9	315.1
29	57.9	54.6	26.9	46.2	94.0	86.1	-6.7	272.3
30	63.1	71.6	29.4	45.2	86.7	93.2	-7.1	269.0

Data in this table were obtained from peaches of Loring cultivar, picked on July 3, 1992 at Porter, Oklahoma.

TABLE 18

## PEACH IMPULSE TESTING DATA FOR RUSTON RED CULTIVAR (FRESH)

No.	BM70-220	PRF2-1	PRT2-1	P2/T	F2	Effegi	Color	Mass
	(%)	(%)	(%)	(v/ms)	(Hz)	(N)	(a)	(g)
1	46.0	37.0	16.4	34.2	83.0	87.9	7.8	206.6
2	44.9	36.5	15.2	27.9	83.0	89.0	11.5	197.1
3	47.6	40.4	16.6	35.0	83.0	93.4	8.2	202.5
4	47.5	41.8	17.4	33.6	83.0	106.8	-1.6	201.8
5	43.9	34.6	14.6	29.4	81.8	85.6	7.6	181.2
6	48.7	40.3	17.9	34.2	83.0	115.7	-3.6	170.9
7	48.4	40.4	17.2	35.5	83.0	110.1	1.2	193.7
8	45.4	35.2	16.8	31.8	83.0	76.7	1.4	203.2
9	51.6	38.3	19.6	42.8	84.2	101.2	2.2	184.9
10	45.7	42.2	16.2	31.3	83.0	110.1	7.6	182.2
11	47.5	37.6	17.6	32.3	87.9	96.7	3.0	167.6
12	52.3	45.2	20.4	46.3	84.2	112.3	-2.4	183.2
13	50.6	44.7	18.8	39.6	83.0	104.5	1.1	194.8
14	49.9	42.8	19.8	40.3	89.1	111.2	-2.4	161.1
15	52.7	42.5	21.5	44.4	89.1	102.3	4.4	160.1
16	47.4	32.9	17.2	38.5	85.4	95.6	2.1	149.7
17	49.6	37.2	18.7	40.9	89.1	112.3	5.7	152.8
18	49.0	37.0	18.3	35.6	85.4	112.3	-2.7	175.5
19	50.0	39.7	19.1	40.0	86.7	109.0	-2.9	176.9
20	50.7	34.9	19.8	42.4	87.9	105.0	-2.5	195.8
21	42.8	31.4	15.1	28.7	83.0	103.4	-2.0	180.3
22	49.4	43.3	18.7	33.3	83.0	106.8	-1.6	193.5
23	42.8	29.5	15.2	28.6	80.6	87.9	0.5	235.3
24	48.3	33.2	18.1	35.2	89.1	105.6	-5.8	170.5
25	47.4	37.2	16.6	30.7	84.2	103.4	-3.6	163.4
26	46.3	33.6	16.0	31.7	86.7	113.4	-2.4	150.3
27	45.1	32.7	16.4	31.8	87.9	104.5	-6.0	171.2
28	45.2	35.6	16.3	29.4	83.0	104.5	-4.5	201.7
29	43.9	30.9	15.3	27.1	87.9	85.6	1.8	172.3
30	41.1	25.5	14.8	28.3	83.0	75.6	3.9	188.3

Data in this table were obtained from peaches of Ruston Red cultivar, picked on July 15, 1992 at Porter, Oklahoma.

TABLE 19

## PEACH IMPULSE TESTING DATA FOR CRESTHAVEN CULTIVAR (FRESH)

No.	BM70-220	PRF2-1	PRT2-1	P2/T	F2	Effegi	Color	Mass
	(%)	(%)	(%)	(v/ms)	(Hz)	(N)	(a)	(g)
1	42.8	22.1	16.6	30.5	75.7	82.7	0.2	251.2
2	44.8	23.1	18.3	32.8	75.7	90.1	-3.9	243.0
3	40.5	17.3	14.8	25.7	75.7	69.8	2.7	241.0
4	44.0	21.5	18.2	33.7	85.4	111.2	-3.1	221.7
5	44.3	22.3	17.7	30.0	84.2	89.0	2.0	214.7
6	40.4	20.1	15.8	27.1	84.2	91.2	3.9	221.1
7	42.3	21.1	17.3	30.2	86.7	100.1	-3.3	234.5
8	45.5	23.3	19.0	37.9	85.4	93.4	-0.6	258.7
9	48.0	27.9	20.8	44.3	85.4	95.2	-0.7	239.2
10	37.9	16.5	14.3	24.3	92.8	93.4	1.6	195.3
11	41.6	19.4	15.9	26.2	92.8	105.6	-3.0	223.4
12	41.4	19.7	16.7	29.8	95.2	107.9	-1.3	193.2
13	43.4	20.4	16.9	30.9	95.2	111.2	-3.3	201.6
14	41.0	20.2	16.4	25.5	92.8	80.1	5.4	174.2
15	46.9	24.3	19.2	41.6	86.7	141.2	-8.1	227.2
16	49.6	27.6	21.1	40.8	83.0	142.3	-0.6	218.3
17	49.3	27.0	21.0	48.3	92.8	114.5	-8.0	199.8
18	47.0	23.9	20.0	35.7	95.2	127.9	-6.2	192.8
19	41.6	18.8	16.8	30.8	90.3	100.5	-4.8	192.3
20	50.7	29.5	23.6	58.6	100.1	142.3	-6.7	180.8
21	51.1	27.8	23.5	62.5	102.5	151.2	-8.6	193.6
22	40.0	18.0	15.7	27.3	95.2	92.7	0.7	188.3
23	51.6	30.2	22.6	55.7	95.2	120.1	-7.0	187.5
24	51.0	30.3	22.8	51.7	95.2	129.0	-7.9	196.1
25	49.3	28.3	21.1	46.4	96.4	119.0	-3.4	196.1
26	50.0	27.5	22.0	45.5	95.2	130.1	3.7	217.0
27	43.4	20.8	17.4	28.6	78.1	97.9	-7.6	212.7
28	47.6	25.4	20.2	36.7	92.8	111.2	-3.4	201.4
29	42.6	23.1	17.1	30.6	78.1	105.6	-4.4	222.8
30	45.5	22.0	18.8	38.4	102.5	94.5	-6.0	211.1

Data in this table were obtained from peaches of Cresthaven cultivar, picked on July 21, 1992 at Porter, Oklahoma.

TABLE 20

## PEACH IMPULSE TESTING DATA FOR JEFFERSON CULTIVAR (FRESH)

No.	BM70-220	PRF2-1	PRT2-1	P2/T	F2	Effegi	Color	Mass
	(%)	(%)	(%)	(v/ms)	(Hz)	(N)	(a)	(g)
1	40.6	28.1	19.4	40.2	92.8	120.1	-4.6	207.1
2	36.0	20.1	16.1	32.4	101.3	104.5	-6.9	181.2
3	31.7	17.5	15.0	29.7	92.8	86.7	-5.5	186.6
4	35.5	21.9	16.9	29.9	95.2	115.7	-4.2	177.8
5	31.6	15.1	13.7	24.8	91.6	85.6	-1.2	192.8
6	35.8	23.1	16.7	29.3	92.8	89.0	-5.1	177.3
7	35.2	19.9	15.6	29.7	92.8	92.3	-4.7	212.5
8	29.8	14.4	12.7	20.3	80.6	55.4	2.1	243.5
9	25.0	10.6	9.3	14.9	98.9	24.5	4.1	214.8
10	37.0	21.7	16.0	27.1	84.2	93.4	0.7	220.2
11	30.1	16.1	12.7	24.6	92.8	64.5	4.2	193.3
12	30.0	13.4	11.8	19.8	81.8	55.6	-2.7	198.7
13	31.7	15.5	13.0	22.7	91.6	68.5	0.8	225.3
14	31.6	15.4	13.5	23.1	91.6	82.3	-3.4	211.3
15	34.7	19.1	15.7	26.7	91.6	94.5	-3.7	219.9
16	36.0	18.4	16.1	26.1	90.3	77.8	-1.0	204.4
17	32.1	17.1	14.0	21.2	107.4	64.1	-3.1	187.2
18	36.3	18.6	16.1	29.9	92.8	114.5	-3.8	192.9
19	33.9	16.0	15.9	29.7	98.9	77.4	-1.9	193.4
20	37.6	19.6	16.8	28.9	91.6	90.1	-3.3	214.7
21	34.1	17.3	14.5	24.7	90.3	82.3	-3.4	199.8
22	40.6	29.4	20.0	39.7	92.8	99.4	-5.1	198.9
23	34.9	18.1	14.9	27.7	86.7	93.4	-2.9	203.1
24	39.8	23.8	18.8	33.2	91.6	100.1	-4.8	197.5
25	32.5	16.8	14.4	24.9	91.6	83.4	-3.9	222.7
26	36.6	19.6	17.7	31.0	90.3	92.3	-5.0	215.7
27	37.4	19.6	17.8	30.4	97.7	97.9	-4.8	191.6
28	36.9	20.6	17.9	35.7	102.5	84.5	-6.2	181.1
29	38.4	22.4	18.9	36.0	95.2	100.5	-5.3	185.2
30	39.4	25.0	20.7	37.6	95.2	94.5	-5.3	193.3

Data in this table were obtained from peaches of Jefferson cultivar, picked on July 27, 1992 at Porter, Oklahoma.

