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Effect of Ripening Methods and Harvest Time on Vitamin Content of Tomatoes

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성숙방법과 수확시기가 토마토의 비타민 함량에 미치는 영향

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Abstract

Effect of ripening methods and harvesting time on vitamin content of 5 tomato varieties was investigated in 1978 and 1979. Ascorbic acid content in the breaker ripened tomatoes was significantly higher than that in the vine ripened tomatoes, and the result was consistent for two consecutive years. Ascorbic acid content in the vine ripened tomatoes markedly increased as the season progressed, early harvested tomatoes containing significantly less ascorbic acid. Carotene content was not significantly affected by the ripening method. Higher carotene content, however, was observed for tomatoes harvested in the late season. This result could indicate the effect of temperature for carotenogenesis around the harvest time. Thiamin and riboflavin contents in the vine ripened tomatoes were significantly higher than those in the breaker ripened tomatoes in the 1978 season, but these differences were not observed in the 1979 season. Thiamin and riboflavin contents in the vine ripened tomatoes decreased considerably as the season progressed. Thiamin and riboflavin contents in tomatoes harvested in the early season were significantly higher than those in the mid and late seasons.

Introduction

The outstanding food value of tomatoes in the nutrition is due to high vitamin content, especially ascorbic acid and carotenes. The reported results indicate that many factors cause a wide variation of the vitamin composition in tomatoes.

Maclinn and Fellers[1] reviewed the literature on the ascorbic acid content of tomatoes and reported that concentrations ranging from 5 to 60*mg* per 100*g* fresh weight for American vieties. This variation is the result of a number of factors, such as the variety, the location grown, the season, and the treatment which the fruit receives before and after placing them in the market.

Data concerning the ascorbic acid content during the development and the ripening of tomato fruits are inconsistent. Some earlier investigators[2-4] reported little changes, while more recent work has indicated an increase in ascorbic acid concentrations during maturation[5-6].

Fresh, ripe tomatoes or juice contain 1000 *I.U.* of vitamin A per 100*g*[7]. On the basis of this figure, a small tomato or a glass of tomato juice would supply 20% or more of the recommended dietary adult allowance of 5000 *I.U.* The major carotenoid found in tomato is lycopene, which comprises 75% of the total carotenoids present[8]. Hamner and Maynard[9] reported that carotene content in tomatoes varied, according to degree of ripeness, variety and exposure to light. Boe and Salunkhe[10] showed that lycopene and carotene was

increased in ripe fruit by illimination at any stage during maturation.

Baker and Wright[11] reported that tomato pulp contained 40 *I.U.* of thiamin per 100*g*, and Secomska[12] indicated that fresh tomatoes contained 42μg of thiamin per 100*g* and fresh juice 48μg per 100*g*. Early studies indicated the riboflavin content of tomatoes to be rather low. A study by Hodson[13] using the fluorometric method showed value of 52μg per 100*g*. Using rat assay, Lanford et al.[14] found a value of 37.7μg per 100*g*. Recently, Secomska et al.[12] showed fresh tomatoes contained 27μg/100g of riboflavin and tomato juice 34μg/100*g*.

The objectives of this study were to investigate vitamin composition of vine ripened and breaker ripened tomatoes and variations in vitamin composition as affected by harvest time.

Materials and Methods

Variety

Five tomato varieties were selected to study vitamin composition of fresh tomatoes as affected by ripening methods in 1978 and 1979. Effect of havest time on vitamin composition of vine ripened tomatoes was studied with the same 5 varieties in 1978. Each variety consisted of 50 tomato plants with 3 replications per variety.

Harvest Time

To study effect of harvest time on vitamin composition of fresh tomatoes, vine ripened tomatoes were picked 3 times at 1 week intervals. Vine ripened and green matured tomatoes, to study effect of ripening methods on vitamin composition of fresh tomatoes, were picked on the same day at the peak harvest time of the variety.

