plasts isolated from citrus juice are the natural form in which the characteristic pigments of orange juice are found in the fruit.

Before concluding it should be mentioned that another method of enhancing color of orange juice by natural means (6, 7) has been developed. This other method involves the use of orange peel carotenoids in contrast to intact chromoplasts as presented in this paper.

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EQUIVALENT COLOR SCORES FOR FLORIDA FROZEN CONCENTRATED ORANGE JUICE*

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ABSTRACT

Color data obtained from the examination of 428 reconstituted commercial samples of frozen concentrated orange juice (FCOJ), collected from Florida processing plants during 2 citrus seasons were statistically analyzed. Correlation coefficients and a multiple regression equation were computed relating Hunterlab Citrus Colorimeter (HCC) Citrus Red (CR) and Citrus Yellow (CY) values to average visual color scores. The fit of the multiple regression equation was quite good and explained 97.1% of the observed variation (% R). Using this relationship a nomograph was constructed to estimate equivalent color scores from colorimeter values.

The range between the mean scores of 5 judges was 0.75 of a visual score point. When 5 instruments were compared in 4 tests, the ranges of CR means were equivalent to 0.34, 0.20, 0.15 and 0.08 of a score point.

INTRODUCTION

In a statistical study in which an instrument, the Hunterlab D45 Citrus Colorimeter and its measurements, Citrus Red (CR) and Citrus Yellow (CY) are being evaluated, the existence of a high correlation between instrument color values and visual color scores must be established if instrument color values are to be an acceptable indication of average visual color scores. Differences in average performance among personnel composing a panel for judging color score must be determined. Subjective and objective methods of determining color of reconstituted frozen concentrated orange juice

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(FCOJ) must be compared. When several instruments are to be used, instrument to instrument variability must be investigated. A method of instrument calibration is necessary to limit variation to acceptable levels. An accurate prediction equation that best "fits" the data must be derived so that instrument values may be expressed in terms of equivalent visual scores. These requirements must be fulfilled before realistic comparisons can be made between objective and subjective methods of determining color of FCOJ.

The purpose of this paper is to present a nomograph constructed from a prediction equation for determining equivalent visual color score from colorimeter values. Data is presented showing the magnitude of variation found between mean subjective scores of color panel members. Variation between instruments is discussed.

Experimental Procedures

Data for statistical analysis.—A Hunterlab Citrus Colorimeter (HCC), Model D45, developed by Hunter (3), was used to obtain orange juice color values. Samples were collected on a semimonthly basis from 25 processing plants packing concentrate in retail size 6- or 12-ounce cans. Measurements were determined during the 1965-66 and 1966-67 citrus seasons on 428 commercial samples of frozen concentrated orange juice (1, 10, 11).

A panel of 5 Citrus Experiment Station (CES) personnel, one observer at a time, scored the visual color score of each reconstituted orange juice. The color of a juice was determined by comparing each juice with USDA plastic Orange Juice Color Standards (8, 9) according to specified procedures using a light source of 7500°K.

Individual scores were used to obtain average difference between panelists. The mean color score given by a panel was used to derive correlation coefficients and to calculate a prediction equation relating color score of a juice to HCC values. The regression relationship was estimated separately for each season. The proposed model fitted to the data was of the form:

$$\text{Average Visual Score} = b_0 + b_1(CR) + b_2(CY)$$

The actual regression relationship was estimated in a step-wise manner (2). Under this procedure, no term was included in the final equation unless its inclusion significantly reduced the residual mean square. To determine significance, a confidence level of 95% was used.

Factorial experiment.—A modified factorial experiment was structured to probe and measure differences in citrus red color values existing among 5 colorimeters. The test was conducted by preparing 5 samples of reconstituted orange juices having visual color levels approximately equivalent to visual scores of 36, 37, 38, 39 and 40, respectively. Two coded sample tubes were filled from each beaker. Randomly, 2 of these 10 coded tubes were placed by each of 5 colorimeters located in different rooms. Five operators then visited each instrument and measurerd CR and CY values for the 2 samples. When all operators had finished their determinations and turned in their data sheets, each pair of sample tubes was moved in rotation to a different instrument.

