and 0.70 percent. On the basis of these findings, it would seem advisable to manufacture grapefruit oils during the months of February, March, and April to obtain oils with the best odor and flavor characteristics. The production of early season oils should be avoided since they appear to have less desirable odor and flavor qualities.

Physical and chemical properties.—A progressive increase in the nootkatone content of the expressed grapefruit oils from 0.065 to 0.810 percent was observed as the fruit became more mature, Table 1. This is greater than a tenfold increase and could probably be used as a measure of fruit maturity. The physical and chemical characteristics of the six oils are presented in Table 2. It can be seen from these data that the values for: specific gravity, refractive index, optical rotation, evaporation residue, acid number, %-free acid, %-ester before acetylation, and %-free alcohol remained more or less constant throughout the processing season. There was a tendency for the %-total alcohol and %-ester after acetylation to decrease, but this is due to aging of the oil samples rather than to fruit maturity. The %-aldehyde increased as the fruit ripened, reaching a plateau in February, March, April, and May, but decreased in June. This is contrary to what the authors (2) have found for coldpressed Valencia orange oil. Since both the nootkatone and aldehyde content increase with fruit maturity, and since these are factors which apparently contribute to flavor as evidenced by the organoleptic studies, it would seem that the ideal time to recover oil from the standpoint of good odor and flavor quality would be when both of these factors reach a combined optimum.

The seriously lower yield of oil obtained when processing grapefruit of greater maturity requires careful consideration by the processor as to the importance of nootkatone and aldehyde content to the potential buyer of his oil since other unknown variables may exist which also have an influence on flavor. The yield of oil recovered from the fruit diminished from 2.55 lb/ton fruit to 0.50 lb/ton fruit as the first ripened (5). A compromise can possibly be made between yield and good flavor quality in order to make oil production economically feasible.

ACKNOWLEDGMENTS

Grateful acknowledgment is made to: Fritzsche Brothers, Inc., New York; International Flavors & Fragrances (U. S.), New York; and Neumann-Buslee & Wolfe, Chicago, for their help and assistance in the organoleptic evaluation of the oils. The fruit used in this study was supplied courtesy of Cypress Gardens Citrus Products, Inc., Winter Haven, Florida. For all of their courtesies and contributions, the authors express their appreciation and thanks.

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CITRUS SIZING — METHODS AND ECONOMIC EFFECT

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Citrus fruit is referred to in terms of size most frequently by a specified number of fruit which are packed into a 1-3/5 bushel capacity crate. For example, size 96, 125, 163, 200, etc. for oranges and size 46, 54, 64, 70, etc. for grapefruit. The same kind of designation applies to other citrus fruits, such as tangerines, temples and tangelos.

Belt and roll sizers have long been used in Florida citrus packinghouses to mechanically size fruit. They were mounted on each row of bins from which fruit was manually place-packed. In recent years, where changes involving the sizing equipment have been made in citrus packinghouses, mostly "central" or "master" sizers still employing the belt and roll principle have been installed. In a few cases, perforated belt sizers have been installed, mainly for tangerines, and drop-roll or expanding roll type sizing equipment, mainly for oranges and grapefruit.

In the day-to-day activity of a fresh citrus packinghouse, the actual dimensions of fruit packed may be treated somewhat casually since the official requirements specify number of fruit per container. There is need for management to keep alert relative to means of sizing and to dimensions of fruit packed as compared to standards, however, in order to make decisions about equipment and obtain maximum returns from the fruit input. Since there is overlap in the diameter dimension ranges for different sizes of fruit, such as oranges or grapefruit, adjustments in sizing can be made which affect either favorably or unfavorably the number of boxes packed on the count basis from a given fruit input. Changes in packing methods or plant layout, for example, may influence the design features of sizing equipment.

There are a number of ways in which sizing of fruit and other produce can be accomplished mechanically. Some that are commonly known are referred to in equipment terminology as chain (mesh belt), perforated belt, belt and roll, expanding roll, and weight. All of the mechanical arrangements mentioned except the weight-type do what is termed dimension sizing. That is, the equipment measures the physical size of the product by either two-point sizing or four-point sizing. The chain type represents a means of four-point sizing while the belt and roll type represents a means of two-point sizing.

Citrus fruits fall into two geometric shape categories - oblate and prolate spheroids. Grapefruit which are usually "squeezed in" on the stem blossom axis making this dimension less than the diameter are classed as oblate spheroids. Lemons or limes, for example, which normally have a polar dimension (the stem blossom axis) greater than their diameter are classed as prolate spheroids. It is necessary that the make-up of mechanical sizing equipment take this into account.

