EFFECT OF LIGHT ON THE ASCORBIC ACID CONTENT OF TOMATOES RIPENED ARTIFICIALLY

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ABSTRACT

EFFECT OF LIGHT ON THE ASCORBIC ACID CONTENT OF TOMATOES RIPENED ARTIFICIALLY

By

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Tomatoes ripened artificially contain less ascorbic acid (vitamin C) than tomatoes ripened on the vine. The purpose of this experiment was to study the effect of fluorescent light on the ascorbic acid content of tomatoes ripened off the vine.

Tomatoes of two cultivars, Rutgers and Marglobe, were harvested mature-green from the field and placed in three groups. One group was analyzed for ascorbic acid by the AOAC method immediately after harvesting, a second group was placed as a monolayer under fluorescent light (800 foot candles), and a third group was placed in darkness. The last two groups were ripened in a cubicle in which the air was constantly moving and maintained at 68 ± 2 F and 85-90% relative humidity.

The ascorbic acid content of the artificially ripened tomatoes was determined at 3 and 6 days after harvesting and also when they turned fully red. Tomatoes left on the vine were also analyzed for ascorbic acid when they turned red. It was found that in both varieties the tomatoes which were ripened under artificial light contained

approximately 20% more ascorbic acid than those ripened in darkness. In fact, the ascorbic acid content of the artificially ripened red tomatoes under light was almost as high as that of red tomatoes harvested from the vine.

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INTRODUCTION

From the time it was discovered that a nutritional factor, vitamin C, present in fresh fruits and vegetables prevents scurvy, these commodities have gained additional appreciation in the human diet. Tomatoes (*Lycopersicon esculentum*) are a good source of vitamin C in addition to having excellent organoleptic qualities.

Wide variation in the ascorbic acid content of ripe tomatoes have been reported. Genetic, environmental and methodological factors may be responsible for these variations. The amount of sunlight has been recognized to be an important factor determining the ascorbic acid content of tomatoes ripened on the vine.

A large proportion of the fresh tomatoes reaching retail channels throughout the year are harvested in the mature-green stage and are ripened at the point of destination. Ripening of mature-green tomatoes requires several days to a week or even longer at temperatures between 60 and 70 degrees F.

Although substantial research has been directed toward the vitamin C content of tomatoes and its relation to light during the development of the fruit on the plant, no reports have been found with respect to the effect of light on the ascorbic acid content during artificial ripening of tomatoes. The objective of this research was to study the effect of fluorescent light upon the ascorbic acid content of tomatoes harvested at mature-green stage and ripened artificially.

LITERATURE REVIEW

Vitamin C, ascorbic acid, was the first nutritional adjunct whose deficiency was recognized as a cause of a disease. The vitamin C of foods and biological materials is associated with its reduced L - ascorbic acid content (Assoc. of Vitamin Chemists, 1966).

Reduced L - ascorbic acid and its oxidation product, dehydroascorbic acid, constitute a reversible redox system in the animal organism. Depending on the prevailing condition, dehydroascorbic acid can be irreversibly converted to 2,3,diketo-gulonic acid and its vitamin C value lost (Penney and Zilva, 1943).

Roe (1936), reported that L - ascorbic acid exists in the reduced form only, in the plants and animal tissues examined. Mills (1949) supported Roe's theory and extended this observation by analyzing not only fresh but processed and dehydrated foodstuffs. He found that fresh foods contained less than 5% of their total vitamin C content as the inactive diketo-gulonic acid while processed foods have more of this form and dehydrated ones showed the greatest amount of diketo-gulonic acid. McHenry and Graham (1935), demonstrated that there is a different value for reduced L - ascorbic acid and total vitamin C in different fruits and vegetables, but for the tomato fruit, there was no difference between these 2 values. Ignatius et al. (1944) supported this observation and stated that tomatoes do not contain any reversibly oxidized ascorbic acid.

A review of the literature concerning the nutritive value of the tomato fruit has indicated that tomatoes may contribute significant amount of ascorbic acid and pro-vitamin A to the human diet (Hamner et al., 1942). That the tomato is a very good antiscorbutic agent is generally acknowledged, although the various reports show considerable variations in vitamin C content (Maclinn et al., 1936). An average value for the ascorbic acid content of tomatoes is 23 mg per 100 g of fresh fruit (Agr. Handbook No. 8, 1963).

The literature on the ascorbic acid content of tomatoes shows that considerable research has been directed toward identification of genetic and environmental factors that may affect the ascorbic acid concentration in tomatoes. However, there is a lack of general agreement concerning the importance of each of these factors except on intensity of illumination and the position of the cluster on the plant (Jones and Nelson, 1930).

Tomatoes produced for the fresh market are havested at various stages of maturity, ranging from the "green-mature" crop of the distant shipper, to the "red-ripe" fruit harvested by the local truck gardener. Similarly the time elapsed between harvest and the consumption may be only a few hours or may be many days. The effect of these factors upon the ascorbic acid content of the tomato has not been precisely defined in the literature (Scott and Kramer, 1949).

For a number of years it has been recognized that the amount of light is an important factor determining the ascorbic acid content of various crops (Somer et al., 1950). However, it appears that the effect of light upon vitamin C during the ripening of the tomatoes harvested at mature-green stage has not been investigated. The demonstration that the concentration of vitamin C is augmented during the maturation of some vegetables and that larger amounts of vitamin C are present in the periphery than nearer the center of certain fruits and vegetables indicates that light is one of the factors influencing production of vitamin C (Murphy, 1939).

It has been shown by numerous investigators that the ascorbic acid content of tomato may vary under certain conditions. The factors reported by various investigators as being responsible for the fluctuations are as follows: variety and strain, stage of maturity, condition of growth and ripening, soil and fertilizer, size of fruit, position of the cluster and processing.

The effect of variety and strain of tomatoes on the vitamin C content has been established by many investigators. Sansome and Zilva (1936) found that tomatoes with a tetraploid number of chromosomes (24 pairs) have approximately 40 percent more vitamin C than diploid (12 chromosome pairs) tomatoes. The tomato shows considerable variation in ascorbic acid content in different varieties and there are marked differences in vitamin C content among different strains of the same variety (Maclinn et al., 1936).

Marglobe and Rutgers were two cultivars of tomato which were used in this study. The Marglobe introduced by Pritchard and Porte in 1925. Marglobe is the result of a cross between Globe and Marvel made in a greenhouse of the U.S.D.A. in Washington in 1918. Globe has considerable resistance to wilt but it is very susceptible to nailhead rust. Marvel is highly resistant to both. Marglobe proved highly resistant to wilt and nailhead.

The New Jersey station distributed the Rutgers variety in 1934. It is a cross between Marglobe and J.T.D. and has been reported especially valuable on light sandy soils (Yearbook of Agriculture, 1937).

According to Hamner et al. (1945), the ascorbic acid content of fruit of cv Marglobe varied from 14.4 ± 2.12 to 30.6 ± 2.04 mg/100 g fresh fruit, while those of cv Rutgers varied from 8.4 ± 5.0 to 19.7 ± 1.17 mg/100 g fresh fruit. Of the two cultivars, Marglobe and Rutgers, the former consistently had more ascorbic acid at any particular location, except at Madison, Wisconsin.

The investigations on the relationship between stage of maturity and the ascorbic acid content of tomatoes are conflicting. Genetic, environmental and methodological factors may be responsible for the discrepancies. Malewski and Markakis (1971), reported that four cultivars of tomatoes grown in a Michigan field reached their highest ascorbic acid content about 6 weeks after anthesis (flower opening) and just before the entire fruit turned red. Clow and Marlatt (1930) and Jones and Nelson (1930) demonstrated by bioassay that the ascorbic acid content of tomatoes increased as the fruit matured. Clow and Marlatt stated that fruit ripened off the vine seemed to be as effective a source of vitamin as vine-ripened fruit; Jones and Nelson reported that naturally ripened tomatoes contained the most vitamin C, fullgreen, green came next, and the small, immature fruit contained the least of all. On the other hand, MacLinn and Fellers (1938) and MacLinn, Fellers, and Buck (1936) found no difference in ascorbic acid content due to maturity and no loss in ascorbic acid from ripe fruits which were stored for 10 days at room temperature. According to Scott et al. (1949) the ascorbic acid content of the tomatoes increases slightly with increasing maturity of the fruit at the time of harvest. Hamner et al. (1945) reported a small but continuing increase in ascorbic acid content through the overmature stage, while LoCoco (1945) found a rather large (88%) increase up to the red-mature stage with a subsequent decrease as the fruit over-matured. Accordingly, Fryer et al. (1954) found a definite increase in ascorbic acid content as the fruit developed from mature-green to mature-red, this increase being twice as large in the field-grown as in the greenhouse-grown tomatoes. However, Ignatius et al. (1944) stated no significant difference in ascorbic acid values in green and ripe tomatoes collected at the same time.

