THE RELATIONSHIPS AMONG SEVERAL PHYSICAL AND CHEMICAL MEASUREMENTS MADE ON ORANGES

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With rapidly increasing orange production, it becomes more important to maintain or expand the fresh fruit market. Twelve million boxes of the 20.5 million box yield increase in 1961-62 over 1960-61 went to the fresh fruit market. The prices received in the 1961-62 season also proved to many growers how important it is to maintain two market outlets for their fruit.

One method of maintaining or improving fresh fruit sales would be to upgrade the average quality of packed fruit by removing the relatively poorer quality fruit from any lot. Long, et al. (4, 5, 6) have shown strong relationships for Marsh and Duncan grapefruit between fruit weight, specific gravity, juice volume, and diameter and juice volume. These reports show less strong relations between juice volume and soluble solids, or citric acid, or their ratio. Long (2) has pointed out that in the Murcott honey orange strong correlations exist between taste test results and the Hunter "a" value for rind, or chlorophyll absorption, or peak wave length of transmitted light. These correlations were stronger than those between taste and soluble solids, citric acid or their ratio.

The objective of the work reported here was to study in Florida oranges the relationship among physical and chemical measurements.

MATERIALS AND METHODS

In the main study, measurements were made on Pineapple and Valencia oranges at approximately two-week intervals beginning in September, 1961, continuing until February, 1962, for Pineapples and until May for Valencias.

The periodic samples consisted of five fruits from each of five trees, picked at random around the canopy between two and seven feet above the ground. Fruits were washed and the measurements taken. Each fruit was calipered and weighed, and the volume was taken by water displacement (10, 11). The Hunter "a" values were determined for the rind by taking two readings at random around the equator of each fruit. The fruits were cut and the Hunter "a" value of the pulp determined (9). The juice was extracted, the volume measured, and the Hunter "a" value determined. The total solids was determined with a hand refractometer and citric acid by titration with a standard sodium hydroxide solution using phenolphthalein as the indicator.

In other studies, Valencias (June) were washed, waxed to prevent shrinkage, sized, and stored until the measurements could be made. Fruit were weighed, calipered, and volume taken by water displacement. Fruits were juiced and the volume measured. Total solids were measured with a hand refractometer.

RESULTS

The results of these periodic measurements are shown in Tables 1 and 2. The Hunter "a" values for rind color changed from minus (green) to plus (red) and increased with the season. Fruit size, weight, and volume increased progressively. Soluble solids increased while the acid decreased.

Calculations of the linear correlation coefficients between the pairs of measurements showed good correlation between the Hunter "a" value and solids (Table 3). However, stronger correlations existed between fruit size (diameter) and weight, fruit size and juice volume, juice volume or fruit weight. This resembles the conclusions made previously by Long, et al. for grapefruit (4, 5). Such calculations were not made for Murcotts (2), but from the data in a later report (6) such correlations would appear to exist.

Studies on mature Valencias tested the relationship between size, fruit volume, or fruit weight and juice volume. Results show that the linear correlation coefficients (r) were stronger between size (diameter) or fruit weight, and juice volume than with other measurements (Table 4). The "r" values were high for individual mature fruits, supporting the possibility that elimination of the low weight fruits or relatively poor colored fruits would improve the juice volume and probably the internal qualities of oranges.

DISCUSSION

Previous reports (4, 5, 8) have pointed out the fact that soluble solids and citric acid con-

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Table 1. Changes in measurements on Pineapple oranges during the season. Average of five 5-fruit samples.

Sample Date	Hunter "a" Rind	% Juice	Fruit Wt. g.	Diameter Inches	% Solids	% Acid
9/25	-.66	--	144	--	8.5	1.8
10/9	-.65	52	148	2.63	9.5	1.6
10/23	-.55	55	155	2.69	10.2	1.4
11/6	-.50	57	161	2.56	10.2	1.3
11/20	-.10	54	158	2.69	10.7	1.1
12/4	.22	53	177	2.81	11.2	1.0
12/18	.47	51	171	2.75	11.8	1.0
2/1	.79	50	171	2.75	12.6	1.0

Table 2. Changes in measurements on Valencia oranges during the season. Average of five 5-fruit samples.

