rootstock. Since the fruit was harvested at specific times (when a Brix-acid ratio of near 8 was reached), this study does not reflect the natural maturation kinetics which would occur with a single tree or grove. In addition, this initial study was done for only 110 days of a single harvest season. Since it is generally agreed and accepted that grapefruit quality is variable from one year to the next, it will be important to continue this study for several seasons and also ultimately include the effects of the unknown parameters, listed above, into future analyses. Only then can a true measure of the inherent variation which occurs within the grapefruit population be presented.

Literature Cited

1. Mansell, Richard L. and Elmar W. Weiler. 1980. Radioimmunoassay for the Determination of Limonin in Citrus. *Phytochemistry* 19:1403-1407.
2. Weiler, Elmar W. and Richard L. Mansell. 1980. Radioimmunoassay of Limonin Using a Tritiated Tracer. *J. Agric. Food Chem.* 28(3):543-545.
3. Mansell, Richard L. and Elmar W. Weiler. 1980. Immunological Tests for the Evaluation of Citrus Quality. *Am. Chem. Soc. Symposium Series.*
4. *SAS User's Guide: 1979 edition.* SAS Institute, Inc., Raleigh, N.C. in conjunction with the SAS computer pack.
5. Zar, Jerrold H. 1974. *Biostatistical Analysis.* Prentice-Hall, Inc. Englewood Cliffs, N.J.

Proc. Fla. State Hort. Soc. 93:293-295. 1980.

COLOR AND PROCESSING CHARACTERISTICS OF 'STAR RUBY' GRAPEFRUIT[1]

S. V. Ting, R. L. Huggart and M. A. Ismail
Florida Department of Citrus,
Agricultural Research and Education Center,
P. O. Box 1088, Lake Alfred, FL 33850

Additional index words. Grapefruit juice color, processing.

Abstract. **'Star Ruby', a new cultivar of red grapefruit, was found to have excellent color both in the flesh and in the juice, even in late season. The color is sensitive to heat, but the juice, after pasteurization and concentration, retains sufficient color so that it may be used to enhance the color of pink grapefruit juice.**

The red color of the flesh of the pink and red grapefruit is known to fade with fruit maturity (4, 5). As a result, when the flavor quality of the fruit is at its best, the red color may have decreased to a very low level. The juice from such fruit becomes unacceptable as a pink grapefruit juice because of its low color, yet appears to be too reddish to meet white grapefruit juice color standards. Processing these juices with white grapefruit juice yields a muddy brown colored product which has poor appearance on account of its color.

There has been considerable demand for red colored grapefruit as fresh fruit and as processed products. A recent finding in new varieties is the 'Star Ruby' cultivar which has strikingly red colored flesh. This grapefruit was originated in Texas. It was grown from irradiated seeds of the 'Hudson', a seedy red grapefruit with relatively coarse texture (3). The highly colored 'Star Ruby' fruit is essentially seedless and has not been reported to revert to its parent seedy characteristics. The fruit has been well received in the fresh fruit trade and ranks second to the standard 'Ruby Red' grapefruit in number of cartons shipped out of Texas in 1978 (1). This paper describes the seasonal change of the flesh and juice color of the 'Star Ruby' and compares it with that of 'Ruby Red' grapefruit. The effect of heating, pasteurization, and concentration on the color of the juice of the 'Star Ruby' grapefruit and its potential use to increase the color of other grapefruit juices were also studied.

[1]Florida Agricultural Experiment Stations Journal Series No. 2737.
The authors wish to thank Dr. Mortimer Cohen and Mr. Robert Pelosi of the Agricultural Research Center, Fort Pierce, FL for providing the fruit used in this study.

Materials and Methods

Sampling. For determining the color change of the flesh and juice, 20 'Star Ruby' grapefruit were obtained at monthly intervals beginning November, 1978 and ending in June, 1979 from the Agricultural Research Center (ARC), University of Florida, at Fort Pierce. Six fruit taken from each sample were used for measuring flesh color, and the remainder for the study of juice color and other juice characteristics.

Fruit used to study the effect of heat pasteurization on the color of the juice were obtained from the Fort Pierce ARC in December, 1977. Two 90-lb. boxes of the fruit were washed and the juice extracted.