There is little in the literature dealing specifically with a possible relationship between the vertical position of a cluster of tomatoes on a plant and the concentration of ascorbic acid in the tomatoes of the cluster. There are, however, several reasons to expect that some relationship might exist and be important. Generally, the bottom cluster on a tomato plant produces ripe fruits before the higher clusters on the same plant do (Fryer et al., 1954). It is believed (Frazier et al., 1954) that the amount of illumination on the fruits definitely affects their ascorbic acid content. It is possible, however, that temperature, humidity and other environmental factors may change enough from the bottom of a plant to its top to increase the ascorbic acid content of the fruits higher on the plant.

Hassan and McCollum (1954) compared the second and third cluster on the plant with the fourth and fifth. They make their comparisons with both pruned and unpruned greenhouse plants, and with bagged and unbagged clusters on both the pruned and unpruned plants. They found the concentration of ascorbic acid to be higher in the higher clusters even when the clusters were bagged. Hence, they concluded that light intensity is not the only factor involved in the relationship between cluster position and ascorbic acid content. Fryer et al. (1954) found that when the tomatoes were harvested red-ripe, there is an essentially linear increase in ascorbic acid concentration with increasing cluster number up the plant. He also pointed out that it is possible that this regression is affected by the season in which the tomatoes are grown. He obtained the larger regression coefficients for the spring crops, but the differences between the regression coefficients for the fall and spring crops were not statistically significant. He concluded that average increase in ascorbic acid concentration with each higher cluster on the plant may be as low as 3 or 4 percent, and it also may be as high as 10 percent, according to the 95 percent confidence intervals. But this regression for greenhouse grown tomatoes did not hold for tomatoes grown in the field where there is plenty of sunlight and an abundant supply of soil nutrients.

The effect of size of fruit on the vitamin C content of tomatoes was studied by MacLinn et al. (1938). They found no correlation between size of a tomato and its vitamin C content. On the other hand, McHenry and Graham (1935) found that there is an inverse relationship between size and vitamin C content of ripe tomatoes. They also concluded that at least part of the difference in ascorbic acid content between the tetraploid and diploid tomatoes may have resulted from the difference in size of these fruits, because the former fruits are smaller than the latter ones. Wokes and Joan (1943) showed that in unripe tomatoes weighing 0.3-11 g. the average concentration of vitamin C was about 34% higher than in unripe tomatoes weighing 30-87 g. However, they pointed out that the difference was scarcely significant because of the wide variation in vitamin C content between tomatoes of similar weights.

Regarding the influence of mineral nutrition, Hamner et al. (1942) found that ascorbic acid concentration showed little or no correlation with the macronutrient supply. Hamner (1945) found the same for the minor elements. The same author in another report, Hamner et al. (1945), however, indicated that nitrogen fertilization may cause a slight decrease in the ascorbic acid content of tomatoes.

The effect of storage on the ascorbic acid content of tomatoes have been studied by numerous investigators, but there is a lack of general agreement. Pantos and Markakis (1973) reported that there was a decline in the ascorbic acid content of mature-green tomatoes with time of storage at temperatures between 55 to 70 degrees F. Scott and Kramer (1949) and Craft and Heinze (1954) used the Rutgers variety in their studies but the first group reported loss of ascorbic acid during storage of green-mature tomatoes at 70°F and riper tomatoes at 35-50°F, while the second group found no pronounced change in the ascorbic acid content of mature-green tomatoes stored at 32, 40, 50, 65 and 75°F for periods up to 14 days. Murneek et al. (1945) stated that greenhouse tomatoes picked "green" are relatively low in ascorbic acid content, but upon ripening at room temperature they reach a value almost equal to that of vine-ripened fruit. However, field grown tomatoes often showed the highest content during the early stages of maturity, and fruit harvested while green seemed to lose ascorbic acid upon ripening.

Hamner et al. (1945) stored green mature tomatoes at 65, 70, 75, 80 and 90 degrees F analyzing the ripened fruit at the end of 1, 2, and 3 weeks. Two weeks' storage at the three lower temperatures did not appreciably affect the ascorbic acid content, but at the end of 3 weeks at 65, 70 and 75 degrees F, or after 2 weeks at 80 or 90 degrees F, there was a marked decrease. MacLinn et al. (1936) found no effect of storage of ripe tomatoes on the vitamin C content for 10 days at room temperature. Fryer et al. (1954) stated that if greenhouse green-mature tomatoes are ripened to the red-mature stage out of direct sunlight and at a temperature of about 75 degrees F, the ascorbic acid content of them is less than those fruits ripened on the plant. House et al. (1929), in their study of the effect of artificial ripening on tomatoes, found that air-ripened and ethylene-ripened tomatoes were richer in vitamin C than the green fruit; vine-ripened tomatoes were superior to either the artificially ripened or to the green tomatoes.

Verkerk (1955) has pointed that light intensity averaging 1139.9 foot-candles (fc) daily during the growth of the tomato plants had a greater effect in promoting chlorophyll formation, fruit production, and photosynthetic efficiency than light of a daily average of 583.1 fc and this, in turn, had a similar greater effect than 261.0 fc.

Reports in the literature give abundant supporting evidence of the influence of light intensity on ascorbic acid content. This evidence includes reports that the amount of ascorbic acid in individual fruits on one tree may be proportional to the amount of light received during ripening. Cloudy weather has been reported to decrease ascorbic acid, and the side of individual fruits exposed to the sun has been found to be richer in ascorbic acid than the shaded side (Hamner et al., 1945). Wokes et al. (1943) found that the distribution of vitamin C usually runs parallel with the ascorbic acid oxidase activity, being 2 or 3 times higher in the skin than in the juice or flesh. Matsuoka (1936) supported Wokes et al's work and reported that germination of various seeds in the sunlight produced a notable amount of vitamin C, and showed that although light was not an absolutely necessary factor for the production of vitamin C, the ascorbic acid content of seeds was affected by the light. An increased formation of ascorbic acid in etiolated seedlings was found by Sugawara

(1939) under light. He also pointed out that the radiation frequency plays an important part in the production of ascorbic acid. Regarding the formation of ascorbic acid white light was most effective followed by red, orange-red, green, and blue light.

Reid (1943) has pointed out that some plants lose vitamin C during periods of darkness. She observed net losses as high as 20 percent during the night and net increases up to 25 percent during bright days. Hamner et al. (1945) assumed that light intensity previous to harvest plays a dominant role in determining ascorbic acid levels in tomato fruit of a given variety. McCollun (1946) studied the relationship between the exposure of tomato fruits to the sun and their ascorbic acid content. He concluded that the amount of illumination received directly by the fruits determined their ascorbic acid content. The same author, in another study (1944), found that vitamin C is concentrated in the portion of the fruit most exposed to light and the wall tissue having the greatest exposure to light to be highest and the tissue least exposed, namely, the lower placenta of large fruit, to be lowest in ascorbic acid. He also pointed out that the larger fruits have a higher content than the smaller fruits especially in the upper wall tissue. This observation is not in agreement with the work of Maclinn and Fellers (1938) showing that ascorbic acid was concentrated in the gelatinous material about the seed. However, Maclinn and Fellers used greenhouse tomatoes which undoubtedly received less light exposure than unshaded field grown fruits. According to McCollum (1944) ascorbic acid varies to a greater extent with reference to sunlight exposure than with respect to the morphological region of the fruit. Furthermore, he stated that cracked fruits were higher in vitamin C than uncracked fruits. He then concluded that since exposed fruits seem to be more susceptible to cracking than shaded ones, it is quite likely that the difference in ascorbic acid was due to light exposure. He also stated that tomato varieties having dense foliage may be desirable in preventing sun-scald but not for the production of fruits high in ascorbic acid. He reported that tomatoes from defoliated plants were higher in ascorbic acid than those from normal plants. He considered this is to be due to direct irradiation of the fruits.

With regard to the quantity of light energy infringing on plants in relation to the length or duration of the light days, the investigations of Hamner et al. (1945) are pertinent. They found an increase of only 17 percent in the ascorbic acid concentration of fruits subjected to a 16-hour photoperiod (artificial light in control chambers) compared with an 8-hour photoperiod. The intensity of the light energy supplied, however, was low.

