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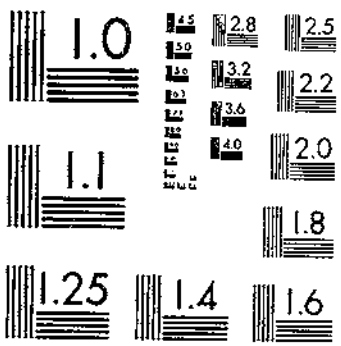
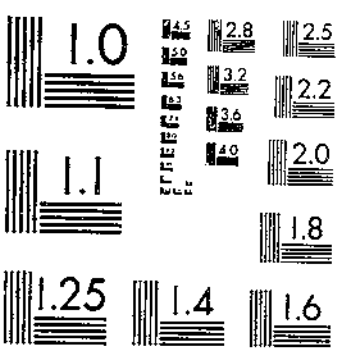


MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A



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NATIONAL BUREAU OF STANDARDS-1963-A

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EFFECT OF VARIOUS TEMPERATURES ON THE STORAGE AND RIPENING OF TOMATOES

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INTRODUCTION

Since the issuance of the publications by Sando (*6*)[2] on the process of ripening in tomatoes and by Diehl (*2*) on the chilling of tomatoes, interest in the subject of the ripening of tomatoes has increased and a considerable demand has developed for further information. Of especial interest is the effect on their subsequent ripening of exposing tomatoes to low temperatures while in the mature green stage. Other problems needing investigation are the effects of different storage temperatures on the ripening and holding of both green and ripe fruit. Such information is of particular interest to shippers and carriers of southern-grown tomatoes that are commonly shipped to northern markets during the winter months when they are subject to low temperatures while in transit. It is also of value to those northern growers interested in determining the proper temperatures for the storing and ripening of tomatoes after freezing weather has stopped natural development on the vines. The object of this publication is to enlarge upon and supplement the investigations reported by Diehl.

The question of the effect of low temperatures on tomatoes has been the subject of considerable discussion and even of litigation. Among many commercial handlers the opinion seems firmly fixed that

[1] Credit is due L. A. Hawkins, formerly leader of the project under which this work was done, for helpful suggestions and criticisms during the progress of the work.

[2] Italic numbers in parentheses refer to Literature Cited, p. 34.

tomatoes, when subjected to temperatures of 40° F. and below, within a comparatively short time are rendered incapable of ripening properly when subsequently put in a favorable ripening temperature. Investigators have long recognized that some of the conditions found in shipped tomatoes and attributed to chilling injury very often are not due to chilling. Link [3] says:

> The soft and flabby, as well as the wrinkled and shriveled condition noted in Mexican tomatoes, is generally assumed to be due to freezing or chilling. My observations made in Los Angeles, Mexicali, Calexico, Nogales, Houston, and New Orleans markets, show that this assumption is incorrect. Mexican tomatoes examined in these markets showed the same symptoms noted in our northern markets. The assumption is finally and completely disposed of by my finding the same symptoms in 33 cars of Mexican tomatoes which I inspected at Nogales, Mexico. These shipments, just as those noted at Los Angeles, Mexicali, Calexico, Houston, and New Orleans, had not been chilled "coming over the mountains," as is generally stated, because there are no mountains to come over, and because they had not been within a hundred miles of freezing temperatures.

Ramsey [4] further states that—

> * * * produce dealers recognize injury due to delayed ripening and poorly flavored tomatoes, but sometimes fail to appreciate the fact that many factors other than temperature may play an important part in accounting for poor quality of the stock. Unsatisfactory ripening may be due to chilling, to immature poor quality fruit, or to poor handling in the ripening room.

It was demonstrated by Diehl (*2*) that tomatoes could be exposed to low temperatures just above their freezing point for as long as five days without apparent injury. Another writer (*1*) concludes from his experience that tomatoes stored for five or six days at 34° F. will not thereafter ripen normally, and injury will follow storage at 50° "for more than a short time," as indicated by failure to develop normal color and the rapid development of decay on removal. On the other hand, Plank and Schneider (*7*) report from results obtained in 1926 that ripe tomatoes can be held four to five weeks at 32° without injury. MacGillivray (*4*) in 1926 reported a smaller loss in sugar and acid in ripe fruit stored at 52.5° than at higher temperatures.

It is a more or less common and well-known practice after the first killing frost to remove the remaining tomatoes from the vines or to lift the entire vine with the tomatoes attached and allow the tomatoes to ripen in a cellar, coldframe, or other suitable place. The existence of such a custom shows that temporary chilling at comparatively low temperatures does not in itself prevent ripening.

From certain studies in the storage and ripening of tomatoes, Rosa (*5*) concluded that tomatoes ripened most favorably at a temperature of 77° F., while at 51.8° the ripening process was very slow, and at 46.4° and 39.2° ripening was almost inhibited.

The present investigations were conducted during the seasons of 1925 to 1928, inclusive, on tomatoes grown on the Arlington Experiment Farm near Washington and in 1930 on Florida-grown fruit purchased on the market in Washington. The varieties grown for this work were Globe, Stone, and the new variety Marglobe, which promises to become of great commercial importance owing to its productiveness, hardiness, and resistance to nailhead rust. On the ground used for growing tomatoes for these experiments the Marglobe produced considerably more desirable fruits than the other

[3] LINK, G. K. K. CHILLING AND FREEZING INJURY OF TOMATOES. U. S. Dept. Agr., Bur. Markets Memo. 40, 3 p., Mar. 30, 1920. [Mimeographed.]
[4] RAMSEY, G. B. FREEZING AND CHILLING INJURY OF TOMATOES. U. S. Dept. Agr., Bur. Agr. Econ. Memo. 69, 3 p., Jan. 10, 1929. [Mimeographed.]

varieties; consequently the majority of the experiments were carried on with this variety.

