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ULTRASONIC DEVICE FOR AVOCADO SHELFLIFE PREDICTING AND MATURITY DETECTION.

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Abstract

An ultrasonic testing technique was applied to a post-harvested avocado fruit to predict its shelf life and to assess its quality. Measurements of ultrasonic wave amplitude and transit time over the peel of the fruit were used for calculation of wave attenuation and velocity in each individual fruit. Nondestructive ultrasonic tests were performed daily on avocado fruits, until full ripening was detected. Penetration measurements of firmness and physiological tests of dry weight and oil content of the fruit tissue were conducted using accepted methods. Results of the ultrasonic tests were compared with destructive penetration tests, and with physiological tests. Average values of the ultrasonic wave attenuation could be correlated well with storage time and with the ripening process of the avocado. A linear model well represented the changes in attenuation of the ultrasonic signals in the fruit and second-order polynomial expressions the changes in the firmness of the fruit, during storage at room temperature. The wave attenuation increased during storage while the firmness of the fruits decreased. The dry weight of avocado and its oil content were correlated with its ultrasonic parameters and mechanical properties. It is suggested that changes in the ultrasonic parameters during storage may be used to evaluate oil content and firmness to predict shelf life of avocado fruit.

Keywords: Ultrasonic, nondestructive testing, shelf life, quality, fruit, avocado

1. Introduction

Quality-related factors in avocado such as firmness, maturity, oil content and dry weight are important for both growers and customers. Most of these factors are related to each other. Studies have shown that avocado firmness correlates well with fruit maturity and expected storage time (Lewis, 1978). The firmness decline rate is moderate at the beginning, increases later and then stops at full maturity (Zauberman and Fuchs, 1981). Firmness differences in avocado fruits are good indicators of differences to be expected in their ripening stages, since a softer fruit will fully ripen sooner than a harder one. Classifying fruits according to firmness would allow proper distribution of avocado fruit to distant markets and a longer shelf life. Nondestructive firmness control is important, since even a small quantity of ripe fruits in a shipment may trigger a chain reaction and cause premature ripening of the whole 'shipment, due to a high level of ethylene production (Zauberman and Fuchs, 1973). Distinction between hard (unripe), medium (firm ripe), and soft (overripe) fruit may be made by hand. However, it is almost impossible for the human sorter to distinguish between a high-quality freshly picked fruit and a fruit collected from the ground, which may have low quality and short shelf life. This classification is commonly done by a penetrometer, but this is a destructive technique. A nondestructive method for sorting avocado fruit into two or more firmness classes may be of considerable economic interest for all production and consuming stages.

Mizrach *et al.* (1989) evaluated the use of high-power, low-frequency ultrasonic excitation for determination of fruit tissue properties. An experimental system was designed for determination of basic acoustic properties of some fruits and vegetables, namely, wave propagation velocity and attenuation. Further studies by Mizrach *et al,* (1991, 1992) showed strong correlation between the ultrasonic properties and some ripening parameters of the fruit tissue. Galili *et al.* (1993) measured ultrasonic surface waves developed on the peel of a fruit and examined their connection to its internal properties. They found that the ultrasonic attenuation, monotonically increased with the duration of storage time and that the wave velocity have a non-monotonic complex relationship with the storage time.

Mizrach *et al.* (1994) applied the ultrasonic testing technique to the nondestructive quality evaluation of avocado fruits (cv. 'Ettinger') and suggested a technique to reduce the scattering in results by normalizing the time scale of measurements to the day of maximum ripeness. The authors used a non-linear regression procedure for determining models for relating variation in the ultrasound parameters and firmness to storage time, and concluded that models of this type may be used to predict ripening and shelf life of avocado fruit.

The objective of the present paper was to examine the influence of oil content and dry weight on the acoustical measurements, and to assess the avocado properties non- destructively, in terms of firmness, maturity and shelf life.