The time of application of the light involved has also received consideration. Somers et al. (1950) reported that the amount of light during a period of 18 days before harvest, correlated closely with the ascorbic acid content of field grown tomatoes. Somers et al. (1954), however, were unable to confirm this finding but stated that the close correlation observed was due to the extensive defoliation of the plants in the former study, thus allowing direct light inpingement on the fruits, and that only under such conditions would this close correlation exist. Somers et al. (1950) further stated that their work and that of Hamner et al. (1945) indicate that it requires about two to three weeks for a change in illumination to produce significant changes in the ascorbic acid content of fruit that ripens on the vine. Frazier et al. (1954) measured the ascorbic acid content of two groups of tomatoes, one of which matured in a greenhouse without supplemental light and another group which matured in the same greenhouse but with supplemental light (two lamps emitting in the ultraviolet region, one emitting at 5800-5900 A and one incandescent lamp). He found no consistent increase in ascorbic acid concentration in the greenhouse grown fruit when irradiated during daylight hours with supplemental lighting. He, thus, concluded that neither the addition of small bands of electromagnetic radiation of relatively high energy value in the ultraviolet region of the spectrum, nor bands of general radiation of relatively low energy in the visible region of the spectrum increased the ascorbic acid concentration of greenhouse grown fruits consistently.

Several workers have reported that supplementary energy supplied in the ultraviolet range did not increase the ascorbic acid concentration of plants and plant parts. Wokes and Organ (1943) irradiated harvested tomatoes during ripening. Green fruits were treated daily with a mercury vapor lamp that provided no appreciable amount of radiation below 2500 A and that was switched off a few moments every 10-15 minutes to diminish heating. Total irradiation time was one hour the first day and increased to two hours on subsequent days. There was no increase in ascorbic acid concentration over the controls in fruits so irradiated for four to seven days. Miller and Schomer (1947) found that ultraviolet light from a lamp that emitted energy between 2537 A and 5780 A with, the lower wavelength representing 83 percent of the total, apparently retarded certain aspects of the ripening process in harvested tomato fruits.

METHODS AND MATERIALS

Seedlings of two tomato cultivars, Marglobe and Rutgers, obtained from the market, were transplanted on June 10, 1973 on the Michigan State University Horticultural Farm. Twelve plants were grown from each cultivar. The plants were irrigated, but not fertilized or sprayed with pesticides. Tomatoes were harvested mature-green, when a whitish area appeared around the blossom end of the fruit. They were placed in a plastic bag with the name of the variety and the date of harvest.

The first collection of fruits occurred about five weeks after the first flower opening. Subsequently, samples were obtained whenever the fruits reached the mature-green stage, which was approximately every other day. Upon arrival at the laboratory, the tomatoes of each cultivar were divided into three groups. One group was analyzed for ascorbic acid content immediately. On each remaining tomato a small label was posted on the stem scar, indicating cultivar and harvest date. These tomatoes were divided into two groups, each with equal distribution in size and maturity. One group was placed as a monolayer under a battery of 10 fluorescent tubes, 42 inches long. The distance between the fluorescent lamps and tomatoes was approximately 30 inches. A second group was placed in shallow baskets the sides of which were covered with aluminum foil and placed under the platform of the illuminated tomatoes. These two groups were ripened in a cubicle in which the air was constantly moving and maintained at 68 ± 2°F and 85-90% relative humidity. The tomatoes which were exposed to the light were turned over every day so that both sides of the tomatoes received the same amount of light. The illumination intensity was measured by a Weston Foot-Candle Meter, and found to be approximately 800 foot-candles at the upper surface of the tomatoes.

The ascorbic acid content of the artificially ripened tomatoes was determined by the 2,6-dichlorophenol indophenol visual titration, according to the procedure of the AOAC method at 3 and 6 days after harvesting and also when they turned fully red. Tomatoes left on the vine were also analyzed for ascorbic acid content when they turned fully red.

In each determination at least three tomatoes were selected randomly. They were cut into sectors from different sides of tomatoes and placed in a Waring Blender, covered with equal weight of 6% metaphosphoric acid, a stabilizing solution, and blended for 3 minutes at high speed. Nitrogen gas was introduced to the head space of the blender jar during blending. The weighted portion of the slurry, 20 to 30 g, was diluted to 100 ml with 3%

metaphosphoric acid solution and then filtered. Two aliquots of filtrate, 10 ml each, were titrated according to the AOAC (1970) method. The replicate titration differed by less than 5% from each other. A blank sample was run in each determination and this value was subtracted from the average of the two titration values. Recoveries of at least 95%, were obtained with this visual method.

RESULTS AND DISCUSSION

This study has dealt primarily with the influence of light on ascorbic acid content during artificial ripening of tomatoes, harvested mature-green.

The data from both cultivars of tomatoes analyzed for ascorbic acid the day of harvest and periodically until they turned red are given in Table 1, Table 2 and Table 7.

Statistical analyses of ascorbic acid content of mature-green tomatoes after being stored for 3 and for 6 days in darkness or in light for both cultivars are summarized in Table 3 and Table 4. The average ascorbic acid content of these tomatoes is plotted in Figure 1 and Figure 2. Table 3 shows that on the average the ascorbic acid concentration of tomato fruits in cv Rutgers stored for 3 and 6 days under the light is significantly higher than in darkness. After 3 days in darkness, the ascorbic acid content was 14.6 ± 1.1 mg/100g fresh fruit, and in the light 17.9 ± 1.1 mg/100 g fresh fruit; after 6 days in darkness, the ascorbic acid content was 12.7 ± 1.0 and in the light 15.3 ± 1.1 mg/100 g fresh fruit. Table 4 shows that there is a statistically significant difference between the ascorbic acid concentration of tomatoes stored in darkness and those in the light for 3 and 6 days in cv

TABLE 1. Ascorbic acid content (mg/100g fresh fruit) of tomatoes harvested mature-green at various dates and stored at 68° ± 2 F in darkness (D) or light (L) for different periods until they reached redness (r indicates redness), cv Rutgers.

Date of harvesting		Days from Harvesting 0	3	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
8/3	D	14.9	7.3	9.3														3.4					5.5r					
	L		11.7	10.6														13.3r										
8/4	D	12.4	10.1	8.0																				6.8r				
	L		12.6	9.1																11.5r								
8/6	D	15.5	10.6	8.2																			7.2r					
	L		13.1	11.4												12.5r												
8/7	D	14.0	13.0	5.8															5.4			4.1				10.0r		
	L		13.6	9.5															12.7r			12.0r						
8/8	D	10.5	7.6	12.0											5.2													
	L		13.6	11.9											15.3r					11.4r								
8/11	D	10.0	13.8	10.8															5.0				4.6			10.2r		
	L		14.6	12.8															12.4r				11.6r					
8/16	D	14.5	15.3	11.9																						9.2r		
	L		16.3	13.9														13.5r										
8/20	D	14.5	12.8	17.9						12.9												10.0						
	L		17.4	16.7						18.3r					15.1r		14.3r											
8/23	D	20.4	16.3		13.5										9.1										8.9r			
	L		21.6		17.6r										17.0r													
8/29	D	17.8	14.9	16.7				18.4r			17.7r							13.9r										
	L		16.8	17.7				20.2r			18.7r							18.0r										
8/31	D	15.5	16.6	15.7				13.8r	13.1r							12.7r												
	L		20.2	18.3				15.3r	17.1r		17.7r					13.9r												
9/4	D	19.8	16.7	14.9	17.3r		15.8r							15.2r														
	L		19.0	17.7	18.4r		17.4r							15.3r														
9/7	D	17.8	21.2	16.2r					20.8r		15.9r				15.4r			13.6r					11.4r					
	L		22.7	17.6r					21.5r		18.6r																	
9/10	D	18.8	19.8		18.7r			17.9r																				
	L		26.9		19.1r							18.5r	15.2r					13.0r			11.4r					11.1r		
9/12	D	24.7	20.2	17.0		17.2r				18.1r			20.1r					19.6r										
	L		24.0	19.6		20.1r																						
9/14	D	22.9	17.6	14.0			16.3r		16.2r							15.1r												
	L		20.7	20.6			22.1r		19.7r		17.7					19.0r												
9/19	D	23.3	13.7	12.3		17.4r	17.7r			15.6r	15.3r			15.6r						11.7r				11.8r				
	L		19.4	21.6		21.4r				19.1r	17.4r			20.5r						16.4r				16.3r				

TABLE 2. Ascorbic acid content (mg/100g fresh fruit) of tomatoes harvested mature-green at various dates and stored at 68° ± 2 F in darkness (D) or light (L) for different periods until they reached redness (r indicated redness), cv Marglobe.

