Seasonal Trends of Four Quality Factors in Processing Tomatoes (*Lycopersicon esculentum* Mill.)[1]

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Abstract. Four processing tomato cvs. Chico III, Merit, Dorchester and Campbell 28 were sampled biweekly throughout the harvesting season in 1972 and 1973. Seasonal variation was noted in soluble solids, pH, ascorbic acid and color. The color and pH of tomatoes reached maximum values between 89 and 105 days after planting while soluble solids were generally higher between 76 and 106 days after planting. There was no trend in the variation of ascorbic acid throughout the sampling period. In some cases, however, there was a lower ascorbic acid content in fruits toward the end of the harvesting season. Of 5 climatic factors measured in both years, temperature and radiation were implicated as affecting tomato fruit quality.

The use of mechanical harvesting, field application of ethephon, and new cultivars adapted for mechanization have made production of processing tomatoes more efficient and profitable. With the progress in cultivar development and mechanization, there has arisen concern about quality of tomatoes, especially quality factors related to nutritional value. In the past, the appearance of the fruit has traditionally been emphasized, but more attention is now being focused on nutritional factors and on the effect of climatic conditions on these factors.

The effect of climatic condition on quality factors in tomatoes has been reported by many investigators over the past 50 years (4, 5, 6, 7, 8). With the experimental data available, researchers have not been able to determine which climatic factors are responsible for small changes in fruit quality. Fluctuations in fruit quality during the harvesting season have not been fully explained by environmental parameters (3, 7, 11, 12).

Our purpose was to study the effect of climatic conditions on fruit quality of several tomato cultivars through the determination of pH, ascorbic acid, soluble solids, and color in mature field tomatoes.

Materials and Methods

'Chico III', 'Merit', 'Dorchester' and 'Campbell 28' were transplanted on May 15 in Norfolk sandy loam soil at the University of Maryland, Vegetable Research Farm, Salisbury, in 1972 and 1973. Cultural practices recommended for commercial tomato production were utilized both years. Samples consisted of 5 uniform red-ripe fruits picked at random from each replicate during the harvesting season each Tuesday and Thursday in 1972 and Monday and Thursday in 1973. Field design was a split plot with 3 replicates, 18 plants per plot. Fruits harvested for laboratory analysis were thoroughly washed, placed into 2 quart plastic bags, and immediately frozen.

Frozen samples were partially thawed and divided into 2 sub-samples. A 100 g sub-sample for ascorbic acid analysis was homogenized in a Waring blender for 2 minutes with 50 ml of a 6% meta-phosphoric acid solution in a constant stream of purified N_2 gas.

Fifty ml of each ascorbic acid sub-sample was mixed with 10 ml of a 10 mg/ml standard ascorbic acid solution and neutralized with 4 ml of a 5N NaOH solution. A modified method of Chaiet and Chaiet (2) was used for the determination of ascorbic acid. Twelve mm blank antibiotic discs were saturated with a sample and allowed to diffuse for 1 hour on a 2,6-dichlorophenolindophenol and agar mixture. The diameter of the diffused ascorbic acid after 1 hour was measured to the nearest 0.1 mm with a vernier caliper. Values for ascorbic acid (mg/100g fresh wt) were then interpolated from a standard curve.

The sub-samples for pH, color, and soluble solids were homogenized until a slurry was formed and 150 to 200 ml of the slurry was retained under refrigeration (5°C). Soluble solids content was determined with an ATAGO hand refractometer. The pH was read on a Beckman Zeromatic pH Meter. Color expressed as an a/b ratio was measured with a Gardner Color and Color Difference Meter. Mean separation following statistical analysis of the data was completed using Duncan's multiple range test at the 5% level.

Weather data were collected daily during 1972 and 1973 at the University of Maryland Vegetable Research Farm. Records were kept for maximum and minimum temperature, precipitation, wind speed (Km/day) and total solar radiation (Table 1).

