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COLOR ASPECTS OF FLORIDA COMMERCIAL GRAPEFRUIT JUICES, 1976-77[1]

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Abstract. **During the 1976-77 citrus season, 135 Florida commercial grapefruit juice samples were obtained from 19 processing plants completing a second year of study. Of the samples examined, 74 were packed in cans, 36 in glass; 25 were as concentrate. Color of juices was ranked by number from white to pink using prepared synthetic color guides. The color rank of the juices was correlated against Citrus Red, Citrus Yellow, Hunter L (lightness), a (redness) and b (yellowness) measurements, date of pack and flavor score. Citrus Red, Citrus Yellow, a and b color measurements correlated well with color rank, r = 0.819 or greater. White grapefruit juice CY color was significantly related to flavor, r = 0.448 (20%). Hue angle, and saturation index explain outlying colors.**

All orange juice concentrate plants in Florida are required to use a colorimeter acceptable to the USDA for measuring orange juice color (1). The measurements are in terms of Citrus Red (CR) and Citrus Yellow (CY) color values and are used to calculate orange juice color score in ascertaining USDA grade for frozen orange juice concentrate and other orange juice products. With the emphasis on grapefruit juice quality and its good market acceptance packed in glass, concentrate plants are interested in controlling their grapefruit juice color quality. At the present time, there are no officially accepted objective (4, 5) methods of measuring color in either white or pink grapefruit juice products. The purpose of this part of the symposium is to present data showing the relationship between Hunterlab Citrus Colorimeter measurements and visual evaluation of grapefruit juice colors. The relationship of color to flavor is shown for white and pink juices.

Materials and Methods

During the 1976-77 season, 135 grapefruit juice samples were obtained as follows: 74 single strength juice samples packed in cans; 36 packed in glass; and 25 packed as concentrate. These samples were collected as part of the Grapefruit Juice Survey discussed in another part of this symposium, from 19 different Florida processing plants beginning in November of 1976 and ending in May of 1977. As there are no official USDA color guides for grapefruit juices (4, 5), synthetic samples ranging in color from greenish white to pink were prepared (0 = greenish white, 1 = white, 2 = yellow, 3 = pinkish yellow, 4 = light pink and 5 = pink). The selected array was used to judge an order number for each sample. As juices were collected, samples were evaluated for flavor and visual color rank by a panel of trained personnel (12 for flavor, 5 for color) at the Agricultural Research and Education Center. CR and CY color measurements were obtained (2) using a Hunter-lab D45/D2 Citrus Colorimeter (referred to as D2). The instrument was nulled to the 0J4 tube as for orange juice measurements. CIE, Y, X and Z were also measured and calculated to the Hunter *L (lightness), a* (redness) and b (yellowness) color notation (3). Data were tabulated for the entire season and separated into white and pink groups on a visual basis for relating color to flavor. The groups were classified by visual evaluation: greenish white to yellows as white juices; yellows with a suggestion of pink to pinks, as pinks.

Results and Discussion

Approximately 64% of the season's pack was classified as white and 36% as pink juices by visual methods. As shown in Table 1, the average CR value was 7.85 for white and 17.56 for pink juices. The pink juices have a higher CR to CY ratio than do the whites. The rank order of color was in general agreement with USDA visual color scores based upon color measurements obtained from a display prepared by the Inspection Service during the 1976-77 citrus season. A rank of 1 was about equivalent to a score of 18, with 2 about equivalent to 20 for white juices. A rank of 2.5 was near a score of 16 for pink juices, with 5 close to a score of 20 pink.

Table 1. Mean, minimum and maximum color measurements and flavor scores for white and pink grapefruit juices during the 1976-77 season.