For the preparation of concentrate, a 10-box sample was obtained from the same source in January, 1979. These fruit were picked from 'Star Ruby' trees on several rootstocks from a rootstock experiment plot at the Fort Pierce ARC. These trees are about 6 years old and do not bear many fruit on each tree. The fruit was also brought to the Center at Lake Alfred and washed before extraction.

'Ruby Red' grapefruit for color comparison studies were picked at regular intervals from an experimental plot at the Center in Lake Alfred. The samples for flesh and juice color studies consisted of 20 fruit each.

Flesh color measurement. Fruit used for flesh color measurements were cut transversely into halves. The halved fruit was inverted on a glass plate over the aperture of a Hunter Color and Color Difference Meter (HCDM) model D25D. The Hunter "a" and "b" values were determined at two positions on each half of the fruit as described by Ting and Deszyck (5). The readings of all the stem halves and those of the stylar end halves were averaged separately, and the calculated Hunter "a"/"b" values were averaged for each monthly samples.

Juice extraction. The juice was extracted from fruit on an FMC In-line juice extractor, model 091B, with a 0.025 inch finishing tube using 16 lb. air pressure. The juice from the first 5 fruit of each sample was not used in the juice color measurement studies in order to minimize the color dilution from the residue in the finishing tube from previous samples. The °Brix, total acidity, and juice yield are determined in the usual manner (6).

The juice used in processing studies was extracted on an FMC In-line juice extractor model 591 with a 0.040 inch finishing tube. The juice was then passed through an FMC model 35 finisher with a 0.020 inch screen.

Juice processing. The 1977 sample for juice pasteurization study was deaerated and passed through a plate type pasteurizer at 88°C (190°F) for 10 seconds. The juice was allowed to cool under room temperature before the color measurement was taken. Another portion of the juice was pasteurized in a similar manner but was cooled immediately in the cooling cycle of the pasteurizer before color measurement was taken. The color of the unpasteurized juice, and that of a sample of the same juice which has been subjected to boiling for one minute, were also determined.

For concentration, 50 gal of the finished juice was pumped directly into the Center pilot scale TASTE evaporator and concentrated to 55° Brix. A small sample (1 liter) of the juice was evaporated at 60°C under vacuum to nearly the same concentration in a laboratory rotary evaporator. All color measurement of the concentrates was made after they were diluted to 10° Brix with distilled water.

Color measurement of the juice. The juice samples were placed in 25 x 150 mm screw-capped glass tube and measured in a Hunter Citrus Colorimeter model D 45-D2 for the C_R and C_Y values. The tristimulus values x, y and z were also measured and used for the calculation of Hunter "a" and "b" values.

In the measurement of the blended juice, 'Marsh Seedless' grapefruit juice was mixed with varying amounts of the reconstituted 'Star Ruby' grapefruit juice. The blended juice was then determined for their color in a similar manner as described before.

Results and Discussion

Internal quality. The internal quality of the 'Star Ruby' grapefruit sampled monthly from November through June is shown in Table 1. Since these fruit were picked from relatively young trees, it was not surprising to find that the soluble solids was only around 8° Brix throughout the season, and there was a drop in the soluble solids content of the sample picked in June. The titratable acidity decreased with maturity and the Brix/acid ratio increased from 7.8 in November to nearly 11 in April. It decreased as the season advanced thereafter. The juice yield average about 48% for the season. These juice characteristics are not different from those of the other colored grapefruit of comparable age (2).

Table 1. Seasonal changes in the internal quality of 'Star Ruby' grapefruit.

Date of picking	Total soluble solids °Brix	Titratable acidity %	Brix/acid ratio	Juice yield %
Nov. 18	8.2	1.05	7.8	49.2
Dec. 15	8.4	1.08	7.8	—
Jan. 18	8.0	.89	9.0	50.1
Feb. 28	8.2	88	9.3	59.6
Mar. 30	8.4	.89	9.4	49.0
Apr. 27	8.3	.77	10.8	43.3
May 17	8.1	.78	10.4	39.5
June 11	7.2	.73	9.9	47.4

Flesh color. The color of the flesh of the 'Star Ruby' grapefruit, as measured by the Hunter "a"/"b" ratios, showed only a very gradual decrease with season (Fig. 1). Even in the sample picked in June, the color remained excellent. The color of the flesh of 'Ruby Red' grapefruit was shown to be only about 1/6 of that of 'Star Ruby' as determined by their Hunter "a"/"b" ratios. Toward the end of the season, the color contrast of the flesh of these two fruit was very pronounced.