Results

There was no seasonal trend in the ascorbic acid content of the 4 tomato cultivars during both years; although in 1973, the ascorbic acid content of 'Campbell 28' remained the same from July 30 to August 16 (Table 2). The range in variation was consistent within cultivars and between years. There was no significant difference in ascorbic acid between cultivars (Table 2).

There was a tendency for soluble solids to reach a maximum value during the middle of the harvesting season—96 days after planting (Table 3). The average soluble solids content of tomatoes was about 0.5% higher in 1973 than in 1972. Furthermore, the range in variation of soluble solids was greater in 1973 than in 1972. There was no significant differences in soluble solids among cultivars in 1972; but 'Chico III' was significantly higher in soluble solids than 'Merit' and 'Campbell 28' in 1973.

'Dorchester' had better fruit color than any of the other cultivars (Table 4). All cultivars had a tendency to have better fruit color as the season progressed, especially in 1973. In 1972, 'Campbell 28' developed poorer fruit color toward the end of the harvesting season (Table 4).

Tomato fruits had lower pH values in 1973 than in 1972 (Table 5). 'Campbell' had the lowest pH value of all cultivars. The range in variation in pH was inconsistent within cultivars and between years. Generally, higher pH readings were observed from August 30 to September 1 in 1972 and August 30 to September 6 in 1973.

There were differences in almost all of the macro-climatic factors measured in 1972 and 1973 (Table 1). Of the 4 climatic factors measured, no more than 45% of the variation in ascorbic acid, soluble solids, pH, or color could be explained by temperature, precipitation, radiation, and wind speed for both 1972 and 1973 (Table 6).

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Table 1. Climatological data-Vegetable Research Farm for 1972 and 1973: Weekly means during the harvesting season.

Week of Harvest	Temperature °C Max.		Temperature °C Min.		Precipitation cm		Solar radiation Langleys/day		Wind speed km/day	
	72	73	72	73	72	73	72	73		
1—(7/30–8/3)	28.3	30.6	18.9	21.1	8.41	0.69	376	476	68	47
2—(8/6–8/10)	27.8	31.7	16.7	18.9	0.05	0.13	501	589	84	45
3—(8/13–8/17)	27.2	30.6	17.2	21.1	4.52	5.82	338	466	53	61
4—(8/20–8/24)	30.0	25.0	17.2	16.1	0.00	14.17	492	376	45	92
5—(8/27–8/30)	27.2	32.8	18.9	20.6	9.55	2.01	313	516	90	56
6—(9/1–9/6)	25.0	30.6	14.4	20.0	0.94	5.94	386	425	77	32
7—(9/8–9/13)	—	25.6	—	14.4	—	2.11	—	393	—	85

Table 2. Seasonal variability of ascorbic acid in 4 tomato cultivars.

Harvest date		Chico III	Merit	Dorchester	Campbell 28
		Ascorbic acid (mg/100g frwt)			
1972					
Aug.	3	23.45	21.10	23.97	16.67
	8	21.10	20.58	24.23	18.50
	10	23.97	22.14	21.10	15.63
	15	17.98	13.55	21.88	19.54
	17	16.15	21.88	21.62	22.92
	22	17.71	21.88	18.50	22.40
	24	20.84	19.28	23.97	24.75
	30	18.24	16.15	16.41	21.07
Sept.	1	23.44	19.42	19.80	19.28
	6	19.02	15.37	18.49	16.94
	8	20.32	19.80	21.81	19.80
MEAN		20.20a[z]	19.20a	21.07a	19.77a
1973					
July	30	19.02	22.40	23.97	20.84
Aug.	2	20.32	21.88	21.62	20.84
	6	22.14	22.40	22.40	20.58
	9	16.15	18.23	19.93	20.32
	13	27.87	20.06	25.01	20.58
	16	23.18	22.92	20.84	20.84
	20	25.27	17.71	19.54	21.10
	23	18.50	17.32	16.67	21.62
	27	18.50	20.06	23.18	25.27
	30	17.98	19.28	21.10	19.01
Sept.	3	20.06	20.06	20.32	23.96
	6	23.70	23.44	18.23	18.24
	10	18.24	17.98	20.06	25.01
	13	17.97	17.19	19.79	21.10
MEAN		20.64a[z]	20.07a	20.90a	21.38a

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

Table 3. Seasonal variability of soluble solids of 4 tomato cultivars.