Variable	Mean	Minimum	Maximum
	White Juices (87 samples)		
CR	7.85	4.80	11.70
CY	34.40	28.10	40.50
L	41.73	37.30	44.61
a	-2.73	-3.58	-1.81
b	10.10	7.84	12.20
Flavor	5.65	4.00	7.30
Visual color rank	1.14	0.00	2.00
	Pink Juices (48 samples)		
CR	17.56	10.30	32.40
CY	41.71	35.10	50.90
L	40.73	38.08	44.27
a	-0.91	-2.89	1.86
b	11.90	9.51	14.71
Flavor	5.40	2.90	6.60
Visual color rank	3.07	2.02	4.67

As it would be economically desirable to use existing Hunter Citrus Colorimeters (HCC) Model D45, for measuring grapefruit juice colors, color measurements obtainable on the HCC and D2 were correlated with color rank and are presented in Table 2. The CR measurement (CR, CY system) correlated (simple correlation r) with visual color rank at r = 0.949, and was the best single indicator of color score. When CR and CY values were used in a multiple correlation (multiple correlation R), the relationship improved to R = 0.955, and was the best method for predicting color using CR and CY measurements. The prediction equation derived was:

$$\text{Color Rank} = 0.131 \times CR + 0.061 \times CY - 1.891$$

Hunter L, a and b measurements (Fig. 1) were also investigated as there is a relatively large change in hue from white to pink juices together with a change in chroma or intensity (saturation) of color. The a/b (red to yellow)

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Table 2. Correlation coefficients between Hunterlab Citrus Colorimeter measurements and Visual Evaluation of Color Rank in 135 grapefruit juice samples collected during the 1976-77 citrus season.

Colorimeter measurement	Correlation Coefficient	Percent variation explained[z]
Citrus Yellow (CY	0.896	80.3
Citrus Red (CR)	0.949	90.1
CY/CR Ratio	0.928	86.1
CR and CY multiple correlation	0.955	91.2
L (Hunter lightness)	-0.142	2.0
a (Hunter red color)	0.852	72.6
b (Hunter yellow color)	0.819	67.1
a/b ratio	0.934	87.2
chroma and hue angle (saturation and color)	0.965	93.1

[z]Coefficient of determination X 100.

ratio agreed well with visual color rank at r = 0.934, Table 2. The L or lightness measurement alone was associated with visual evaluation at r = 0.570 in white juices and at r = -0.165 in pink juices, Table 4. L correlated with date of pack (maturity) at r = 0.397 for whites, r = 0.343 for pinks and r = 0.346 overall for the season. For this reason, it was expected that L would show as strong a correlation with visual evaluation of color as a or b, but the interaction of the positive trend for white juice L values with the negative trend of L values in pink juices confused the relationship for the season's samples.

Chroma (saturation) and hue angle (Fig. 1) agreed best with visual evaluation reaching a correlation of r = 0.965.