TABLE 21

## PEACH IMPULSE TESTING DATA FOR ELBERTA CULTIVAR (FRESH)

No.	BM70-220	PRF2-1	PRT2-1	P2/T	F2	Effegi	Color	Mass
	(%)	(%)	(%)	(v/ms)	(Hz)	(N)	(a)	(g)
1	35.4	16.8	13.2	19.2	87.9	13.3	1.7	191.8
2	40.8	19.7	16.8	28.0	100.1	21.1	5.3	182.2
3	39.2	19.4	15.5	22.8	100.1	22.2	7.0	191.7
4	46.5	26.0	20.3	38.0	91.6	60.1	-2.8	223.9
5	44.3	21.5	19.3	37.9	107.4	66.7	-0.5	186.3
6	46.8	26.1	19.7	39.9	102.5	67.6	-6.8	175.3
7	44.1	25.4	18.8	27.1	72.0	71.2	-3.1	249.3
8	42.7	21.7	17.6	26.4	102.5	71.2	-3.1	228.8
9	44.5	24.7	18.0	32.6	105.0	76.7	-2.2	160.8
10	43.5	21.7	17.7	34.4	103.8	82.3	-5.2	186.4
11	47.8	25.6	20.5	39.5	107.4	84.5	-7.7	192.6
12	45.3	26.9	19.7	32.2	75.7	86.7	-7.0	234.4
13	42.9	22.5	18.0	26.8	86.7	90.1	-4.0	218.1
14	45.6	24.4	18.7	34.3	91.6	90.1	-3.9	209.0
15	47.1	26.6	20.9	33.7	91.6	92.3	-7.0	263.6
16	44.3	24.0	18.5	28.9	91.6	94.5	-5.6	217.5
17	45.6	23.9	19.3	32.7	102.5	95.6	-1.2	204.3
18	44.9	21.5	19.0	36.1	102.5	95.6	-3.1	232.8
19	46.7	26.1	19.3	41.1	102.5	96.7	-1.3	167.4
20	45.7	24.4	20.2	33.7	102.5	105.0	-7.0	247.6
21	51.0	30.7	23.9	51.9	107.4	105.6	-8.6	176.3
22	53.4	33.7	25.7	55.9	102.5	106.3	-7.3	193.5
23	45.6	25.2	18.6	33.7	102.5	107.9	-8.7	178.5
24	49.5	27.5	22.9	46.5	109.9	107.9	-7.7	178.6
25	52.6	33.5	24.6	54.3	106.2	125.7	-7.1	174.8
26	44.7	24.0	19.0	30.5	106.2	127.9	-5.7	182.6
27	44.3	24.2	18.6	30.6	102.5	133.4	-4.7	182.9
28	47.6	25.9	20.7	32.8	92.8	137.9	-7.7	193.4
29	49.9	30.2	22.2	42.5	103.8	140.1	-6.9	191.1
30	49.5	29.0	22.3	41.5	105.0	155.7	-9.3	185.3

Data in this table were obtained from peaches of Elberta cultivar, picked on July 31, 1992 at Porter, Oklahoma.

## APPENDIX B

### STORED PEACH TESTING DATA

Appendix B contains the stored data of peaches tested on three days. For each of five cultivars, two tables are presented, one contains the data set and the other shows all of the linear correlation coefficients. In the data tables, one peach each line, the value under each impulse parameter and Effegi firmness is averaged from two impulse sites.

TABLE 22

## PEACH IMPULSE TESTING DATA FOR LORING CULTIVAR (STORED)

Day	BM70-160	PRF2-1	PRT2-1	P2/T	F2	Effegi	Color	Mass
	(%)	(%)	(%)	(v/ms)	(Hz)	(N)	(a)	(g)
0	46.2	38.1	20.2	35.9	101.3	89.0	-6.7	332.5
0	50.2	46.9	24.1	45.1	102.5	102.3	-6.9	346.3
0	38.0	29.5	14.4	21.9	102.5	58.9	-4.4	324.6
0	44.9	41.0	18.5	27.2	102.5	85.6	-6.2	350.4
0	51.1	45.7	23.2	38.0	101.3	111.2	-7.3	306.8
0	46.9	42.4	21.9	40.2	96.4	67.4	-4.0	306.9
0	49.6	43.8	23.1	37.7	103.8	92.3	-8.3	306.5
0	50.7	57.1	23.7	40.7	96.4	92.3	-5.2	307.5
0	48.3	42.5	22.2	34.8	106.2	90.1	-6.3	330.6
0	48.4	46.4	22.2	39.1	95.2	90.1	-8.7	334.1
0	49.6	49.1	23.7	35.1	106.2	110.1	-7.3	341.8
0	39.8	30.3	16.3	22.6	106.2	28.2	-0.8	294.0
0	51.0	50.0	24.6	38.8	101.3	107.6	-7.7	272.3
0	35.4	23.7	13.1	20.8	106.2	33.1	-3.0	291.2
0	48.1	39.2	21.7	31.6	98.9	91.9	-5.6	291.5
0	51.5	59.9	28.7	51.4	95.2	106.5	-7.9	253.3
0	46.1	40.1	20.1	28.7	102.5	75.0	-6.0	277.8
0	46.7	43.3	20.8	27.7	96.4	49.2	-3.5	268.8
0	38.5	27.5	14.9	20.7	106.2	8.9	-2.7	265.0
0	49.0	43.5	22.1	33.7	105.0	103.9	-7.2	296.4
0	45.1	33.9	18.7	29.1	105.0	71.2	-5.2	263.6
0	45.2	35.0	19.5	30.3	107.4	80.1	-6.2	320.9
0	47.5	39.3	21.5	39.3	92.8	100.1	-6.4	307.8
0	54.1	63.1	27.6	37.8	79.3	99.0	-7.4	310.3
0	49.2	48.0	23.5	36.6	96.4	105.6	-8.4	259.8
0	50.0	57.2	27.0	44.0	95.2	97.2	-7.5	284.7
0	42.5	33.5	17.0	22.7	102.5	43.4	-2.1	290.0
0	47.4	44.7	21.0	27.2	102.5	99.2	-6.9	315.1
0	50.4	54.6	26.9	46.2	94.0	86.1	-6.7	272.3
0	55.5	71.6	29.4	45.2	86.7	93.2	-7.1	269.0
1	33.8	18.6	12.7	20.8	97.7	35.6	-4.7	286.3
1	33.4	17.1	12.7	20.1	109.9	51.2	-5.7	350.9
1	28.2	12.2	9.0	15.5	120.8	37.4	-5.0	296.1
1	43.3	32.3	19.0	32.9	75.7	106.8	-8.5	291.3
1	34.3	19.5	13.6	22.2	96.4	91.2	-7.7	277.7
1	33.8	18.2	12.4	20.4	86.7	50.0	-5.3	282.4
1	40.2	26.0	15.7	25.5	76.9	122.3	-8.4	272.7
1	35.4	20.9	13.7	24.3	96.4	84.5	-7.8	255.2
1	43.3	34.9	18.5	32.6	80.6	113.4	-6.5	281.6
1	38.6	24.3	15.8	28.1	81.8	106.8	-9.4	265.3
1	35.9	20.9	14.0	24.9	97.7	73.4	-5.3	272.7

TABLE 22 (Continued)