Harvest date		Chico III	Merit	Dorchester	Campbell 28
		% Soluble solids			
1972					
Aug	3	5.03	4.23	4.83	4.83
	8	4.53	4.53	4.73	5.10
	10	4.70	4.27	4.70	4.80
	15	4.50	4.20	4.60	4.97
	17	4.57	4.43	4.47	4.53
	22	4.83	4.97	4.60	4.73
	24	4.80	4.87	4.83	4.63
	30	5.13	4.73	4.97	5.00
Sept.	1	5.17	4.77	4.90	5.03
	6	4.87	4.60	4.87	4.97
	8	4.83	4.73	4.87	5.10
MEAN		4.82a[z]	4.58a	4.76a	4.88a
1973					
July	30	5.53	5.27	5.73	5.66
Aug.	2	5.53	5.00	5.20	5.23
	6	5.30	5.23	5.00	5.03
	9	5.30	5.23	5.37	5.47
	13	5.43	5.40	5.50	5.07
	16	5.60	5.13	5.73	5.36
	20	5.70	5.00	5.43	5.40
	23	5.63	5.07	5.50	5.40
	27	5.53	5.13	5.87	5.30
	30	5.37	5.10	5.37	5.07
Sept.	3	5.47	5.07	5.63	5.23
	6	5.57	4.53	5.30	5.43
	10	5.57	4.77	4.77	5.07
	13	5.26	4.86	5.06	5.46
MEAN		5.49a[z]	5.06c	5.39ab	5.30b

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

Table 4. Seasonal variability in color of 4 tomato cultivars.

Harvest date		Cultivar			
		Chico III	Merit	Dorchester	Campbell 28
		Color (a/b ratio)			
1972					
Aug.	3	2.10	1.83	2.16	2.37
	8	2.19	2.17	2.34	2.52
	10	2.22	2.04	2.47	2.57
	15	2.11	2.04	2.21	2.38
	17	1.92	1.79	2.09	2.24
	22	2.25	2.14	2.40	2.18
	24	2.22	2.30	2.38	2.27
	30	2.07	2.27	2.64	2.22
Sept.	1	2.13	2.39	2.50	2.24
	6	2.45	2.24	2.62	2.41
	8	2.38	2.51	2.74	2.09
MEAN		2.19b[z]	2.16b	2.41a	2.32a
1973					
July	30	2.04	1.86	2.43	2.05
Aug.	2	2.22	1.88	2.35	1.78
	6	2.00	1.82	1.90	1.81
	9	2.26	2.31	2.53	2.28
	13	2.16	2.16	2.55	2.29
	16	2.28	2.41	2.34	2.03
	20	2.24	2.47	2.79	2.53
	23	2.34	2.67	2.85	2.49
	27	2.58	2.78	2.97	2.71
	30	2.49	2.67	2.84	2.51
Sept.	3	2.50	2.50	2.92	2.54
	6	2.46	2.18	2.62	2.41
	10	2.42	2.27	2.54	2.59
	13	2.24	2.75	2.71	2.58
MEAN		2.30b[z]	2.34b	2.60a	2.33b

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

Table 5. Seasonal variability of pH in 4 tomato cultivars.