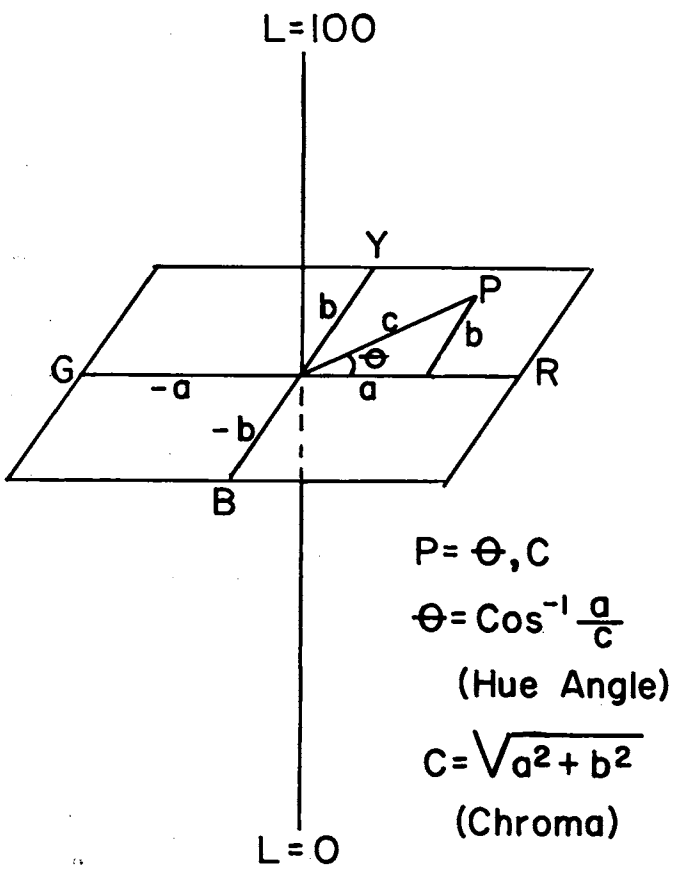

Fig. 1. Hunter L, a, b Color Solid showing color point P located by hue angle theta and chroma intensity line C. R = red, Y = yellow, G = green and B = blue color, L = lightness, O = black, 100 = white. (Hunterlab Associates Laboratory, Inc., 9529 Lee Highway, Fairfax, VA 22030).

Chroma is found by extracting the square root of $a^2 + b^2$. The hue angle theta is found by determining cosine $^{-1}$ of a/c. Color can be defined by three dimensional variables color, saturation and lightness (3). At times, if two of the variables are relatively constant, then visual appearance can be predicted by measuring variation in only one of the dimensions. If chroma and hue angle are used, the correlation with visual classification will usually be a little better. A ratio figure of a/b (or b/a), which is essentially an indication of hue angle, will give good correlation with visual evaluation when the difference in appearance is being influenced largely by variation in color angle alone. If hue appearance is also influenced by color saturation in certain samples, then there will be false prediction of color rank if only the a/b or CR/CY ratio is used for prediction. Some of the grapefruit juice samples, identified as containing a high mixture of 'K-Early'[1] juice, had an acceptable a/b ratio, but were visual mismatches with normal juices because of a higher saturation than that measured in grapefruit juices.

Color rank using the CR and CY measurements in a multiple correlation equation is simpler to calculate and easier to use than hue angle and chroma values which involve square roots and cosines, both being difficult to work with without a programmable calculator.

Simple correlation coefficients between flavor and color measurements are presented in Table 3. The month during which samples were packed (maturity date) correlated with flavor, r = 0.487 for all samples indicating that flavor improved slightly with maturity. From the coefficients r = 0.330 and r = 0.448, it appeared that CR and CY values and flavor increased slightly with maturity in white juices. The relationship was inverse or negative for pink juices which had a CR and CY flavor correlation of -0.205 and -0.294 respectively.

Table 3. Simple correlation coefficients (r) between flavor and month packed, CR, CY, L, a, b or visual rank.

	Flavor -vs-						
		Citrus	Citrus	Hunter			Visual
Samples	Month	Red	Yellow	L	a	b	rank
White	0.517	0.330	0.448	0.147	-0.127	0.386	0.316
Pink	0.483	-0.205	-0.294	0.114	-0.134	-0.213	-0.197
All season	0.487	-0.161	-0.075	0.175	-0.199	-0.015	-0.113

As the trends were opposite in white and pink juices, flavor correlation for the season was diminished by interaction between the trends. The slight trends in L, a and b measurements with flavor showed the same effect when the trends were similar, L and a, Table 3, the correlation was slightly higher for a season as a group of white and pink juices combined. Visual rank showed a small but significant correlation with flavor of r = 0.316 for white juices. Approximately 10% of the change in visual color was associated with a change in flavor. Average flavor of the white juices was slightly higher than that of the pink juices, 5.65 to 5.40, and the lowest flavor score, 2.90, was given to a pink juice (Table 1).

Simple correlation coefficients with visual color rank as the dependent variable and month packed, CR, CY, L, a and b as independent variables are presented in Table 4. The visual color rank in the white juices was associated with maturity, r = 0.544. Visual color rank was also closely associated with CR and CY measurements of white

[1]A grapefruit x tangerine hybrid. Ed.

Table 4. Simple correlation coefficients (r) between color rank and month packed, CR, CY, L, a, b or flavor.