2. Experimental setup

An experimental setup was designed and constructed for local ultrasonic inspection of whole fruit (Mizrach *et al.,* 1989). The basic setup included a Krautkramer USL 33 high- power low-frequency ultrasonic pulser/receiver, a pair of 50-kHz narrow-band ultrasonic transducers, an electronic gauge to monitor the contact force of the transducers, and a microcomputer system for data acquisition and analysis (Fig. 1). Exponential Plexiglas energy concentrators were used to match each transducer with a chisel-type contact at the fruit surface. A through-transmission mode was selected for the ultrasonic setup. The pulser caused the transmitter to oscillate and launch a narrow-band ultrasonic pulse into the fruit peel this induced waves across the peel and fruit tissue and activated the receiver. The output signal was amplified and displayed on the CRT monitor, where the pulse amplitude and transit time could be visually examined. In parallel, a built-in peek-detector and microprocessor-controlled serial interface captured the signal amplitude and the transit time, and sent the digitized data to the external microcomputer. The stored data used to determine the velocity of wave propagation and the attenuation coefficient of the fruit.

3. Materials and methods

3.1. Fruit selection and procedure

Avocado fruits *(Persea americana* Mill., cv. 'Fuerte'), were taken in a packinghouse during the harvest season. The fruits were taken after the pre-cooling and sizing process and were stored in a cooling room at 5^{o}C for 24 h. The fruits were then placed in an air-conditioned lab of 20^{o}C and about 60% humidity, for acoustical, mechanical, oil content and dry weight tests.

Each fruit was marked on the peel in five locations: one for ultrasonic non-destructive testing (NDT), and four for penetration tests. The four locations for penetration tests were placed so that the diagonals between them crossed at right angles, while the NDT location was marked between two penetration spots. This arrangement minimized the influence on the repeated NDT tests, of local bruising caused by the firmness penetration test.

Destructive tests were conducted after the ultrasonic tests, to determine some of the quality-related parameters of the fruit. These included mechanical parameters (measured by firmness penetration tests) and physiological properties (oil content and dry weight percentage). The relevant test procedures are listed below. All the avocado fruits were subjected to both, ultrasonic NDT and destructive tests.

3.2. Ultrasonic tests

Each fruit was subjected to ultrasonic NDT, daily at one point, and on every second day to a penetration test at one of the other marked points. The acoustical parameters of the fruit, namely the transit time of the acoustical wave and the pulse amplitude, were measured daily until full ripening was detected. The propagation velocity, Cp, of the acoustic wave in the material was obtained by measuring the time t required for the pulse to traverse the gap, l, between the probes and using the expression $Cp=l/t$. The attenuation of the ultrasonic signal was calculated according to the exponential expression (Krautkramer and Krautkramer, 1990): $A = A_0\, e^{-al}$ where A and A_0, respectively are the signal amplitude at the beginning and the end of a distance l along the propagation path of the ultrasonic wave, and α is the apparent attenuation coefficient of the signal.

3.3. Penetration tests

The penetration tests were performed on unpeeled fruit, using a Chatillon durometer (John Chatillon & Sons, New York) with a 6.35-mm diameter cone head and 60º cone angle. Each fruit was subjected to a penetration test every second day at a different marked point. The test was performed in the radial direction near the location of the ultrasonic test (Mizrach *et al.*, 1991). Maximum penetration force (firmness) was recorded at a penetration rate of 3 mm/s. Maximum penetration depth was about 7 mm.

3.4. Oil content and dry weight determination

The oil content of the fruit was determined by means of the refractive index technique (Shannon, 1949). The procedure is described in detail by Lee (1981). Avocado tissue is ground with chloronaphthalene (Halowax oil) and the refractive index of the mixture is measured to determine the oil content.

The dry weight of avocado was determined according to Lee *et al.* (1983). A sample of about 10 g of avocado tissue was taken from the location in which NDT had been performed earlier, and was weighed and dried in a 105ºC forced-air oven for 3 h before being re-weighted for dry weight percentage calculation.

4. Results

The means, standard deviation, and the minimum and maximum values obtained in of the ultrasonic NDT and the destructive tests, which were primarily measured in the avocado batch received from the packing house, are shown in Table 1. Data obtained from of ultrasonic NDT and destructive tests for avocado fruits between harvest and full ripening at room temperature, ranged between 2-5 dB/mm, for attenuation, 105-450 m/s for velocity and 5-100 N for firmness. The oil content of avocado fruits (cv. 'Fuerte') ranges from 10% up to 20%.

Originally, the fruits were tested seven times during 7 days. The variation among fruits in oil content on the first day indicated that the fruits were probably harvested at different stages of maturity. By means of a technique suggested by Mizrach *et al.* (1994), the results were analyzed after normalizing at the same scale of maturity and time base was expended to 216 h in 24 h intervals. The results of measurements of the acoustical, mechanical and physiological properties of the avocado fruits from harvest to full ripeness after normalization procedure are summarized in Table 2.