Harvest date		Cultivar			
		Chico III	Merit	Dorchester	Campbell 28
		pH			
1972					
Aug.	3	4.25	4.18	4.23	4.18
	8	4.23	4.32	4.28	4.28
	10	4.32	4.30	4.18	4.23
	15	4.32	4.28	4.35	4.25
	17	4.17	4.22	4.30	4.20
	22	4.33	4.33	4.33	4.22
	24	4.38	4.35	4.35	4.20
	30	4.33	4.35	4.38	4.20
Sept.	1	4.38	4.40	4.43	4.17
	6	4.23	4.18	4.22	4.07
	8	4.22	4.23	4.23	4.05
MEAN		4.30a[z]	4.29a	4.30a	4.19b
1973					
July	30	4.12	4.07	4.12	4.07
Aug.	2	4.20	4.13	4.15	3.95
	6	4.10	4.13	4.00	3.95
	9	4.07	4.15	4.10	4.17
	13	4.25	4.10	4.20	4.17
	16	4.18	4.25	4.07	3.98
	20	4.25	4.27	4.17	3.97
	23	4.30	4.23	4.12	4.17
	27	4.28	4.30	4.23	4.13
	30	4.18	4.30	4.33	4.13
Sept.	3	4.37	4.33	4.32	4.17
	6	4.47	4.17	4.32	4.12
	10	4.35	4.07	4.17	4.00
	13	4.32	4.27	4.32	4.17
MEAN		4.25a[z]	4.20a	4.23a	4.08b

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

Table 6. Coefficients of determination of climatic variables with quality factors of 4 processing tomato cultivars.

Quality factor	Cultivar				
	Chico III	Merit	Dorchester	Campbell 28	Mean
Ascorbic acid	22%	15%	34%	45%	26%
Soluble solids	22%	39%	44%	21%	33%
Color	23%	8%	6%	7%	7%
pH	16%	25%	45%	22%	34%

Discussion

Variation in ascorbic acid, color, soluble solids, and pH in fruits of tomato cultivars is attributable in part to climatic factors. This variation occurs both within year (seasonal) and between years. In our study, the variation in ascorbic acid, pH, soluble solids, and color of tomato fruits can be explained partially by the differences in day and night temperatures and solar radiation between 1972 and 1973 (Table 1). Temperature and radiation readings were considerably higher in 1973, with a more uniform distribution of rainfall. Our results on tomato fruit quality are in general agreement with those of other authors.

Denisen (6) and Vogele (15) concluded that both temperature and light affected the pigment formation of tomato fruits. The percent of soluble solids increased with reduction in available soil moisture (1) and with periods of high temperatures (10). Moore et al. (13) observed a sharp reduction in pH with low night temperatures towards the end of the harvesting season. Currence (5) concluded that ascorbic acid in tomato cultivars is irregular and inconsistent and is sensitive to minor variations in the environment. Seasonal variation in ascorbic acid was affected by the rate of ripening in tomato fruits (3). Hopp and Lamden (9) in sampling vegetables for ascorbic acid content found variation between cultivars, harvest dates, and between years. They concluded that the amount of ascorbic acid in tomatoes was directly affected by sunshine and temperature.

Our data does not entirely support the conclusions of Hopp and Lamden (9). There was little difference in the mean ascorbic acid content of individual cultivars between 1972 and 1973 (Table 2); even though there was a large difference in both temperature and radiation readings for those 2 years. There was a 20% variation in ascorbic acid of all tomato cultivars for both 1972 and 1973. This was not true for pH, color, and soluble solids. The conclusions of Currence (5) and Clutter and Miller (3) give some support to seasonal variation of ascorbic acid in tomatoes. The rate of fruit ripening is dependent on environmental conditions which are constantly changing from day to day. This type of development would explain the variation in ascorbic acid within a growing season.

One can expect a seasonal variation of 20% in the ascorbic acid content of tomato cultivars. Furthermore, macro-climatic conditions will have no effect on the variation of ascorbic acid from year to year. Soluble solids, pH, and color are affected by climatic conditions and variability in these quality factors will be different from year to year as well as seasonally. Finally, our study did not look at the microenvironment of fruits which may be responsible for 50% or more of the unexplained variation in the above quality factors of tomatoes.

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