The fruits were harvested randomly to provide a representative sample of the experimental plots. Each sample composed of 8 or more typical fruits of the variety.

Sample Handling

The harvested ripe fruits were placed in perforated polyethylene bags and stored in a controlled temperature cubicle maintained at 12°C and 90% RH. Storage time was kept at a minimum so that assay would reflect nutrient levels in the freshly harvested fruits as closely as possible. Green-mature tomatoes (breakers) were ripened at 19°C and 90% RH for a week, and then used for vitamin analysis.

Analysis of Ascorbic Acid

Ascorbic acid was determined using a modification of the method reported by Loeffler and Ponting[15]. 50*g* of freshly sliced tomatoes sampled from several fruits were blended for 3 *min* with 450*ml* of 0.5% oxalic acid solution, and then the slurry was filtered through Whatman No. 5 filter paper to clarify.

One *ml* portions of the extract were pipetted into 3 matched colorimeter tubes. Nine *ml* of water were added to one tube which was used to adjust the colorimeter (Bausch and Lomb Spectronic 20) to read 100% T. To each of other tubes, 9*ml* of working dye solution was added. The reading on each tube was taken within 10 *sec* from the beginning of the dye solution.

Ascorbic acid content in the tomato was calculated using the following formala:

Ascorbic acid (*mg*/100*g*)

$$= 10.0\,(L_1 - L_2)\frac{ml\ \text{acid} + g\ \text{sample}}{g\ \text{sample}}$$

where L_1 is the average absorbance of dye blank and L_2 is that of sample tubes. The factor 10 was determined as the slope of a standard curve using solutions of ascorbic acid.

Analysis of Carotenes

Carotenes were determined using a modification of the method described in Methods of Vitamin Assay (Association of Vitamin Chemists, Inc., 1966) and the procedure outlined in Official Methods of Analysis (AOAC, 1975).

Two 10*g* samples of tomato slurry were weighed into 250*ml* beakers and 140*ml* of an ethanol (95%)-hexane solution (2:1 v/v) was added to beakers. After stirring for 5 *min* with magnetic stirrer, the sample was filtered through a coarse fritted glass filter under suction. The residue on the filter was washed with two 25*ml* of 95% ethanol followed by one 25*ml* of hexane.

The liquid was transferred to a 500*ml* separatory funnel and total carotenes was extracted according to the Methods of Vitamin Assay. The extract was transferred to a colorimeter for measurement of total carotenes at 436*nm*.

A 100*ml* of carotene extract was placed in a 150*ml*

beaker for further purification and separation of the alpha- and beta-carotene fraction. This aliquot was evaporated by air to a volume of 10*ml* and subjected to column chromatography, following the procedure outlined in Official Methods of Analysis. The elute collected in a 100*ml* flask and diluted to volume with hexane. The absorbance was measured at 436*nm*.

Extraction of Thiamin and Riboflavin

Two 75*g* of tomato slurry were weighed into a 400*ml* beaker and 65*ml* of 2.5N-HCl was added. After mixing, the sample was covered with aluminum foil and held in a boiling water bath for 30 *min* with occational swirling. After the digestion, the beaker was placed in a 1°C refrigerator to cool. The cooled sample was adjusted to pH 4.5 with 10*N*-NaOH and 2.5*M*-sodium acetate using a pH meter.

The digest was transferred to a 200*ml* volumetric flask which contained several *mg* of fungal pectinase. The flask was swirled and allowed to incubate at room temperature for 3 to 4 hours or in a refrigerator overnight. After incubation, the flask was made to volume with water and filtered through Whatman No. 5 filter paper into a brown bottle. The extract was stored under refrigeration and was subsequently used for analysis of thiamin and riboflavin.

Analysis of Thiamin

25*ml* of the vitamin extract was added to 50*ml* of isobutanol in a 125*ml* separatory funnel. The mixture was then shaken for 2 *min* and allowed to separate for at least 30 *min*. The lower aquous layer was used for thiamin analysis.