5. Discussion

When comparing the results measured on the first day with those obtained in the previous studies, the data recorded (Table 1) show wide variability in attenuation and oil content and a relatively narrow distribution of firmness values. The attenuation measured corresponds to the oil content of the fruit. Figure 2 relates the attenuation and oil content measurements on the first day: the measured attenuation was found to be greater for higher then for lower oil content. An exponential expression was selected for the direct relation between the parameters (Chi2=0.0515). It might be suggested that nondestructive ultrasonic attenuation measurements of avocado on the first day after harvest provide an indication of the oil content.

Dry weight (DW) is an acceptable and convenient indicator for evaluation of oil content in avocado when performing the physiological tests. In several previous studies (see, e.g., Lee *et al.*, 1983), the authors indicated a close correlation between oil content and dry weight during maturation. Figure 3 matches the attenuation measurements in avocado fruits against their % DW on the 7th day of this study. It was found that the dry material content of the avocado, which was measured destructively on the 7th day, correlated quite closely with the ultrasonic attenuation of the fruit on the same day (R=0.8127). However, the trend in Figure 3 is opposite to that for oil content mentioned in Figure 2. It might be suggested that the attenuation is influenced by the % DW much more than by oil content.

The calculated velocities and attenuation of the NDT ultrasonic wave in avocado fruits and the firmness, as measured by the destructive tests, during 9 days are illustrated in Figure 4. The firmness diminished with passing time, but not at a constant rate. Small changes could be observed in the mechanical parameters of the fruits during the first days of storage. Then, within about 24 hours, the firmness reduced sharply and the fruits became much softer.

A non-linear regression procedure was used for determining curve fitting to relate variations in firmness and ultrasound parameters to storage time. The nature of the curves for the present study was suggested in previous work by Mizrach *et al.* (1994).

A parabolic function was fitted to the data mean values to describe the model relating the variation of firmness with time and it provided *relatively good correlation (R=0.9946).* It suggests that the firmness of avocado could be predicted satisfactorily from nondestructive measurements of the ultrasonic attenuation in the fruit during the softening on-shelf processes. A monotonic increase in the attenuation of the ultrasonic signal with time suggested selection of a linear model (R=0.9941). A cubic equation was chosen for the velocity versus time curve (R=0.8204). Models of this type may be used for ripening prediction and shelf-life evaluation of avocado fruit.

References

Galili, N., Mizrach, A., and Rosenhouse, G., 1993. Ultrasonic testing of whole fruit for nondestructive quality evaluation. ASAE Paper No. 936026. American Society of Agricultural Engineers, St. Joseph, MI, USA.

Krautkramer, J., and Krautkramer, H., 1990. Ultrasonic Testing of Materials. Springer- Verlag, Heidelberg, Germany.

Lee, S.K., 1981. Method for percent oil analysis of avocado fruit. Calif. Avo. Soc. Yearb. 65:133:141.

Lee, S.K., Young, R.E., Schiffman, P.M., and Coggins, C.W. Jr., 1983. Maturity studies of avocado fruit based on picking dates and dry weight. *J. Amer. Soc. Hort. Sci.* 108:390-394.

Lewis, C. E., 1978. The maturity of avocados - A general review. *J. Sci. Fd Agric. 29:* 875-866.

Mizrach, A., Galifi, N., and Rosenhouse, G., 1989. Determination of fruit and vegetable properties by ultrasonic excitation. *Trans. ASAE* 32:2053-2058.

Mizrach, A., Galili, N., Rosenhouse, G., and Teitel. D.C., 1991. Acoustical, mechanical and quality parameters of winter grown melon tissue. *Tran. ASAE* 34:2135-2138.

Mizrach, A., Galifi, N., and Rosenhouse, G., 1992. Half-cut fruit response to ultrasonic excitation. ASAE Paper No. 923017. American Society of Agricultural Engineers, St. Joseph, MI, USA.

Mizrach, A., Gan-mor. S., Galili, N., Flitsanov, U., and Prigozin, 1., 1994. Model for analyzing ultrasonic signal to assess avocado properties. Presented at the *XII CLG.F' Word Congress and AgEng 94 Conference on Agricultural Engineering*, Milan, Italy. Paper no. 94-G-032.

