10. Milbrath, J. A., E. Hanson, and H. Hartman. 1940. Defoliation of rose plants with ethylene gas. *Science* 91:100.
11. _____ and H. Hartman. 1942. The cause and control of defoliation in cut holly. *Oregon Agr. Expt. Sta. Bul.* 413. 11 p.
12. Piersol, J. R. and J. J. Hanan. 1975. Effect of ethylene on carnation growth. *J. Amer. Soc. Hort. Sci.* 100:679-681.
13. Tjia, B., M. N. Rogers, and D. E. Hartley. 1969. Effects of ethylene on morphology and flowering of *Chrysanthemum morifolium* Ramat. *J. Amer. Soc. Hort. Sci.* 94:35-39.
14. Zimmerman, P. W., A. E. Hitchcock, and W. Crocker. 1931. The effect of ethylene and illuminating gas on roses. *Contr. Boyce Thompson Inst.* 3:359-481.

J. Amer. Soc. Hort. Sci. 104(6):880–882. 1979.

Effects of Stage of Maturity, Storage, and Cultivar on Some Quality Attributes of Tomatoes[1]

Ali M. H. Al-Shaibani and J. K. Greig[2]
Department of Horticulture, Kansas State University, Manhattan, KS 66506

Additional index words. Lycopersicon esculentum, pH, ascorbic acid, β-carotene, sugars

Abstract. **Fruits of tomato (*Lycopersicon esculentum* Mill cvs. Jet Star and Floramerica) were harvested at various maturity stages and ripened at 20°C and 80% relative humidity. Differences in pH between field-ripened and storage-ripened fruits of either cultivar were not significant. Ascorbic acid of 'Jet Star' fruits increased slightly during ripening both on and off the plant; 'Floramerica' fruits showed no changes in ascorbic acid content during ripening. Field-ripened fruits had significantly higher ascorbic acid than storage-ripened fruits. The β-carotene content significantly increased with ripening for both cultivars, with no significant differences between field- and storage-ripened fruits. Fruits of 'Jet Star' contained more β-carotene than 'Floramerica' fruits. Total sugars increased during ripening up to the firm ripe stage. Total sugar content of field-ripened fruits was significantly higher than storage-ripened fruits in 'Jet Star' but not in 'Floramerica'. Fruits harvested in the breaker stage retained the highest total sugar content during storage.**

The quality of fresh tomatoes available in markets has been a concern of retailers and consumers. McCollum and Skok (15) reported that tomatoes harvested in the mature green stage and ripened in storage would have poorer quality than fruits ripened on the plant. Recently, Kader et al. (7) reported that tomatoes picked at earlier stages of ripeness and ripened at 20°C were evaluated as being less sweet, more sour, less "tomato-like" and having more "off-flavor" than those picked at the table-ripe stage. Many studies have shown that factors such as cultivar (10), harvest date (9), and stage of ripeness (5) influence pH values in tomato fruits, but that sunlight exposure and post-harvest storage temperature did not. However, Lambeth et al. (9) and Lower and Thompson (10) reported that field-ripened fruits had a higher pH than chamber-ripened fruits. Hanna (5) found a difference in pH between cultivars. The pH is highest just after fruit set, decreases as the fruit grows, is lowest at the breaker stage, and increases slightly as the fruit ripens.

Wokes and Organ (21) showed that tomatoes harvested green and ripened at room temperature in sunlight and field-ripened fruits contained similar ascorbic acid contents but the content was appreciably lower in fruits ripened in the dark at room temperature. An apparent increase in ascorbic acid associated with tomato fruits maturing was shown (4, 12). However, Maclinn et al. (11) reported that stage of ripeness had no effect on ascorbic acid content. Bisogni et al. (2) and Kays (8) reported a remarkably uniform loss of ascorbic acid from tomatoes ripening in storage.

McCollum (14) reported that β-carotene content of tomato fruits ripened at a constant temperature (23.9°C) under sufficient light had higher carotene contents than those ripened in the dark at the same temperature. Watada et al. (19) indicated that differences in Vitamin A activity were wider among cultivars than among ripeness stages. Meredith and Purcell (16) reported that β-carotene content of green 'Homestead' tomatoes increased through all stages of maturity to the light red, then decreased. Watada et al. (19) reported that tomatoes ripened on the plant had significantly higher average β-carotene content than those ripened after harvesting.

Numerous studies dealing with soluble solids (60% sugar) have been reported. Winsor et al. (20) stated that total sugars in the expressed juices increased significantly from the mature green to the red ripe stage, but decreases once the fruit has begun to color.

The objectives of this study were to compare pH, ascorbic acid, β-carotene, and total sugar of storage-ripened with field-ripened tomatoes, and to determine compositional attributes of 2 cultivars primarily grown for local marketing.