The operators again determined CR and CY values for the 2 samples until each operator had made a CR and CY measurement for each of the 5 juices in duplicate on each of the 5 colorimeters. Each instrument was nulled against its OJ4 plastic USDA orange juice color standard comparator tube. Such tubes had been calibrated by Hunter Associates Laboratory. Scale expansion was checked with a calibrated OJ2 tube. In subsequent variance tests of the colorimeters, the same plan was followed in presenting juices and operators to each instrument. In these tests, however, a specific calibration method suggested by Hunter was used to determine if between instrument variation could be reduced. A set of juices of various color levels were used to carry CR and CY values from a master or reference instrument to each colorimeter (11). The CR and CY values of instrument calibration tubes were corrected slightly to compensate for metameric and other errors of an instrument.

Duncan's Multiple Range Test (4, 5, 7) was used to determine significance of the differences between the instrument mean CR values, as well as that between the mean visual scores of judges.

Results and Discussion

Instrument variation.—When the first test was conducted, 2 of the instruments were found to be in agreement, and 3 were significantly different at the 1% level (Table 1). The great-

Table 1. Duncan's Multiple Range Test of Hunterlab Citrus Colorimeter mean citrus red (CR) values.

Test						Range of means	Equivalent OJ score points
No. 1							
Instrument No.	5	1	4	3	2		
Ranked Mean[1]	40.652	39.896	39.766	39.499	39.254	1.398	0.34
No. 2							
Instrument No.	3	4	2	5	1		
Ranked Mean	38.954	38.712	38.638	38.424	38.324	0.630	0.15
No. 3							
Instrument No.	4	3	1	5	2		
Ranked Mean	39.104	38.960	38.706	38.578	38.272	0.832	0.20
No. 4							
Instrument No.	3	4	1	2	5		
Ranked Mean	36.536	36.534	36.244	36.242	36.200	0.336	0.08

[1]Any two means underscored by the same line are not significantly different. Any two means not underscored by the same line are significantly different at the 1% level.

est difference in means between instruments was 1.398 CR units or 0.34 equivalent OJ score point. In this study the maximum allowable range between instruments was arbitrarily set at ¼ score point.

Hunter investigated and found, as reported (11), 3 sources of disparities: (a) solarization of the projection lens in 2 instruments; (b) small but definite spectral differences in instrument filters; and (c) a significant dip in the range between 520 and 570 millimicrons in the spectral reflectance curves of USDA Orange Juice Color Standards compared to those of orange juice samples that indicated a metameric condition between standards and juices (6).

The replacement of the lenses and specific calibration technique, previously indicated, thus reduced the disparity between instruments from 0.34 score point, Test 1, Table 1, to less than ¼ of a point, as shown by Tests 2, 3 and 4, with a range of 0.15, 0.20, and 0.08, respectively. Although the instrument differences were significant at the 1% level, they were reduced to less than ¼ score point. As Richmond (7) points out, numerically, a difference may be statistically significant, but the magnitude of the difference be of no practical importance.

Variation in Visual Scores.—Means of the visual scores, which included all color levels, for the 5 judges are listed in Table 2. The range of means was ¾ths (0.75) of a color score point. Differences between judges were significant at the 1% level.

When variation between visual scores at different color levels was investigated, significant differences were found for juices scored 38. Juices scored 36, 37, 39 or 40 must be at least "equal to" the color of OJ tubes 5, 4, 3 or 2, respectively. Juice color 38 must be, "much better than USDA OJ 4" (8, 9).

Prediction equation.—Of main interest, was whether a satisfactory prediction relationship between the CR and CY values and the visual score could be obtained. Based on the linear correlation between the average visual score and the color values determined by the Hunterlab Citrus Colorimeter, the prospects of finding a meaningful relationship looked good. Kramer and Twigg (4) consider a correlation coefficient of 0.90 or better an excellent indicator of human evaluation. All of these simple correlation coefficients (Table 3) are greater than 0.90 and

Table 2. Duncan's Multiple Range Test of mean visual color scores.

						Range of means	Equivalent CR values
Judge No.	5	1	2	3	4		
Ranked Mean[1]	38.10	38.05	37.75	37.65	37.35	0.75	3.08

[1] Any two means underscored by the same line are not significantly different. Any two means not underscored by the same line are significantly different at the 1% level.

correlation with the CR values are consistently higher than that with CY values. The CR coefficient for both seasons combined explains 92.5% of the variation (% R) while the CY coefficient would explain only 85.7%.