Days from Harvesting

Date of harvesting		0	3	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
8/6	D L	20.5	11.7 13.0		5.6 10.2												2.9 14.9r							8.5r					
8/7	D L	17.0	6.8 10.1		6.3											5.0 11.7r											10.2r		
8/8	D L	15.5	12.0 12.3		13.7									5.0 15.3r				3.3 11.3r						7.7r					
8/9	D L	17.6	11.1 15.0		9.8 13.8											6.4 13.2r												7.7r	
8/11	D L	16.6	13.0		10.9										5.8				5.0r							10.2r			
8/20	D L	16.3	14.7 16.2		13.6 15.7				16.1r		7.6 17.8r				8.4 20.8r	11.9 19.2r		15.6r	14.4r 14.3r			9.3r							
8/23	D L	20.8	15.[illegible] 16.2		12.5 16.3						15.9 16.7r								16.5r										
8/29	D L	23.4	17.3 17.6		14.2 16.5				20.2r 20.5r			17.9r 18.7r							11.8r 16.7r										
8/31	D L	13.5	19.9 23.9		19.5 21.8		20.5r 20.2r			16.5r 18.4r		17.0r							14.4r										
9/4	D L	18.0	15.1 16.7		16.6 23.9r	19.8r 21.1r	19.2r	18.4r							18.0r														
9/7	D L	15.8	21.8 24.1	20.5r 22.7r	21.6r 22.0r					17.6 18.5r						18.8r	16.5r												
9/10	D L	20.1	16.0 21.8			16.8r 22.1r				20.5r			19.4r							16.0r									
9/12	D L	28.8	19.7 20.5		18.0 19.0		17.7r 17.1r				16.5r 20.3r				21.7r		21.1r		13.1r									11.1r	
9/14	D L	19.1	15.2 18.7		19.7 22.3	19.3r			13.6r 18.0r							11.4r 15.9r					12.0r				10.2r				
9/19	D L	21.3	12.7 18.3		11.8 20.7			17.1r 21.0r			15.1r 17.7r	17.6r 21.3r			16.9r 20.4r						17.5r				15.5r				

TABLE 3. Statistical analysis of ascorbic acid content (mg/100g fresh fruit) of mature-green tomatoes stored in darkness (D) or light (L) for 3 and 6 days after harvesting, cv Rutgers.

	3 days					6 days				
No's indicate groups of tomatoes, picked on the same day.	D X_2	L X_1	Difference $D-X_1-X_2$	Deviation = D-d	Squared Deviation d^2	D X_2	L X_1	Difference $D = X_1 - X_2$	Deviation $d = D - d$	Squared Deviation d^2
1	7.3	11.7	4.4	1.1	1.21	9.3	10.6	1.3	-1.3	1.69
2	10.1	12.6	2.5	-0.8	.64	8.0	9.1	1.1	-1.5	2.25
3	10.6	13.1	2.5	-0.8	.64	8.2	11.4	3.2	0.6	0.36
4	13.0	13.6	.6	-2.7	7.29	5.8	9.5	3.7	1.1	1.21
5	7.6	13.6	6.0	2.7	7.29	12.0	11.9	- .1	-2.7	7.29
6	13.8	14.7	.9	-2.4	5.76	10.8	12.8	2.0	-0.6	0.36
7	15.3	16.3	1.0	-2.3	5.29	11.9	13.9	2.0	-0.6	0.36
8	12.8	17.4	4.6	1.3	1.69	17.9	16.7	-1.2	-3.8	14.44
9	16.3	21.6	5.3	2.0	4.0	-	-	-	-	-
10	14.9	16.8	1.9	-1.4	1.96	16.7	17.7	1.0	-1.6	2.56
11	16.6	20.2	3.6	0.3	.09	15.7	18.3	2.6	0	0
12	16.7	19.0	2.3	-1.0	1.0	14.8	17.7	2.9	0.3	0.09
13	21.2	22.7	1.5	-1.8	3.24	16.2	17.6	1.4	-1.2	1.44
14	19.8	26.9	7.1	3.8	14.44	-	-	-	-	-
15	20.2	24.0	3.8	.5	.25	17.0	19.6	2.6	0	0
16	17.6	20.7	3.1	-0.2	.04	14.0	20.6	6.6	4.0	16.0
17	13.7	19.4	5.7	2.4	5.76	12.3	21.6	9.3	6.7	44.89
TOTAL	247.5	304.3	56.8	0	60.59	190.6	229.0	38.4	0	92.94
MEAN	14.6	17.9	d= 3.3		$SD^2 = \frac{60.59}{16} = 3.79$	12.7	15.26	d= 2.6		$SD^2 = \frac{92.94}{14} = 6.63$

$SD = \sqrt{3.79} = 1.95$ $sd^2 = \frac{3.79}{17} = 0.22$ $sd = .47$ $SD = \sqrt{6.63} = 2.57$ $sd^2 = \frac{6.63}{15} = .44$ $sd = .66$

$t = \frac{3.3 - 0}{0.47} = 7.021$ d.f = 16 Sign = beyond 0.001 $t = \frac{2.6 - 0}{0.66} = 3.9393$ d.f = 14 Sign = .005 to .001

TABLE 4. Statistical analysis of ascorbic acid content (mg/100g fresh fruit) of mature-green tomatoes stored in darkness (D) or light (L) for 3 and 6 days after harvesting, cv Marglobe.

	3 days					6 days				
?'s indicate ?roups of tom?toes picked ? the same ?y	D X_2	L X_1	Difference $D = X_1 - X_2$	Deviation $d = D - \bar{d}$	Squared Deviation d^2	D X_2	L X_1	Difference $D = X_1 - X_2$	Deviation $d = D - \bar{d}$	Squared Deviation d^2
1	11.7	13.0	1.3	-1.1	1.21	5.6	10.2	3.6	0	0
2	6.8	10.1	3.3	0.9	.81	-	-	-	-	-
3	12.0	12.3	0.3	-2.1	4.41	6.3	13.7	7.4	3.8	14.44
4	11.1	15.0	3.9	1.5	2.25	9.8	13.8	4.0	0.4	0.16
5	13.0	13.1	0.1	-2.3	5.29	10.9	12.0	1.1	-2.5	6.25
6	14.7	16.2	1.5	-0.9	0.81	13.6	15.7	2.1	-1.5	2.25
7	15.0	18.2	3.2	0.8	0.64	12.5	16.3	3.8	0.2	0.04
8	17.3	17.6	0.3	-2.1	4.41	14.2	16.5	2.3	-1.3	1.69
9	19.9	23.9	4.0	1.6	2.56	19.5	21.8	2.3	-1.3	1.69
10	16.1	16.7	0.6	-1.8	3.24	16.6	23.9	7.3	3.7	13.69
11	21.8	24.1	2.3	-0.1	0.01	21.6	22.0	.4	-3.2	10.24
12	16.0	21.8	5.8	3.4	11.56	-	-	-	-	-
13	19.7	20.5	0.8	-1.6	2.56	18.0	19.0	1.0	-2.6	6.76
14	15.2	18.7	3.5	1.1	1.21	19.7	22.3	2.6	-1.0	1.0
15	12.7	18.3	5.8	3.4	11.56	11.8	20.7	8.9	5.3	28.09
?OTAL	223	259.5	36.7	0	52.54	180.1	227.9	46.8	0	87.95
?EAN	14.9	17.3	$\bar{d} = 2.4$		$SD^2 = \frac{52.54}{14} = 3.753$	13.9	17.5	$\bar{d} = 3.6$		$SD^2 = \frac{87.95}{12} = 7.32$