Citrus sizing was studied in a cooperative research program of the Florida Citrus Experiment Station and Agricultural Research Service, United States Department of Agriculture. Purposes of the research effort were: to obtain data on the performance of central sizing equipment employing the belt and roll principle as compared to belt and roll sizers on bins; to explore the sizing action and adaptability of different types of equipment as applied to citrus; and, to develop guide lines for improved equipment and practices for sizing citrus.

Procedure for the studies in commercial packinghouses was to take samples at random of fruit coming from the sizer. Identical procedure was followed for various size groups with 100 fruit in each sample. In some cases the samples were taken from the bins and in others they were taken from the belt conveyors carrying the fruit away from the sizer. This depended primarily upon whether a central sizer was being used or whether there was belt and roll sizing equipment mounted on bins. Each fruit was measured for the polar dimension and for the equitorial diameter. The "sizer setting" was determined, i.e., the distance between the belt and roll for each size group, was measured, or the hole diameter in a perforated belt sizer or distance between rollers at the drop-through point for a drop roll sizer, respectively. The surface speed of the belt and of the rolls was obtained where equipment of that type was used in sizing the fruit which was sampled.

In the analysis of data which has been made, a number of points have received attention.

The ratio of height (polar dimension) to the equitorial diameter was computed for all samples and ranged from .92 to .98 for oranges, from .83 to .88 for grapefruit, and from .75 to .78 for tangerines.

The average fruit diameter in samples was compared to the sizer setting for belt and roll sizing equipment in several different packinghouses and for one drop-roll sizer installation. A pattern was indicated in the fruit diameter sizer setting relationship for belt and roll equipment in which the sizer setting was found to be slightly greater than the average fruit diameter for oranges while for grapefruit the opposite relationship, sizer setting slightly less than the average fruit diameter, was found (figs. 1 and

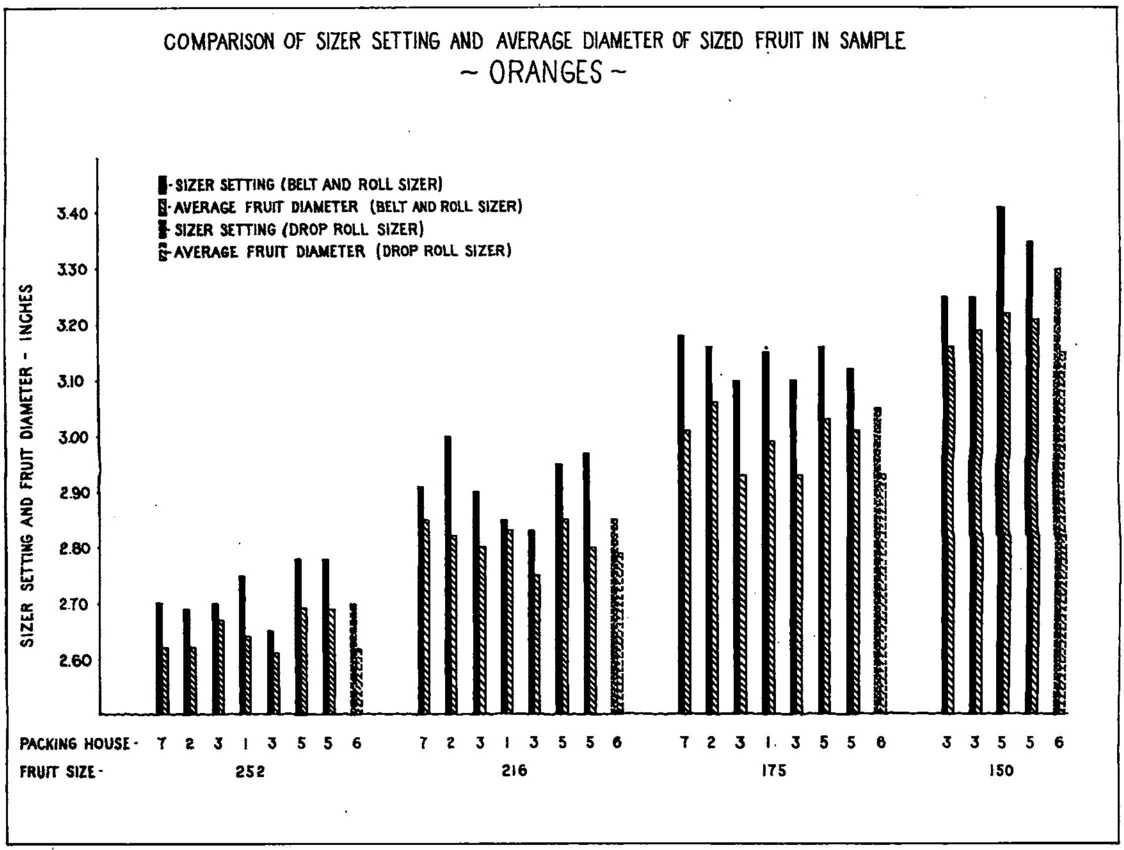

Figure 1

2). The average difference was 0.11 inches for 25 samples of 100 oranges and minus 0.05 inches for 21 samples of 100 grapefruit. This pattern must be recognized by personnel who set belt and roll sizers and who made adjustments to them, in order to obtain the desired sizing results.