In outlining these experiments two principal objectives were in view. One was to determine the effects of chilling on tomatoes at various degrees of maturity and the other to determine the rate of ripening at various temperatures. It will be noted that the time required for ripening under optimum conditions, as reported herewith, is apparently greater than that required in commercial ripening rooms. However, it must be remembered that commercial southern-grown tomatoes usually have a 4-day to 6-day haul before getting into ripening rooms, whereas the tomatoes used in these experiments were put into ripening or storage rooms directly after being picked.

RESULTS IN 1925

Plants of proper size were set in the field on May 25, 1925. In preparation for the storage and ripening investigations and in order to have definite knowledge of the state of maturity of the experimental material used, freshly opened blossoms were periodically marked by attaching small paper tags to the stems, as described in previous investigations on this subject. Tagging commenced July 8 and was repeated at 3-day or 4-day intervals, until August 31, only freshly opened blossoms of the day the tagging was done, or possibly the day previous, being used. By exercising care, blossoms usually not over a day old could be selected, and later the tagged fruit within a day of any age desired could be selected when wanted. As different colored tags were used for each successive period, lots of tomatoes of various ages sufficient for sampling were easily found when needed; also, successive pickings of fruit tagged the same day could easily be made. Most of the blossoms tagged after July 30 dropped, and those that did set produced very few desirable fruits.

LOW-TEMPERATURE EXPOSURE AND RIPENING

In the first experiments carried out to determine the effect of certain low temperatures on the ripening of tomatoes, lots of mature green Globe and Marglobe fruits 42 days from blossoming were packed in 4-quart baskets, and put in 32° F. storage. When picked, all showed a whitening about the blossom ends, but no pink color had developed. After exposure to the 32° temperature for 1, 2, 3, 4, and 8 days, baskets of each variety were removed to the ripening room and held at 70° with a relatively high humidity (85 per cent). Inspections to determine the number of ripe specimens were made 7, 11, 14, and 19 days after picking. The actual number of days in the ripening room may be determined from the difference between the number of days after picking and the length of exposure to the storage temperatures used. Fruits passed as ripe were at least three-fourths fully colored. The results of the inspections are shown in Table 1.

The results of the tests shown in Table 1 indicate that ultimate ripening in all of the specimens was not prevented by exposure to 32° F. for as long as 4 days, and no great difference in rate of ripening was shown in the lots exposed from 1 to 4 days. After the 8-day period of exposure to a temperature of 32°, ripening was so delayed that specimens classed as ripe were not found until the

inspection on the nineteenth day after picking. At the time of this inspection 31 per cent of Marglobes and 25 per cent of Globes were ripe, and although a few of those not yet ripe were in good condition and apparently would have ripened had the experiment been continued, most of the yet unripened fruit showed evidence of breaking down or actual decay at this time. After the other periods of exposure, 100 per cent of the fruits were found to be fully ripe by the nineteenth day, although ripening was delayed in proportion to the length of such exposure.

TABLE 1.—*Rate of ripening of Marglobe and Globe tomatoes in the ripening room at 70° F. after varying periods of exposure to a temperature of 32°, as determined by successive inspections*

Period of previous exposure at 32° F.	Percentage of fruit ripened (at 70° F.) at intervals shown after picking—							
	Marglobe				Globe			
	7 days	11 days	14 days	19 days	7 days	11 days	14 days	19 days
1 day	19	31	87	100	1	30	69	100
2 days	0	29	94	100	0	9	18	100
3 days	6	12	31	100	0	8	50	100
4 days	6	6	25	100	0	0	10	100
8 days	------	0	0	31	------	0	0	25

In the next experiment it was desired to compare the effect of low-temperature exposure on tomatoes of different ages; therefore three duplicate lots of tagged tomatoes of the Marglobe variety, representing those that were 40, 37, and 33 days from bloom, were picked. Two or three specimens of those that were 40 days from bloom showed faint traces of pink. The remainder at this age were mostly green, but showed a whitening around the blossom ends. The other two groups were quite green and averaged somewhat smaller in size. The difference in the ages of these two groups could not have been determined without the aid of the tags. The specimens of these three lots were, on the whole, not so large as the average of the succeeding lots, because of a 2-week drought which occurred shortly after the tagging. A 4-quart basket of tomatoes of each group was held as a check or control at a temperature approximating 70° F., while an additional basket of each was held at 32° for 24 hours and then placed with the checks. Inspections were made after 3, 6, and 10 days.

Table 2 shows that, although exposure for 24 hours at 32° F. apparently delayed the ripening of green tomatoes 40, 37, and 33 days from bloom, the delay was slight, and at the time of the third inspection, 10 days after picking, all the exposed tomatoes as well as those not exposed were ripe. Three and six days after picking the control lots 40 and 37 days from bloom showed more ripe tomatoes, but it should be noted that in all cases the control lots were in the ripening room 24 hours longer than the exposed lots, which were exposed to a temperature of 32° during this extra day. In all lots of tomatoes, low-temperature exposure delayed ripening but did not prevent ultimate normal ripening by the tenth day. The rate of ripening, as shown by the third-day inspection, increased as the age of the fruit from blossoming increased.