Day	BM70-160	PRF2-1	PRT2-1	P2/T	F2	Effegi	Color	Mass
	(%)	(%)	(%)	(v/ms)	(Hz)	(N)	(a)	(g)
1	42.6	30.6	17.7	34.8	80.6	112.3	-5.5	275.6
1	36.8	22.0	14.7	23.6	81.8	122.3	-6.6	261.9
1	35.7	20.6	14.8	25.6	98.9	70.1	-5.8	258.3
1	33.6	17.8	13.0	21.1	83.0	18.2	-4.7	258.4
1	34.2	17.7	12.7	20.7	73.2	21.1	-5.5	261.6
1	38.7	24.2	15.0	27.7	79.3	93.4	-9.5	260.9
1	39.2	25.9	16.0	27.3	81.8	111.2	-10.2	242.1
1	35.6	19.8	14.8	22.9	101.3	114.5	-6.1	250.5
1	41.9	31.5	17.6	29.9	81.8	97.9	-7.5	259.8
1	31.9	15.4	11.8	18.8	97.7	48.9	-6.0	255.2
1	34.8	18.8	13.6	20.9	94.0	71.2	-3.3	262.8
1	37.7	24.8	14.7	26.5	81.8	92.3	-7.4	244.9
1	35.0	19.8	13.8	24.2	83.0	74.5	-8.9	251.1
1	38.3	23.4	15.6	24.7	83.0	122.3	-5.7	258.8
1	35.1	22.9	14.1	25.1	87.9	64.5	-6.0	245.1
1	38.3	22.3	14.9	22.9	83.0	76.7	-3.9	242.6
1	41.8	28.7	17.0	31.1	83.0	72.3	-4.4	235.2
1	34.4	18.7	13.2	20.9	83.0	87.9	-6.4	240.3
2	28.4	13.8	11.0	19.6	97.7	40.5	-4.1	231.1
2	27.5	12.4	9.5	15.2	119.6	30.7	-4.4	221.5
2	29.5	14.6	11.1	19.0	102.5	35.6	-8.8	196.3
2	31.0	16.5	11.9	19.9	87.9	16.7	-5.2	205.6
2	23.9	11.0	7.6	12.4	120.8	11.1	-6.0	249.4
2	30.0	14.1	11.4	19.9	120.8	45.2	-6.8	212.4
2	23.6	12.2	8.9	18.9	102.5	18.9	-5.4	244.3
2	26.2	12.5	9.7	15.7	114.7	27.6	-4.5	204.2
2	28.1	13.0	10.4	17.8	91.6	22.7	-6.5	231.0
2	29.3	12.8	10.4	18.3	122.1	17.6	0.1	242.5
2	29.7	15.1	11.5	21.5	97.7	16.2	-5.6	233.2
2	27.4	14.2	9.9	17.8	119.6	20.5	-6.0	277.0
2	27.9	12.1	10.5	17.8	118.4	30.0	-5.6	220.1
2	36.6	19.9	15.1	29.1	103.8	34.5	-5.5	282.0
2	35.2	21.9	14.9	31.0	86.7	36.7	-6.3	197.0
2	27.6	14.6	9.8	16.9	100.1	11.6	-3.6	220.1
2	29.2	14.7	11.2	19.4	120.8	40.0	-5.5	212.3
2	30.3	14.5	11.5	19.2	119.6	25.1	-7.3	216.8
2	31.5	15.6	12.1	19.3	120.8	21.6	-5.3	241.0
2	23.0	10.3	8.0	13.7	120.8	4.5	-0.2	241.4
2	27.7	13.4	10.4	17.6	120.8	18.2	-3.9	214.5
2	28.1	13.3	11.0	18.8	120.8	13.6	-1.9	251.8
2	31.1	14.3	11.7	18.9	102.5	43.2	-4.0	221.4
2	27.7	12.0	10.5	18.3	116.0	29.1	-5.7	215.9
2	26.9	11.4	9.8	16.7	122.1	19.1	-4.8	214.9
2	34.1	18.1	13.5	27.4	80.6	31.8	-5.0	235.7
2	34.1	19.9	13.7	23.9	83.0	28.0	-8.7	204.7

TABLE 23

CORRELATION COEFFICIENTS OF DATA FOR STORED LORING CULTIVAR

	BM70-160	PTF2-1	PRT2-1	P2/T	F2	Effegi	Color	Mass	Time
BM70-160	1.0000								
PRF2-1	0.9593	1.0000							
PRT2-1	0.9778	0.9819	1.0000						
P2/T	0.9137	0.9121	0.9508	1.0000					
F2	-0.3775	-0.2768	-0.3286	-0.3786	1.0000				
Effegi	0.7576	0.6612	0.7178	0.7053	-0.5106	1.0000			
Color	-0.3702	-0.3260	-0.3806	-0.4362	0.4244	-0.5984	1.0000		
Mass	0.6598	0.6091	0.5909	0.5204	-0.0746	0.4991	-0.1122	1.0000	
Time	-0.8846	-0.8400	-0.8282	-0.7126	0.2519	-0.6411	0.1841	-0.7769	1.0000

TABLE 24  
PEACH TESTING DATA FOR RUSTON RED CULTIVAR (STORED)

Day	BM70-160	PRF2-1	PRT2-1	P2/T	F2	Effegi	Color	Mass
	(%)	(%)	(%)	(v/ms)	(Hz)	(N)	(a)	(g)
0	39.8	37.0	16.4	34.2	83.0	87.9	7.8	206.6
0	39.8	36.5	15.2	27.9	83.0	89.0	11.5	197.1
0	41.0	40.4	16.6	35.0	83.0	93.4	8.2	202.5
0	41.5	41.8	17.4	33.6	83.0	106.8	-1.6	201.8
0	39.1	34.6	14.6	29.4	81.8	85.6	7.6	181.2
0	41.6	40.3	17.9	34.2	83.0	115.7	-3.6	170.9
0	42.4	40.4	17.2	35.5	83.0	110.1	1.2	193.7
0	39.1	35.2	16.8	31.8	83.0	76.7	1.4	203.2
0	42.6	38.3	19.6	42.8	84.2	101.2	2.2	184.9
0	41.4	42.2	16.2	31.3	83.0	110.1	7.6	182.2
0	41.1	37.6	17.6	32.3	87.9	96.7	3.0	167.6
0	43.5	45.2	20.4	46.3	84.2	112.3	-2.4	183.2
0	43.9	44.7	18.8	39.6	83.0	104.5	1.1	194.8
0	41.9	42.8	19.8	40.3	89.1	111.2	-2.4	161.1
0	43.9	42.5	21.5	44.4	89.1	102.3	4.4	160.1
0	39.5	32.9	17.2	38.5	85.5	95.6	2.1	149.7
0	40.8	37.2	18.7	40.9	89.1	112.3	5.7	152.8
0	40.9	37.0	18.3	35.6	85.5	112.3	-2.7	175.5
0	42.9	39.7	19.1	40.0	86.7	109.0	-2.9	176.9
0	41.2	34.9	19.8	42.4	87.9	105.0	-2.5	195.8
0	37.5	31.4	15.1	28.7	83.0	103.4	-2.0	180.3
0	43.5	43.3	18.7	33.3	83.0	106.8	-1.6	193.5
0	38.0	29.5	15.2	28.6	80.6	87.9	0.5	235.3
0	40.1	33.2	18.1	35.2	89.1	105.6	-5.8	170.5
0	41.3	37.2	16.6	30.7	84.2	103.4	-3.6	163.4
0	39.2	33.6	16.0	31.7	86.7	113.4	-2.4	150.3
0	38.4	32.7	16.4	31.8	87.9	104.5	-6.0	171.2
0	40.4	35.6	16.3	29.4	83.0	104.5	-4.5	201.7
0	37.8	30.9	15.3	27.1	87.9	85.6	1.8	172.3
0	36.6	25.5	14.8	28.3	83.0	75.6	3.9	188.3
0	37.9	33.2	16.1	31.8	83.0	86.7	1.1	177.0
0	39.7	32.8	16.8	33.4	84.2	105.6	-2.6	163.0
0	44.2	44.0	20.3	37.5	85.5	101.2	1.2	187.9
0	37.4	30.3	15.2	26.7	83.0	81.2	0.7	210.9
1	27.7	15.7	10.8	18.8	91.6	68.9	8.9	162.5
1	27.9	14.4	10.9	18.0	116.0	40.0	0.9	232.0
1	42.0	31.0	18.0	35.1	81.8	79.0	-2.5	214.2
1	30.1	16.0	11.5	18.0	100.1	76.7	-0.6	159.6
1	41.0	30.7	18.9	37.3	84.2	104.5	-0.4	198.2
1	39.0	34.5	16.2	31.8	84.2	74.5	3.5	189.2
1	35.1	24.1	13.2	21.2	76.9	99.0	-1.4	192.8

TABLE 24 (Continued)

Day	BM70-160	PRF2-1	PRT2-1	P2/T	F2	Effegi	Color	Mass
	(%)	(%)	(%)	(v/ms)	(Hz)	(N)	(a)	(g)
1	35.7	25.1	13.9	23.2	84.2	91.2	1.0	185.9
1	38.7	29.6	15.9	24.9	84.2	91.2	-4.7	183.9
1	36.9	24.4	14.0	22.1	84.2	97.9	-4.7	177.9
1	31.7	17.9	11.1	16.6	87.9	51.2	-2.1	183.8
1	33.4	18.9	12.8	19.1	85.5	51.8	1.6	190.4
1	38.7	30.5	15.9	24.3	85.5	107.2	-5.1	198.3
1	31.3	17.6	10.6	14.9	72.0	82.3	5.8	190.6
1	35.7	23.8	13.5	21.6	78.1	62.3	5.1	196.8
1	28.6	17.5	10.2	15.5	79.4	32.3	6.9	169.5
1	33.1	18.7	11.6	18.2	79.4	100.1	-2.1	185.0
1	34.0	21.1	12.5	19.1	84.2	100.1	-0.6	173.6
1	33.7	21.7	11.9	20.0	87.9	100.5	3.4	159.1
1	41.0	36.6	18.6	34.7	89.1	85.2	6.4	144.7
2	24.3	14.3	8.0	12.9	74.5	45.8	0.8	226.5
2	21.8	9.3	7.0	10.6	84.2	15.8	2.9	165.1
2	25.3	13.7	8.6	14.1	85.5	23.4	0.2	170.6
2	28.4	17.7	9.4	14.7	74.5	55.2	2.0	211.4
2	27.7	16.6	10.1	18.1	90.3	64.9	-1.8	143.9
2	24.5	14.6	8.6	12.1	75.7	16.2	6.4	186.0
2	30.6	17.1	11.6	18.4	79.4	41.8	2.1	179.6
2	23.7	12.0	9.3	16.8	86.7	77.4	-6.5	158.8
2	33.4	22.0	11.8	20.2	80.6	54.3	-3.3	159.3
2	26.5	14.4	9.8	15.6	80.6	33.8	-0.8	172.8
2	32.5	21.7	12.5	19.8	91.6	113.4	-4.4	164.8
2	34.8	24.2	13.6	25.0	87.9	90.1	-2.8	147.0
2	30.1	16.5	10.7	17.3	90.3	55.6	2.1	162.6
2	27.1	14.4	9.8	15.5	78.1	84.1	-5.5	153.8
2	20.7	10.2	6.6	9.7	74.5	32.5	-1.0	150.5
2	36.5	25.5	13.9	22.3	86.7	74.5	-0.1	158.3
2	30.2	16.8	10.8	17.5	78.1	104.5	-3.4	163.1
2	20.1	8.9	6.7	10.5	74.5	16.2	3.1	165.1
2	23.3	10.1	8.2	12.4	89.1	69.6	1.4	158.4
2	22.8	11.2	7.1	9.6	83.0	46.7	0.7	181.1
2	17.7	7.4	5.1	7.1	96.4	32.3	-2.4	166.3
2	18.8	7.5	5.8	7.6	96.4	36.7	1.2	145.1
2	22.8	11.0	6.7	9.0	73.2	16.7	-1.3	184.2
2	22.7	10.2	8.1	11.6	73.2	12.2	1.5	171.5
2	23.4	10.4	7.8	13.0	85.5	8.9	8.2	168.8
2	17.8	7.8	5.3	8.1	95.2	38.9	1.4	155.1
2	20.1	9.1	6.4	9.7	85.5	60.3	0.1	133.6
2	22.3	10.7	7.4	10.7	83.0	28.2	-0.7	151.1
2	21.5	10.1	6.9	9.8	73.2	22.2	1.4	172.0
2	22.4	10.5	7.2	9.9	84.2	45.6	5.7	173.7
2	20.0	8.4	6.7	10.2	80.6	67.8	0.2	133.8
2	34.1	19.9	13.7	23.9	83.0	28.0	-8.7	204.7