On the drop-roll sizer with smooth, straight rolls, the fruit diameter-sizer setting relationship for oranges was essentially the same as already given on the belt and roll sizers. For grapefruit, the difference was in the same direction as for belt and roll sizers, but conspicuously greater (figs. 1 and 2). The amount of difference indicates a deficiency, virtually complete lack of needed orientation action, with respect to sizing grapefruit or other citrus fruit in the oblate spheroid classification.

The distribution of diameters in each size category for each study was examined. Frequency charts were plotted (fig. 3) and standard deviation computations were made.

The range, which is the difference between the minimum and the maximum diameters in a sample of sized fruit, and the average diameter, both are determined by the distribution. In turn, these affect the proportion of sized fruit which is within the desired dimension range (fig. 3).

The standard deviation gives a measure of variability of any group of diameter measurements. Thus, standard deviation values provide a means for comparing variability between different sizing treatments such as equipment types, speeds and settings. Also, the standard deviation for a group of sized fruit diameter measurements is an indicator of the minimum and maximum dimensions between which, when the same sizing treatment is given, a specific proportion of the diameter dimensions may be expected to fall.

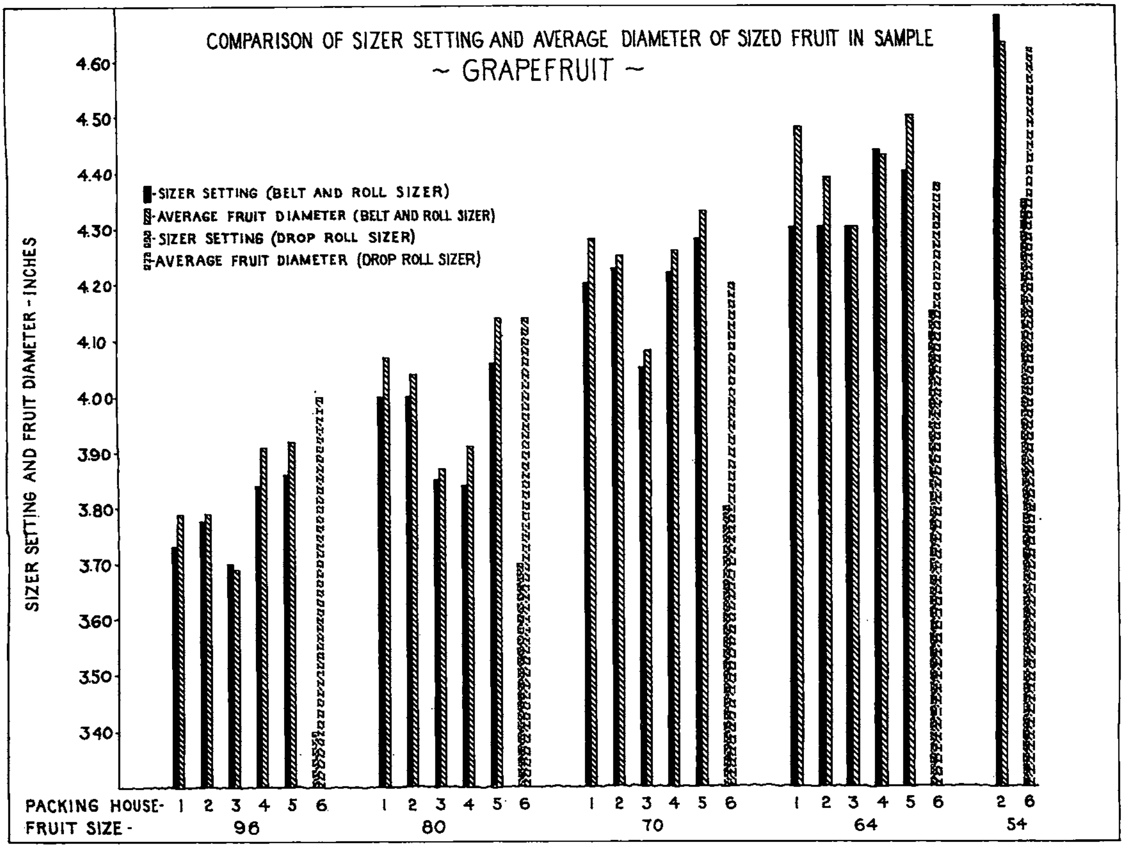

Figure 2

For example, this proportion would be 95 percent if the minimum and maximum diameters are taken as minus two standard deviations and plus two standard deviations, respectively, from the average fruit diameter for the group (fig. 3).

