mental factors resulting from these treatments. The SEB and browning of rib margins correspond to increased moisture loss due to treatment. Moisture loss may occur more rapidly from the stem end of the fruit and/or at the margin of the ribs than from the main portion of the fruit. The airflow rate to which fruit were subjected during treatment may also influence the amount of moisture loss, especially tissue at the rib margins. Decreasing airflow rates during treatment may decrease SEB and rib-browning.

Increases in treatment temperature seemed to retard the depletion of peel green color more than increased treatment time. Reducing treatment temperature below 47°C, with some corresponding increase in treatment time, may provide an environment to achieve probit 9 mortality of CFF larvae and result in a more normal degreening of peel color. Carambolas are generally harvested with green peel, but a uniform yellow color is most desirable for marketing. If they would respond to degreening by ethylene like citrus and tomatoes and change quickly to a uniform acceptable yellow, then the problem of green retention would be eliminated.

From this investigation, we conclude that treatment temperatures above 47°C are not acceptable at the treatment durations of 90, 120 or 150 min. Treatment at 47°C for 90 to 120 min is probably near the T/T threahold for stress that carambolas can tolerate. Further investigations will be conducted during the 1990-91 season which will include lowering the treatment temperature and increasing treatment duration.

Literature Cited

1. Campbell, C. A., D. J. Huber, and Karen E. Koch. 1987. Postharvest response of carambolas to storage at low temperatures. Proc. Fla. State Hort. Soc. 100:272-275.
2. Campbell, C. W., and R. J. Knight. 1985. Carambola production in Florida. Proc. Fla. State Hort. Soc. 98:145-149.
3. Crane, J. H. 1989. Acreage and plant densities of commercial carambola, mamey sepote, lychee, longan, sugar apple, atemoya, and passion fruit plantings in south Florida. Proc. Fla. State Hort. Soc. 102:239-242.
4. Gould, W. P. and J. L. Sharp. 1990. Cold-storage quarantine treatment for carambolas infested with the Caribbean fruit fly (Diptera: Tephritidae). J. Econ. Entomol. 83:458-460.
5. Hallman, G. J. 1989. Quality of carambolas subjected to hot water immersion quarantine treatment. Proc. Fla. State Hort. Soc. 102:155-156.
6. Hallman, G. and J. Sharp. 1990. Hot water immersion quarantine treatment for carambolas infested with Caribbean fruit fly (Diptera: Tephritidae). J. Econ. Entomol. 83:1471-1474.
7. SAS Institute. 1982. SAS User's Guide: Statistics. SAS Institute. Cary, NC.

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AUTOMATIC DENSITY MEASUREMENTS FOR QUALITY SORTING OF 'MARSH' GRAPEFRUIT

W. M. Miller and W. L. Verba
University of Florida, IFAS
Citrus Research and Education Center
700 Experiment Station Road
Lake Alfred, FL 33850

Additional index words. grading, machine-learning.

Abstract. **A 2-lane automatic sizer was utilized to measure the density of 'Marsh' grapefruit. Tests were conducted throughout one season to compare laboratory measurements of mass, volume, and density with those obtained from the automatic sizer. The prototype sizer used a cup conveying system with load cells (mass) and a line scan camera (dimensional). Seasonal sampling of grapefruit indicated density levels ranging from 0.74 to 0.86 g/cm³. A test panel was also established to obtain a human's perception of fruit size relative to the physical measurements collected. A linear relationship was found between their classification and actual fruit diameter.**

Quality assessment of fresh fruits and vegetables by nondestructive techniques has been the objective of numerous postharvest engineering projects (1). A multitude of sensor techniques are now available: optical (spectral reflectance, light transmittance, delayed light emission), mechanical (firmness, quasistatic or dynamic, vibrational response, ultrasonic and sonic transmission or emission), dielectric and physical (x-ray attenuation surface roughness). This research project was directed toward real-time measurement of an inferential quality indicator, density, by means of an automated weighing and dimensional measuring system.