For each season, it was found that both CR and CY made a significant contribution to the relationship. The fit of these equations as determined by the percentage of observed variation explained by the relationship is quite good. These equations explained 97.6 and 97.1% of the observed variation in the 2 seasons, respectively. In view of the goodness of fit obtained with this relationship, no attempt was made to explore other models. Statistical tests were performed to determine if the same relationship could be used for both years. The results of these tests indicated that the regression equations were not significantly different from each other. In view of this conclusion, a single regression equations were not significantly different from each other. In view of this conclusion, a single regression equation based on both years' data was obtained. This equation explained 97.1% of the observed variation. This implies that the relationship is

Table 3. Correlation between visual color scores and Hunterlab Citrus Colorimeter Citrus Red (CR) and Citrus Yellow (CY) values for reconstituted commercial frozen concentrated orange juices packed during two citrus seasons.

Date Packed	Number of samples	Simple correlation coefficients (r) HCC CR	CY
1965-66	208	0.971**	0.940**
1966-67	220	0.961**	0.907**
Both seasons	428	0.962**	0.926**

** Significant at the 1% level.

fairly stable from season to season. Thus, one would probably feel fairly confident in using the combined season equation presented below to predict visual score.

$$\text{Average Visual Score} = 22.510 + 0.165\ \text{CR} + 0.111\ \text{CY}$$

It must be remembered, however, that this equation predicts the average visual score as determined by a set of 5 judges. Clearly, the fit of this equation would not have been as good if only the results of a single judge were used.

The term "Equivalent Color Score" (ECS) will be used to designate a score based on instrument values for juices and thus avoid confusion with the Average Visual Score of a panel of judges. To estimate ECS, substitute CR and CY readings for a reconstituted orange juice in the above equation and solve for ECS.

Nomograph.—A nomograph (Figure 1) for estimating ECS from CR and CY readings was constructed using the above equation. To locate the ECS 35.5 line, 35.5 was substituted in the equation for average visual score, a value of 25 was substituted for CR, and the equation was solved for CY. A second pair of coordinates for the 35.5 ECS line was obtained by substituting a value of 30 for CR and again solving for CY. The two points were connected to locate the 35.5 line. This process was repeated using appropriate CR values to locate the color level lines shown on the nomograph at equivalent color scores of 35.5, 36.5, 37.5, 38.5, 39.5, and 40.5. These lines separate CR and CY values of

