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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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.

3Florida Citrus Experiment Station, Lake Alfred.

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and interpretation of results are presented by Francis (1). Kramer and Twigg (7) discussed methods of relating color specifications of a food product, that can be measured by the simplest possible procedures, to those color dimensions of interest to the consumer.

The Hunter Color and Color-Difference Meter (HCDM) has been used to measure the color of Florida frozen concentrated orange juices and reconstituted juices. The relationship between HCDM values and visual colors of such products was reported by Wenzel and Huggart (11). Three values are obtained when the HCDM is used. The *Rd* value results from the measurement of the diffuse reflectance and is an indication of lightness (whiteness) of the juice; the *a* indicates redness or greeness; and the *b* yellowness or blueness (6,7). All of these HCDM values are necessary to designate specifically a juice color. However, Wenzel and Huggart (11) pointed out that the *a* and *Rd* correlated very favorably with visual color of concentrates and reconstituted juices, whereas correlation using the *b* value was quite low.

The *a* value for orange concentrate, a measure of redness, was shown to correlate very well with visual color of the reconstituted juice. A correlation coefficient (r) of +0.927 was reported (11). It had been suggested previously (3) and since then has been used as an indication of the relative color quality of reconstituted orange juices. During a recent evaluation of a colorimeter for measuring relative colors of citrus juices (2), it was noted that the *a* value of the concentrate or reconstituted juice, when the sample was presented to the HCDM in a Hellige tube (4), might indicate an acceptable color. Nevertheless, the juice would be rejected, when visually inspected, because of excessive whiteness. A wide range of juice colors were represented in composited commercial samples. Whenever one of these products was rejected, it was found to have a higher *Rd* than the usual group in which the *a* value placed the sample. This increase in lightness results from a greater diffuse reflectance of light from the extremely fine pulp particles, that become suspended in juice during processing. The quantity of such suspended particles has increased in frozen concentrated orange juice since the 1953-54 citrus season. Therefore, the optical properties of reconstituted juices prepared from concentrates packed during the 1963-64 season have been found to be different than those in juices from concentrates processed in 1953-54. Thus, it has become necessary to consider both the HCDM *Rd* (lightness) and *a* (redness) values to obtain good correlation between visual and instrumental color values.

The purpose of this paper is to present a nomograph relating HCDM *Rd* and *a* values of orange juice to visual scores. To obtain data necessary for this nomograph, changes in procedure for sample presentation to the instrument were made. Thus, measurements of both lightness (*Rd*) and redness (*a*) of a juice could be used to determine its visual color score.

Experimental Procedures

Frozen concentrated orange juice samples.—Color data were obtained from the examination of 179 samples of commercial frozen concentrated orange juice. Of these samples, 164 were collected during the 1963-64 season from 21 Florida plants packing in retail size 6 or 12 oz. cans. These products were collected semi-monthly during the processing period from December through June. Fifteen samples examined were supplied by different processors at the end of the 1964-65 season. These were described as being "typical" as possible of juices that had been assigned a minimum Grade A color score of 36 points. This score corresponded to that assigned to the USDA OJ5 plastic color comparator tube (9, 10).

Measurement of color.—Visual color scores of reconstituted commercial concentrates were determined by the authors, together with assistance of other interested personnel, so that each juice was graded individually by at least 4 judges. The juices were filled into 1-inch diameter, glass, screw cap culture tubes, and then scored using USDA color comparator tubes as guides (8, 9). The juices and comparator tubes were viewed together in a Macbeth Examolite Daylight Model EBA-220 with a rated color temperature of 7400° Kelvin. The averages of the total points given by judges to each juice were used in the statistical analysis.

The HCDM, a photoelectric tristimulus instrument, the design and operation of which have been described by Hunter (5) and Judd (6), was used to determine lightness (*Rd*), redness (*a*) and yellowness (*b*) of each juice. The instrument was standardized using a NBS enamel plaque, test number G13383, with values of $Rd = 60.7$; $a = -2.0$; and $b = 22.7$. A 12 cm square plexiglass dish with a clear bottom and 4.8 cm deep was used as a sample holder to set over the viewing window. A white Carrara glass plate was lowered into the juice to act as a reflector and also to fix the thickness of the Juice through which light had to pass. A large area of illumination, a large aperture and the *Rd* scale were used.

Statistical analysis.—Correlation coefficients (r) were calculated between visual color scores for reconstituted orange juices and HCDM *Rd*, *a*, and *b* values. The least square method for simple, linear correlation was used with the short-cut grouping method utilized (7).

The mean *Rd* value for each of 6 (33 to 38) visual score point groups (9) was plotted against the mean *a* value for each group. A regression line was calulated from these mean score points. This regression line shows the relationship between visual color scores and the HCDM *Rd* and *a* values for juices ranging in color from pale yellow to dark orange.

Results and Discussion

Using a white Carrara glass plate to study the effect of juice thickness presented to the instrument for viewing, best correlation coefficients were found when the plate was lowered into the juice to leave a depth of 0.6 cm above the viewing window. Agreement between instrument readings and visual scores are indicated by correlation coefficients (r) of -0.884, 0.842, and 0.562 for the HCDM *Rd*., *a*, and *b*, respectively. Low correlation between visual scores and the *b* values indicated that they would be of little use in determining color scores of orange juices.