For citrus, relatively large changes in density are observed after freeze-damage occurs. The commercial packinghouse practice has been to install a fruit separator unit, based either on flotation in an oil and water emulsion or hydrodynamic separation (3). These liquid separation procedures have limited accuracy and reduce packingline capacity (5). Electronic sensors with computer control for weight sizing have been widely adopted in the United States for certain commodities such as apples. With the recent advances in solid state cameras for optical-based dimensional measurements, the weight and dimensional measurements required for density sorting can be achieved at acquisition rates necessary for commercial citrus packing. Typically, this rate is considered 5-10 fruit/sec/lane. Questions remain unanswered as to the required accuracy for density separation (2), resolution to detect quality differences as a function of variety, season, etc., and the correlation of density with fruit quality. Regarding the latter, it has been cited for oranges that specific gravity of the whole fruit was found to correlate with the pounds-solid (4).

In this paper, results will be discussed related to the following objectives:

1. Analyze the accuracy of weight and optical-based dimensional measurements for density separation of grapefruit.
2. Measure density variations for one citrus variety, 'Marsh' grapefruit, throughout one season.

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As an addendum to this study, a sizing panel was formed to evaluate human performance in assessing fruit size.

Materials and Methods

'Marsh' grapefruit samples were harvested from the same block of trees at the Lake Alfred Citrus Research and Education Center during the 1986-87 season on 10 different test dates. The first sample was harvested on 21 Oct 1986 and the last on 27 Apr 1987. All fruit were washed and waxed on a small packingline simulating commercial practice. A 25-count subsample for panel sizing tests was randomly selected from a harvested sample of approximately 400 fruit. Of the initial sample, 100 were used to obtain weight and dimensional data.

All automated weight, dimensional, and density measurements were acquired with a 2-lane prototype sizer provided by Durand-Wayland, LaGrange, GA. The mechanical system consisted of a singulator section, settling wheels, and a 2-lane cup conveyor system typically operated at 4 cups/s. Real-time data acquisition and control hardware was interfaced with an IBM-XT microcomputer for operator control of drop schedules, breakpoints, etc. Data acquisition programs were written in Pascal to acquire and statistically analyze weight, diameter, and density values. Weight values were measured with a strain gage load cell, 4.5 kg (10 lb) capacity, associated with each lane of the conveying system. Dimensional measurements were taken with a line scan camera with 0.15 cm (0.06 in.) resolution [38 cm (15 in.)/256 pixels, 15 cm (.06 in.)/100 scans]. For measuring a fruit's dimensions, a program had been developed to a) find the center of the product from its 2-dimensional planar image, b) take 8 cross-sectional measurements at 22.5° increments, and c) rank the 8 measurements from minimum to maximum. From this ranked order, the arithmetic average of dimensions 2, 6, and 7 was used for volume calculations representative of an oblate spheroid. For laboratory measurements, the mass was found with a top loading balance, 0.1 g (0.0002 lb) resolution, and the volume was obtained by water displacement. Based on the volume, an average diameter was calculated:

$$\bar{d} = (6V/\pi)^{0.333}$$

A sizing panel of 6 individuals was instructed to place a 25 grapefruit subsample into 1 of 5 size categories (1 = smallest, 5 = largest). For half of the panel, other fruit in the sample were hidden as the panelist made the classification. For the other half of the panel, all 25 fruit were available for comparison. This panel member arrangement was altered after each test. After 10 tests, each panelist had been asked to size 5 sets with no comparison and 5 sets with the complete sample set available for comparison.