Shannon, A. F. 1949. Refractive index and other extraction methods for oil in avocados. *Bull Calif. Dept. Agric.* 38:127-132.

Zauberman, G., and Fuchs, Y., 1973. Ripening processes in avocado stored in ethylene atmosphere in cold storage. *J. Amer. Soc. Hort. Sci.* 98: 477-480.

Zauberman, G., and Fuchs, Y., 1981. Effect of wounding on 'Fuerte' avocado ripening. *HortScience* 16: 496-497.

Table 1 - Values of properties of fresh avocados on the 1st day (*7th day for DW).

Property	No. of fruits	Mean	STD	Minimum	Maximum
Velocity (m/s)	50	338.07	55.686	106.43	448.42
Attenuation (dB/mm)	50	2.97	0.498	2.20	4.79
Firmness (N)	50	111.62	4.967	99.00	121.00
DW* (%)	23	30.84	2.855	25.00	35.50
Oil content (%)	9	15.34	2.621	10.30	18.90

Table 2 - Acoustical, mechanical and physiological properties of avocado fruits.

Time (h)	No. of fruits	Velocity (m/s)		Attenuation (dB/mm)		Firmness (N)	
		Mean	STD	Mean	STD	Mean	STD
24	10	361.4	34.4	2.681	0.440	114.67	4.150
48	14	344.0	38.2	2.995	0.778	112.19	5.114
72	33	330.4	69.6	3.045	0.569	109.85	5.424
96	20	344.4	36.6	3.276	0.619	102.50	4.373
120	47	350.5	56.9	3.412	0.585	97.56	7.468
144	42	357.3	49.3	3.729	0.659	82.56	7.858
168	34	348.0	26.2	3.956	0.627	61.74	21.534
192	18	353.4	38.3	4.211	0.679	24.69	17.634
216	34	385.8	87.1	4.333	1.476	4.98	1.765

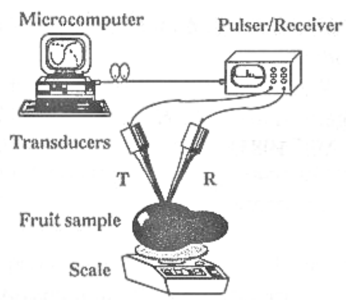

Figure 1 - Schematic diagram of the setup for ultrasonic testing of avocado fruit.

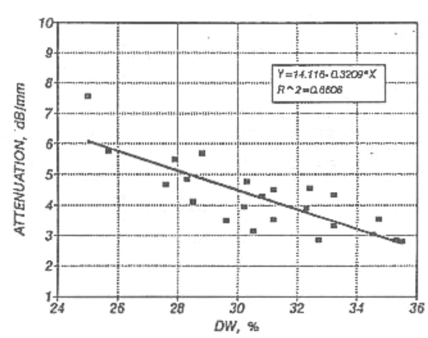

Figure 2 - The ultrasonic attenuation data in avocado fruits versus their oil content on the first day.

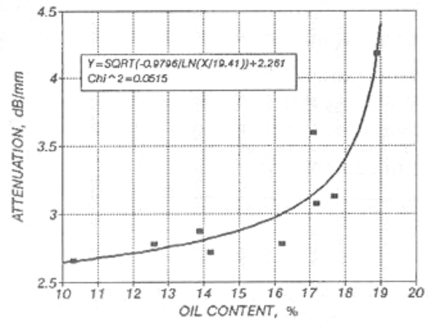

Figure 3 - The ultrasonic attenuation data in avocado fruits versus their % DW on the 7th day.

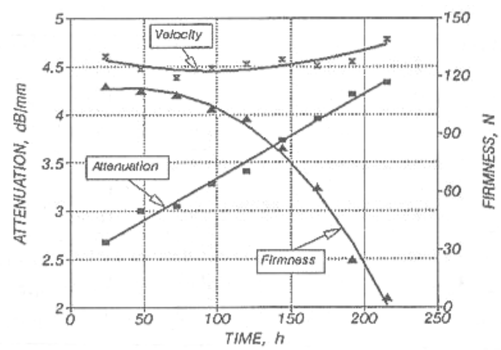

Figure 4 - The means of data points and the suggested model curves for the firmness of fruits, the wave attenuation and the wave velocity versus storage time during 9 days at room temperature.