An automated method[16] was used for the analysis of thiamin. Thiamin was oxidized to thiochrome with alkaline potassium ferricyanide. The thiochrome was then extracted into isobutanol and the fluorescence of the extract was measured at 436*nm* using a Technicon Autoanalyzer (Technicon Instrument Corp., New York).

Analysis of Riboflavin

10*ml* of the vitamin extract was placed into a test tube and a drop of conc. HCl and 0.5*ml* of 3% $KMnO_4$ were added to it. The contents were mixed, and allowed to stand exactly 2 *min*. Then, 0.5*ml* of 3% H_2O_2 was added and mixed. The red color disappeared within 10 *sec*.

Technicon Autoanalyzer system was used for the riboflavin analysis and the automated procedure reported by Kirk[16] was followed. The prepared sample was pumped into the machine and dialyzed against dilute NaCl solution before the fluorescence of the sample was measured. The sample was excited with 436*nm* light and the fluorescence was measured at 510*nm*. Sample blanks were measured by quenching fluorescence with $Na_2S_2O_4$.

Statistical Analysis

Significance of each factor in various observations of samples was determined by analysis of variance. Mean separation was made by Duncan's Multiple Range test wherever significant difference at the 5% level was found by analysis of variance. All calculations for statistical analysis were made using a CDC 6500 computer.

Results and Discussion

Ascorbic Acid Content

The ascirbic acid content in vine ripened tomatoes

Table 1. Ascorbic acid content of tomatoes (*mg*/100*g* fresh weight)

Variety	1978		1979	
	Vine ripened	Breaker ripened	Vine ripened	Breaker ripened
Setmore	21.7	23.9	15.2	19.9
Campbell-1327	12.6	14.4	13.9	15.9
Jet Star	19.7	19.8	19.0	20.9
Springset	20.5	23.4	19.5	21.6
Campbell-721	15.3	15.0	17.6	16.8
Mean	18.0	19.3	17.0	19.0
Significance		5%		1%

and in breaker ripened tomatoes are summarized in Table 1. Ascorbic acid content of breaker ripened tomatoes was significantly higher than that of vine ripened tomatoes, and this result was consistent for two consecutive years. It was also found that ascorbic acid content in tomatoes significantly varied among varieties tested, and Setmore, Jet Star and Springset contained more ascorbic acid in fruits than other varieties. However, there was no significant yearly variation in ascorbic acid content between 1978 and 1979 seasons.

Hammer et al.[17] stored green mature tomatoes at 60, 70, 75, 80 and 90°F analyzing the ripened fruits at the end of 1, 2 and 3 weeks. They found 2 weeks' storage at the 3 lower temperatures did not appreciably affect the ascorbic acid content. Similar results were also reported by Craft and Heinze[18]. However, Pantos and Markakis[19] and Scott and Kramer[20] reported loss of ascorbic acid during storage of green-mature tomatoes at 70°F. It appeared that variety, harvest time and ripening temperature should be considered together, when ascorbic acid content in vine ripened and breaker ripened tomatoes were compared.

In 1978, the relationship between harvest date and ascorbic acid content was determined. Harvest date of Aug. 13, Aug. 20 and Aug. 27 represented early, middle and late season. The results indicated that the ascorbic acid content in the early harvested tomatoes was significantly lower than that in the mid and late season harvested tomatoes (Table 2).

Twomey and Ridge[21] studied the ascorbic acid content of English early tomatoes harvested in the spring and early summer. They found that the ascorbic acid content increased from 12.3 *mg*/100*g* in May to 22.1 *mg*/100*g* in July. Somers et al.[22] and Masui et al.[23] indicated that light intensity and temperature affected the ascorbic acid content in tomatoes. It appeared that high ascorbic acid content in the mid and late season might be partially due to an increase in sunlight falling on fruits and high temperature.