Results and Discussion

Machine accuracy. With the data from the 10 grapefruit tests, comparisons were made of the automatic sizing unit values for mass, diameter, and density with laboratory determined values. In Fig. 1, the mass values have been plotted and, in Fig. 2, a corresponding plot for dimensional data has been generated. Mass values determined on the automatic unit and measured in the laboratory were highly correlated ($r^2 = 0.99$) with close to a 1:1 correspondence in slope ($dy/dx = 0.99$). In the case of the dimensional comparison, more variability, and a lower correspondence

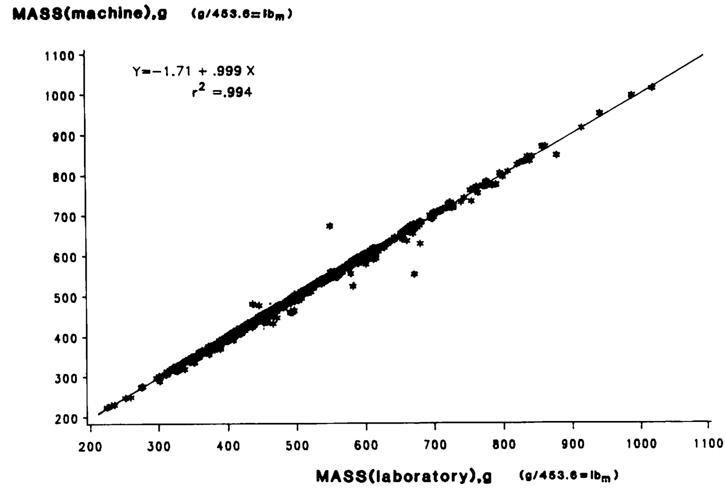

Fig. 1. Mass-machine versus mass-experimental for 'Marsh' grapefruit.

($dy/dx = 0.92$) was found although the linear regression was highly significant ($r^2 = 0.886$). Another trend observed was greater variability with larger fruit size. An error analysis of the required accuracy for 1% RMS density accuracy was developed by Miller (2) where it was noted that a 0.024 cm (0.0094 in.) diameter accuracy was required for the ideal case of spheroidal fruit. Required accuracy for mass was 3.2 g to achieve this 1% density accuracy.

With a camera resolution of only 0.15 cm (0.06 in.) and the volume calculation based on average diameter cubed, a large scatter was obtained when plotting density-machine versus density-laboratory (Fig. 3). However, the r^2 value of 0.141 was highly significant. A major question that arises is: Based on the variability of the data of Fig. 3, what percentage of the fruit would be correctly classified by the machine? To answer this query, 3 breakpoints (i.e., separation point(s) between grades) were considered at densities of 0.75, 0.80, and 0.85 g/cm^3 (46.8, 49.9, and 56.6 lb/ft^3). By intersecting lines of machine-calculated densities with laboratory densities at these levels, values falling in the first and third quadrants would be correctly classified. Mis-

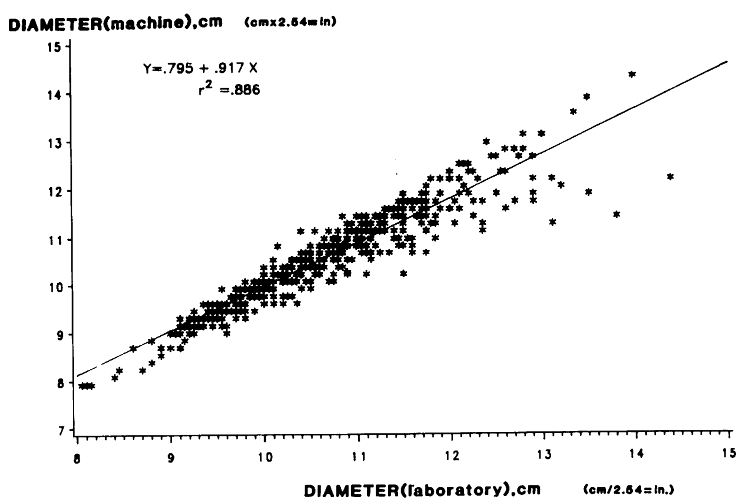

Fig. 2. Diameter-machine versus diameter-experimental for 'Marsh' grapefruit.