Materials and Methods

'Jet Star Hybrid' and 'Floramerica Hybrid' tomato plants were grown at Ashland Horticultural Farm, Kansas State University, during the summer of 1977 using conventional cultural practices. Both cultivars were harvested at:

1. *Mature green,* a completely green skin that will turn red either on or off the vine.
2. *Breaker,* primarily green with a tinge of yellow or pink, usually at the blossom-end.
3. *Pink,* 50% or more pink or red skin.
4. *Firm ripe,* fully red but firm.
5. *Overripe,* fully red, but soft.

Fifteen fruits of each cultivar at each stage were selected for chemical analyses. Then 3 replicates of 5 fruits each were picked at random from the 15 fruits. Fruits of each sample were quartered so a portion from each could be used in chemical analyses.

[1]Received for publication August 12, 1978. Contribution 79-16-J, Department of Horticulture, Agricultural Experiment Station, Kansas State University, Manhattan, 66506.
The cost of publishing this paper was defrayed in part by the payment of page charges. Under postal regulations, this paper must therefore be hereby marked *advertisement* solely to indicate this fact.

[2]Graduate student in Food Science and research horticulturist, respectively.

Both cultivars were harvested at the different stages of maturity, ripened in storage at 20°C and 80 percent relative humidity in the dark and analyzed at each maturity stage.

Portions were analyzed immediately after sampling for pH and ascorbic acid; whereas, portions for β-carotene and total sugar analyses were weighed (50 g), transferred to glass vials, and held at −20°C until analyzed.

pH. Five fruits per sample at each stage were washed; one quarter of each was blended and the entire puree was analyzed for pH with a Horizon (digital) pH meter.

Ascorbic acid. The official microfluorometric method of AOAC (1) was used to determine ascorbic acid contents with one modification; instead of 2 g Norit A, 4 g was used. One quarter each of 5 washed tomato fruits was weighed, extracting acid solution (3% HPO_3 − 8% HOAC) was added, and the mixture was blended. Then 50 g of slurry was diluted to volume (100 ml) with the same extracting acid solution. Ascorbic acid was oxidized to dehydroascorbic acid in the presence of Norit. The form reacted with 0-phenylenediamine to produce fluorophor. Fluorescence intensity was proportional to ascorbic acid concentration.

β-carotene. Analyses were made for β-carotene by a modified AOAC (1) chromatographic method. Sample size was increased to 50 g and alcohol volume, 5 fold for extraction. Instead of using 10% acetone in hexane (Skellysolve B), we used 4% acetone in Skellysolve B to slow down elution of carotene. Color intensity was measured at 436 nm with a Beckman spectrophotometer and β-carotene content was calculated by Beer-Lambert's Law.

Total sugar. The official colorimetric method of AOAC (1) for total sugar analyses was used. The absorbances were measured at 745 nm with a Beckman spectrophotometer. Then total sugar content was determined using a standard curve.

Results and Discussion

pH. The trend of pH changed similarly for 'Jet Star' and 'Floramerica' field-ripened and storage-ripened fruit (Tables 1, 2). In general, pH decreased significantly in both cultivars with the first appearance of pink (breaker) in the fruits then increased slightly with each maturity stage to overripe. The results agreed with those of some other investigators (5, 6, 10).

Significant differences between the pH values of field-ripened and storage-ripened fruits were not consistent for either cultivar (Tables 1, 2), which agrees with other reports (2, 13); however, the average pH value of field-ripened 'Jet Star' fruits was 0.7 unit higher than storage-ripened fruits. For 'Floramerica' fruits the same comparison differed in only 0.01 pH unit. The pH of 'Floramerica' fruits was lower than that of 'Jet Star' fruits at all stages of maturity for both field-ripened and storage-ripened fruits.

Ascorbic acid. No consistent trend in ascorbic acid concentrations was established during field ripening of either cultivar or during storage ripening of 'Jet Star' (Tables 1, 2). 'Jet Star' fruits, however, tended to increase in ascorbic acid as they ripened on but not off the plant while ascorbic acid did not change during ripening of 'Floramerica' on the plant but it did off the plant. Ascorbic acid concentrations of field-ripened tomatoes were significantly higher than those of storage-ripened fruits particularly overripened 'Jet Star' fruits but not for 'Floramerica' (Tables 1, 2), which agrees with reports by other workers (2, 18). Fruits of neither cultivar harvested mature green and ripened in storage retained ascorbic acid during storage. But neither had significant losses of ascorbic acid during storage when picked at the breaker, pink, or firm ripe stage except for the overripened 'Jet Star' fruits picked at the pink and firm ripe stages. Ascorbic acid was slightly higher in 'Jet Star' than 'Floramerica' during most stages of maturity.

