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VITAMINS A AND C IN RIPE TOMATOES AS AFFECTED BY STAGE OF RIPENESS AT HARVEST AND BY SUPPLEMENTARY ETHYLENE

ABSTRACT

The ascorbic acid (vitamin C) and β-carotene (provitamin A) contents of ripe tomatoes harvested at different stages of ripeness or treated with supplementary ethylene were determined. Vitamin C activity in 100g ranged from 15–50% U.S. Recommended Daily Allowance (RDA) among cultivars. Vitamin C activity was not affected by stage of ripeness at harvest, but was slightly higher in a few cultivars treated with ethylene. The vitamin A activity in 100g ranged from 10–140% U.S. RDA among cultivars. Vitamin A activity was not affected by ethylene, but was slightly higher in ripe fruit that had been harvested ripe than those harvested mature-green. However, fruit harvested mature-green or breaker, the stages at which most fresh market tomatoes are harvested, did not differ in vitamin A activity for three of the four cultivars tested.

INTRODUCTION

A FRESH, ripe, tomato fruit weighing 100g supplies 10.4–44.6 mg ascorbic acid (vitamin C) and 0.21–0.80 mg β-carotene (provitamin A) (Lincoln et al., 1943). Vitamin contents of tomatoes differ with cultural practices, cultivars and postharvest handling practices (Hamner and Maynard, 1942).

Tests on the effect of stage of ripeness at harvest and of supplementary ethylene on ascorbic acid content have produced contradictory results. Clow and Marlatt (1930) observed that ripe tomatoes harvested as mature-green and as ripe fruit contained the same quantity of ascorbic acid. In contrast Scott and Kramer (1949) and Pantos and Markakis (1973) reported that ripe fruit harvested mature-green had ascorbic acid levels different from those harvested ripe. Clow and Marlatt (1930) found that the ascorbic acid contents of tomatoes treated with and without ethylene were similar; whereas, Jones and Nelson (1930) found that ethylene-treated tomatoes contained less ascorbic acid than those untreated.

Ascorbic acid content increases and then decreases with ripening (Malewski and Markakis, 1971), thus conflicting results could have been due to differences in ripeness at time of analysis. Some workers could have considered the fruit ripe when the ascorbic acid level happened to be maximum; whereas, others could have considered the fruit ripe at a later stage when the level was decreasing. These workers determined ripeness visually, so the stage at which ascorbic acid was analyzed is not known.

Earlier studies indicate that the stage of ripeness at harvest or supplementary ethylene has no effect on the vitamin A potency of the fruit (Jones and Nelson, 1930; House et al., 1929; and Morgan and Smith, 1928). Potency was based on the survival of rats that were fed canned juice of canned fruit prepared from the treated lots.

We reexamined the effect of stage of ripeness at harvest and of supplementary ethylene on ascorbic acid and β-carotene of ripe tomatoes, determining ripeness objectively by the light-transmittance technique (Worthington, 1974). Fresh market tomatoes generally are harvested prior to or at incipient ripening; thus, fruit at these stages, as well as ripe fruit, were used for the study on stage of harvest. Green fruit prior to ripening are called "mature-green" and those at incipient ripening are termed "breaker" (USDA, AMS, 1975). Supplementary ethylene is used to hasten ripening of many mature-greens, but not breakers; thus only mature-greens were used for the ethylene study.

MATERIALS & METHODS

Stage of harvest

Tomato fruit of ten cultivars were harvested when mature-green and ripe in 1973, and five cultivars were harvested at the mature-green, breaker and ripe stages in 1974. Two lots, each of ten fruit, of each maturity were selected in 1973, and two to five lots of each maturity were selected in 1974. Fruit were held at 21.1°C and analyzed when ripe. The conclusions of the studies for the 2 yr were similar; thus most of the comments are based on the 1973 study.