$SD = \sqrt{3.753} = 1.93$ $sd^2 = \frac{3.753}{15} = .25$ $sd = .5$

$t = \frac{2.4 - 0}{0.5} = 4.8$ d.f = 14 Sign = beyond 0.001

$SD = \sqrt{7.32} = 2.7$ $sd^2 = \frac{7.32}{13} = 0.56$ $sd = 0.75$

$t = \frac{3.6 - 0}{.75} = 4.8$ d.f = 12 Sign = beyond 0.001

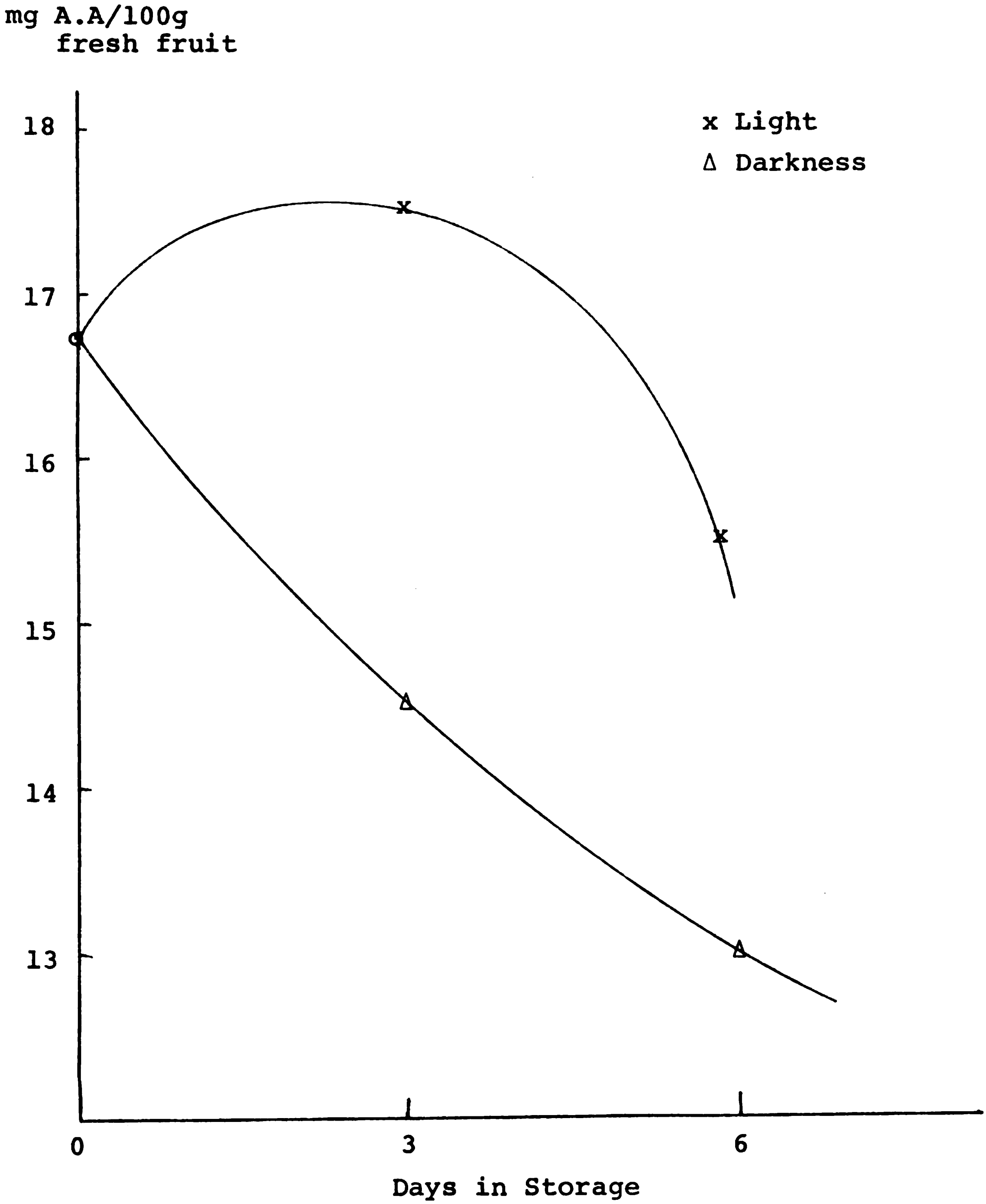

Figure 1. Average ascorbic acid (A.A.) content (mg/100g fresh fruit) of mature-green tomatoes vs days in storage in light or darkness, cv Rutgers.

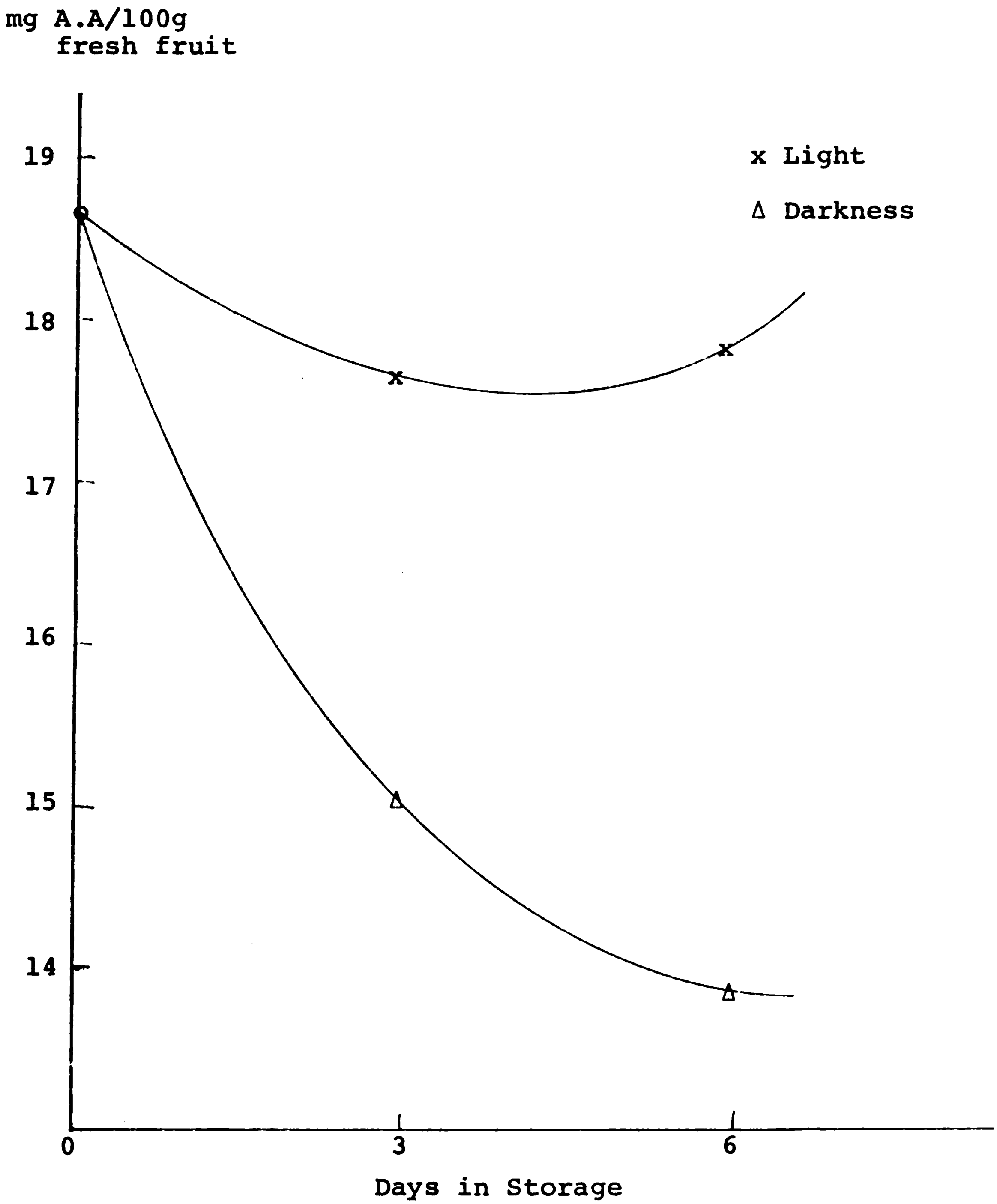

Figure 2. Average ascorbic acid (A.A.) content (mg/100g fresh fruit) of mature-green tomatoes vs days in storage in light or darkness, cv Marglobe.

Marglobe. The ascorbic acid values were 14.9 ± 1.0 mg/100g fresh fruit in darkness and 17.3 ± 1.0 mg/100g fresh fruit in the light after 3 days of storage; and 17.5 ± 1.3 and 13.9 ± 1.5 mg AA/100g fresh fruit, in darkness and the light, respectively, after 6 days of storage. The average ascorbic acid content of tomatoes of cv Marglobe vs days of storage, Figure 2, indicates that under both conditions, darkness and light, the ascorbic acid value decreased from the original value. This is true for cv Rutgers if only storage for 6 days is considered.

Table 5 presents the average ascorbic acid content of tomatoes which became fully red either in darkness or in light for both cultivars throughout the entire experiment. Usually it took more time for tomatoes to ripen in the dark than under the light. In order to exclude this factor which might have an affect on the ascorbic acid content of the tomatoes, the average ascorbic acid content was obtained for the tomatoes which ripened in the light and darkness in the same length of time from the date of harvest. These two values for the light and dark ripened tomatoes were then statistically compared by the paired t - test. For example, the average ascorbic acid content of red tomatoes, which became red after X days in the darkness, was compared with those which became red after X days under the light. Statistical analysis of these data shows that tomatoes which ripened under the light had significantly higher ascorbic acid content than the fruits

TABLE 5. Average ascorbic acid content (mg/100g fresh fruit) of red tomatoes ripened in darkness (D) or light (L).