Sample Date	Hunter "a" Rind	% Juice	Fruit Wt. g.	Diameter Inches	% Solids	% Acid
9/25	-.76	--	135	--	7.3	2.7
10/23	-.72	52	161	2.69	7.9	2.1
11/20	-.63	53	169	2.69	8.3	1.7
12/4	-.54	55	177	2.75	9.0	1.5
12/18	-.17	55	187	2.81	9.4	1.4
2/1	.33	54	192	2.81	10.2	1.3
2/15	.39	55	214	2.94	9.9	1.1
2/26	.46	56	207	2.88	10.3	1.2
3/7	.52	57	226	3.00	11.3	1.0
3/25	.55	58	222	2.94	10.6	1.0
4/8	.54	58	206	2.88	11.6	1.0
4/22	.46	57	199	2.88	11.4	0.9
5/6	.52	56	230	3.00	11.4	0.9

tent of citrus fruit are not infallible guides to consumer acceptance. Long, et al. (4, 5, 6), investigating relation of physical measurements to internal quality, reported strong relationships between fruit weight, volume, or size to juice volume. In other papers (2, 3, 7) they noted strong correlations between color measurements and results of taste tests (palatability). In these studies, fruit weight, volume, or size was also found to be strongly related to juice volume.

Weight sizers are available and commonly used for apples and avocados. Specific gravity separators (1, 10, 11) have been used for years to separate frozen from unfrozen citrus, or

Table 3. Linear correlation coefficients (r) between measurements on Valencia and Pineapple oranges.

Measurement X	Measurement Y	Correlation Coefficients Pineapple	Valencia
Hunter "a"	Solids	.78	.87
Hunter "a"	Juice Volume	.78	.71
Fruit Volume	Juice Volume	--	.94
Fruit Weight	Juice Volume	.89	.97
Fruit Weight	Diameter	.97	.97
Diameter	Juice Volume	.81	.94

grapefruit with thick and thin rinds for juicing or sectionizing. However, lighter than water emulsions are difficult to handle and often are flamable. Electronic color sorters are expensive.

Table 4. Linear correlation coefficients (r) between fruit weight or diameter and juice volume of mature Valencia oranges.

Size	Lot No. 1 Fruit Weight X Juice Volume	Lot No. 1 Diameter X Juice Volume	Lot No. 2 Fruit Weight X Juice Volume
125	0.75**	0.70**	0.84**
150	.31 N.S.	.21 N.S.	.71**
176	.71**	.51**	.48**
200	.70**	.55**	.76**
216	.49**	.42**	.63**
252	.73**	.41**	.71**

Table 5. Number of fruits, minimum and maximum juice volume and fruit weights of Valencia oranges.[a]

Fruit Size	No. of Fruits	Juice Volume Min.	Juice Volume Max.	Fruit Weight Min.	Fruit Weight Max.
125	21	132	168	278	331
150	40	102	140	237	305
176	37	100	138	210	258
200	117	60	124	182	240
216	86	70	106	170	207
252	52	74	104	153	192
288	41	53	90	113	160
324	12	46	76	112	137

[a]Lot 1.

Consequently, weight sizing appears to be a possibility for upgrading the juice volume and fruit quality by removal of "low juice fruits," and will be the subject of further experimentation.

SUMMARY

Measurements made at intervals of two weeks on Pineapple and Valencia oranges and on mature Valencia oranges show highly significant linear correlation coefficients between fruit size, fruit weight and juice volume. The potential use of size and weight to remove low juice fruit and possibly upgrade fruit quality is pointed out.

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