β-carotene. The sequence of changes in β-carotene concentrations was parallel for both field-ripened and storage-ripened

Table 1. Means of indicated quality factors as affected by ripening treatment and stage of maturity of 'Jetstar' hybrid tomato fruits.

Treatment	pH	Ascorbic acid (mg/100 g fresh wt)	β-carotene (mg/100 g fresh wt)	Total sugar (% fresh wt)
Field ripened				
Mature green	4.53a[z]	22.57cde	0.16e	3.34bc
Breaker	4.33cde	22.20cdef	0.18e	2.65fg
Pink	4.44b	23.40bcd	0.35abcd	3.35bc
Firm ripe	4.30cdef	20.57defg	0.43abc	3.54b
Overripe	4.35cd	27.77a	0.31cd	3.98a
Storage ripened				
Break from mature green	4.35cd	19.23fg	0.26de	3.04cde
Pink from mature green	4.25f	18.73g	0.39abc	3.07cde
Firm ripe from mature green	4.26ef	19.80efg	0.34abcd	3.06cde
Overripe from mature green	4.34cde	18.37g	0.45a	2.46g
Pink from breaker	4.37cb	23.07bcd	0.32bcd	3.16cd
Firm ripe from breaker	4.27def	21.30cdef	0.35abcd	3.20cd
Overripe from breaker	4.30cdef	25.47ab	0.46a	2.98de
Firm ripe from pink	4.38cb	22.13cdef	0.36abcd	3.00de
Overripe from pink	4.32cdef	22.10cdef	0.38abc	2.80ef
Overripe from ripe	4.32cdef	23.83bc	0.43ab	3.28bcd

[z]Mean separation within rows by Duncan's multiple range test, 5% level.

Table 2. Means of indicated quality factors as affected by ripening treatment and stage of maturity of 'Floramerica' hybrid tomato fruits.

Treatment	pH	Ascorbic acid (mg/100 g fresh wt)	β-carotene (mg/100 g fresh wt)	Total sugars (% fresh wt)
Field ripened				
Mature green	4.52a[z]	22.50ab	0.05e	2.98defg
Breaker	4.14gh	22.33ab	0.17cd	3.09bcde
Pink	4.15fgh	20.57abc	0.14d	2.94efg
Firm ripe	4.23cdefg	21.37ab	0.26ab	3.25abc
Overripe	4.21defgh	23.27a	0.32a	3.20abcde
Storage ripened				
Breaker from mature green	4.19efgh	17.27de	0.22bc	3.08bcde
Pink from mature green	4.24cdef	19.37bcd	0.25ab	3.37a
Firm ripe from mature greem	4.22defgh	19.43bcd	0.26ab	3.20abcde
Overripe from mature green	4.34b	15.80e	0.24ab	2.74fg
Pink from breaker	4.14h	18.17cde	0.22bc	3.43a
Firm ripe from breaker	4.19efgh	21.67ab	0.29ab	2.99cdef
Overripe from breaker	4.24cdef	22.10ab	0.31a	2.73g
Firm ripe from pink	4.25bcde	21.20ab	0.25ab	3.30ab
Overripe from pink	4.32bc	22.80a	0.28ab	3.25abc
Overripe from firm ripe	4.30bcd	21.93ab	0.27ab	3.24abc

[z]Mean separation within rows by Duncan's multiple range test, 5% level.

fruits of both cultivars (Tables 1, 2). β-carotene generally increased significantly through all stages of ripeness and was highest at the overripe stage, except that field-ripened 'Jet Star' had the most β-carotene at the firm ripe stage. Meredith and Purcell (16) stated that changes in concentrations of β-carotene may result from the rate of synthesis being constant and independent of the precursor concentration, while the rate of destruction increases with maturity. Conversely, the rate of ring closure may decrease in the late stages of maturity while the rate of destruction remains constant.

β-carotene contents did not differ significantly between field-ripened and storage-ripened fruits of either cultivar (Tables 1, 2) except that storage overripened 'Jet Star' had higher β-carotene content than the field-overripened fruits. This generally is consistent with the report by Nettles et al. (17) who found that light exposure did not significantly affect β-carotene contents of tomatoes and that β-carotene did not differ between tomatoes ripened on or off the plant.

Tomatoes picked at mature green, breaker, pink, or firm ripe stages continued to synthesize β-carotene for the entire storage period. 'Jet Star' fruits contained more β-carotene content than 'Floramerica' fruits. Highest β-carotenes were 0.46 mg/100 g fresh weight for 'Jet Star' and 0.32 mg/100 g for 'Floramerica'.