Ripeness was determined objectively by the light-transmittance technique as described by Worthington (1974) and is expressed as the difference between the absorbance (ΔA) at two wavelengths (nm). The mature-green fruit had a ΔA (510–600 nm) of 0.2–0.4 and required about 5 days at 21.1°C to ripen to breaker stage, which had a ΔA (510–600 nm) of about 1.5. Ripe fruit had a ΔA (600–690 nm) of 2.6–3.0. An exception to this was the orange 'Caro-Red' fruit which had a ΔA (600–690 nm) of 0.6–1.0. Fruit were rated ripe on the basis of comments by a sensory panel in earlier tests.

Ethylene

'Walter' tomatoes were obtained from 11 Florida growers–four in May, three in December, and four in March. A box of graded fruit from each grower was placed in a commercial gassing chamber, where the ethylene concentration was calculated to be 8000 ppm, for 24–36 hr at 22.2°C. A second box was held at a comparable temperature during the treatment period, and both boxes were shipped to Beltsville, Md., where the fruit were ripened at 21.1°C. Two lots of 15 fruit each were analyzed from each box for ascorbic acid and β-carotene when the ΔA (600–690 nm) was 2.6–3.0.

Ascorbic acid

The ascorbic acid was analyzed by a modified AOAC method (AOAC, 1970). A 7-mm wedge from each of the 10 or 15 fruit samples was immersed directly into the meta-phosphoric-acetic acid extraction solution and macerated. The macerate was centrifuged, and 2,6-dichloro-indophenol Na salt used in the titration was obtained from Sigma Chemical. Each sample was analyzed in duplicate. The vitamin C is reported in mg per 100g fresh weight (gfw) and as percentage of U.S. Recommended Daily Allowance (RDA), which is 60 mg. The percentages are expressed in multiples of five for levels from 10 through 50% and in multiples of ten for levels above 50% (USDHEW, 1973).

β-Carotene

A 7-mm wedge from each of the 10 or 15 fruit samples was heated to 74°C in a microwave oven and stored at −20°C until analysis. The β-carotene was analyzed by a modified AOAC method (AOAC, 1970) and was extracted with an acetone-hexane mixture. The MgO-Hyflo-Supercel chromatographic column was washed with 0.5% acetone in hexane so that isomerization of carotenoids would be minimized (Wiseman et al., 1952). β-Carotene was eluted with 5% acetone in hexane. The concentration of β-carotene was based on the absorbance at 451 nm with an extinction coefficient of 2505 (Goodwin, 1955). Vitamin A

activity is presented as percentage of U.S. RDA. One International Unit (IU) of vitamin A equals 0.6μg β-carotene and 5000 IU equals 100% U.S. RDA. Percentages are expressed in multiples of five or ten as described for ascorbic acid (USDHEW, 1973).

RESULTS & DISCUSSION

Stage of harvest

Average ascorbic acid contents of ripe tomatoes were 17.6 and 18.7 mg/100 gfw, respectively, for fruit harvested mature-green and ripe (Table 1). These values were not significantly different and represented 30% U.S. RDA of vitamin C. Of the cultivars, only 'Double-Rich' had significantly more vitamin C in fruit that had been harvested ripe than those harvested mature-green. The U.S. RDA of vitamin C was 5 percentage points more in fruit harvested ripe than that harvested mature-green.

The ascorbic acid contents ranged from 13.7–31.8 mg/100 gfw for the cultivars harvested ripe (Table 1). A 100-g portion of 'Double-Rich' contained 31.8 mg ascorbic acid, which was 50% U.S. RDA. 'Heinz 1350,' a processing cultivar, contained 23.6 mg/100 gfw, which was 74% of the value for 'Double-Rich.' The ascorbic acid in 100g of the remaining cultivars ranged from 13.7–19.4 mg, which were 44 to 61% of the value for 'Double-Rich.' These quantities represented 20–30% U.S. RDA of vitamin C.

The differences in ascorbic acid content were greater among cultivars than between ripe fruit harvested as mature-green or ripe. The largest difference in U.S. RDA was 30 percentage points among cultivars, and only 5 percentage points between stages of maturity at harvest. In 1974, the differences also were larger among cultivars than among harvest stages, which included mature-green, breaker and ripe.