The variability in sized fruit diameter was not substantially different for fruit from either central or bin-row sizers employing the belt and roll principle.

Standard deviation values of the diameters in samples of sized tangerines were used to compute the coefficient of variation for each sample which indicated more uniformity of sizing with the perforated belt sizer than with the belt and roll type (Table 1).

One study of sizing grapefruit on an expanding-roll sizer with rings on the rolls gave data indicating better orientation of fruit than was the case for the drop-roll sizer with smooth, straight rolls already mentioned. The coefficient of variation, when computed for each sample, indicated uniformity of sizing approaching that generally shown for grapefruit sized on belt and roll sizers. Variation coefficient values for samples of grapefruit of sizes 70, 80 and 96 ranged from 2.75 to 3.96 for the expanding roll sizer and 2.14 to 3.21 for belt and roll sizers.

In addition to the factors mentioned, sizing performance may be affected by: turgidity of fruit, seasonal variations in fruit, surface condition of fruit and surface condition of the belt and rolls. Further research would be necessary to provide data.

When a given type of sizing equipment prevails, standard deviation values can very appropriately be considered when establishing or revising standard size ranges. The results *from* research data on orange sizing with belt and roll

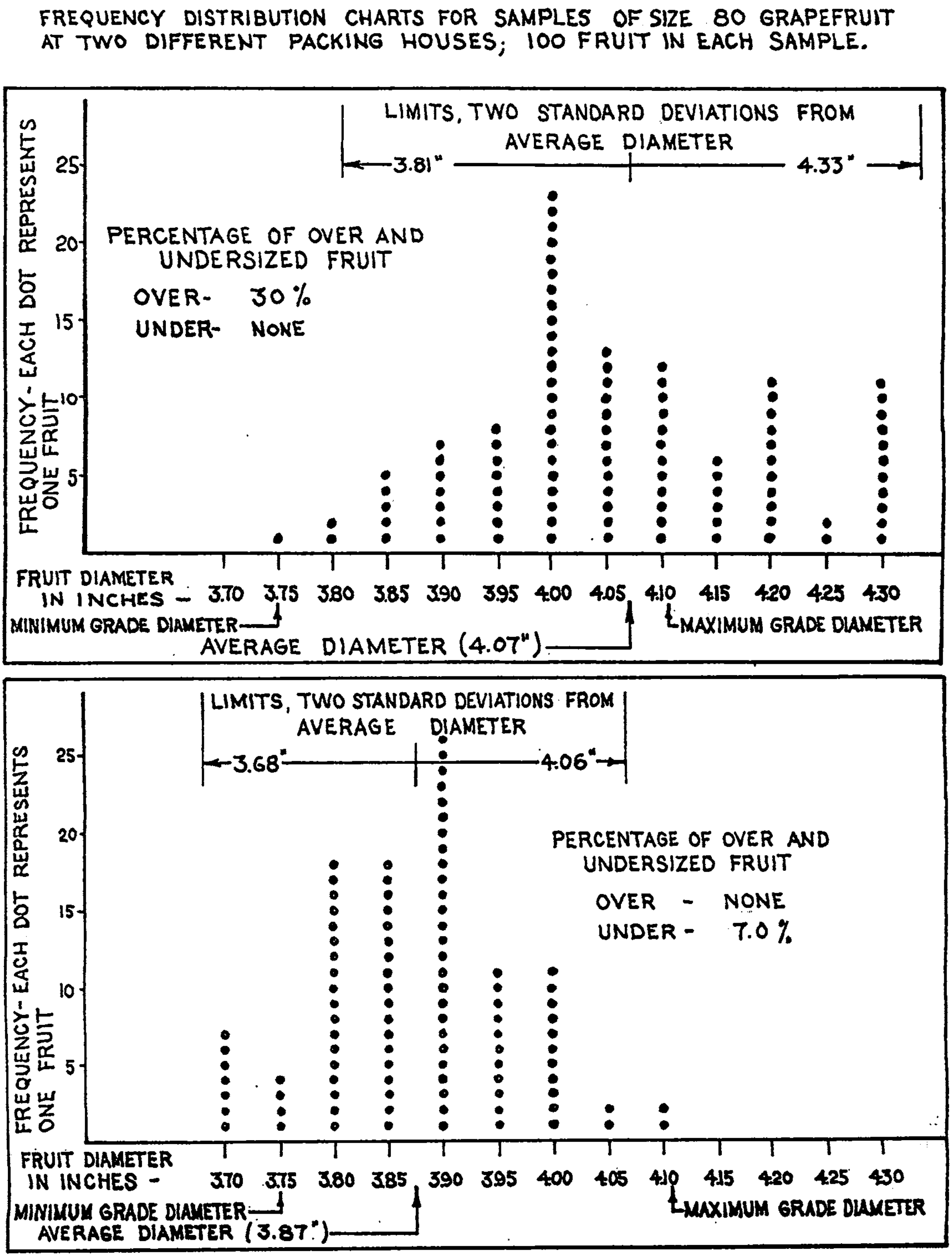
FREQUENCY DISTRIBUTION CHARTS FOR SAMPLES OF SIZE 80 GRAPEFRUIT AT TWO DIFFERENT PACKING HOUSES; 100 FRUIT IN EACH SAMPLE.
LIMITS, TWO STANDARD DEVIATIONS FROM AVERAGE DIAMETER
3.81"
4.33"
PERCENTAGE OF OVER AND UNDERSIZED FRUIT
OVER- 30%
UNDER- NONE
FREQUENCY- EACH DOT REPRESENTS ONE FRUIT
25
20
15
10
5
FRUIT DIAMETER IN INCHES -
3.70 3.75 3.80 3.85 3.90 3.95 4.00 4.05 4.10 4.15 4.20 4.25 4.30
MINIMUM GRADE DIAMETER
MAXIMUM GRADE DIAMETER
AVERAGE DIAMETER (4.07")
LIMITS, TWO STANDARD DEVIATIONS FROM AVERAGE DIAMETER
3.68"
4.06"
PERCENTAGE OF OVER AND UNDERSIZED FRUIT
OVER - NONE
UNDER - 7.0%
FREQUENCY- EACH DOT REPRESENTS ONE FRUIT
25
20
15
10
5
FRUIT DIAMETER IN INCHES -
3.70 3.75 3.80 3.85 3.90 3.95 4.00 4.05 4.10 4.15 4.20 4.25 4.30
MINIMUM GRADE DIAMETER
MAXIMUM GRADE DIAMETER
AVERAGE DIAMETER (3.87")