	Marglobe					Rutgers				
Days from harvesting to redness	D X_2	L X_1	Difference $D = X_1 - X_2$	Deviation $d = D - \bar{d}$	Squared Deviation d^2	D X_2	L X_1	Difference $D = X_1 - X_2$	Deviation $d = D - \bar{d}$	Squared Deviation d^2
5	20.5	22.7	2.2	.43	.18	13.3	16.9	3.6	.78	.60
6	21.6	23.0	1.4	-.37	.13	16.2	17.6	1.4	-1.42	2.01
7	18.3	20.8	2.5	.73	.53	17.3	18.4	1.1	-1.72	2.95
8	19.1	18.8	-.3	-2.07	4.28	16.9	20.8	3.9	1.08	1.16
9	17.8	21.0	3.2	1.43	2.04	15.8	19.8	4.0	1.18	1.39
10	16.9	18.4	1.5	-.27	.07	18.4	20.2	1.8	-1.02	1.04
11	18.2	18.5	.3	-1.47	2.16	16.7	19.4	2.7	-.12	.01
12	15.8	18.9	3.1	1.33	1.76	16.9	18.7	1.8	-1.02	1.04
13	17.5	20.0	2.5	.73	.53	16.3	18.0	1.7	-1.12	1.25
14	-	-	-	-	-	-	-	-	-	-
15	-	-	-	-	-	15.2	20.1	4.9	2.08	4.32
16	17.5	19.0	-1.5	-.27	.07	15.4	17.9	2.5	-.32	.10
17	15.1	15.0	-.1	-1.87	3.49	15.4	15.8	.4	-2.42	5.85
18	-	-	-	-	-	13.9	15.1	1.2	-1.62	2.62
19	-	-	-	-	-	-	-	-	-	-
20	14.0	14.0	.2	-1.57	2.46	13.5	16.7	3.2	.38	.14
21	16.0	17.5	1.5	-.27	.07	-	-	-	-	-
22	-	-	-	-	-	11.7	13.1	1.4	-1.42	2.01
23	-	-	-	-	-	-	-	-	-	-
24	-	-	-	-	-	10.0	12.0	2.0	-.82	.67
25	-	-	-	-	-	5.5	11.6	6.1	3.28	10.75
26	10.2	15.5	5.3	3.53	12.46	9.2	16.3	7.1	4.28	18.31
27	-	-	-	-	-	-	-	-	-	-
28	-	-	-	-	-	-	-	-	-	-
29	-	-	-	-	-	-	-	-	-	-
30	-	-	-	-	-	-	-	-	-	-
TOTAL	238.5	263.3	24.8	0	30.23	242.2	293.3	50.8	0	56.22
MEAN $\bar{x}$	17.03	18.8	$\bar{d} = 1.77$		$SD^2 = \frac{30.23}{13} = 2.325$	13.45	16.29	$\bar{d} = 2.82$		$SD^2 = \frac{56.22}{17} = 3.30$

Marglobe: $SD = \sqrt{2.325} = 1.52$ $\quad s\bar{d}^2 = \frac{2.325}{14} = .166$ $\quad s\bar{d} = .4$

$t = \frac{1.77 - 0}{.4} = 4.425$ $\quad$ d.f = 13 $\quad$ Sign → 0.001

Rutgers: $SD = \sqrt{3.30} = 1.81$ $\quad s\bar{d}^2 = \frac{3.3}{18} = .183$ $\quad s\bar{d} = .427$

$t = \frac{2.82 - 0}{.427} = 6.6$ $\quad$ d.f = 17 $\quad$ Sign – 0.001

ripened in the darkness in both varieties. In fact, the values for each variety are as follows: in cv Marglobe, the average ascorbic acid content of red tomatoes ripened in darkness and in light and for a period of days which was equal for ripening in dark or light were 17.03 and 18.8 mg/100g fresh fruit, respectively. In Rutgers, these values were 13.45 for the dark-ripened tomatoes and 16.29 for the light-ripened.

In another statistical treatment, tomatoes which were harvested on the same date but ripened either in the light or in darkness were compared for ascorbic acid content when they turned red. The results of this comparison are shown in Table 6, in which 15 Marglobe or 17 Rutgers "Pairs" indicate 15 or 17 different dates on which tomatoes were harvested, and divided in two groups one of which was subsequently ripened in the light and other in darkness. Table 6 shows a definite difference in ascorbic acid concentration associated with exposure to light. The average ascorbic acid values of tomatoes ripened under the light is significantly larger than the average of the dark-ripened ones for both varieties, being 13.7 ± 1.1 and 17.4 ± .9 mg A.A/100g fresh fruit for Marglobe and 11.8 ± 1.0 and 15.9 ± .8 mg A.A/100g fresh fruit for Rutgers in darkness and light, respectively.

The effect of light intensity upon the ascorbic acid concentration of tomatoes has been studied by a number of investigators. However, most of them have dealt with this

TABLE 6. Average ascorbic acid content (mg/100g fresh fruit) of red tomatoes in each pair ripened in darkness and light (pairs in the tomato groups, one in light the other in dark, harvested on the same day).

No. of Pairs	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	X ± SE (n)	SD	t	Probability of a large value, Sign Ignored
MARGLOBE																					
Dark	8.5	10.2	7.7	7.7	10.2	13.1	16.5	16.6	15.9	18.7	19.0	17.8	15.9	12.5	14.8			13.7 ± 1.1(15)	4.0	2.6	0.025 to 0.01
Light	15.0	11.7	13.3	13.2	12.3	17.6	19.7	18.6	19.3	21.4	21.1	20.8	19.7	17.7	18.9			17.4 ± .9(15)	3.4		
RUTGERS																					
Dark	5.5	6.8	7.2	10.0	7.6	10.2	9.2	10.0	8.9	16.7	13.2	15.4	15.6	18.3	14.3	15.9	15.0	11.8 ± 1.0(17)	4.0	3.3	0.005 to 0.001
Light	13.3	11.5	12.5	12.3	13.3	12.0	13.5	15.9	17.3	19.1	16.0	17.4	19.2	18.8	19.9	19.9	19.9	15.9 ± .8(17)	3.0		

$SD = \sqrt{\frac{\Sigma(x^2)}{n} - \frac{(\Sigma x)^2}{n}}$, $SE = \frac{SD}{\sqrt{n-1}}$, $t = \frac{|\bar{x}_L - \bar{x}_D|}{\sqrt{(SE_L)^2 + (SE_D)^2}}$, $d.f = n_1 + n_2 - 2$

effect prior to harvest. It has been shown that light intensity prior to harvest plays the dominant role in determining ascorbic acid content in tomato fruits (Hamner et al., 1945). According to Reid (1943), losses of vitamin C at night amounting to as much as 20 percent of the total quantity, and possibly even more, may occur in some types of plants. She also concluded that similar losses of the vitamin may occur during the day but the quantity thus lost is not readily measurable because the vitamin is manufactured more rapidly than it is used. The net result is an increase up to 25 percent in vitamin C. She also has pointed out that manufacture at a slower rate occurs at night, but its magnitude is difficult to determine because the vitamin is lost much more quickly than it is made. These facts suggest that vitamin C is used by the plant in the process of growth. The function of vitamin C in the plant is not well understood; the speculation exists that it is used in growing regions of the plant such as the tips of the roots and stems and in the development of the young leaves.

Studies indicate that the tomato fruit functions as a photosynthetic organ even though it has no stomates or lenticels (McCollum, 1946). As a consequence of its own life processes both anabolism and catabolism of vitamin C may take place. Furthermore, anabolism of ascorbic acid in tomato fruits exposed to the light occurs at a more rapid rate than those in the darkness. As a result, tomatoes ripened off the vine, but under light would be expected to have more vitamin C than tomatoes ripened in darkness. In this respect, the results of this study are in agreement with the work of previous investigators, who found an increase in ascorbic acid concentration in tomatoes when the fruits on the plant were exposed to light prior to harvest.

In following the ascorbic acid content of the mature-green tomatoes and also mature-green tomatoes left on the vine, rather large fluctuations in the titration values were observed for samples collected on different days. This may be attributed to the biological variability of fruit composition and the rather small size of sample (3 to 7 tomatoes were used to prepare the mixed sample).