The average β-carotene contents of tomatoes ripened on and off the plant were 475 and 385 μg/100 gfw, respectively, which were significantly different (Table 2). The average values did not include 'Caro-Red,' which was developed for high β-carotene content. In terms of vitamin A activity, 475 and 385 μg are equivalent to 15% U.S. RDA.

The β-carotene level of fruit ripened on and off the plant differed significantly only with some of the cultivars (Table 2). Fruit of 'Fantastic,' 'Double-Rich,' 'Heinz 1350,' one set of 'Walter,' and 'Caro-Red' contained higher β-carotene when ripened on the plant. Except for 'Caro-Red,' the difference in the U.S. RDA of vitamin A due to harvest maturity was only 5 percentage points. The difference was 80 percentage points for 'Caro-Red.' Although the β-carotene levels of the remaining cultivars were not significantly different, the levels were higher in fruit ripened on the plant.

The second year's study confirmed that the β-carotene contents of ripe tomatoes varied directly with ripeness of the fruit at harvest (Table 3). The average content of a 100g ripe fruit was 82 μg greater when harvested as ripe than as breaker and 103 μg greater when harvested as breaker than as mature-green. Thus, although the increases were not always significant, β-carotene of all cultivars increased with ripeness of fruit at harvest. McCollum (1954) showed that tomato fruit exposed to sunlight during ripening contained more β-carotene than those ripened in shade. In our study, fruit harvested at a riper stage were exposed to more sunlight, which probably was the cause for the difference.

The differences in vitamin A activity were greater among cultivars than between stage of ripeness at harvest (Table 2). The vitamin A activity of 'Caro-Red,' the cultivar with highest activity, was 5–11 times that of other cultivars. The difference between stage of maturity at harvest was only 1/4 or less of the differences observed with cultivars.

Ethylene

The average ascorbic acid content of tomatoes treated with supplementary ethylene was higher than that of untreated fruit, and the differences were significant for May and December lots (Table 4). However, differences may not have been due to the direct effect of ethylene on ascorbic acid. Ascorbic acid in tomatoes increases to a maximum level and then decreases with ripening (Malewski and Markakis, 1971). The supplementary ethylene may have hastened color development sufficiently for the ripe color to develop when the ascorbic acid was near the maximum level; whereas, the untreated fruit may have developed ripe color when ascorbic acid was decreasing. In terms of percentage of U.S. RDA of vitamin C, only the

Table 1—Ascorbic acid content and percent of U.S. Recommended Daily Allowance (RDA) of vitamin C in ripe tomatoes of several cultivars that were harvested mature-green or ripe in 1973[a]

	Stage of harvest			
	Mature-green		Ripe	
Cultivar	mg/100 gfw	% US RDA[c]	mg/100 gfw	% US RDA
Double Rich	26.6 b[d]	45	31.8 a	50
Heinz 1350	22.8 bcd	40	23.6 bc	40
Fantastic	18.5 defg	30	19.4 cde	30
Manapal	17.2 efgh	30	18.9 def	30
Rutgers	15.8 efgh	25	18.8 def	30
Cal-Ace	18.0 efg	30	17.5 efgh	30
Caro-Red	15.5 efgh	25	17.0 efgh	30
Walter (a)[b]	15.4 efgh	25	15.6 efgh	25
Homestead	17.2 efgh	30	15.0 efgh	25
Campbell 1327	12.8 h	20	14.5 fgh	25
Walter (b)	14.2 fgh	25	13.7 gh	20
Average	17.6 m	30	18.7 m	30

[a] Values are averages of two lots of ten fruit each.
[b] The two sets of 'Walter' were harvested from different plantings.
[c] Percentages expressed in multiples of five for values from 10 through 50%. (USDHEW, 1973)

Table 2—β-Carotene content and percent of U.S. Recommended Daily Allowance (RDA) of vitamin A in ripe tomatoes that were harvested mature-green and ripe in 1973[a]