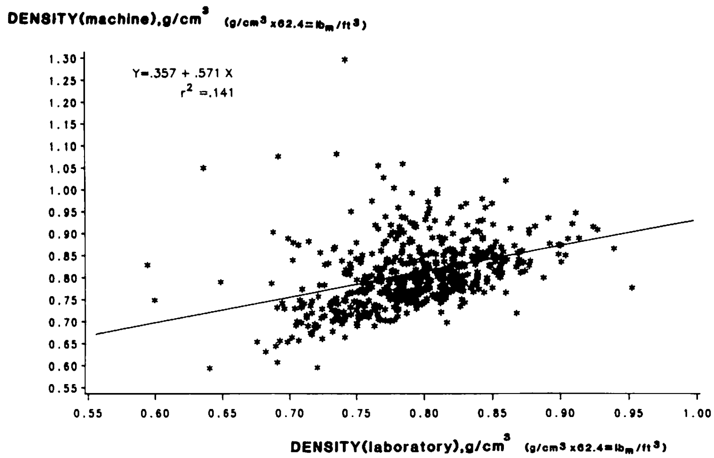

Fig. 3. Density-machine versus density-experimental for 'Marsh' grapefruit.

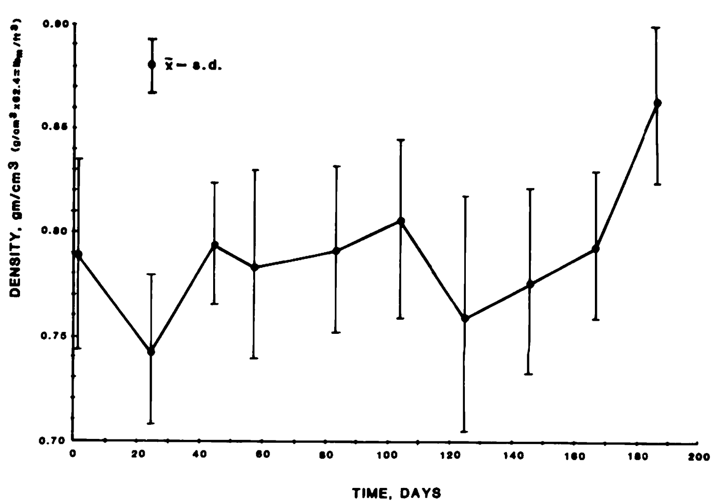

Fig. 4. Seasonal fluctuation in density values of 10 samples of 'Marsh' grapefruit.

classifications would fall into the second and fourth quadrants. From the values calculated for Table 1, the midrange breakpoint of 0.80 yielded the lowest correct classification of 65.2%. At a 0.75 breakpoint, the correct classification was 81.8% and, at 0.85, 73.0% of the fruit were correctly classified. Note that quadrant II represents grapefruit that machine sorting identified as acceptable (> breakpoint) which actually were unacceptable while quadrant IV contains data representing fruit the machine identified as unacceptable (< breakpoint) which actually were acceptable.

Seasonal variation. Density variability found throughout a season would be an important consideration with respect to the breakpoint analysis presented previously. Samples of 'Marsh' grapefruit were harvested over a 190-day season to establish what variability in density might be anticipated. A minimum average density [ρ = 0.743 g/cm^3 (ρ = 49.4 lb/ft^3)] was found in the 14 Nov 1986 sample w hile the maximum average [ρ = 0.864 g/cm^3 (ρ =57.5 lb/ft^3)] was measured for the last sampling date, 27 Apr. 1987. In all samples, a wide variation in density was observed (Fig. 4). Standard deviations ranged from ± 0.029 to ± 0.056 g/cm^3 (1.80 to ± 3.49 g/cm^3).

To investigate how fruit with these density measurements would be classified, a normal distribution equation:

$$f(x) = \left(\frac{1}{\sigma\sqrt{2\pi}}\right) e^{-\frac{1}{2}\frac{(x-\mu)^2}{\sigma}}$$

was used to generate probability areas for breakpoints of 0.75, 0.80, and 0.85 g/cm^3 (46.8, 49.9, and 56.6 lb/ft^3) used previously. At the 0.75 breakpoint, 2 samples would have resulted in classification of less than 70% acceptance (Table 2). At the 0.80 and 0.85 breakpoint level, the percentage of fruit classified acceptable was reduced markedly. Other than the final sample, less than 60% of the fruit would have been classed as acceptable at the higher breakpoints.