TABLE 25

CORRELATION COEFFICIENTS OF DATA FOR STORED RUSTON RED CULTIVAR

	BM70-160	PRF2-1	PRT2-1	P2/T	F2	Effegi	Color	Mass	Time
BM70-160	1.0000								
PRF2-1	0.9635	1.0000							
PRT2-1	0.9792	0.9619	1.0000						
P2/T	0.9411	0.9536	0.9790	1.0000					
F2	0.0560	0.0503	0.1141	0.1263	1.0000				
Effegi	0.8349	0.8037	0.8198	0.7907	0.1404	1.0000			
Color	-0.0597	-0.0094	-0.0846	-0.0444	-0.0844	-0.2756	1.0000		
Mass	0.3454	0.3056	0.2921	0.2464	-0.1525	0.1100	0.1067	1.0000	
Time	-0.8645	-0.8883	-0.8614	-0.8630	-0.1209	-0.7360	-0.0599	-0.3491	1.0000

TABLE 26

## PEACH TESTING DATA FOR CRESTHAVEN CULTIVAR (STORED)

Day	BM70-160	PRF2-1	PRT2-1	P2/T	F2	Effegi	Color	Mass
	(%)	(%)	(%)	(v/ms)	(Hz)	(N)	(a)	(g)
0	38.9	22.1	16.6	30.5	75.7	82.7	0.2	251.2
0	40.6	23.1	18.3	32.8	75.7	90.1	-3.9	243.0
0	36.5	17.3	14.8	25.7	75.7	69.8	2.7	241.0
0	39.0	21.5	18.2	33.7	85.5	111.2	-3.1	221.7
0	40.2	22.3	17.7	30.0	84.2	89.0	2.0	214.7
0	36.8	20.1	15.8	27.1	84.2	91.2	3.9	221.1
0	38.1	21.1	17.3	30.2	86.7	100.1	-3.3	234.5
0	38.8	23.3	19.0	37.9	85.5	93.4	-0.6	258.7
0	40.8	27.9	20.8	44.3	85.5	95.2	-0.7	239.2
0	34.3	16.5	14.3	24.3	92.8	93.4	1.6	195.3
0	37.7	19.4	15.9	26.2	92.8	105.6	-3.0	223.4
0	36.9	19.7	16.7	29.8	95.2	107.9	-1.3	193.2
0	37.4	20.4	16.9	30.9	95.2	111.2	-3.3	201.6
0	36.2	20.2	16.4	25.5	92.8	80.1	5.4	174.2
0	41.0	24.3	19.2	41.6	86.7	141.2	-8.1	227.2
0	42.8	27.6	21.1	40.8	83.0	142.3	-0.6	218.3
0	41.2	27.0	21.0	48.3	92.8	114.5	-8.0	199.8
0	40.3	23.9	20.0	35.7	95.2	127.9	-6.2	192.8
0	35.4	18.8	16.8	30.8	90.3	100.5	-4.8	192.3
0	40.8	29.5	23.6	58.6	100.1	142.3	-6.7	180.8
0	40.8	27.8	23.5	62.5	102.5	151.2	-8.6	193.6
0	34.6	18.0	15.7	27.3	95.2	92.7	0.7	188.3
0	42.5	30.2	22.6	55.7	95.2	120.1	-7.0	187.5
0	42.6	30.3	22.8	51.7	95.2	129.0	-7.9	196.1
0	41.9	28.3	21.1	46.4	96.4	119.0	-3.4	196.1
0	42.2	27.5	22.0	45.5	95.2	130.1	3.7	217.0
0	39.3	20.8	17.4	28.6	78.1	97.9	-7.6	212.7
0	41.3	25.4	20.2	36.7	92.8	111.2	-3.4	201.4
0	38.3	23.1	17.1	30.6	78.1	105.6	-4.4	222.8
0	39.0	22.0	18.8	38.4	102.5	94.5	-6.0	211.1
0	42.4	27.6	21.0	43.6	87.9	142.3	-7.9	205.3
0	39.0	21.8	19.1	36.3	97.7	124.5	-5.0	209.8
0	37.2	20.3	17.6	39.9	89.1	112.3	-4.6	211.1
0	38.2	19.1	17.1	30.0	112.3	102.3	-6.6	181.7
0	39.8	24.2	21.0	47.6	107.4	121.7	-6.2	203.1
0	40.6	23.8	19.2	32.6	85.5	105.6	-3.5	228.0
0	37.9	22.7	17.0	30.4	84.2	100.1	-3.3	213.7
0	38.9	21.6	17.9	31.0	84.2	106.8	-2.6	229.8
0	37.2	18.5	16.3	27.4	87.9	97.2	-2.4	197.8
0	36.3	18.6	17.0	33.2	100.1	101.2	2.5	208.3

TABLE 26 (Continued)

Day	BM70-160	PRF2-1	PRT2-1	P2/T	F2	Effegi	Color	Mass
	(%)	(%)	(%)	(v/ms)	(Hz)	(N)	(a)	(g)
0	36.2	21.5	18.8	43.1	107.4	126.8	-4.7	185.8
0	42.5	26.7	21.1	42.1	79.4	117.9	-7.4	222.1
0	37.9	27.5	16.4	24.8	72.0	75.6	-3.1	275.9
0	39.3	21.9	18.1	34.4	83.0	101.2	-5.6	171.5
0	38.3	20.8	16.6	28.0	74.5	115.0	-2.9	201.7
0	36.9	20.8	16.6	30.6	96.4	114.5	-5.4	217.2
0	40.7	23.1	21.0	50.6	95.2	137.9	-4.1	217.3
0	37.9	21.1	19.0	40.0	102.5	104.5	-9.1	187.8
0	39.8	23.2	20.2	43.6	87.9	113.0	-5.3	181.4
0	36.5	18.6	16.2	25.8	75.7	104.5	-5.8	194.7
0	37.2	21.9	18.6	41.6	101.3	126.3	-2.5	164.6
0	36.6	20.6	19.4	41.0	107.4	105.6	1.0	174.4
0	39.2	21.6	19.0	36.0	95.2	133.4	-1.9	164.5
0	36.6	19.9	18.2	38.3	102.5	122.3	-5.3	184.9
0	38.0	20.0	18.1	37.9	95.2	134.3	-5.8	189.7
1	34.5	20.7	13.9	24.0	81.8	63.4	3.2	222.0
1	37.8	23.6	16.1	23.9	73.2	97.9	-2.2	225.9
1	32.0	16.1	12.4	19.3	107.4	54.5	-0.2	209.3
1	35.6	19.7	15.9	29.2	102.5	90.3	0.1	224.9
1	36.8	19.5	15.9	26.8	102.5	101.2	-4.0	202.4
1	32.1	16.4	13.1	22.0	102.5	70.1	-0.4	196.3
1	33.3	16.5	13.7	24.6	102.5	77.8	-0.4	199.2
1	32.9	19.2	13.4	19.5	89.1	104.5	-0.8	226.5
1	37.5	20.1	17.1	25.9	100.1	115.7	2.2	213.0
1	34.4	18.2	14.2	22.2	80.6	93.4	-4.8	247.1
1	36.8	19.7	15.1	24.9	90.3	124.5	-4.8	207.2
1	35.4	19.1	14.4	23.8	90.3	85.6	-0.9	225.3
1	36.4	18.4	15.5	29.4	102.5	73.4	-1.5	205.0
1	31.4	16.4	12.2	19.7	89.1	40.0	0.8	211.0
1	34.6	19.5	14.7	21.4	70.8	65.6	10.4	249.7
1	38.5	24.9	17.7	33.7	83.0	132.3	-7.4	225.5
1	35.6	19.0	14.8	23.5	107.4	135.7	-4.5	206.5
1	34.7	19.8	15.6	29.4	107.4	83.4	-5.2	221.0
1	37.7	19.9	17.5	26.8	100.1	133.4	-8.6	223.4
1	34.8	18.2	14.9	23.7	108.6	121.2	-6.9	196.5
1	34.1	22.2	13.7	20.9	70.8	119.0	-5.8	230.1
1	34.2	17.6	14.8	23.3	111.1	124.5	-3.6	212.9
1	31.0	16.5	12.5	18.1	89.1	89.4	-3.1	205.7
1	31.2	18.4	11.6	16.5	70.8	102.3	-7.6	234.8
1	34.4	20.2	15.5	31.6	75.7	62.3	-2.8	201.8
1	31.1	15.6	12.5	20.1	81.8	34.5	5.4	202.9
1	30.8	15.6	12.4	19.8	107.4	85.2	2.1	159.9
1	38.0	21.1	17.0	28.7	108.6	131.2	-3.0	182.2
1	36.0	19.6	15.0	23.3	91.6	97.0	-3.6	190.6
1	32.0	16.2	12.7	20.2	109.9	99.4	-4.3	187.1