Table 2. Effect of harvest time on ascorbic acid content of vine ripened tomatoes in 1978 (*mg*/100*g* fresh weight)

Variety	Harvest date		
	Aug. 13	Aug. 20	Aug. 27
Campbell-1327	11.0	14.5	13.9
Campbell-721	14.3	16.6	17.6
Setmore	16.0	20.7	20.2
Jet Star	14.7	19.9	19.0
Springset	18.5	20.5	22.5
Mean	14.9	18.4	18.6
Duncan's Mulciple Range test at 1%	: 14.9, 18.4, 18.6		

Carotene Content

The carotene content of tomatoes harvested at breaker ripe stage and then ripened was not significantly different from that of the vine ripened tomatoes in either year (Table 3). Sayre et al.[24] and Matthews et al.[25] showed that tomatoes picked at either breaker or pink stage and then ripened did not differ significantly in beta-carotene content from tomatoes picked at the ripe stage. However, Sadana and Ahmad[26] reported that vine ripened fruits were more potent sources of vitamin A than fruits detached while partially green and ripened in air.

Changes in the carotene content of tomatoes with

Table 3. Carotene content of tomatoes (*mg*/100*g* fresh weight)

Variety	1978		1979	
	Vine ripened	Breaker ripened	Vine ripened	Breaker ripened
Setmore	0.68	0.66	1.06	1.09
Campbell-1327	0.66	0.80	1.04	1.06
Jet Star	0.74	0.72	1.15	1.14
Springset	0.77	0.58	1.14	0.93
Campbell-721	0.60	0.64	0.93	1.03
Mean	0.69	0.68	1.06	1.05
Significance	N.S.		N.S.	

harvest time are summarized in Table 4. The results showed that there was no significant difference in corotene content of tomatoes harvested on Aug. 13 and Aug. 20, but carotene content in tomatoes harvested on Aug. 27 was significantly higher. Vogele[27] stated that temperature had a significant effect on carotenogenesis in normal tomatoes, and 24°C was the optimum temperature for carotene formation. The significant increase in carotene content of tomatoes harvested on Aug. 27 could be due to optimum environmental conditions around the harvest time.

Table 4. Effect of harvest time on carotene content of vine ripened tomatoes in 1978 (*mg*/100*g* fresh weight)

Variety	Harvest date		
	Aug. 13	Aug. 20	Aug. 27
Campbell-1327	0.67	0.70	1.04
Campbell-721	0.65	0.71	0.93
Setmore	0.70	0.75	1.06
Jet Star	0.79	0.82	1.15
Springset	0.80	0.85	1.14
Mean	0.72	0.77	1.06
Duncan's Multiple Range test at 5%	: 0.72, 0.77, 1.06		

Thiamin Content

The thiamin content in vine ripened tomatoes was significantly higher than that in breaker ripened tomatoes. However, in the 1979 season, breaker ripened tomatoes had significantly higher thiamin content than vine ripened tomatoes (Table 5). Because of these conflicting results, it was not possible to evaluate the effect of ripening method upon the thiamin content of tomatoes. Jones and Nelson[28] observed that green mature tomatoes contained less thiamin than vine ripened fruits. But they did not study the difference in the thiamin content between the vine ripened and breaker ripened tomatoes.

The thiamin content in the vine ripened tomatoes decreased considerably as the season progressed (Table 6). The thiamin content in tomatoes harvested on Aug. 13 was significantly higher than the others.

Table 6. Effect of harvest time on thiamin content of vine ripened tomatoes in 1978 (*mg*/100*g* fresh weight)

Variety	Harvest date		
	Aug. 13	Aug. 20	Aug. 27
Campbell-1327	0.059	0.047	0.039
Campbell-721	0.069	0.057	0.053
Setmore	0.058	0.048	0.048
Jet Star	0.050	0.045	0.042
Springset	0.060	0.047	0.047
Mean	0.059	0.049	0.046
Duncan's Multiple Range test at 5%	: 0.046, 0.049, 0.059		