As it is shown in Table 1 and 2, within each pair of tomatoes, that is light-ripened and dark-ripened tomatoes picked from the plant on the same day, the fruits which ripened faster usually had more ascorbic acid than those ripening late regardless of condition of light or darkness. This can also be seen in Figure 3 and Figure 4 which show the amount of ascorbic acid of red tomatoes vs the days taken to ripen. It is apparent from these two figures that the longer the period of storage to ripen the mature-green tomatoes, the less ascorbic acid content resulting in the red tomatoes. This is in agreement with the work of Pantos and Markakis (1973), who found a decline in the vitamin C content of the mature-green tomatoes with the time of storage at different temperatures. Hamner et al. (1945) in

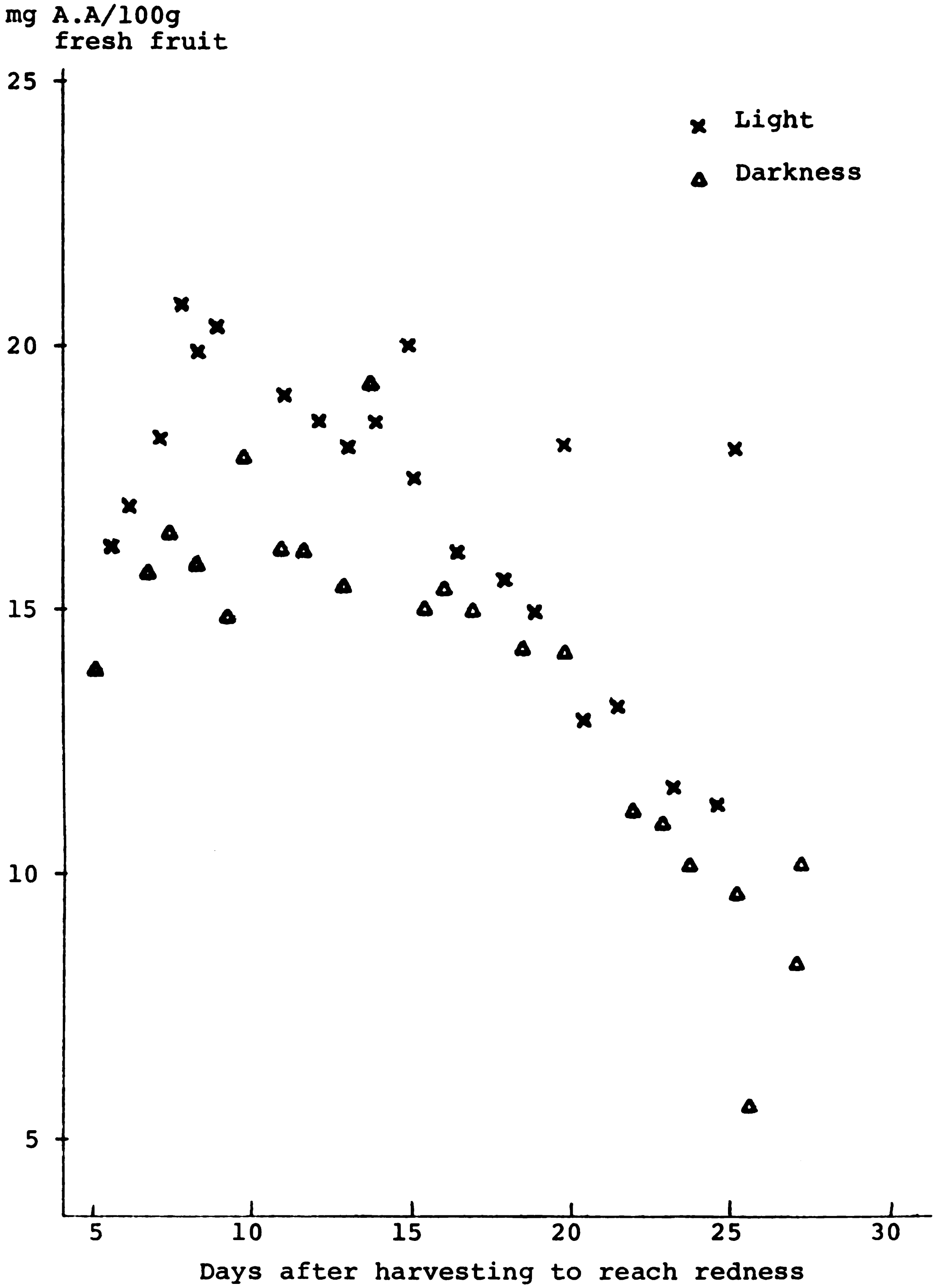

Figure 3. Ascorbic acid (A.A.) content (mg/100g fresh fruit) of red tomatoes vs days after harvesting to reach redness, cv Rutgers.

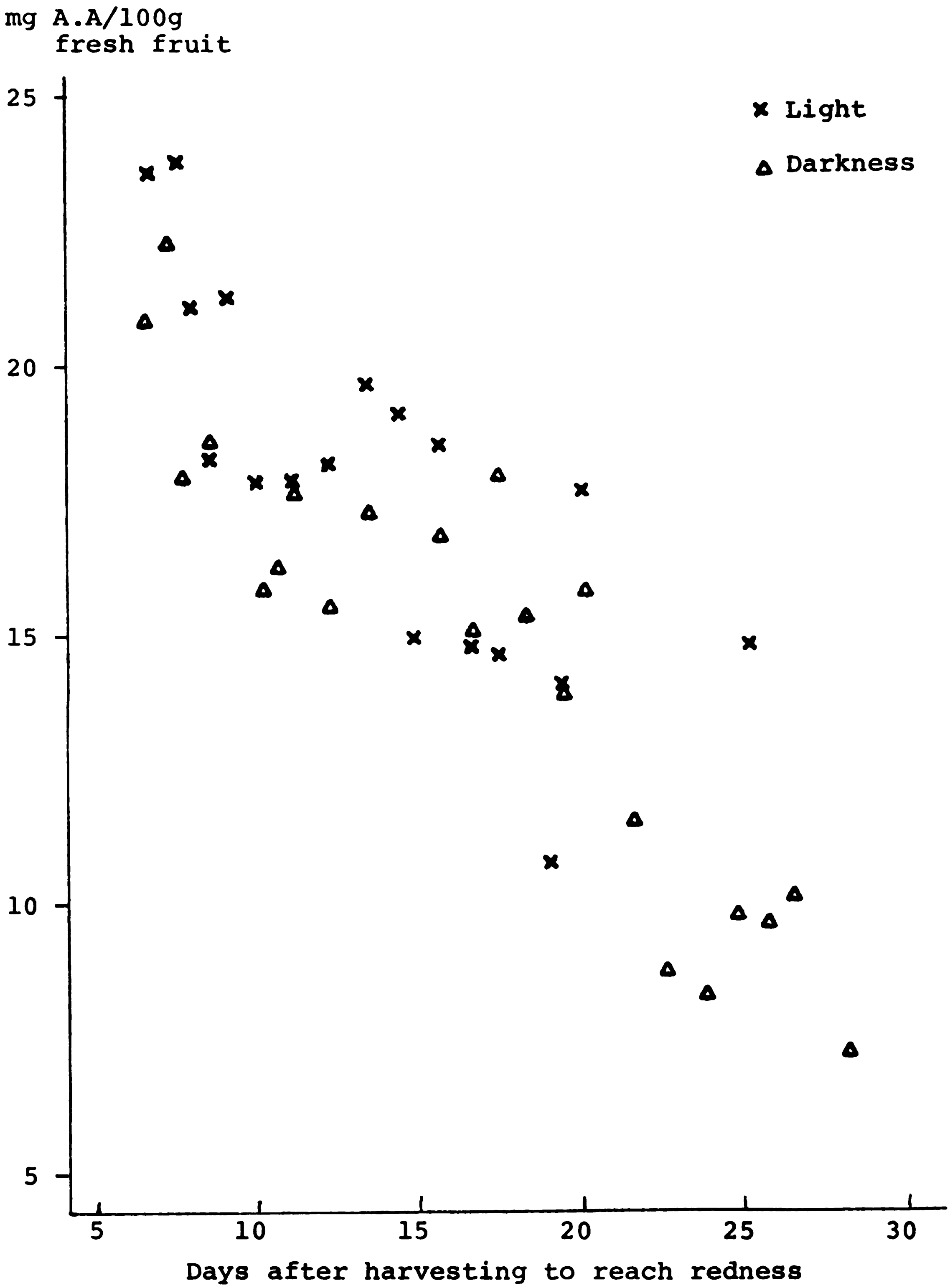

Figure 4. Ascorbic acid (A.A.) content (mg/100g fresh fruit) of red tomatoes vs days after harvesting to reach redness, cv Marglobe.

their experiment also showed a marked decrease in ascorbic acid content of green mature tomatoes stored for two weeks at 80 or 90 degrees F, or after three weeks at 65, 70 and 75 degrees F. Scott and Kramer (1949) reached the same conclusion and reported loss of ascorbic acid during storage of green-mature tomatoes at 70 degree F.

From Figures 3 and 4 it is apparent that the tomatoes stored in the light turned red sooner than those stored in darkness. This is based on crude observation, however, and cannot be supported statistically since no systematic counting of the numbers of tomatoes reaching redness in dark or light was performed. This is in agreement with findings of Ellis and Hamner (1943) who found that exposure of tomatoes to light will influence the carotenoids content.

It is obvious from the data that cv Marglobe had more ascorbic acid than cv Rutgers whether mature-green tomatoes or fully red tomatoes were ripened on the vine or off the vine. This supports the work of Hamner et al. (1945), who found that cv Marglobe consistently had more ascorbic acid than Rutgers at any particular location, except Madison, Wisconsin.