Figure 3

TABLE 1.-- Diameter and coefficient of variation for samples of tangerines from specified sizing equipment

Fruit size	Sizing equipment	Fruit in sample	Average diameter	Diameter range Min.	Max.	Coefficient of variation
Count per box	Type 1/	Number	Inches	Inches	Inches	
210	P.B.	100	2.41	2.30	2.50	2.01
	B.R.	100	2.45	2.30	2.70	3.49
		100	2.40	2.25	2.60	3.11
		100	2.48	2.30	3.00	5.61
		100	2.45	2.00	2.85	6.08
176	P.B.	100	2.50	2.35	2.65	2.19
		100	2.57	2.45	2.65	1.60
	B.R.	100	2.58	2.35	2.85	3.64
		100	2.50	2.25	2.75	3.50
		100	2.51	2.35	2.75	3.36
		100	2.54	2.35	3.00	4.21
		100	2.47	2.30	2.80	3.66
150	P.B.	100	2.64	2.50	2.80	2.34
	B.R.	100	2.78	2.55	3.00	3.71
		100	2.63	2.45	2.80	2.64
		100	2.72	2.50	2.95	3.53
		100	2.72	2.55	2.95	3.45
		100	2.65	2.50	2.90	3.18
120	P.B.	100	2.84	2.65	3.15	3.01
	B.R.	100	2.79	2.65	2.95	2.44
		100	2.89	2.70	3.05	3.22
		100	2.95	2.60	3.15	3.76
		100	2.83	2.65	3.00	2.58

1/ P.B. indicates perforated belt type sizer
B.R. indicates belt and roll type sizer

equipment in commercial packinghouses illustrate this. Only the smallest standard deviation of diameters for any sample of 100 oranges (one out of 25 samples) gave a range of 0.25 inch in which 95 percent of the fruit diameters could be expected to fall. Therefore, standard size ranges of 0.25 inch (for oranges 150 size and smaller, "uniform in size") may be expected to be difficult to meet in practice. Wider ranges were provided when standard dimension ranges for oranges were revised in 1958.

For grapefruit, only two out of 21 samples of size 64 and smaller grapefruit from belt and roll sizers gave a standard deviation small enough that 95 percent of the fruit could be expected to fall within a range of 6/16 inches which is the standard range for grapefruit "uniform in size" of 64 size and smaller.

A small capacity belt and roll sizer, a part of the equipment in the Campus Packinghouse of the Fruit Crops Department, University of Florida, was modified to provide variable speed drive for the belt and rolls for research purposes. With this equipment, tests were run to investigate the effect on sizing performance of different belt and roll speeds. Belt speeds of 350, 300 and 250 feet per minute were used. With each belt speed, roll surface speeds of 280, 140 and 0

TABLE 2.--Increase per day in 1-3/5 bushel boxes of oranges and gross income from sales by specified change in sizing practice at given packed fruit output rates.