TABLE 26 (Continued)

Day	BM70-160	PRF2-1	PRT2-1	P2/T	F2	Effegi	Color	Mass
	(%)	(%)	(%)	(v/ms)	(Hz)	(N)	(a)	(g)
1	34.7	18.4	15.8	27.9	107.4	106.8	-5.8	209.6
1	37.8	21.5	17.9	28.7	112.3	129.0	-6.9	199.2
1	36.0	19.9	16.0	33.6	101.3	106.8	-7.9	205.2
1	36.2	20.3	16.3	31.6	114.8	121.2	-6.7	197.9
1	36.7	20.0	15.8	27.5	108.6	106.8	-5.8	196.2
2	37.0	20.9	15.1	23.6	73.2	136.6	-5.1	226.0
2	28.8	15.2	10.5	15.1	70.8	17.8	-2.7	203.2
2	37.4	20.6	16.1	27.7	95.2	126.8	-4.4	207.4
2	29.5	15.4	10.9	17.5	70.8	20.0	-1.7	216.4
2	30.2	16.2	11.3	15.5	72.0	35.6	-3.9	215.6
2	35.8	18.6	15.3	26.6	101.3	100.1	-4.1	195.0
2	32.3	17.5	12.7	17.7	90.3	57.4	4.2	211.6
2	33.4	19.3	14.1	23.4	91.6	70.1	-5.2	221.3
2	27.9	13.7	9.6	13.7	90.3	26.0	4.0	222.9
2	24.7	13.6	7.4	10.0	89.1	31.6	-1.5	218.0
2	24.0	12.5	8.2	12.4	70.8	8.9	3.9	215.4
2	36.2	19.2	15.7	26.5	90.3	105.6	-5.2	227.7
2	26.6	13.4	9.6	13.2	89.1	17.8	-1.0	222.7
2	27.3	14.0	9.6	13.9	89.1	44.3	-4.1	209.5
2	29.3	16.8	10.5	15.7	72.0	86.5	-3.6	205.2
2	36.9	19.6	16.4	27.9	94.0	124.5	-4.7	189.8
2	28.7	15.8	10.4	14.7	70.8	18.0	6.7	208.0
2	35.0	19.2	14.7	20.9	89.1	142.3	-6.7	194.7
2	31.1	15.4	12.8	19.6	108.6	115.7	-5.7	179.9
2	27.7	15.7	9.6	13.3	70.8	64.5	0.4	217.0
2	33.3	21.8	12.6	17.7	70.8	71.0	-1.6	241.2

TABLE 27

CORRELATION COEFFICIENTS OF DATA FOR STORED CRESTHAVEN CULTIVAR

	BM70-160	PRF2-1	PRT2-1	P2/T	F2	Effegi	Color	Mass	Time
BM70-160	1.0000								
PRF2-1	0.8824	1.0000							
PRT2-1	0.9522	0.8917	1.0000						
P2/T	0.8358	0.8409	0.9471	1.0000					
F2	0.1726	0.0146	0.2758	0.3015	1.0000				
Effegi	0.7602	0.6418	0.7542	0.6627	0.4024	1.0000			
Color	-0.3787	-0.3670	-0.3943	-0.3991	-0.2528	-0.5764	1.0000		
Mass	-0.0330	0.0678	-0.1614	-0.2281	-0.5410	-0.2476	0.1670	1.0000	
Time	-0.7504	-0.6173	-0.7643	-0.7133	-0.1378	-0.4934	0.1473	0.1014	1.0000

TABLE 28

## PEACH TESTING DATA FOR JEFFERSON CULTIVAR (STORED)

Day	BM70-160	PRF2-1	PRT2-1	P2/T	F2	Effegi	Color	Mass
	(%)	(%)	(%)	(v/ms)	(Hz)	(N)	(a)	(g)
0	40.6	28.1	19.4	40.2	92.8	120.1	-4.6	207.1
0	36.0	20.1	16.1	32.4	101.3	104.5	-6.9	181.2
0	31.7	17.5	15.0	29.7	92.8	86.7	-5.5	186.6
0	35.5	21.9	16.9	29.9	95.2	115.7	-4.2	177.8
0	31.6	15.1	13.7	24.8	91.6	85.6	-1.2	192.8
0	35.8	23.1	16.7	29.3	92.8	89.0	-5.1	177.3
0	35.2	19.9	15.6	29.7	92.8	92.3	-4.7	212.5
0	29.8	14.4	12.7	20.3	80.6	55.4	2.1	243.5
0	25.0	10.6	9.3	14.9	98.9	24.5	4.1	214.8
0	37.0	21.7	16.0	27.1	84.2	93.4	0.7	220.2
0	30.1	16.1	12.7	24.6	92.8	64.5	4.2	193.3
0	30.0	13.4	11.8	19.8	81.8	55.6	-2.7	198.7
0	31.7	15.5	13.0	22.7	91.6	68.5	0.8	225.3
0	31.6	15.4	13.5	23.1	91.6	82.3	-3.4	211.3
0	34.7	19.1	15.7	26.7	91.6	94.5	-3.7	219.9
0	36.0	18.4	16.1	26.1	90.3	77.8	-1.0	204.4
0	32.1	17.1	14.0	21.2	107.4	64.1	-3.1	187.2
0	36.3	18.6	16.1	29.9	92.8	114.5	-3.8	192.9
0	33.9	16.0	15.9	29.7	98.9	77.4	-1.9	193.4
0	37.6	19.6	16.8	28.9	91.6	90.1	-3.3	214.7
0	34.1	17.3	14.5	24.7	90.3	82.3	-3.4	199.8
0	40.6	29.4	20.0	39.7	92.8	99.4	-5.1	198.9
0	34.9	18.1	14.9	27.7	86.7	93.4	-2.9	203.1
0	39.8	23.8	18.8	33.2	91.6	100.1	-4.8	197.5
0	32.5	16.8	14.4	24.9	91.6	83.4	-3.9	222.7
0	36.6	19.6	17.7	31.0	90.3	92.3	-5.0	215.7
0	37.4	19.6	17.8	30.4	97.7	97.9	-4.8	191.6
0	36.9	20.6	17.9	35.7	102.5	84.5	-6.2	181.1
0	38.4	22.4	18.9	36.0	95.2	100.5	-5.3	185.2
0	39.4	25.0	20.7	37.6	95.2	94.5	-5.3	193.3
0	36.3	21.0	16.4	30.0	100.1	106.8	-1.7	182.0
0	39.4	24.0	19.4	37.2	92.8	124.5	-5.4	191.8
0	35.3	18.9	16.8	29.7	100.1	106.8	-6.2	197.3
0	38.0	22.9	20.2	43.8	103.8	83.0	-2.9	169.1
0	37.2	21.9	18.6	35.2	94.0	96.7	-4.3	179.2
0	36.6	18.1	16.4	28.2	98.9	102.3	-5.9	188.4
0	34.5	17.2	14.7	26.9	83.0	106.8	-4.2	191.6
0	36.8	20.9	17.8	31.7	92.8	100.1	-7.8	185.8
0	36.3	19.6	17.5	33.1	107.4	95.2	-8.7	179.2
0	36.4	20.3	17.6	36.4	90.3	102.3	-4.6	183.1

TABLE 28 (Continued)