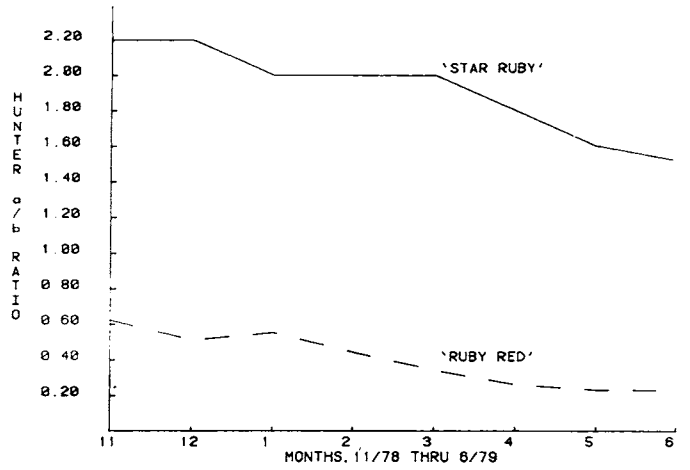

Fig. 1. Seasonal changes in flesh color of 'Star Ruby' and 'Ruby Red' grapefruit.

Slightly higher color was found in the stem end halves of the fruit than the stylar end halves. This difference, although not significant, was also found with 'Ruby Red' and pink grapefruit (4). The decrease in the Hunter "a"/"b" ratios with fruit maturity of the 'Star Ruby' grapefruit was found to be mainly due to the decrease in the Hunter "a" values (redness) since the Hunter "b" values (yellowness) did not vary appreciably. The latter did increase slightly toward the end of the season (Fig. 2).

Juice color. The comparison of the juice color of the 'Star Ruby' and 'Ruby Red' grapefruit is shown in Table 2.

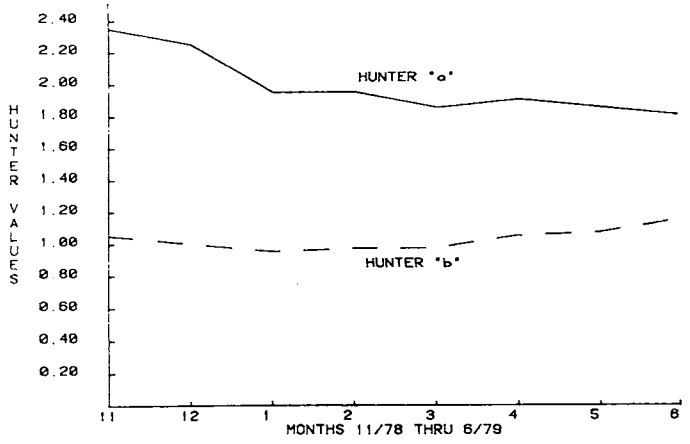

Fig. 2. Seasonal variations in Hunter "a" and "b" values of 'Star Ruby' grapefruit.

Table 2. Seasonal changes in juice color (Hunter "a"/"b" ratios) of 'Star Ruby' and 'Ruby Red' grapefruit.

Month	Cultivars 'Ruby Red'	'Star Ruby'
October	0.42	—
November	0.32	1.62
December	0.23	1.61
January	0.16	1.53
February	—	1.34
March	0.13	0.88
April	—	1.19
May	0.14	1.10
June	—	1.18
July	0.21	—

The 'Star Ruby' juice had Hunter "a"/"b" values about 5 to 6 times higher than the juice of 'Ruby Red'. The rate of color decrease was also significantly lower for the 'Star Ruby' juice.