Table 1. Percent correctly classified via machine as a function of three breakpoint settings.

Breakpoint, g/cm^3 (lb/ft^3)	Correct classification, %
0.75 (46.8)	81.8
0.80 (49.9)	65.2
0.85 (53.0)	73.0

Human sizing performance. In conjunction with the principal objectives of this study, we attempted to assess human performance in sizing. Based on 5 size categories, the panel performed well in sizing assessment (Fig. 5). Their sizing classifications were highly correlated (r^2 = 0.760)with experimentally measured diameters. No significant difference was found between the 2 sample presentation methods; either no sample comparison or complete sample set comparison.

Summary

An automatic sizing unit initially designed to separate fruit based either on weight or optical-based dimensions

Table 2. Density variations and percent acceptable fruit for 10 'Marsh' grapefruit samples taken over one season.

Sample no.	Density[z] g/cm^3 (lb/ft^3)	Acceptable, %		
		BP[y]=0.75	BP=0.80	BP=0.85
1	0.789 ± 0.046 ab[x] (49.2 ± 2.9)	0.80	0.41	0.09
2	0.743 ± 0.036 a (46.4 ± 2.2)	0.42	0.06	0.00
3	0.795 ± 0.029 ab (49.6 ± 1.8)	0.94	0.43	0.03
4	0.784 ± 0.046 ab (48.9 ± 2.9)	0.77	0.36	0.08
5	0.792 ± 0.040 ab (49.4 ± 2.5)	0.85	0.42	0.07
6	0.802 ± 0.043 ab (50.0 ± 2.7)	0.89	0.52	0.13
7	0.761 ± 0.056 a (47.5 ± 3.5)	0.58	0.24	0.06
8	0.777 ± 0.045 ab (48.5 ± 2.8)	0.72	0.31	0.05
9	0.794 ± 0.036 ab (49.5 ± 2.3)	0.89	0.43	0.06
10	0.864 ± 0.039 b (53.9 ± 2.4)	1.00	0.95	0.64
Overall	0.790 ± 0.031 (49.3 ± 1.93)	0.82	0.41	0.12

[z]Mean ± std. deviation.
[y]BP = breakpoint (separation point between grades).
[x]Duncan's test (5% significance level).

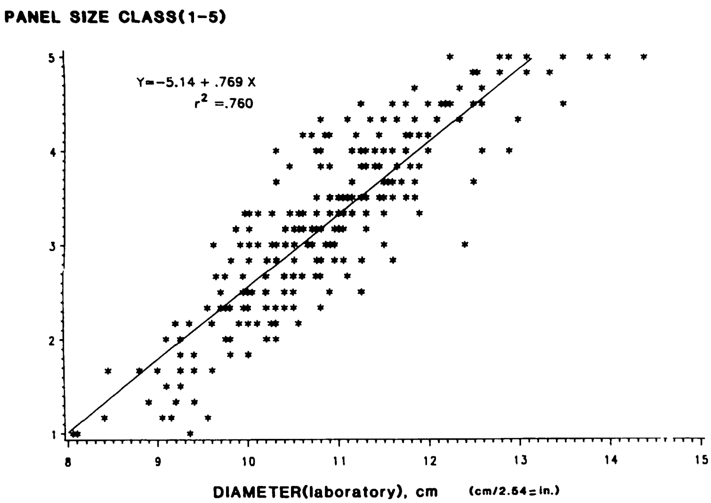

Fig. 5. Human performance is sizing; panel classification versus experimentally determined diameter.