Total sugar. The total sugar of both cultivars increased from the mature green stage to the overripe stage, although a decrease once the fruits reached the breaker stage in 'Jet Star' and the pink stage in 'Floramerica' was found (Tables 1, 2). Sugar increased more in 'Jet Star' than in 'Floramerica' fruits. Davies and Kempton (3) and Winsor et al. (20) reported similar findings.

Field-ripened 'Jet Star' tomatoes contained significantly more total sugar than storage-ripened 'Jet Star' except for the breaker stage (Table 1). These results were parallel with the observations of Kader et al. (7). But that was not true for 'Floramerica' (Table 2). When ripened in storage, fruits of both cultivars harvested at the breaker stage retained more total sugar than those harvested at other stages of maturity. 'Jet Star' fruits generally contained more total sugar than 'Floramerica' fruits.

Literature Cited

1. Association of Official Agricultural Chemists. 1975. Official Methods of Analysis. Washington, D.C.
2. Bisogni, C. A., G. Armbruster, and P. E. Brecht. 1976. Quality comparisons of room ripened and field ripened tomato fruits. *J. Food Sci.* 41:333-338.
3. Davies, J. N. and R. J. Kempton. 1975. Changes in the individual sugars of tomato fruit during ripening. *J. Sci. Food Agric.* 26:1103-1110.
4. Fryer, H. C., L. Ascham, A. B. Cardwell, J. C. Frazier and W. W. Willis. 1954. Relation between stage of maturity and ascorbic acid content of tomatoes. *Proc. Amer. Soc. Hort. Sci.* 64:365-371.
5. Hanna, G. C. 1961. Changes in pH and soluble solids of tomatoes during vine storage of ripe fruit. *Proc. Amer. Soc. Hort. Sci.* 78: 459-463.
6. Iwahori, S. and J. M. Lyons. 1970. Maturation and quality of tomatoes with preharvest treatments of 2-chloroethyl phosphonic acid. *J. Amer. Soc. Hort. Sci.* 95:88-91.
7. Kader, Adel A., M. Allen Stevens, Marjorie Albright-Holton, Leonard L. Morris, and Margaret Algazi. 1977. Effect of fruit ripeness when picked on flavor and composition in fresh market tomatoes. *J. Amer. Soc. Hort. Sci.* 102:724-731.
8. Kays, W. R. 1948. Effect of contact icing on retention of quality of fruits and vegetables. *Ice & Refrig.* 7:115.
9. Lambeth, V. N., M. L. Fields, and D. G. Huecker. 1964. The sugar-acid ratio of selected tomato varieties. *Missouri Agr. Exp. Sta. Res. Bul.* 850.
10. Lower, R. L. and A. E. Thompson. 1966. Sampling variation of acidity and solids in tomatoes. *Proc. Amer. Soc. Hort. Sci.* 89:512-552.
11. Maclinn, W. A., C. R. Fellers, and R. E. Buck. 1936. Tomato variety and strain differences in ascorbic acid (Vitamin C) content. *Proc. Amer. Soc. Hort. Sci.* 34:543-552.
12. Malewski, W. and P. Markakis. 1971. Ascorbic acid content of the developing tomato fruits. *J. Food Sci.* 36:537.
13. McCollum, J. P. 1946. Effect of sunlight exposure on the quality constituents of tomato fruits. *Proc. Amer. Soc. Hort. Sci.* 48:413-416.
14. _____. 1954. Effects of light on the formation of carotenoids in tomato fruits. *Food Res.* 19:182-189.
15. _____ and J. Skok. 1960. Radiocarbon studies on the translocation of organic constituents into ripening tomato fruits. *Proc. Amer. Soc. Hort. Sci.* 75:611-616.
16. Meredith, F. I. and A. E. Purcell. 1966. Changes in the concentration of carotenes of ripening tomatoes. *Proc. Amer. Soc. Hort. Sci.* 89:544-548.
17. Nettles, V. F., C. B. Hall, and R. A. Dennison. 1955. The influence of light on color development of tomato fruits. *Proc. Amer. Soc. Hort. Sci.* 65:349-352.
18. Pantos, C. E. and P. Markakis. 1973. Ascorbic acid content of artificially ripened tomatoes. *J. Food. Sci.* 38:550.
19. Watada, A. E., B. B. Aulenbach., and J. T. Worthington. 1976. Vitamins A and C in ripe tomatoes as affected by stage of ripeness at harvest and by supplementary ethylene. *J. Food Sci.* 41:856-858.
20. Winsor, G. W., J. M. Davies, and D. M. Massay. 1962. Composition of tomato juice. III. Juices from whole fruit and levels at different stages of ripeness. *J. Sci. Food Agr.* 13:108-115.
21. Wokes, F. and J. G. Organ. 1943. Oxidizing enzymes and Vitamin C in tomatoes. *Biochem J.* 37:259-265.