Packed fruit per day	Percent of fruit in each size shifted to next larger size 1/					
	5		10		15	
Car loads 2/	Boxes	Dollars 3/	Boxes	Dollars 3/	Boxes	Dollars 3/
4	25	90	50	180	75	270
8	50	180	100	360	150	540

1/ Using sizes 125, 163, 200 and 252; no fruit shifted into size 252 from smaller size.
2/ A carload represents 500 1-3/5 bushel boxes.
3/ Based upon gross f.o.b. Florida per box price for oranges, average for 1954-55 through 1958-59 seasons, Fla. State Marketing Bureau, Annual Agricultural Statistical Summary.

feet per minute were used. Fifty fruit each of three different size groups were provided by hand calipering for the desired size ranges. Each fruit was numbered and measurements were recorded relative to the identifying number. The fruit especially calipered for the research activity were run through the sizer three times for each belt and roll speed combination. Fruit of all three sizes were randomly mixed together to go into the sizer for each run. The results expressed in terms of the percentage of fruit of each size going into the proper bin for that size, into a bin for a smaller size and into a bin for a larger size are given in figures 4 and 5. It is indicated that relatively large differences in roll speed materially affect the sizing performance. Changes in sizing performance were small in the range of belt speed which was used. The equipment did not have capability for testing higher belt speeds and drastically reduced belt speed would result in unacceptably low flow rate of fruit through the sizer. Generally, belt and roll sizing equipment in commercial packinghouses was found to be operating at speeds within the range desirable for this type of equipment as indicated by these tests.

In addition to the consideration of performance as reflected in the diameter measurements of fruit samples, other factors and comparative relationships for different kinds of sizing equipment are:

Belt and roll sizing equipment

This type of equipment may be easily and quickly changed to size either oranges, grapefruit or tangerines. Such flexibility is of high importance for most citrus packinghouses. Without it, the need for having additional sizing equipment in a packinghouse because of the different citrus fruits handled must be considered. Also, belt and roll sizers are relatively easy to adjust for changes which may be desired in sizing. This type of sizing equipment performs a creditable job according to the research data. "Central" or "master" sizers employing the belt and roll mechanism adapt to more efficient packing arrangements such as roll-board manual packing or machine packing, and other possibilities for improved space utilization.

Perforated belt sizing equipment

This type of equipment lacks flexibility for changing from one kind of citrus fruit to another or for making any adjustment in the sizing. It is necessary to change belts in order to make any change for kind of fruit or adjustment in the way any fruit is sized. With fruit passing through a full circle opening there is not as much opportunity for variability in sizing as with types of equipment in which contact with the fruit is limited to two points only.

Expanding roll sizing equipment

This type of equipment is in the category of two-point sizing means, as mentioned earlier, when straight rolls are used. When rings are placed on the rolls, the sizing action is different and possibly should be considered in the four-point category. Comments on performance aspects, with each of the two kinds of rolls, are given.

Straight rolls—Inherently it is not well suited to sizing grapefruit or any fruit in the oblate spheroid classification since there is a serious lack of needed orientation action. It offers the possibility of satisfactory sizing for fruits that are in the spherical or prolate spheroid classification. Also, it permits easy adjustment for changes in sizing and for different size ranges of spherical fruit. Good capacity relative to floor space requirements for the equipment is also a feature.

Rolls with rings—The basic mechanism is the same as for expanding roll sizing equipment with straight rolls. The use of rings on the rolls provides better orientation and control of the fruit as it is handled by the sizer. It was