	Color Rank -vs-						
		Citrus	Citrus	Hunter			
Samples	Month	Red	Yellow	L	a	b	Flavor
White	0.544	0.786	0.688	0.570	0.008	0.743	0.316
Pink	-0.093	0.957	0.810	-0.165	0.892	0.677	-0.197
All season	0.162	0.948	0.898	-0.142	0.851	0.819	-0.113

and pink juices. The L value was related to color rank in white juices at r = 0.570. Changes in a and b values were associated with visual evaluation of pink juices. The a value apparently was not related to visual evaluation of white juices at an r = 0.008.

Summary

Visual color changes in white and pink grapefruit juices were closely associated with Hunter Citrus Colorimeter measurements. Changes in both hue and saturation were associated with visual appearance. Visual changes in color were slightly but significantly related to flavor differences. Visual color in white juices were associated with maturity date. Many grapefruit visual colors *could be predicted* from hue or chroma measurements, but the use of both hue and chroma improved the correlation.

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SPECTRAL CHARACTERISTICS OF COMMERCIALLY PREPARED GRAPEFRUIT JUICES[1]

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Abstract. **Commercially prepared Florida grapefruit juices obtained during the 1976-77 season, were investigated for their characteristic visible and ultraviolet absorption obtained from alcoholic solutions of the juices. The samples were also analyzed for naringin by both the Davis Test and high pressure liquid chromatography (HPLC), and for color and flavor. Visible absorbance appeared to be related to the degree of whiteness, chamois yellowness and pinkness of the product. Ultraviolet absorbance at 284 nm correlated well with naringin as determined by either the Davis Test or HPLC. Flavor did not correlate with chemical or instrumental characteristics.**

With increasing grapefruit production in Florida the quality of processed grapefruit juice has become a growing concern of the grower, processor and consumer. The Florida Department of Citrus has responded by initiating a grapefruit quality improvement program. This investigation is one of several that make up this program.

Product color has a great influence on consumer preferences and purchases. A consumer survey (2) revealed that the color of orange juices or orange drinks directly affected the consumer opinion concerning flavor, body, sweetness and other characteristics associated with the quality of these products. Importance of color as a quality factor is evident in that it is included in the U.S. Standards for Grades of Grapefruit Juice (8). The grading system allows up to 20 quality points for juice color out of a total of 100 points used in determining product grade. However, instrumental methods or visual color standards for determining color quality points have been lacking. Huggart and Petrus (5) investigated the color of Florida canned commercial grapefruit juices. Liquid standards were prepared using FD&C dyes and clouding agents. The grapefruit juices were then compared with the standards by a trained panel. It was found that the sum of visible absorbance at 504, 470 and 445 nm appeared to be associated with the degree of whiteness, yellowness or pinkness of the juices.

Naringin is known to be one of the principal bitter components of grapefruit juice. Its bitterness is claimed to be so pronounced that it can be detected when 1 part is dissolved in 50,000 parts of water (1).

Analyses presented in this paper include visible and ultraviolet absorption, naringin by the Davis Test and high pressure liquid chromatography (HPLC), visual color ranking and flavor.

The object of the investigation was to determine the relationship of various spectral characteristics with other analyses and flavor of grapefruit juice.

Florida experienced a major freeze during January, 1977 and the results reported may not be typical of those obtained during a normal season.

Materials and Methods

Samples were collected biweekly from the processing plants by USDA supervisory inspectors and delivered to the Agricultural Research and Education Center, Lake Alfred, Florida.

The samples were analyzed for naringin by the Davis Test (3) and HPLC (4), visual color score by a trained panel using prepared synthetic liquid standards (6) and flavor by an experienced taste panel using a 9-category hedonic scale (where 1 = dislike extremely and 9 = like extremely). Alcoholic solutions of the samples were investigated for their characteristic visible and ultraviolet absorption (7). A Coleman Model 124 recording spectrophotometer employing an R-136 photomultiplier detector

[1]Florida Agricultural Experiment Stations Journal Series No. 866.