In order to compare the artificial ripening of tomatoes with natural ripening on the vine, some tomatoes were harvested when they turned red on the plant. The ascorbic acid analysis of these tomatoes is shown in Table 7. It can be concluded from the available data that if tomatoes are ripened artificially under light, their ascorbic acid

TABLE 7. Ascorbic acid content (mg/100g fresh fruit) of red tomatoes ripened on the plant.

Date of Harvesting	Marglobe	Rutgers
8/16	--	19.8
8/20	18.5	--
9/4	18.3	17.8
9/7	16.1	16.1
9/10	18.6	15.9
9/12	18.1	15.5
9/14	17.5	17.0
9/19	23.4	18.3
Average	18.6	17.2

is very close to those ripened on the plant. However, tomatoes ripened off the vine and in darkness had vitamin C value much lower than tomatoes ripened naturally.

Suggestions:

1. On the basis of these findings and should the fresh tomato industry be interested in the vitamin C content of tomatoes, it would be advisable to artificially ripen tomatoes under light.

2. In future work in this area it would be worthwhile to investigate the effect of higher and lower intensities of illumination (than 800 fc) on the ascorbic acid content of tomatoes ripened off the vine.

BIBLIOGRAPHY

AOAC. 1970. "Method of Analysis". Assoc. of Off. Analytical Chem., Washington, D.C.

Association of Vitamin Chemists, Inc. 1966. Methods of Vitamin Assay. New York: Interscience Publ. 3rd edition. pp. 294, 320.

Clow, B. and Marlatt, A. L. 1930. Studies of Vitamin C in fresh and canned tomatoes. J. Agr. Res. 40:767.

Craft, C. C. and Heinze, P. H. 1954. Physiological studies of mature-green tomatoes in storage. Proc. Amer. Soc. Hort. Sci. 64:343-350.

Crane, M. B. and Zura, S. S. 1949. The influence of some genetic and environmental factors on the concentration of L - ascorbic acid in the tomato fruit. Jour. Hort. Sci. 25:36-49.

Ellis, G. H. and Hamner, K. C. 1943. The carotene content of tomatoes as influenced by various factors. J. Nutrition, Vol. 25, p. 539.

Frazier, J. C., Lean Ascham, Cardwell, A. B., Fryer, H. C. and Willis, W. W. 1954. Effect of supplemental lighting on the ascorbic acid concentration of greenhouse tomatoes. Proc. Amer. Soc. Hort. Sci. 64:351-359.

Fryer, H. C., Ascham, L., Cardwell, A. B., Frazier, J. C. and Willis, W. W. 1954. Relation between stage of maturity and ascorbic acid content of tomatoes. Proc. Amer. Soc. Hort. Sci. 64:365-371.

Fryer, H. C., Leah Ascham, Cardwell, A. B., Frazier, J. C. and Willis, W. W. 1954. Effect of fruit cluster position on the ascorbic acid content of tomatoes. Proc. Amer. Soc. Hort. Sci. 64:360-364.

Hamner, K. C. 1945. Minor elements and vitamin content of plants. Soil Sci. 60:165-171.

Hamner, D. C., Bernstein, L. and Maynard, L. A. 1945. Effect of light intensity, day length, temperature and other environmental factors on the ascorbic acid content of tomato. J. Nutrition 29:85.

Hamner, K. C., Lyon, C. B. and Hamner, C. L. 1942. Effect of mineral nutrition on the ascorbic acid content of the tomato. Bot. Maz. 103:586-616.

Hamner, K. C. and Maynard, L. A. 1942. Factors influencing the nutritive value of the tomato. A review of the literature. U.S.D.A. Misc. Pub. 502, p. 23.

Hassan, D. B. and McCollum, J. P. 1954. Factors affecting the content of ascorbic acid in tomatoes. ILL. Expt. Sta. Bul. 573.

House, M. C., Nelson, P. M. and Haber, E. L., 1929. Vitamin A, B, and C content of artificially versus naturally ripened tomatoes. J. Biol. Chem. 81:495-504.

Jones, D. B. and Nelson, E. M. 1930. Vitamin content of ethylene treated and untreated tomatoes. Am. J. Pub. Health 20:387.

Kask, I.K., G. L. Wesster and Kirck, E. R. 1944. Ascorbic acid content of tomatoes. Food Res. 9:386-391.

LoCoco, G. 1945. Composition of northern California tomatoes. Food Res. 10:114-121.

Maclinn, W. A. and Fellers, C. R. 1938. Ascorbic acid (vitamin C) in tomatoes and tomato products. Mass. Agr. Expt. Sta. Bul. 354.

Maclinn, W. A. and Fellers, C. R. and Buck, R. E. 1936. Tomato variety and strain differences in ascorbic acid (vitamin C) content. Proc. Am. Soc. Hort. Sci. 34:543.

Malewski, W. and Markakis, P. 1971. Ascorbic acid content of the developing tomato fruit. J. Food Sc. 36:537.

Massey, D. M. and Winsor, G. W. 1956. The composition of tomato fruit in relation to variety, state of ripeness and fruit quality. III. Chemistry. Glasshouse. Res. Inst. Ann. Ref. p. 52.

Matsuoka, T. 1936. Studies on vitamin C. XVIII. The effect of light upon production of vitamin C. Agr. Chem. Soc. Japan Jour. 12:1203-1210. (English abstract, pp. 160-161) (Chem. Abs. 31:3103. 1937).

McCollum, J. P. 1946. Effect of sunlight exposure on the quality constituents of tomato fruits. Proc. Amer. Soc. Hort. Sci. 48:413-416.

McCollum, J. P. 1944. Some factors affecting the ascorbic acid content of tomatoes. Proc. Amer. Soc. Hort. Sci. 45:382-386.

McHenry, E. W. and Graham, M. 1935. Observations on the estimation of ascorbic acid by titration. Biochem. Jour. 29:2013.

Miller, E. V. and Schomer, H. A. 1947. The effect of ultraviolet light on subsequent ripening of the fruit of the tomato (Lycopersicon esculentum). Plant Physiol. 22:603-607.

Mills, M. B., Damron, D. M. and Roe, J. H. 1949. Ascorbic acid, dehydroascorbic acid and diketogulonic acid. Anal. Chem. 12:707.

Murneek, A. E. and Flynn, Laura M. 1945. Effect of storage of maturity, environmental factors, and "hormone" sprays on vitamin content of tomatoes. National Cooperative Project. Conservation of Nutritive Value of Foods, Missouri. Notes No. 4, Jan. 1945.

Murphy, E. 1939. Vitamin C and light. Amer. Soc. Hort. Sci. Proc. (1938) 36:498-499.

Pantos, C. E. and Markakis, P. 1973. Ascorbic acid content of artificially ripened tomatoes. J. Food Sci. 38:550.

Penney, J. R. and Zilva, S. S. 1943. Chemical behavior of dehydro L-ascorbic acid in vitro and in vivo. Biochem. J. 37:403.

Porter, A. M. 1937. Effect of light intensity on the photosynthetic activity of tomato plants. Plant Physiol. 12:225-232.

Reid, M. F. 1943. Sunshine and the food value of plants. J. New York Botan. Gard. 44:162-164.

Roe, J. H. 1936. Determination of ascorbic acid furfural and a comparison of the results obtained by this method and by indophenol titration. J. Biol. Chem. 116:609.

Sansome, F. W. and Zilva, S. S. 1936. Polyploidy and vitamin C. Biochem. Jour. 30:54.

Scott, L. E. and Kramer, A. 1949. The effect of storage upon the ascorbic acid content of tomatoes harvested at different stages of maturity. Proc. Am. Soc. Hort. Sci. 54:277.

Somers, G. F., Hamner, K. C. and Kelly, W. C. 1950. Further studies on the relationship between illumination and the ascorbic acid content of tomato fruits. Jour. Nutrition 40:133-143.

Somers, G. F., Hamner, K. C. and Nelson, W. L. 1954. Field illumination and commercial handling as factors in determining the ascorbic acid content of tomatoes received at the cannery. Jour. Nutrition 30:425-433.

Sugamara, T. 1939. Studies on formation of ascorbic acid (vitamin C) in plants. II. The influence of radiation of different wave-lengths on the ascorbic acid contents in etiolated seedlings. Japan. Jour. Bot. 10:325-333, illus.

USDA. 1963. "Composition of Foods". Agr. Handbook No. 8 U.S. Dept. of Agric., Washington, D.C.

Verkerk, K. 1955. "Temperature, light and the tomato". Dissertation published by H. Vernman and Zonen, Wajeningen.

Victor, R. Boswell. Yearbook of Agriculture 1937. pp. 176-187.

Wokes, G. and Organ, J. G. 1943. Oxidizing enzymes and vitamin C in tomatoes. Biochem. Jour. 37:259-265.