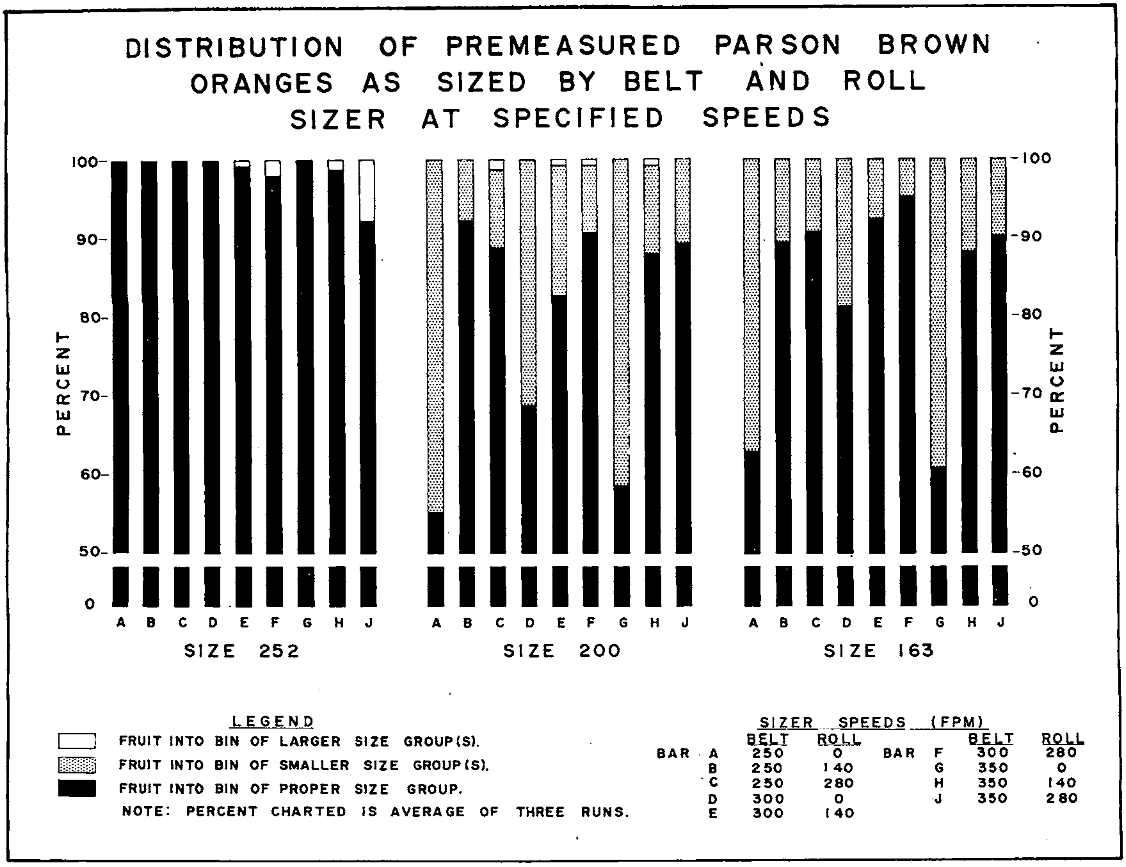

Figure 4

indicated from limited studies on one such machine that fruit in the oblate spheroid classification can be sized satisfactorily with this sizer. Thus, it offers possibilities in one machine for satisfactorily sizing both oblate and prolate spheroidal classes of fruit. A practical expression of this would be in the possible flexibility to size lemons with the same sizer as used for grapefruit and oranges.

Weight sizing equipment

This means of sizing is not generally used in citrus packinghouses. Test runs for weight sizing were not included in the research. A number of points appear to be important in considering weight sizing as compared to dimension sizing. For example, the additional attention and adjusting involved because of variations in specific gravity of the fruit which is not involved in dimension sizing; possible greater initial cost of the equipment for given output capacity; means for carrying (cups or holders) different kinds of fruit through the machine for satisfactory weighing to permit use of the machine for fruit ranging in physical size from grapefruit to tangerines; maintenance requirements to sustain satisfactory performance and weighing accuracy; equipment floor space needs for given output capacity versus floor space for other types of sizing equipment.

Sizing practice is important in connection with "packout" of fruit which is obtained. That is, the number of packed containers of saleable fruit obtained from a given input quantity. "Packout" directly influences the monetary returns to the packinghouse and must be of vital concern for management personnel. (1, 2)

Even though the distribution of diameter measurements in given fruit size categories is