TABLE 2.—*Rate of ripening of Marglobe tomatoes picked 33, 37, and 40 days from bloom, in the ripening room at 70° F., after exposure to a temperature of 32°, for 24 hours, as determined by successive inspections*

Treatment	Percentage of fruit ripened (at 70° F.) at intervals shown after picking								
	Lot 33 days from bloom			Lot 37 days from bloom			Lot 40 days from bloom		
	3 days	6 days	10 days	3 days	6 days	10 days	3 days	6 days	10 days
Control [1]	7	25	100	18	55	100	39	72	100
Exposed 24 hours at 32° F.	0	25	100	12	33	100	25	46	100

[1] Put directly into ripening room when picked.

In the next three experiments tomatoes of the Marglobe variety were picked on successive dates in order to obtain lots of different stages of maturity tagged at the same time. Therefore, tomatoes of the group tagged July 25 were picked 31, 35, and 39 days from this date. Owing to more favorable conditions, those in this group were considerably larger and smoother than those in previous experiments. These lots were immediately packed in 4-quart baskets and stored as follows: One basket of each was put directly into 70° F. storage and held as a check; 1 was held at 25° from 18 to 21 hours, and 3 were held at 32° for 3, 5, and 7 days, respectively. Although 25° is below the freezing point, which is given as 30.46° (*3*), experience showed that under the conditions named single tomatoes could be exposed for about 21 hours before actual freezing would take place. No doubt these tomatoes had cooled to the freezing point or even below the freezing point under the exposure described.[2] This very probably would not apply to tomatoes in the ordinary channels of trade. Here other factors would enter which might cause injury at this temperature in a much shorter time, but they are not discussed in this bulletin. Each lot, after its respective period of exposure to the low temperatures, was removed to the 70° ripening room. The results are shown in Table 3. In the first general lot, 31 days from bloom, the first inspection in the ripening room was made 9 days after picking. No ripe tomatoes were found. Subsequent inspections were made 15, 19, and 23 days after picking. Since tomatoes of these varieties ripen on the vines under field conditions in this locality in about 40 to 45 days from bloom, it is apparent that those in this experiment were immature.

The next lot of tomatoes tagged the same day as those in the preceding experiment were picked 35 days from bloom. They were treated in exactly the same way as in former experiments except that those in 25° F. storage were accidentally left for 21 hours instead of 18, and five specimens showed slight localized freezing injury; these, however, colored up normally except over the injured areas. (Pl. 1, A.) Inspections were made 7, 11, 15, and 19 days after picking, with the results shown in Table 3.

[2] For a discussion of undercooling, see Department Bulletin 1133 (*3*, p. 2).

TABLE 3.—*Rate of ripening of Marglobe tomatoes picked 31, 35, and 39 days from bloom, in the ripening room at 70° F., after varying periods of exposure to low temperatures, as determined by successive inspections*

Treatment	Percentage of fruit ripened (at 70° F.) at intervals shown after picking										
	Lot 31 days from bloom				Lot 35 days from bloom				Lot 39 days from bloom		
	9 days	15 days	19 days	23 days	7 days	11 days	15 days	19 days	7 days	11 days	15 days
Control [1]	0	71	100	100	36	71	100	100	61	100	100
18 hours at 25° F	0	53	100	100					40	60	60
21 hours at 25° F					7	100	100	100			
3 days at 32° F	0	31	100	100	0	66	100	100	43	100	100
5 days at 32° F	0	14	57	100	0	0	72	100	28	43	100
7 days at 32° F	0	0	0	100	0	8	50	100	0	0	100

[1] Put directly into ripening room when picked.

The next picking of tomatoes of this same group was 39 days from bloom. Some of these were just beginning to show signs of turning when picked. They were handled as before, and inspections were made 7, 11, and 15 days after picking. These results are also shown in Table 3.

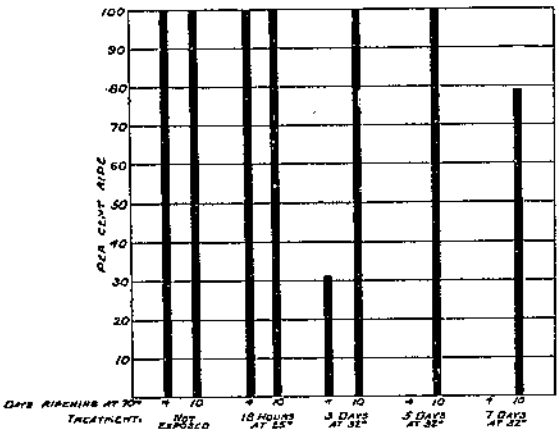


FIGURE 1.—Ripening of Marglobe tomatoes at 70° F., after low-temperature exposures; picked 43 days from bloom

It is of particular interest to note that in all the lots in this experiment exposure to a temperature of 25° F. did not prevent ultimate ripening. However, in the lot 39 days from bloom, ripening was somewhat delayed. At this temperature, decay, which appeared to be due to mechanical rather than to freezing injury, prevented some of the fruit from ripening. Three days' exposure to a temperature of 32° slowed up ripening somewhat, and five and seven days' exposure delayed it to a greater extent, but these exposures did not prevent the ultimate ripening of most of the fruits, which appeared normal in every way.