Day	BM70-160	PRF2-1	PRT2-1	P2/T	F2	Effegi	Color	Mass
	(%)	(%)	(%)	(v/ms)	(Hz)	(N)	(a)	(g)
0	38.1	21.0	19.2	33.9	100.1	83.4	-5.1	191.2
0	36.0	22.2	19.7	47.2	122.1	96.7	-4.9	179.9
0	36.3	20.0	17.8	32.1	92.8	90.1	-4.6	177.6
1	25.9	11.4	10.2	16.1	106.2	24.2	-3.0	196.0
1	33.4	17.6	14.1	23.6	91.6	92.3	-5.3	200.1
1	32.8	17.9	14.0	24.6	87.9	57.8	0.3	218.1
1	30.9	14.4	12.5	21.2	91.6	68.9	-1.3	199.7
1	29.9	13.4	12.1	20.6	107.4	82.7	-3.2	192.5
1	28.5	13.1	11.2	16.9	92.8	70.1	-4.5	168.6
1	29.2	13.9	12.2	20.0	95.2	71.2	-0.6	171.6
1	30.8	14.6	12.2	19.4	83.0	92.3	1.0	219.0
1	29.3	15.1	12.5	21.7	92.8	61.4	0.4	196.3
1	32.1	15.9	13.9	21.6	105.0	71.6	0.7	199.9
1	26.6	11.3	9.9	14.1	84.2	43.4	-0.1	177.7
1	25.6	10.9	9.8	15.3	100.1	8.0	2.9	178.0
1	29.8	14.7	11.9	20.9	102.5	97.2	-7.1	173.3
1	31.3	16.5	13.4	18.7	92.8	81.2	-4.4	177.5
1	29.5	14.3	11.3	19.6	90.3	45.2	0.6	202.9
1	31.9	15.6	13.4	22.3	95.2	100.1	-2.9	188.2
1	31.3	15.6	13.1	27.4	102.5	110.1	-4.9	156.6
1	32.9	17.4	13.1	21.7	85.5	136.8	-2.2	177.3
1	30.9	17.8	12.8	22.0	92.8	82.3	-4.2	172.9
1	29.6	16.5	12.8	25.6	92.8	76.7	-4.7	174.1
1	28.9	13.4	11.7	17.9	105.0	61.2	-4.6	190.9
1	32.9	19.0	14.0	24.4	92.8	100.1	-5.0	184.1
1	27.1	13.3	10.8	15.8	91.6	63.4	-1.9	179.2
1	32.7	19.5	14.6	25.8	92.8	116.3	-3.4	181.6
1	32.4	16.4	13.3	26.1	94.0	61.2	-1.1	189.3
1	28.7	13.6	11.7	18.5	91.6	51.2	-2.0	174.4
1	26.2	11.3	10.2	15.4	95.2	34.5	0.7	195.5
1	27.7	12.6	11.0	19.2	95.2	50.0	2.5	179.3
1	26.4	11.2	9.9	16.5	92.8	48.3	-0.7	188.3
1	29.6	13.5	11.8	19.4	94.0	82.7	-5.2	184.7
1	27.7	12.3	11.1	18.4	105.0	74.5	-1.7	171.8
1	29.2	15.6	11.9	18.3	94.0	85.2	-8.2	174.8
1	27.6	13.7	10.9	17.2	92.8	46.7	-1.3	170.1
1	33.9	17.8	14.3	25.3	95.2	82.3	-3.4	179.2
1	26.8	12.3	10.3	17.2	95.2	50.0	-2.6	177.6
2	27.6	13.5	11.4	16.0	102.5	12.2	-0.6	153.7
2	26.4	12.5	10.3	14.9	107.4	22.2	5.1	153.4
2	33.1	18.6	14.7	24.1	107.4	46.0	-3.0	169.0
2	34.2	19.4	15.5	26.7	97.7	41.8	-6.0	158.2
2	29.9	15.6	12.7	20.0	107.4	18.5	-2.9	145.7
2	29.0	13.9	11.0	16.0	102.5	19.4	-2.1	170.3
2	29.5	14.6	12.1	17.2	107.4	22.9	-1.0	155.3

TABLE 28 (Continued)

Day	BM70-160	PRF2-1	PRT2-1	P2/T	F2	Effegi	Color	Mass
	(%)	(%)	(%)	(v/ms)	(Hz)	(N)	(a)	(g)
2	27.9	13.3	11.2	16.2	102.5	11.1	3.2	161.0
2	26.4	12.2	10.6	14.9	105.0	22.2	-1.0	157.4
2	32.3	17.2	13.1	20.2	107.4	22.7	-3.2	159.4
2	30.3	16.0	13.5	20.9	102.5	29.6	-3.7	148.8
2	25.0	11.5	8.9	13.6	107.4	9.8	-1.0	155.7
2	29.6	15.3	11.7	17.2	85.5	23.4	-2.3	166.0
2	32.1	16.3	13.9	19.3	107.4	33.8	-1.2	174.1
2	29.7	14.1	11.9	17.7	107.4	14.9	0.4	183.5
2	27.2	12.8	10.5	14.6	89.1	16.0	2.7	187.8
2	27.5	13.3	11.0	16.1	107.4	27.8	-1.5	144.4
2	32.2	16.4	13.8	18.4	107.4	39.8	-2.2	179.9
2	31.8	16.7	14.1	23.1	102.5	18.0	-2.3	189.2
2	31.7	16.0	13.7	21.0	107.4	20.0	1.2	170.7
2	32.9	17.6	14.6	22.4	102.5	31.6	-2.8	167.4
2	28.5	14.4	11.5	16.8	107.4	16.2	-1.0	179.5
2	31.5	15.6	13.3	20.3	107.4	33.4	-2.4	168.4
2	28.4	13.8	12.1	17.4	107.4	20.7	-2.0	165.8
2	32.9	17.4	14.6	21.5	106.2	43.8	-7.3	167.9
2	30.1	14.2	12.4	16.8	107.4	27.4	-0.8	188.8
2	29.7	14.1	12.8	18.5	97.7	16.7	0.8	175.4
2	30.5	15.5	13.4	18.6	107.4	35.6	-4.5	163.4
2	30.1	14.9	12.4	18.1	89.1	16.9	-1.3	187.7
2	27.8	12.9	10.9	16.5	107.4	12.9	-1.4	177.3
2	31.9	16.6	13.7	20.1	107.4	29.8	-0.8	162.1
2	30.2	14.9	13.8	21.0	109.9	16.7	0.1	179.9
2	30.2	14.7	12.8	18.2	107.4	28.2	-2.0	163.1
2	29.3	14.5	12.3	17.5	107.4	24.0	-2.4	163.2
2	33.5	18.0	14.3	21.6	107.4	33.4	-2.3	158.2
2	28.8	13.9	12.5	17.9	107.4	16.9	-2.8	182.7
2	30.4	15.1	13.8	18.5	107.4	16.7	-3.6	151.4
2	31.5	15.8	13.7	19.5	94.0	41.1	-6.4	163.4

TABLE 29

## CORRELATION COEFFICIENTS OF DATA FOR STORED JEFFERSON CULTIVAR

	BM70-160	PRF2-1	PRT2-1	P2/T	F2	Effegi	Color	Mass	Time
BM70-160	1.0000								
PRF2-1	0.9468	1.0000							
PRT2-1	0.9683	0.9415	1.0000						
P2/T	0.9017	0.8981	0.9427	1.0000					
F2	-0.1951	-0.1542	-0.0854	-0.1276	1.0000				
Effegi	0.7057	0.6531	0.6479	0.7184	-0.4738	1.0000			
Color	-0.5605	-0.5402	-0.5645	-0.5227	0.0075	-0.5476	1.0000		
Mass	0.3171	0.2255	0.2464	0.2870	-0.5689	0.4404	0.0767	1.0000	
Time	-0.6088	-0.5380	-0.5921	-0.6933	0.5137	-0.8081	0.3103	-0.6520	1.0000

TABLE 30

## PEACH TESTING DATA FOR ELBERTA CULTIVAR (STORED)

Day	BM70-160	PRF2-1	PRT2-1	P2/T	F2	Effegi	Color	Mass
	(%)	(%)	(%)	(v/ms)	(Hz)	(N)	(a)	(g)
0	42.0	33.5	24.6	54.3	106.2	125.7	-7.1	174.8
0	38.7	25.2	18.6	33.7	102.5	107.9	-8.7	178.5
0	42.4	30.2	22.2	42.5	103.8	140.1	-6.9	191.1
0	37.6	24.7	18.0	32.6	105.0	76.7	-2.2	160.8
0	32.1	16.8	13.2	19.2	87.9	13.3	1.7	191.8
0	38.0	24.0	19.0	30.5	106.2	127.9	-5.7	182.6
0	39.2	26.1	19.7	39.9	102.5	67.6	-6.8	175.3
0	39.5	23.9	19.3	32.7	102.5	95.6	-1.2	204.3
0	43.6	33.7	25.7	55.9	102.5	106.3	-7.3	193.5
0	40.0	30.7	23.9	51.9	107.4	105.6	-8.6	176.3
0	41.4	25.9	20.7	32.8	92.8	137.9	-7.7	193.4
0	40.9	24.4	20.2	33.7	102.5	105.0	-7.0	247.6
0	38.6	22.5	18.0	26.8	86.7	90.1	-4.0	218.1
0	41.8	29.0	22.3	41.5	105.0	155.7	-9.3	185.3
0	38.8	24.2	18.6	30.6	102.5	133.4	-4.7	182.9
0	40.1	27.5	22.9	46.5	109.9	107.9	-7.7	178.6
0	40.2	25.4	18.8	27.1	72.0	71.2	-3.1	249.3
0	40.2	26.9	19.7	32.2	75.7	86.7	-7.0	234.4
0	39.1	26.1	19.3	41.1	102.5	96.7	-1.3	167.4
0	39.6	24.4	18.7	34.3	91.6	90.1	-3.9	209.0
0	42.0	26.6	20.9	33.7	91.6	92.3	-7.0	263.6
0	38.8	21.5	19.0	36.1	102.5	95.6	-3.1	232.8
0	38.8	21.7	17.6	26.4	102.5	71.2	-3.1	228.8
0	40.0	25.6	20.5	39.5	107.4	84.5	-7.7	192.6
0	39.7	24.0	18.5	28.9	91.6	94.5	-5.6	217.5
0	37.5	21.7	17.7	34.4	103.8	82.3	-5.2	186.4
0	40.2	26.0	20.3	38.0	91.6	60.1	-2.8	223.9
0	35.5	19.4	15.5	22.8	100.1	22.2	7.0	191.7
0	35.0	19.7	16.8	28.0	100.1	21.1	5.3	182.2
0	36.2	21.5	19.3	37.9	107.4	66.7	-0.5	186.3
0	39.4	26.3	23.3	47.0	108.6	101.6	-1.7	193.0
0	37.0	20.9	18.1	30.9	108.6	76.7	0.9	209.6
0	39.9	26.4	22.3	44.4	106.2	102.3	-9.4	196.9
0	38.6	23.6	19.7	36.2	102.5	104.5	-6.3	218.1
0	40.1	23.6	19.5	29.0	102.5	92.3	-7.2	219.5
0	37.5	24.4	16.7	25.2	73.2	77.8	-0.6	257.9
0	37.8	22.2	17.3	31.9	80.6	87.9	-4.8	236.8
0	38.9	22.6	19.0	36.0	103.8	48.9	6.3	191.8
0	39.8	23.6	19.8	28.9	102.5	103.4	-7.6	230.4
0	39.9	24.6	21.8	37.4	108.6	104.5	-6.1	194.5