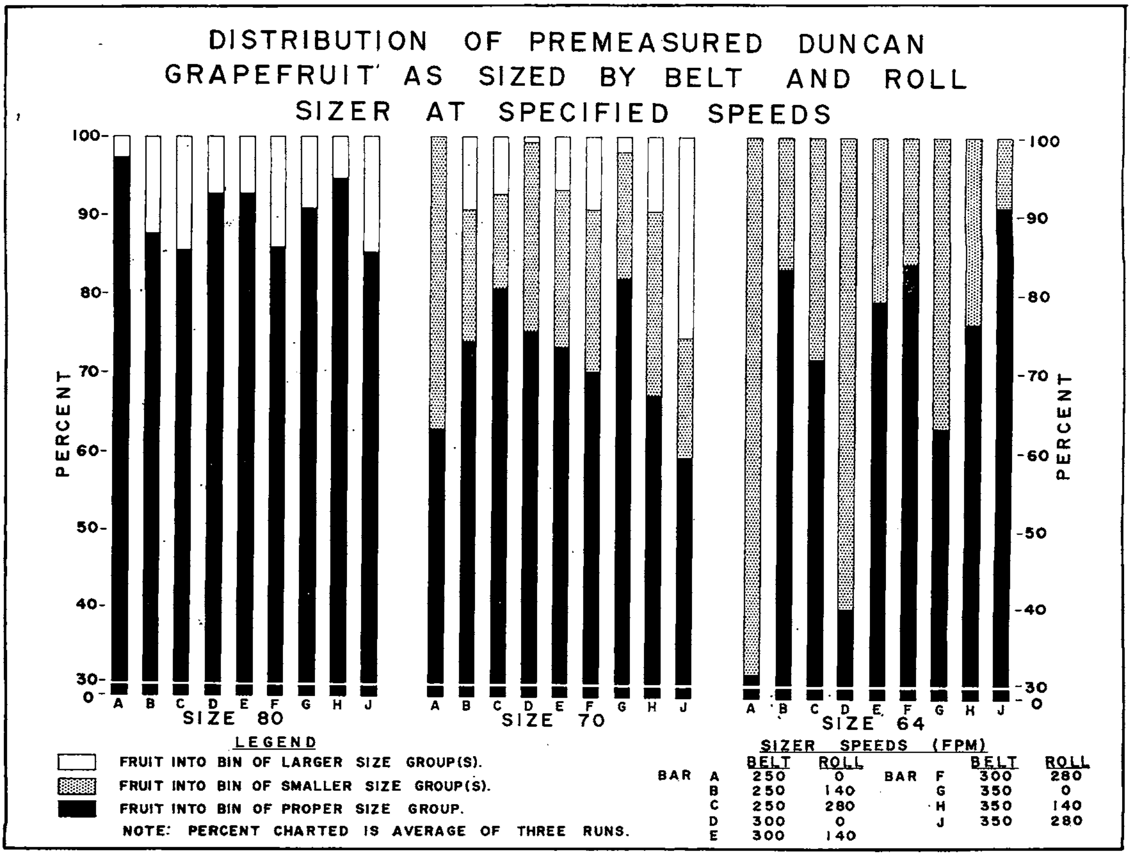

Figure 5

acceptable for difference between minimum and maximum, it must align with the standard dimension range in such a way that undersize fruit is within the tolerance provided and oversize fruit is not only within the tolerance specified, but is held to a minimum in order to obtain the maximum number of filled containers of saleable fruit from the total input. Oversize fruit in a given size range should go in the next larger size insofar as possible without causing poorly filled shipping containers or in some way detracting from favorable acceptance in the market place. Fruit samples taken in commercial packinghouses using belt and roll sizers showed an average of approximately 13 percent oversize and 4 percent undersize for oranges. For grapefruit, the corresponding figuures were approximately 20 percent oversize and 2 percent undersize.

Calculations have been made to provide an example (Table 2) of the increase in boxes of fruit and dollars of revenue theoretically possible by sizing so as to shift given percentages of fruit of each size to the next larger size for packing. The possible effect on revenue indicates a need for regularly scrutinizing the sizing practice in fresh citrus packinghouses.

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Dr. James Soule, Associate Horticulturist, Department of Fruit Crops, University of Florida, coordinated the part of the research which was conducted in the Fruit Crops Department packinghouse, with other programs involving use of the packinghouse facilities. He gave valuable counsel concerning test procedures and analysis of the data. His contribution is gratefully acknowledged.

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A NOMOGRAPH RELATING SUBJECTIVE AND OBJECTIVE METHODS FOR MEASURING COLOR OF FLORIDA ORANGE JUICES[1]

R. L. HUGGART,[2] F. W. WENZEL,[3] AND R. W. BARRON[2]

ABSTRACT

Hunter Color and Color-Difference Meter *a* values (redness) have been reported to correlate very closely with visual color of reconstituted frozen concentrated orange juices. Since the 1953-54 citrus season, the quantity of extremely fine pulp particles that become suspended in concentrate during processing has increased. This has influenced the *Rd* value (lightness). With certain methods of sample presentation, *Rd* and *a* values are of almost equal importance. A nomograph relating the *a* and *Rd* values to visual scores of orange juices is presented.

INTRODUCTION

Color, an important characteristic of citrus juices, depends upon fruit variety, maturity, season, processing methods, and other factors. Accurate, practical and objective means of determining juice colors could enable processors to standarize within a small selected color range throughout a season and from year to year. The blending of rich orange and pale yellow colored juices within such a range could be controlled very closely.

The measurement of color has become a useful tool to the food industry. The basic facts of color, its 3 dimensions, the tools and techniques of measurement, and other facets of this interesting and complex subject are adequately covered by Judd and Wyszecki (6). Color instruments that are being used in the food industry today, with a discussion of methods of application

1. Cooperative research of the Florida Citrus Commission and Florida Citrus Experiment Station.
2Florida Citrus Commission, Lake Alfred.
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