Pasteurization on color of 'Star Ruby' grapefruit juice. Heating the juice had visible effect on the red color of the juice. Heating the juice for 10 seconds at 88°C (190°F) in a plate type pasteurizer with no cooling cycle decreased its Hunter "a"/"b" ratios from 1.8 in the control juice to 1.5 in the pasteurized juice. With a cooling cycle in the pasteurizer, a slightly higher value (1.6) was obtained. Boiling the juice for one minute greatly impaired the color. The Hunter "a"/"b" ratio decreased to 1.3.

Effect of concentration on juice color of 'Star Ruby' grapefruit. Although the prepared concentrate showed a bright red color, there is definitely a change of color of the reconstituted juice as compared with the freshly extracted sample (Table 3). The C_R values decreased slightly, but C_Y values increased markedly in the reconstituted concentrate. There was a substantial decrease of the Hunter "a"/"b" ratios. Prolonged evaporation, even at a low temperature and under vacuum, had the same detrimental effect on the color as shown by the decrease of the Hunter "a"/"b" ratio.

Table 3. Effect of concentration on the color of 'Star Ruby' grapefruit juice.

Treatment	Hunter values		
	C_R	C_Y	a/b Ratio
Freshly Extracted	91.1	38.7	1.85
TASTE Evaporator Recon. 10°Brix	88.9	48.4	1.30
Laboratory evaporator Recon. 10°Brix	86.9	48.6	1.30

Enhancing the red color of grapefruit juice with reconstituted 'Star Ruby' grapefruit concentrate. Even with the loss of color due to the concentrating process, the concentrate and the reconstituted juice are still intensely red in color. Adding varying amounts of the reconstituted red juice to a white grapefruit juice showed a proportional increase in the Hunger "a"/"b" ratio of the blended product (Table 4). A Hunter "a"/"b" ratio of about 0.5 would give the juice a red color considerably higher than that of a standard 'Ruby Red' at its best. At a level of 20% blend of 'Star Ruby' with a white grapefruit juice, the Hunter "a"/"b" ratio was about 0.50. It gives the appearance of excellent color for pink and red grapefruit juice. Less 'Star Ruby' juice will be needed if it is used only to enhance the color of a faded pink or red grapefruit juice.

Table 4. Color of blended grapefruit juice with varying amounts of 'Star Ruby' in white grapefruit juice.

% 'Star Ruby' juice	Hunter values		
	C_R	C_Y	a/b Ratio
0	7.8	31.7	−0.22
20	35.1	35.9	0.51
40	53.4	39.1	0.85
60	68.3	42.1	1.14
80	79.5	44.1	1.24
100	90.7	46.5	1.46

The 'Star Ruby' cultivar produces an intensely red color, both in the juice and in the flesh. The fruit has a coarser texture than the 'Ruby Red'. The flesh color decreased with maturity. However, even in late season, the flesh and juice remained intensely red. The color is reduced during the process of heat pasteurization and concentration, but the reconstituted concentrate and the pasteurized juice is still highly colored. A 20% blend of this juice with white grapefruit juice, or faded pink and red grapefruit juice, resulted in a product with an attractive color.

Literature Cited

1. Anon. 1978. 'Star-Ruby'-finding its niche in Texas Citrus. *Calif. Citrograph,* Vol. 64, No. 1.
2. Florida Crop and Livestock Reporting Service. 1979. Florida citrus maturity test results. November, 1979, Orlando, FL.
3. Hensz, R. A. 1971. 'Star Ruby', a new deep red fleshed grapefruit variety with distinct tree characteristics. *J. Rio Grande Hort. Soc.* 25:54-58.
4. Lime, B. J., Stephens, T. S. and Griffith, F. P. 1954. Processing characteristics of colored Texas grapefruit, I. Color and maturity studies of 'Ruby Red' grapefruit. *Food Tech.* 8:566-569.
5. Ting, S. V. and Deszyck, E. J. 1958. The internal color and carotenoid pigments of Florida red and pink grapefruit. *Proc. Amer. Soc. Hort. Sci.* 71:271-277.
6. Wardowski, W., Soule, J., Grierson, W. Westbrook, G. 1979. Florida citrus quality tests. *University of Florida Ext. Bul.* 158.