Riboflavin Content

In the 1978 season, the riboflavin content in vine ripened tomatoes was very significantly higher than in breaker ripened tomatoes ($P<0.0005$). However, in the 1979 season, no significant difference in the riboflavin content was obtained between the vine ripened

Table 5. Thiamin content of tomatoes (*mg*/100*g* fresh weight)

Variety	1978		1979	
	Vine ripened	Breker ripened	Vine ripened	Breaker ripened
Setmore	0.053	0.042	0.048	0.051
Campbell-1327	0.068	0.045	0.039	0.055
Jet Star	0.050	0.046	0.042	0.050
Springset	0.066	0.046	0.047	0.061
Campbell-721	0.061	0.057	0.053	0.058
Mean	0.060	0.047	0.046	0.055
Significance	1%			1%

Table 7. Riboflavin content of tomatoes (*mg*/100*g* fresh weight)

Variety	1978		1979	
	Vine ripened	Breaker ripened	Vine ripened	Breaker ripened
Setmore	0.036	0.032	0.039	0.040
Campbell-1327	0.043	0.031	0.030	0.037
Jet Star	0.052	0.030	0.031	0.033
Springset	0.053	0.031	0.033	0.040
Campbell-721	0.060	0.034	0.038	0.043
Mean	0.049	0.032	0.034	0.039
Significance	0.05%		N.S.	

tomatoes and the breaker ripened tomatoes (Table 7). It remains to be elucidated on the effect of ripening method upon the riboflavin content of tomatoes.

The riboflavin content in the vine ripened tomatoes decreased considerably as the season progressed (Table 8). The riboflavin content in the vine ripened tomatoes harvested on Aug. 13 was significantly higher than those harvested on Aug. 20 and Aug. 27. There was no significant difference in the riboflavin content between tomatoes harvested on Aug. 20 and Aug. 27.

Table 8. Effect of harvest time on riboflavin content of vine ripened tomatoes in 1978 (*mg*/100*g* fresh weight)

Variety	Harvest date		
	Aug. 13	Aug. 20	Aug. 27
Campbell-1327	0.053	0.039	0.039
Campbell-721	0.056	0.041	0.038
Setmore	0.060	0.039	0.039
Jet Star	0.061	0.039	0.031
Springset	0.052	0.041	0.033
Mean	0.056	0.040	0.034
Duncan's Multiple Range test at 5%	: 0.034, 0.040, 0.056		

요 약

토마토 과실의 숙성방법과 수확시기가 비타민 조성에 미치는 영향을 조사하기 위하여, 선정된 5개의 토마토 품종을 대상으로 1978년과 1979년에 걸쳐 연구한 결과를 요약하면 다음과 같다. 토마토 중의 아스콜빈산 함량은 breaker ripened tomatoes가 vine ripened tomatoes보다 유의성 있게 높았으며, 이 결과는 2년동안 일관성 있게 나타났다. 수확시기에 따른 토마토 중의 아스콜빈산 함량은 계절 초기에 수확된 토마토에서 현저히 낮았고, 그 이후에 수확된 것들 간에는 유의성 있는 차이가 없었다. 토마토 중의 캐로틴 함량은 vine ripened tomatoes와 breaker ripened tomatoes 간에 유의성 있는 차이가 없었으며, 이 결과는 2년간 일관성있게 나타났다. 늦은 계절에 수확한 토마토는 그보다 일찍 수확한 것보다 훨씬 많은 캐로틴을 함유하였다. 토마토중의 지아민과 리보후라빈 함량은, 1978년에는 vine ripened tomatoes가 breaker ripened tomatoes보다 유의성 있게 높았으나 1979년에서 유의성있는 차이가 없는 것으로 나타나, 앞으로 더욱 연구가 필요하다고 여겨진다. vine ripened tomatoes 중의 지아민과 리보후라빈 함량은 계절이 진전됨에 따라 감소하는 경향이 있었으며, 계절초기에 수확한 토마토가 그 이후에 수확한 것들보다 유의성있게 높은 지아민 및 리보후라빈 함량을 나타내었다.

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