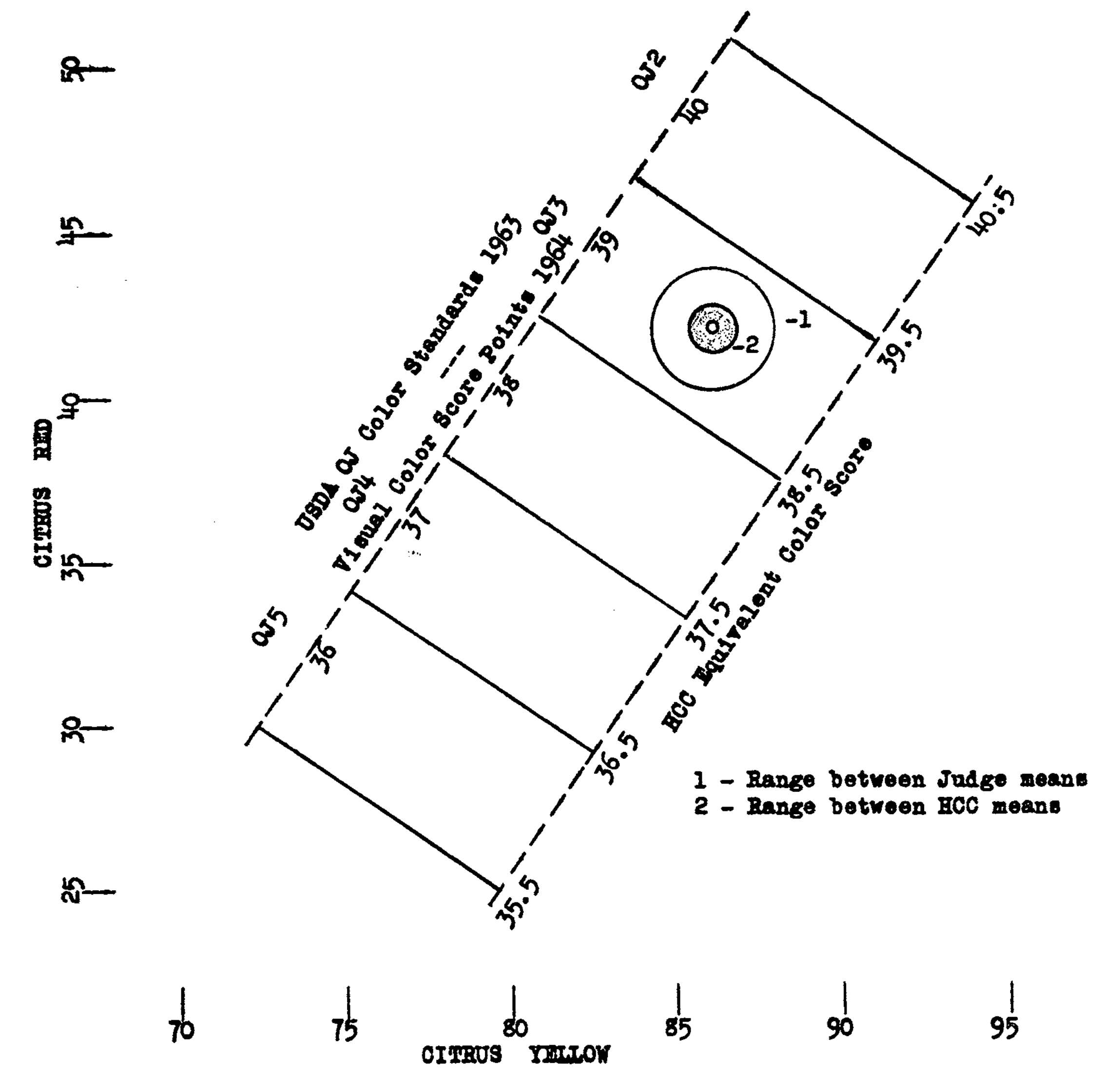

Figure 1.—Nomograph for estimatinf Equivalent Color Score of reconstituted frozen concentrated orange juice in terms of HCC citrus red and citrus yellow values.

juices that were judged by the CES panel to most nearly match the OJ compartor tube or score indicated at the center edge of each group. The ECS lines are limited in length by 2 dashed lines to enclose coordinates of juice colors measured in this study. This nomograph is expected to fit normal reconstituted Florida concentrated orange juice packed in accordance with US standards for grades of this product (9).

Equivalent color score.—Visual color score of FCOJ may be easily and quickly estimated using HCC, CR and CY readings and the nomograph. The citrus red and citrus yellow values for a given juice are entered along their respective coordinates in Figue 1. The score area in which coordinates intersect indicates the visual color of a juice. The coordinates for juices of average color during a season, fall along a curve approximately perpendicular to and bisecting ECS lines. Points along the curve indicate primarily a shift in intensity (chroma) of orange color associated with color score.

Variation in hue.—The nomograph may be used as an aid in evaluating color of juices that are difficult to match with comparator tubes. Such juices are slightly different in color (hue) from those found along the average curve. HCC measurements and visual examination show these juices to have higher or lower than average ratio of citrus yellow to citrus red. Points falling along the CY axis to the right of the average curve are for juices that have a brighter yellow hue; those to the left, a darker red hue.

Equivalent values.—Using the nomograph, it is possible to determine that one OJ score point is equal to 4.10 CR units. A line perpendicular to the ECS lines was drawn. By inspection, a difference in CR of 20.5 on the perpendicular was equal to a difference in OJ of 5.0, $[(48.3 - 27.8) / (40.5 - 35.5) = (4.10)]$. Reciprocally, 1 CR unit value rounds off to 0.24 of an OJ score point. It is thus possible to convert the CR range of means, shown for Duncan's Multiple Range Tests in Table 1, to score points by multiplying CR values by 0.24 which resulted in equivalent color scores of 0.34, 0.15, 0.20, and 0.08 of a score point shown for the respective variance tests.

The large circle drawn on the figure in the 39 score point area represents the ¾ths point difference in visual score that might be given to a juice depending upon the judges selected. The shaded area within the large circle represents the difference that might be found between calculated equivalent color scores due to the variability between instruments used for measuring CR values.

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