was modified to combine the 2 sensor measurements for density calculations. Both laboratory and machine measurements were compiled for 'Marsh' grapefruit to assess the variability expected throughout a harvest season and the accuracy of the automated unit. The weight measurements, laboratory versus machine, compared favorably ($r^2 = 0.994$, dy/dx = 0.99) but more variation was found in the dimensional comparison ($r^2 = 0.886$, dy/dx = 0.92). This dimensional relationship, coupled with a required volumetric calculation based on a planar image of the fruit, resulted in relatively low but significant density correlation ($r^2 = 0.141$, dy/dx = 0.57). Dependent upon the breakpoint setting, this amount of variability may, or may not, be acceptable. At a breakpoint of 0.75 g/cm³ (46.8 lb/ft³), 81.8% of the grapefruit would have been correctly classified. This 0.75 breakpoint appeared to be reasonable based on seasonal sampling of grapefruit. Laboratory density levels fluctuated from 0.743 ± 0.036 to 0.864 ± 0.039 g/cm³ (46.4 ± 2.25 to 53.9 ± 2.44 lb/ft³). In general, samples from later in the season exhibited higher density levels.

Literature Cited

1. Gaffney, J. J. (ed.). 1976. Quality detection in foods. Amer. Soc. Agr. Eng., St. Joseph, MI.
2. Miller, W. M., K. Peleg, and P. L. Briggs. 1986. Computer-based inspection of freeze damaged citrus. ASAE Paper No. 86-6554. St. Joseph, MI.
3. Perry, R. L. and R. M. Perkins. 1968. Separators for frost damaged oranges. The California Citrograph, 53(8):304-305, 307-308, 310, 312.
4. Ting, S. V. and J. G. Blair. 1965. The relation of specific gravity of whole fruit to the internal quality of oranges. Proc. Fla. State Hort. Soc. 78:251-260.
5. Wardowski, W. F. and W. Grierson. 1972. Separation and grading of freeze damaged citrus fruits. IFAS Cir. No. 372. University of Florida, Gainesville, Fla.

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A SIMPLIFIED ANALYTICAL PROCEDURE FOR THIABENDAZOLE IN CITRUS DRENCHER SUSPENSIONS

DAVID J. HALL
Agri-Chem, Inc.
P. O. Box 607477
Orlando, FL 32860-7477

Additional index words. drenchers, fungicide analysis, solvent safety.

Abstract. **A simplified procedure is described for the estimation of thiabendazole (2- (4-thiazolyl)-benzimidazole) in pallet box drenchers. The method is useful in the concentration range of 200 to 1800 ppm without dilution. Suspensions with a higher concentration may be diluted with water. In this method, a representative sample of treating material and sodium hydroxide is added to a screw top culture tube containing a chlorinated hydrocarbon solution of cupric acetate and 1-dimethyl-amino-2-propanol. The mixture is shaken and then allowed to stand while the phases separate. The chlorinated hydrocarbon layer is read on a portable colorimeter. Total time from sampling to result can be less than 10 minutes. Several chlorinated hydrocarbons can be used.**

Appreciation is expressed to B. G. Harmon Fruit Co., Groveland, FL and Fresh Mark Corp., Ocoee, FL for assistance given by their personnel in developing this procedure.

Treating fruit with a fungicide before degreening is an effective method for controlling both Diplodia stem-end rot and green mold. Since delays of more than 24 hr between harvest and treatment can seriously reduce the effectiveness of the treatment (3), pallet box drenchers are becoming common in Florida (7).

Two types of drencher are currently in use, traditional drenchers and truck drenchers. In the traditional drencher, pallet boxes are loaded on a conveyor which carries them under a manifold that floods fungicide suspension onto the boxes (6). In a truck drencher the load is left on the truck which is driven into the applicator which floods the suspension over the load (7, 8). In either case the suspension is collected in a sump for recirculation.

Until the 1989-90 citrus packing season, the fungicide of choice for use in drenchers was benomyl as it was relatively inexpensive and easy to use. With the withdrawal of postharvest uses of benomyl, thiabendazole (TBZ) has become the only practical fungicide available for this application (5, 16). While imazalil will work in drenchers, its use in Florida is limited by its higher cost and lower effectiveness against Diplodia stem-end rot compared to TBZ (3, 4, 5).

Both TBZ and benomyl are insoluble materials, and in an aqueous system there is a tendency to settle out. There is also a tendency for the fungicide to remain on the fruit