The next group of tomatoes studied were Marglobes, tagged July 30, five days after those reported in the previous experiments. In this group tomatoes 33, 36, and 43 days from bloom were used. With minor exceptions these were treated as were those in the preceding group. The results are shown in Table 4 and illustrated in Figure 1. These results are essentially the same as those in the preceding experiment, in that the tomatoes exposed to the low temperature (25° F.) ripened almost as fast as the controls, and those exposed to

a temperature of 32° for periods up to seven days apparently were not prevented from ultimate ripening by this exposure. One lot of those 36 days from bloom was exposed to a temperature of 32° for nine days, and all of them eventually ripened, but the color and quality were not satisfactory.

TABLE 4.—*Rate of ripening of Marglobe tomatoes picked 33, 36, and 43 days from bloom, in the ripening room at 70° F., after varying periods of exposure to low temperatures, as determined by successive inspections*

Treatment	Percentage of fruit ripened (at 70° F.) at intervals shown after picking										
	Lot 33 days from bloom				Lot 36 days from bloom					Lot 43 days from bloom	
	7 days	11 days	15 days	20 days	4 days	8 days	12 days	17 days	20 days	4 days	10 days
Control [1]	27	58	100	100	0	43	57	100	100	100	100
18 hours at 25° F.										100	100
21 hours at 25° F.	18	68	100	100							
3 days at 32° F.	0	7	85	100						31	100
5 days at 32° F.	0	8	58	100	0	0	53	100	100	0	100
7 days at 32° F.	0	7	41	100	0	0	0	100	100	0	70
9 days at 32° F.					0	0	0	38	100		

[1] Put directly into ripening room when picked.

The last group of tomatoes to be exposed and ripened as described were those tagged August 6. Very few blooms tagged after this date matured normally, since before these fruits ripened the vines had apparently produced to their maximum capacity and the later fruits as they matured appeared rather soft and watery and broke down rather quickly after being picked. This lot was 39 days from bloom when picked. Fruits were treated as in former experiments except that none were held longer than five days at 32° F. These were inspected after 5, 7, and 10 days, with the results shown in Table 5. Five days after picking 94 per cent of the checks and 40 per cent of those held at 25° for 18 hours were ripe. Seven days after picking all the checks and all those exposed to a temperature of 25° were ripe; 82 per cent of those exposed for three days to a temperature of 32° were also ripe, but those exposed five days were not ripe. Ten days after picking all had ripened except those exposed five days to a temperature of 32°; 60 per cent of these were ripe, but the color was poor, and the remainder did not show promise of ripening normally.

TABLE 5.—*Rate of ripening of Marglobe tomatoes picked 39 days from bloom, in the ripening room at 70° F., after varying periods of exposure to low temperatures, as determined by successive inspections*

Treatment	Percentage of ripened fruit (at 70° F.) at intervals shown after picking—		
	5 days	7 days	10 days
Control [1]	94	100	100
18 hours at 25° F.	40	100	100
3 days at 32° F.	0	82	100
5 days at 32° F.	0	0	60

[1] Put directly into ripening room when picked.

From the results of the foregoing experiments it seems evident that the exposure of green tomatoes of various stages of maturity to the low temperatures described does not necessarily prevent ripening if the fruit is subsequently changed to favorable conditions. Tomatoes held 18 hours at 25° F. (the maximum length of time they could be held before actual freezing occurred) ripened normally and almost as rapidly as control samples picked at the same time but put directly into the ripening room. In addition, certain specimens that had actually frozen in limited areas colored up normally with the exception of the areas affected, as shown in colors in Plate 1, A. Tomatoes from quite immature stages 31 days from bloom to nearly mature lots 43 days from bloom were exposed to a temperature of 32° for as long as 9 days and were not entirely prevented from ripening satisfactorily when warmed to 70°. Exposure to a temperature of 32° for five to seven days in most instances delayed the ripening somewhat but did not prevent it, and did not delay the ripening of those 40 to 43 days from bloom as much as that of those which were less mature. When the time lost while in the 32° room before going into the ripening room is considered, the so-called chilled tomatoes in most instances ripened almost as rapidly as the ones not exposed. The color of those exposed for the longer periods (five to seven days) was not so good as that of those not exposed, but the difference was not great. In only a few instances were the glazed or shriveled conditions, commonly ascribed by the trade to chilling, found in any of the exposed lots. The only occasion when these conditions prevailed was in individual fruits that had been picked too immature to ripen properly under any condition after being separated from the plant. Although care was exercised to select only mature green fruits, immature ones were taken occasionally, and such individuals developed these symptoms under all storage conditions.

RELATION OF TEMPERATURE TO RIPENING

The next group of experiments was carried on in order to study the influence of various temperatures on the rate of ripening. Information on this subject is of particular interest to growers who desire to store the remainder of their crops at the end of the growing season when danger of frost is imminent, and to those interested in the ripening of green tomatoes as they arrive from southern points during the shipping season. Ordinarily, tomatoes left on the vines at the end of the growing season are inclined to be watery and of poor quality, because the vines are usually past their prime. Some growers, therefore, make a practice of setting plants late in the season in order to have a crop most of which is in the mature green stage at about the close of the growing season. This will usually insure a large quantity of fruit in prime condition for ripening in storage for the market after frost has killed the vines. It is desirable to store these tomatoes so that they will ripen more or less slowly and carry well, in order to prolong their marketing period. In some of the experiments the effect upon the rate of ripening within various temperature ranges from 80° F. down to the limiting or the lowest temperature at which ripening will take place was studied.