	Stage at harvest			
	Mature-green		Ripe	
Cultivar[b]	μg/100 gfw	% US RDA[c]	μg/100 gfw	% US RDA
Fantastic	432 bcde[d]	15	558 a	20
Double Rich	425 bcde	15	573 a	20
Rutgers	403 cde	15	490 abc	15
Homestead	396 cde	15	400 cde	15
Walter (a)[b]	394 cde	15	484 abc	15
Manapal	388 cde	15	408 cde	15
Heinz 1350	382 cde	15	524 ab	15
Cal-Ace	356 de	10	428 bcde	15
Campbell 1327	352 de	10	441 bcd	15
Walter (b)	320 e	10	446 bcd	15
Average	385 m	15	475 n	15
Caro-Red	1918	60	4190	140

[a] Values are average of two lots of ten fruit each. 'Caro-Red' was not included in statistical analysis.
[b] The two sets of 'Walter' were harvested from different plantings.
[c] Percentages expressed in multiples of five for values from 10 through 50% (USDHEW, 1973).
[d] Values not followed by common letters are significantly different (P = 0.05) (Duncan, 1955).

May lot showed differences between treated and untreated fruit, which contained 20% and 15% U.S. RDA vitamin C, respectively.

The average β-carotene contents of ripe tomatoes treated with and without supplementary ethylene were similar (Table 4). All samples had an average of 10% U.S. RDA of vitamin A.

Table 3—β-Carotene content of ripe tomatoes harvested as mature-green, breaker and ripe fruit in 1974[a]

	Stage at harvest		
	Mature-green	Breaker	Ripe
Cultivar	μg/100 gfw	μg/100 gfw	μg/100 gfw
Cal-Ace	416 def[b]	504 bcde	560 abc
MH-1	408 def	513 bcd	601 ab
Rutgers	407 ef	534 bc	651 a
Walter	370 f	440 cdef	532 bc
Average	403 m	506 n	588 o

[a] The number of lots differed with cultivar and stage of harvest. Values are averages of two to five lots of ten fruit each.
[b] Values not followed by common letters are significantly different (P = 0.05) (Duncan, 1955).

Table 4—Ascorbic acid content, percent of U.S. RDA of vitamin C, β-carotene content and percent of U.S. RDA of vitamin A in ripe 'Walter' tomatoes treated with supplementary ethylene at mature-green stage. Tomatoes from different growers at different times of the year[a]

	Ascorbic acid			
	Untreated		Treated	
Lot	mg/100 gfw	% US RDA[c]	mg/100 gfw	% US RDA
May	9.7 a[b]	15	11.8b	20
Dec.	8.6 a	15	10.0 b	15
March	11.0 a	20	12.2 a	20
	β-Carotene			
May	301 a	10	257 a	10
Dec.	287 a	10	240 a	10
March	278 a	10	275 a	10

[a] Average of fruit from four growers in May, three growers in December, and four growers in March.
[b] Values not followed by common letters within the line are significantly different (P = 0.01) (Duncan, 1955).
[c] Percentages expressed in multiples of five for values from 10 through 50% (USDHEW, 1973).

β-Carotene approaches maximum level by the time the fruit are partially ripe (Lampe and Watada, 1971), and, apparently, supplementary ethylene did not hasten color formation sufficiently for the fruit to develop ripe color before the maximum level was reached.

CONCLUSION

THE STAGE of ripeness at harvest and supplementary ethylene had only slight effects, if any, on vitamin A and C activities of ripe tomatoes. Vitamin A activity was slightly higher in ripe tomatoes that had been harvested ripe than mature-green. However, the difference between those harvested mature-green and breaker, the stages at which most fresh tomatoes are harvested, was not significant for most cultivars. Tomatoes of high vitamin activity can best be obtained by proper selection of cultivars. Dependent on the cultivar, a 100-g fruit could supply 15–50% U.S. RDA of vitamin C and 10–140% of U.S. RDA of vitamin A.

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