TABLE 30 (Continued)

Day	BM70-160	PRF2-1	PRT2-1	P2/T	F2	Effegi	Color	Mass
	(%)	(%)	(%)	(v/ms)	(Hz)	(N)	(a)	(g)
0	42.1	28.4	23.1	38.2	106.2	107.9	-5.1	202.1
1	37.5	22.0	17.3	27.4	92.8	77.8	5.9	212.0
1	32.9	19.7	15.3	24.4	92.8	48.9	-4.3	207.1
1	36.6	24.2	17.2	28.7	92.8	42.3	1.3	182.1
1	34.7	20.2	15.2	21.2	92.8	55.6	-0.3	229.1
1	36.0	22.3	17.3	27.9	92.8	89.0	-8.9	215.7
1	36.3	22.5	16.4	26.0	92.8	51.2	-7.7	214.5
1	35.0	21.1	16.3	23.3	92.8	57.8	-1.8	212.9
1	29.8	16.4	13.3	17.3	92.8	16.9	-8.1	204.6
1	39.0	25.1	18.7	31.8	92.8	109.0	-10.0	226.6
1	39.7	26.9	18.6	31.3	92.8	77.8	-5.7	209.4
1	36.8	23.0	16.9	28.5	92.8	94.5	-5.5	216.3
1	37.6	24.2	17.6	27.7	92.8	76.3	-4.6	198.6
1	31.1	17.4	14.0	21.0	92.8	52.3	-1.5	203.0
1	30.2	16.2	12.7	19.0	92.8	29.6	-1.9	237.0
1	31.8	17.5	13.6	22.1	92.8	49.6	-6.2	221.0
1	34.5	19.8	15.8	23.5	91.6	36.0	-1.3	186.5
1	34.7	19.4	15.9	25.7	83.0	60.5	-4.5	236.6
1	33.0	16.8	14.7	19.0	92.8	55.6	-4.1	215.8
1	29.7	15.1	12.6	18.4	92.8	28.0	-6.7	195.5
1	37.0	25.0	19.3	37.3	94.0	99.0	-5.3	182.3
1	37.4	26.0	17.7	31.7	94.0	102.3	-5.7	171.6
1	24.8	12.5	10.6	14.7	91.6	8.5	1.3	165.8
1	32.7	15.9	13.9	20.8	92.8	71.2	-6.9	210.4
1	37.9	27.1	18.9	36.0	94.0	94.5	-10.9	169.6
1	36.7	24.4	17.9	29.6	92.8	102.3	-3.0	210.2
1	28.1	14.7	12.0	17.7	94.0	12.0	-3.7	196.7
1	33.0	18.2	15.0	23.0	90.3	88.1	-5.8	196.4
1	38.4	26.7	20.8	40.7	95.2	94.5	-2.8	194.1
1	34.5	19.0	15.9	25.3	92.8	77.2	1.6	238.5
1	35.2	20.5	16.1	24.0	95.2	46.7	-5.3	202.9
1	29.1	15.4	12.4	18.8	92.8	24.7	-1.3	202.0
1	33.0	19.0	15.1	23.8	92.8	72.7	-7.6	167.8
1	31.6	17.6	14.3	19.9	92.8	40.5	-6.6	229.0
1	35.3	20.9	15.6	24.2	92.8	36.7	-0.8	205.4
1	33.5	18.0	15.1	21.2	81.8	89.6	-2.0	222.6
1	38.6	25.3	18.8	29.5	92.8	66.9	-8.2	199.9
2	28.6	12.6	11.9	17.5	92.8	9.1	-4.5	194.4
2	30.4	15.3	13.5	20.6	89.1	29.8	-5.7	184.2
2	33.4	17.2	15.4	25.1	107.4	31.1	-2.0	194.5
2	23.6	8.9	9.1	12.5	100.1	4.5	-0.2	208.9
2	28.0	12.7	10.6	13.7	70.8	20.0	-7.3	218.0
2	28.8	13.6	12.5	19.4	107.4	10.0	-2.1	175.6
2	31.0	15.1	13.8	19.2	92.8	17.4	-3.7	208.8
2	25.1	10.0	10.2	13.4	114.8	8.5	-6.8	209.4

TABLE 30 (Continued)

Day	BM70-160	PRF2-1	PRT2-1	P2/T	F2	Effegi	Color	Mass
	(%)	(%)	(%)	(v/ms)	(Hz)	(N)	(a)	(g)
2	27.7	11.8	11.5	14.9	92.8	16.7	-9.5	216.9
2	28.7	12.5	12.0	16.9	102.5	24.5	-5.0	201.7
2	28.7	13.6	12.6	17.2	107.4	14.9	9.0	163.2
2	28.3	13.7	12.3	17.8	107.4	16.7	-2.7	165.4
2	28.6	13.1	11.7	17.2	92.8	10.5	-0.7	173.3
2	29.8	13.6	12.7	16.3	70.8	55.6	-9.2	203.2
2	32.0	16.1	14.0	21.0	92.8	36.7	-3.1	202.1
2	31.0	14.6	13.1	20.2	81.8	22.9	-3.1	233.2
2	24.3	9.9	9.7	13.7	86.7	4.5	4.6	207.1
2	36.1	21.0	18.1	32.9	94.0	65.6	-10.8	168.0
2	26.6	12.1	10.4	14.3	70.8	15.6	0.1	230.5
2	28.0	12.5	12.0	17.5	113.5	24.5	-5.6	259.9
2	30.3	14.1	13.3	21.6	81.8	26.7	-7.6	208.3
2	22.3	9.0	8.4	12.4	100.1	3.8	2.8	184.1
2	26.1	10.8	10.3	15.0	95.2	10.0	-2.7	171.7
2	31.6	15.7	14.4	22.1	95.2	38.3	-9.7	179.9
2	27.0	11.7	11.4	16.5	92.8	13.6	-7.5	191.6
2	31.4	15.3	14.3	22.7	97.7	28.2	-8.1	185.5
2	25.8	11.0	10.4	14.8	86.7	22.5	-1.1	238.2
2	27.6	11.9	11.3	17.2	92.8	11.6	-0.6	194.6
2	31.5	17.2	13.9	29.5	95.2	20.5	0.9	156.1
2	25.2	11.1	10.7	15.8	95.2	10.2	-5.7	178.6
2	27.6	13.0	11.6	17.5	92.8	15.4	-3.4	173.2
2	26.4	12.3	11.6	17.8	102.5	13.8	-0.8	163.1
2	31.5	15.2	14.1	22.1	94.0	47.2	-7.8	202.8
2	31.9	15.1	14.1	22.4	92.8	26.7	-8.2	178.6
2	30.1	13.4	12.9	17.8	100.1	46.7	-5.6	177.6
2	29.2	13.1	12.0	17.9	95.2	19.6	-5.1	174.5
2	37.0	21.1	17.5	32.6	100.1	54.0	-9.7	216.5
2	32.5	14.6	13.8	20.8	96.4	33.4	-6.1	215.7

TABLE 31

## CORRELATION COEFFICIENTS OF DATA FOR STORED ELBERTA CULTIVAR

	BM70-160	PRF2-1	PRT2-1	P2/T	F2	Effegi	Color	Mass	Time
BM70-160	1.0000								
PRF2-1	0.9631	1.0000							
PRT2-1	0.9633	0.9672	1.0000						
P2/T	0.8773	0.9187	0.9556	1.0000					
F2	0.2043	0.2103	0.3225	0.3871	1.0000				
Effegi	0.8785	0.8755	0.8776	0.8055	0.2068	1.0000			
Color	-0.2556	-0.2578	-0.2790	-0.2551	-0.0007	-0.3697	1.0000		
Mass	0.1423	0.0426	0.0314	-0.1063	-0.3876	0.1034	-0.0604	1.0000	
Time	-0.8243	-0.8087	-0.7998	-0.7264	-0.2230	-0.7452	0.0162	-0.1525	1.0000

## APPENDIX C

### PRELIMINARY TESTING DATA

Appendix C contains the data for preliminary test. The data from fruit restraint selection test, sampling quality test, within-fruit parameter variation test and temperature test are presented from Table 32 to Table 35 respectively. The No. in Table 32, Table 33 and Table 34 indicates the impulse site number, with each peach having two impulse sites. The parameter in Table 35 is average parameter from two impulse sites of each peach.