Three varieties, namely, Globe, Stone, and Marglobe, were used in these experiments. Sufficient tagged material was not available, so personal judgment alone was exercised in selecting mature green

tomatoes or those in the earlier turning stage. These were usually packed and stored in 4-quart baskets. In the first experiment mature green tomatoes and those in the turning stage showing less than one-half full color were stored at the lower ranges of temperatures, viz, 60°, 50°, and 40° F. Inspections were made after 6, 9, 13, 16, 22, 29, and 34 days. Those classed as ripe were more than one-half fully colored. The results are shown in Table 6. These show ripening at 60° to be satisfactory, although somewhat slower than at 70°, as in former experiments. Mature green tomatoes ripening at 60° began to show signs of breaking down about the twenty-second day. The ripening of tomatoes in the turning stage at 50° was slow but otherwise satisfactory in most cases, but many specimens showed signs of breakdown before becoming ripe. Mature green tomatoes at this temperature ripened very slowly, developing a pale color, and began to break down after about three weeks. At 40° ripening was practically prevented in tomatoes at both stages of maturity.

TABLE 6.—*Rate of ripening at various temperatures of Globe, Stone, and Marglobe tomatoes picked in the mature green and turning stages*

Variety, condition when picked, and ripening temperature (° F.)	Percentage of ripened fruit at intervals shown after picking—						
	6 days	9 days	13 days	16 days	22 days	29 days	34 days
Globe:							
Mature green—							
60°	22	51	72	83	100	100	100
50°	0	9	9	45	91	91	100
40°	0	0	0	0	0	0	0
Turning—							
60°	100	100	100	100	100	100	100
50°	45	100	100	100	100	100	100
40°	1	20	20	100	100	100	100
Stone:							
Mature green—							
60°	0	25	50	67	100	100	100
50°	0	0	0	1	44	66	100
40°	0	0	0	0	0	0	0
Turning—							
60°	57	67	100	100	100	100	100
50°	1	57	57	100	100	100	100
40°	0	0	0	0	0	0	0
Marglobe:							
Mature green—							
60°	25	75	83	83	100	100	100
50°	0	20	20	50	50	80	100
40°	0	0	0	0	0	0	0
Turning—							
60°	100	100	100	100	100	100	100
50°	90	100	100	100	100	100	100
40°	0	20	30	70	70	90	90

While all varieties picked in the turning stage ripened to some extent, the color was pale and unsatisfactory. All those in the green stage when picked failed to color, except to turn a creamy white, when held at 40° F. At the end of the experiment all those held at 40° had turned nearly white, or pale pink in a few cases, and were becoming soft; many were breaking down. Globes picked in the mature green stage and held at 60° were all ripe at the inspection on the twenty-second day, and those held at 50° were all ripe after 34 days, although in the case of those held at the latter temperature the color was rather unsatisfactory. No ripening was noted in those held at 40°.

Globes picked in the turning stage were all ripe when held at 60° for 6 days, at 50° for 9 days, and at 40° for 16 days, although the color of those held at 40° was pale and the fruits soon broke down when removed to a higher temperature. Mature green Stone tomatoes were all ripe in 22 days when held at 60°, in 34 days when held at 50°, and there was no ripening at 40°. Picked in the turning stage, Stones were ripe in 13 days when held at 60°, in 16 days when held at 50°, and there was no ripening when they were held at 40°. Marglobe tomatoes picked mature green were all ripe in 22 days in 60° storage, in 34 days in 50° storage, and there was no ripening in 40° storage. When picked in the turning stage all were ripe after 6 days in 60° storage and after 9 days in 50° storage; when held at 40° 90 per cent were ripe but pale colored, and many were breaking down at the close of the experiment.

In the next experiment five baskets each of selected mature green Stone, Marglobe, and Globe tomatoes were wrapped and stored at

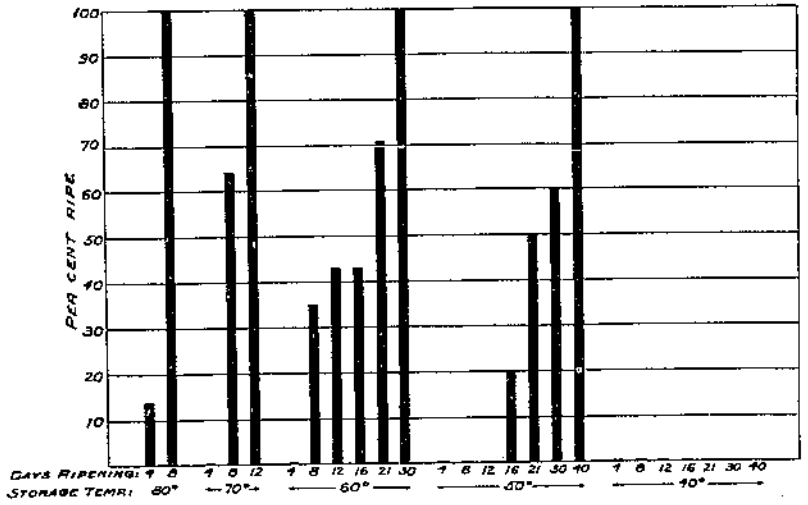


FIGURE 2.—Ripening of Marglobe tomatoes at different temperatures; picked mature green.