Figure 1 is a combination of nomograph and a scatter diagram showing location of points determined by plotting *Rd* values as ordinates (y) against *a* values as abscissae (x) using 0.6 cm viewing depth. Juices with good visual scores

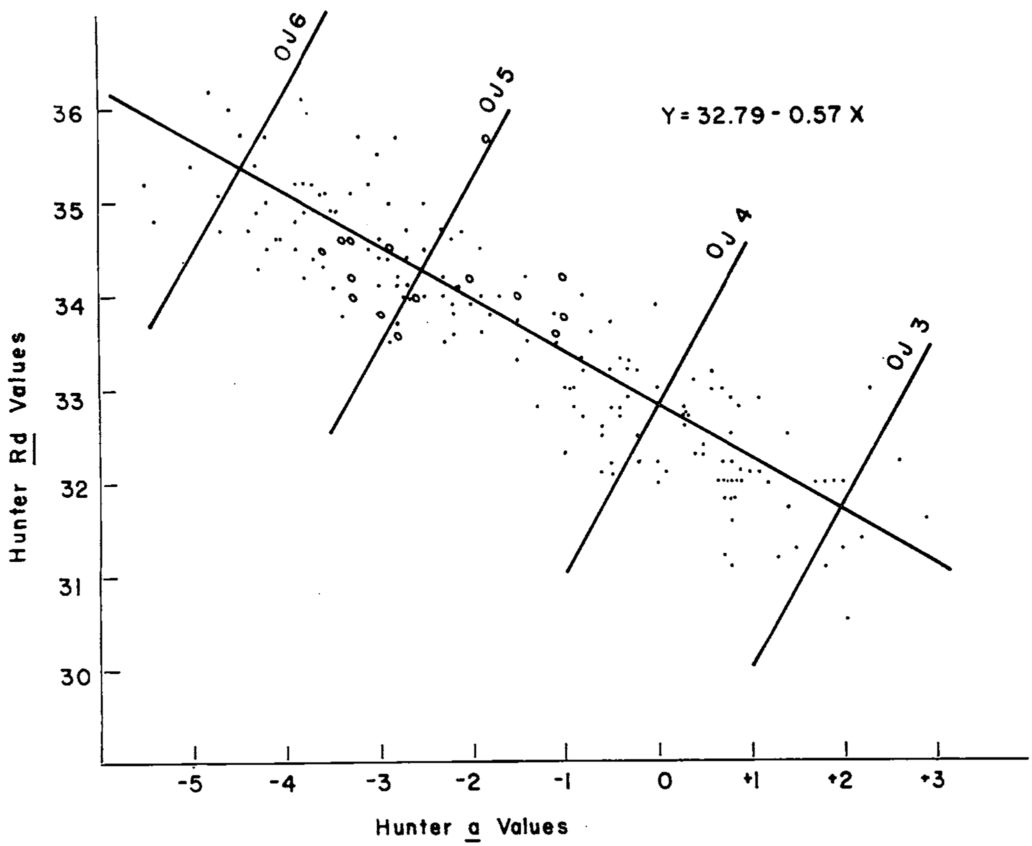

Figure 1.—Nomograph for relationship between USDA visual color scores and the Hunter Rd and a values of orange juices. Also shown is a scatter diagram based on these Hun ter values of 179 reconstituted orange juices.

are located to the right at high *a* values and low *Rd* values. Score lines are drawn at right angles to the regression line for color and are located at the center of each OJ group. Of the 179 juices examined during the 1963-65 seasons, 68 were in the OJ5 group, 86 in OJ4 and 9 in OJ3, respectively. Sixteen juices were in the OJ6 group. It has been pointed out (7) that in a transition from visual to instrument scoring, an instrument will measure differences in both redness (hue) and lightness (value.) However, in visual classification, differences in hue may influence some judges more than value differences when scoring the color of a juice that is a mis-match with the USDA orange juice color standards (10).

The 15 points, plotted as circles in the scatter diagram (Fig. 1), are for samples selected by processors as having color typical to that of the OJ5 standard. There was no practical difference in the color of these juices. They are of interest as a group because they represent the minimum color that meets U. S. Grade A standards. The circles are well distributed in a pattern around the OJ5 score line. The points are evenly divided above and below OJ5, although 2 of them are in the OJ4 group when the HCDM *Rd* and *a* values are used.

To use the nomograph, HCDM measurements are made on the sample of orange juice. The measured *Rd* value was 34.0 and the *a* value was -2.7. Then using Figure 1, locate the point corresponding to an *a* value of -2.7 and a *Rd* value of 34.0. This point will be on the OJ5 line. Therefore, the color of this juice should match the visual color of the OJ5 standard color tube and should be scored 36.

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INSTRUMENTAL METHOD FOR DETERMINATION OF TITRATABLE ACIDITY IN CITRUS JUICE

R. W. KILBURN[1]

INTRODUCTION

Acidity in citrus juice is measured by volumetric titration with standardized sodium hydroxide, using phenolphthalein as an internal indicator. The titration can be mechanized by using an automatic titrimeter. The volumetric measurement of juice sample is tedious in either case. An instrumental method for measuring

[1]Florida Citrus Canners Cooperative, Lake Wales, Florida.

TABLE 1

pK of Potassium Citrate Solutions

Normality	pK	M.V.
.0369	3.89	+ .26
.0738	3.62	+ .42
.1110	3.47	+ .51
.1479	3.37	+ .56