TABLE 32  
DATA OF FRUIT RESTRAINT SELECTION TEST

No.	Type 1	Type 2	Type 3
	BM80-130	BM80-130	BM80-130
	(%)	(%)	(%)
1	27.83	23.73	32.23
2	26.87	23.69	21.01
3	24.57	23.10	24.30
4	24.96	24.66	21.83
5	30.96	29.85	21.59
6	26.67	24.54	23.36
7	24.44	24.11	23.41
8	24.49	21.72	22.83
9	24.86	24.05	22.58
10	24.36	23.54	25.50

TABLE 33  
DATA OF SAMPLING QUALITY TEST

No.	Pulse 1	Pulse 2	Pulse 3	Effegi
	BM70-220	BM70-220	BM70-220	
	(%)	(%)	(%)	
1	53.46	54.38	54.81	91.63
2	45.70	47.09	47.37	81.40
3	51.09	51.74	47.19	96.08
4	48.30	45.10	49.61	101.86
5	43.56	40.41	44.57	66.72
6	41.66	47.20	46.93	59.60
7	36.56	41.03	42.77	32.47
8	42.19	43.40	40.07	49.82
9	42.49	48.61	47.96	82.29
10	43.38	39.96	45.25	90.29
11	45.84	46.49	46.39	102.30
12	52.23	52.23	52.28	95.63
13	42.89	43.98	44.48	22.24
14	42.19	43.28	43.71	33.36
15	51.03	51.81	52.59	100.08
16	51.40	52.60	51.59	106.75
17	51.26	51.74	51.47	88.96
18	48.92	49.76	46.27	88.96
19	50.16	51.74	51.83	120.10
20	51.66	51.46	47.77	115.65
21	37.19	38.68	39.04	71.17
22	53.27	48.67	53.79	111.20
23	53.45	52.80	52.78	82.29
24	54.28	49.76	53.94	77.84
25	53.38	53.00	48.77	108.98
26	51.86	52.18	52.76	111.20
27	49.90	50.10	50.05	84.51
28	47.95	47.70	48.82	35.58
29	42.82	43.74	43.29	64.50
30	45.41	45.97	47.54	82.29
31	41.68	42.25	46.85	75.62
32	44.61	50.26	50.01	94.30
33	45.26	48.46	48.39	75.62
34	49.50	49.84	50.72	97.86
35	47.56	47.98	49.32	91.18
36	49.61	45.56	48.29	94.30
37	47.52	48.10	47.73	113.42
38	52.64	51.57	51.05	124.54
39	49.76	49.31	44.60	53.38
40	42.34	47.77	43.63	57.82

TABLE 33 (CONTINUE)

No.	Pulse 1	Pulse 2	Pulse 3	Effegi
	BM70-220	BM70-220	BM70-220	
	(%)	(%)	(%)	
41	47.29	47.75	42.82	108.98
42	50.66	50.71	51.50	111.20
43	46.73	46.78	47.35	97.86
44	47.00	46.84	47.44	102.30
45	51.42	52.21	50.45	115.65
46	46.27	46.64	48.69	113.42
47	49.39	51.29	51.10	97.86
48	46.68	47.35	47.44	97.86
49	49.03	50.53	49.68	94.30
50	48.64	49.80	49.95	120.10
51	49.72	49.41	50.11	95.63
52	38.94	43.78	44.67	93.41
53	48.54	49.93	49.99	54.27
54	45.28	46.61	47.25	71.17
55	41.50	43.78	43.27	60.05
56	42.12	41.88	42.30	73.39
57	38.42	38.96	38.29	44.48
58	47.50	47.96	48.56	96.08
59	48.19	50.20	49.44	104.53

TABLE 34

## DATA OF WITHIN-FRUIT PARAMETER VARIATION TEST

No.	Side 1			Side 2		
	BM80-130	PRT2-1	Effegi	BM80-130	PRT2-1	Effegi
	(%)	(%)	(N)	(%)	(%)	(N)
1	37.82	24.91	20.00	30.55	15.51	20.00
2	38.16	26.72	22.00	36.93	21.57	24.00
3	33.86	18.72	7.50	24.04	10.02	19.00
4	28.77	11.89	13.50	37.46	25.11	25.00
5	38.33	23.04	23.00	38.86	23.44	27.00
6	36.99	22.63	15.50	34.37	21.07	14.80
7	35.22	20.89	19.50	39.77	25.30	22.00
8	41.28	28.69	22.50	35.25	18.71	19.00
9	36.59	22.76	17.50	35.29	21.70	23.00
10	38.06	26.26	20.50	34.57	18.18	20.00
11	36.16	22.81	22.00	37.28	24.55	27.50
12	32.27	17.86	8.40	28.11	14.65	4.30
13	36.16	22.63	21.90	40.33	26.56	26.50
14	30.71	15.01	9.50	23.00	11.13	5.40
15	36.21	21.69	20.60	36.21	21.69	20.70
16	38.83	26.88	24.50	38.39	30.46	23.40
17	33.45	17.25	15.20	35.52	22.88	18.50
18	38.70	24.43	12.50	32.17	17.25	9.60
19	28.07	13.93	2.00	32.02	15.94	2.00
20	37.16	22.81	23.70	36.27	21.45	23.00
21	34.99	19.31	20.00	33.36	18.08	12.00
22	34.63	19.68	18.00	34.05	19.37	18.00
23	36.68	23.39	22.00	35.09	19.56	23.00
24	39.53	29.59	21.00	39.54	25.51	23.50
25	36.35	21.37	22.00	38.32	25.58	25.50
26	34.57	20.52	17.70	39.24	33.56	26.00
27	32.31	18.27	14.00	31.07	15.72	5.50
28	35.14	20.77	21.00	35.41	21.21	23.60
29	37.48	29.40	19.00	36.92	24.47	19.70
30	40.76	28.36	21.50	42.33	30.36	20.40

TABLE 35  
DATA OF TEMPERATURE TEST

Peach No.	Stored Temp.	BM80-130	Effegi
	(C°)	(%)	(N)
1	2	23.64	124.54
2	2	23.87	111.20
3	2	23.36	71.17
4	2	22.20	17.79
5	2	22.60	62.27
6	2	24.11	120.10
7	2	24.15	115.65
8	2	23.70	48.93
9	2	23.95	120.10
10	2	23.59	90.07
11	2	23.42	112.31
12	2	23.29	31.14
13	2	24.04	115.65
14	2	23.23	82.29
15	2	23.28	115.65
16	2	24.12	113.42
17	2	23.49	100.08
18	2	25.50	128.99
19	2	24.33	121.21
20	2	21.80	26.69
21	2	23.65	88.96
22	2	22.93	75.62
23	2	24.24	124.54
24	2	24.16	118.98
25	2	25.30	115.65
26	2	22.14	34.47
27	2	23.21	45.59
28	2	24.11	115.65

TABLE 35 (CONTINUED)

Peach No.	Stored Temp.	BM80-130	Effegi
	(C°)	(%)	(N)
1	24	24.11	34.47
2	24	25.95	115.65
3	24	24.69	100.08
4	24	25.66	45.59
5	24	25.53	40.03
6	24	24.09	21.13
7	24	24.56	15.57
8	24	25.12	61.16
9	24	25.16	103.42
10	24	26.04	115.65
11	24	25.18	111.20
12	24	25.34	93.41
13	24	26.62	108.98
14	24	25.09	52.26
15	24	26.37	115.65
16	24	24.59	86.74
17	24	25.86	54.49
18	24	25.90	115.65
19	24	25.58	61.16
20	24	26.33	115.65
21	24	25.48	51.15
22	24	25.04	110.09
23	24	25.66	26.69
24	24	24.95	83.40
25	24	25.22	104.53
26	24	26.46	78.95
27	24	24.53	16.15
28	24	26.38	105.64
29	24	24.71	13.34
30	24	25.09	96.74
31	24	23.98	13.34

TABLE 35 (CONTINUED)

Peach No.	Stored Temp.	BM80-130	Effegi
	(C°)	(%)	(N)
1	35	22.96	41.14
2	35	24.45	62.94
3	35	23.16	38.92
4	35	24.10	38.48
5	35	24.73	41.14
6	35	24.14	121.21
7	35	24.10	74.50
8	35	25.51	122.32
9	35	25.09	121.21
10	35	25.30	88.96
11	35	23.39	51.15
12	35	24.34	78.95
13	35	23.90	105.64
14	35	24.71	60.05
15	35	23.40	62.27
16	35	25.94	93.41
17	35	24.87	102.30
18	35	24.03	105.64
19	35	25.77	124.54
20	35	23.54	18.24
21	35	23.80	39.59
22	35	24.46	113.42

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