80°, 70°, 60°, 50°, and 40° F. immediately after picking. Periodic inspections were made to determine the relative rate of ripening, with the results shown in Table 7 and Figure 2. Inspections of the Stone tomatoes were not made at the same intervals as inspections of the other two varieties. These tests show that the rate of ripening of mature green tomatoes decreases rapidly with the lowering of the temperature. A more or less abrupt falling off in rate of ripening is noted below 60° in all varieties. Stone tomatoes stored at 80° were ripe in 11 days; those stored at 70° in 14 days; those stored at 60° in 19 days; and those stored at 50° in 41 days. No ripening occurred at 40°. Globe tomatoes ripened at 80° in 8 days, at 70° in 12 days, at 60° in 16 days, and at 50° in 30 days. Marglobe tomatoes stored at 80° were ripe in 8 days, those stored at 70° in 12 days, those stored at 60° in 30 days, and those stored at 50° in 40 days. At the end of 40 days the tomatoes of all varieties ripened at 60° and 50° were in good condition. Those ripened above these temperatures did not hold up so long as might be expected because of normal breakdown follow-

ing maturity. In no variety did ripening take place at 40°. The tomatoes assumed an almost white color at this temperature, and by the thirtieth day they were soft and showed signs of breaking down while in storage.

TABLE 7.—*Rate of ripening at various temperatures of Globe, Stone, and Marglobe tomatoes picked in the mature green stage*

Variety and ripening temperature (° F.)	Percentage of ripened fruit at intervals shown after picking—														
	4 days	7 days	8 days	11 days	12 days	14 days	16 days	19 days	21 days	23 days	27 days	30 days	32 days	40 days	41 days
Stone:															
80°	27	73		100		100		100		100	100		100		100
70°	18	53		76		100		100		100	100		100		100
60°	20	40		53		73		100		100	100		100		100
50°	0	0		5		19		38		66	66		81		100
40°	0	0		0		0		0		0	0		0		0
Globe:															
80°	14		100		100		100		100			100		100	
70°	0		85		100		100		100			100		100	
60°	7		21		50		100		100			100		100	
50°	0		0		0		50		50			100		100	
40°	0		0		0		0		0			0		0	
Marglobe:															
80°	14		100		100		100		100			100		100	
70°	0		64		100		100		100			100		100	
60°	0		35		43		43		71			100		100	
50°	0		0		0		20		50			60		100	
40°	0		0		0		0		0			0		0	

These studies indicate that when tomatoes are ripened at temperatures varying from 80° to 40°, the rate of ripening decreases with the temperature. At 50° and 60° mature green tomatoes ripened and remained in good condition for as long as 40 days, whereas at 40° softening and a tendency to break down were noted in 20 to 30 days while the tomatoes were in storage, but when they were removed and kept at ordinary room temperature rapid breakdown was apparent in stock that had been held at 40° for 10 to 15 days.

Since tomatoes would not ripen at 40° F., an experiment was begun to determine how long mature green and turning tomatoes could be held at 40° and then be ripened satisfactorily at a higher temperature. Several 4-quart baskets were filled with specimens of Marglobe, Globe, and Stone varieties and stored at 40°. A basket of each variety was removed to a 70° ripening room after three weeks' storage for subsequent ripening tests. In this lot after four days at 70° about 40 per cent were ripe, but with considerable physiological breakdown apparent. After four weeks all tomatoes in 40° storage showed so much breakdown that the experiment was discontinued.

EFFECT OF HIGH TEMPERATURE ON RIPENING

In order to test the effect of heat upon the ripening of tomatoes, a lot of mature green Marglobes was divided, and part of them were put into 70° storage as a control, while the remainder were placed in a temperature of 120° and a relatively high humidity for 24 hours. Subsequent inspections made to determine the percentages of ripeness showed identical results among the heated tomatoes and those held as a check. No difference in appearance was noted between the heated tomatoes and the checks.

RELATION OF LIGHT TO RIPENING

An experiment to determine the effect of light and darkness upon the rate of ripening of tomatoes was conducted with mature green Globes. One basket was kept in full light before a west window at a temperature varying between 70° and 80° F., while another was kept in complete darkness at the same temperature. The results are shown in Table 8. Those ripened in the dark seemed to develop color more rapidly at first; however, all tomatoes of both varieties were ripe in eight days.

TABLE 8.—*Rate of ripening in darkness and full light of mature green Globe and Marglobe tomatoes at a temperature varying from 70° to 80° F.*

Lot and treatment	Percentage of ripened fruit at intervals after picking							
	Globe				Marglobe			
	4 days	5 days	6 days	8 days	4 days	5 days	6 days	8 days
Lot 1:								
Darkness	53	76	88	100				
Light	37	50	62	100				
Lot 2:								
Darkness	7	7	53	100	0	0	44	100
Light	26	46	54	100	8	25	50	100

This experiment was repeated, tomatoes of both the Globe and the Marglobe variety being used, and the results were as shown in Table 8. In this experiment the results were reversed, in that the ripening in both varieties seemed at first to be more rapid in the light, but, as before, all were ripe in eight days.

The difference between tomatoes ripened in light and in darkness was not so marked in the rate of ripening as in the appearance of the fruit. When tomatoes were ripened in the dark the color was more evenly distributed; a gradual blending from green to whitish and then to pink, followed by a full red color, was noted as ripening progressed. In full light, ripening areas starting from the blossom end of the fruits appeared as a bright full red, contrasting with the full-green areas.

RESULTS IN 1926

Some changes in the methods of procedure were followed during the course of the investigations in 1926. For this season's stock of tomatoes for storage studies the Marglobe variety only was used. The young plants were not set in the field until the second week in July, in order to bring the bulk of the yield nearly to maturity late in the fall when local killing frosts can be expected. At that time the vines were still in full vigor and the fruit in such condition that it might be expected to store well. It is at that time that tomatoes are gathered by many growers for storage. Experience has proved that tomatoes from plants that are still in their prime are firmer fleshed and tend to keep longer and in better condition than those from plants that have passed their prime.

On October 15, when a frost seemed imminent, the entire crop of tomatoes of marketable size was picked and separated into the following grades: Green (rather immature and somewhat smaller than

the next grade); mature green (light green to almost white on the blossom ends and usually with yellowish areas over the shoulders); turning (each specimen showing less than one-half pink); and ripe (one-half or more colored but firm). These were stored in half-bushel hampers.

RIPENING IN STORAGE

In one test, hamper lots of each of these grades, with the exception of those that were ripe, were put in storage at 60°, 50°, and 40° F. in order to determine the rate of ripening of the different grades and also to determine at which stage of maturity tomatoes can best be stored for the longest period of time and remain in good salable condition. Inspections were made after 7, 10, 15, 20, 27, 44, and 54 days to ascertain the rate of ripening and breakdown at these temperatures. At each inspection the original lots were separated into color grades corresponding to those used in grading the original lot

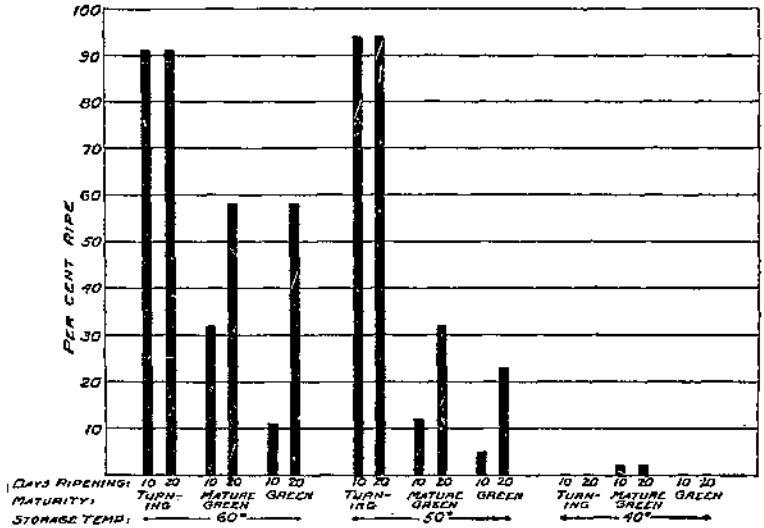


FIGURE 3.—Ripening of Marglobe tomatoes at different temperatures; picked at three stages of maturity

at picking time, and the decayed specimens were discarded in order to prevent additional infection. Decay in those held at 40° and in some cases at 50° was often preceded by a breaking down marked in limited areas on the fruits by a shriveled soft condition. At these temperatures decay seemed to develop at all stages of ripeness, whereas at 60° decay seldom occurred except following full maturity and full color.

After the tomatoes had been seven days in storage an inspection was made. At this time, at 60° most of the tomatoes originally in the turning stage were ripe, many of the mature green ones were turning, and a few of the green ones were beginning to turn. At 50° a few turning tomatoes were becoming ripe, and a very few mature green ones were beginning to turn. At 40° very little change was apparent. After 10 days a change sufficient to record was noted. These results and those noted at the succeeding inspections are given in Table 9 and illustrated in Figure 3. After 10 days considerable

low-temperature injury at 40° was evident, as marked by a certain amount of softening and the development of a creamy white appearance of some of the fruit and much decay. It was difficult at this temperature to make a distinction between the grades of maturity because of the tendency of the fruit to whiten and soften. The results from this first inspection show an almost equal rate of ripening at 60° and 50° and a definite inhibition of ripening at 40°.

TABLE 9.—*Rate of ripening of Marglobe tomatoes picked in the turning, mature green, and green stages and stored at 60°, 50°, and 40° F., as determined by successive inspections*

Ripening period and stage of maturity when inspected	Original condition when picked, storage temperature, and percentage at each stage								
	Turning			Mature green			Green		
	60°	50°	40°	60°	50°	40°	60°	50°	40°
10 days:	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
Ripe	91	94	0	32	12	2	11	5	0
Turning	1	3	6	20	21	15	14	11	3
Mature green				45	64	57	47	77	55
Green							22	7	26
Decayed	8	3	94	3	3	26	6	1	16
15 days:									
Ripe	62			63			32		
Turning	0			19			23		
Mature green	0			8			27		
Green	0						6		
Decayed	38			10			12		
20 days:									
Ripe	14	32	0	58	32	1	58	23	0
Turning	0	0	1	11	31	5	14	26	6
Mature green				2	22	7	6	42	13
Green							0	0	0
Decayed	86	68	99	29	15	87	22	9	81
27 days:									
Ripe	0	0	0	40	24	1	50	18	0
Turning	0	0	0	1	30	5	5	25	6
Mature green				0	11	7	0	37	13
Green							0	0	0
Decayed	100	100	100	59	35	87	45	20	81
44 days:									
Ripe				0	26	0	0	30	0
Turning				0	8	1	0	18	2
Mature green				0	1	0	0	4	2
Green							0	0	0
Decayed				100	65	99	100	48	96
54 days:									
Ripe					13	0		21	0
Turning					5	0	0	10	0
Mature green					0	0		0	0
Green								0	0
Decayed					82	100		69	100

The inspection after 15 days included only those lots stored at 60° F. and showed no increase in the number ripe at this temperature in the lot originally in the turning stage, although the amount of decay had increased. There was an increase in the percentage of ripe fruit in the lots originally classed as mature green and green and also an increase in decay.

When inspected after 20 days, the lots that were in the turning stage when placed in storage at 60° and 50° had all ripened, and decay or breakdown was advanced, as would be expected in fruit so nearly mature which had been held for this period in storage. None of those stored at 40° had ripened. Normal ripening was still progressing in the other two lots stored at 60°; but at 50°, although there was an increase

in those classed as ripe, the color was pale and not normal. After 44 days all those in the original mature green and green lots held at 60° had ripened and subsequently decayed, whereas of those held at 50°, only a few more had ripened, while the number decayed had increased—including some of those fruits that did not reach the ripe stage. After 54 days no further ripening occurred in the lots remaining, and most of the fruit had decayed.

The results of this experiment showed that tomatoes picked in the turning stage of ripening and stored at 60° and 50° F. under the conditions described ripened satisfactorily with good color and quality at either temperature. The rate of ripening at 60° with the corresponding decay following was somewhat more rapid than at 50°. At 40°, even with tomatoes in the turning stage of maturity, no ripening occurred, and rapid decay developed. After 10 days there was 94 per cent decay. With mature green fruit, ripening was much more rapid at 60° than at 50°. A maximum of 63 per cent of those stored at 60° reached full color, while only 32 per cent of those stored at 50° reached the ripe stage.

STORAGE OF RIPE TOMATOES

In an experiment in the storage of ripe tomatoes, half-bushel hampers of firm, field-ripened tomatoes picked at the same time as those in the former experiment were stored at 60°, 50°, and 40° F. and inspected for decay after 10, 15, and 20 days. The object of this test was to determine the best temperature at which to store ripe tomatoes. The results are shown in Table 10 and indicate that 40° is an unsuitable storage temperature for ripe tomatoes.

TABLE 10.—*Condition of firm field-ripe tomatoes after storage for 10, 15, and 20 days at 60°, 50°, and 40° F.*

Storage temperature	After 10 days		After 15 days		After 20 days	
	Sound	Decayed	Sound	Decayed	Sound	Decayed
°F.	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
60	69	31	22	78	16	84
50	73	27			3	97
40	1	99	0	100		

EFFECTS OF STORAGE TEMPERATURES ON SUBSEQUENT RIPENING

In the next set of experiments a rather comprehensive test was made of the ripening at 70° F. of tomatoes in the turning, mature green, and green stages that had been held for 12, 15, 20, 25, and 44 days subsequent to picking, at temperatures of 40°, 50°, and 60°. Since a certain amount of ripening took place at 50° and 60° during the preliminary holding period, only specimens representing the original stages of maturity were selected to put in the 70° ripening room. Periodic inspections to determine the rate of ripening were made. The results of the experiments are shown in Tables 11 and 12. In Table 11 are shown the results of ripening at 70° after 12 days' preliminary storage. Figure 4 illustrates part of these results. The tomatoes of the original turning grade which were stored 12 days at 60° and 50° were all ripe after six days' storage at 70°. Those from 40° storage showed a rapid development of decay in the ripening room, and only 18 per cent actually ripened. Of the mature green

lot, 95 per cent of those stored at 60° subsequently ripened at 70°, and a maximum of 85 per cent of those from 50° storage ripened after 16 days. Of those from 40° storage only 58 per cent ripened, while of the remaining ones 34 per cent decayed. All of those in the green lot from 60° storage were ripe after 16 days, and at the close of the experiment after 24 days in the ripening room only 10 per cent of these had decayed. No record was taken of those from 50° storage. Of those from 40° none ripened, and at the close of the experiment 40 per cent had decayed.

TABLE 11.—*Rate of ripening of tomatoes picked in the turning, mature green, and green stages, at 70° F., after 12 days' previous storage at temperatures of 60°, 50°, and 40° F., as determined by successive inspections*

Ripening period at 70° F. and stage of maturity when inspected	Condition when transferred to ripening room (70° F.) from temperature shown and percentage at each stage								
	Turning			Mature green			Green		
	60°	50°	40°	60°	50°	40°	60°	50°	40°
	Per cent	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
3 days:									
Ripe	70	85	10	10	5	0	20	------	0
Turning	30	15	70	50	20	10	0	------	0
Mature green	------	------	------	40	75	90	10	------	0
Green	------	------	------	------	------	------	70	------	80
Decayed	0	0	20	0	0	0	0	------	20
6 days:									
Ripe	100	100	18	60	25	5	20	------	0
Turning	0	0	9	20	20	20	10	------	0
Mature green	------	------	------	15	55	70	40	------	0
Green	------	------	------	------	------	------	30	------	60
Decayed	0	0	73	5	0	5	0	------	40
10 days:									
Ripe	45	60	19	86	60	17	50	------	0
Turning	0	0	0	9	20	28	20	------	0
Mature green	------	------	------	0	20	38	30	------	60
Green	------	------	------	------	------	------	0	------	0
Decayed	55	40	81	5	0	17	0	------	40
16 days:									
Ripe	------	------	19	95	85	58	100	------	0
Turning	0	------	0	0	10	0	0	------	18
Mature green	------	------	------	0	0	8	0	------	42
Green	------	------	------	------	------	------	0	------	0
Decayed	100	100	81	5	5	34	0	------	40
20 days:									
Ripe	------	------	0	0	76	46	100	------	0
Turning	------	------	0	0	0	0	0	------	60
Mature green	------	------	------	0	0	0	0	------	0
Green	------	------	------	------	------	------	0	------	0
Decayed	------	------	100	100	24	54	0	------	40
24 days:									
Ripe	------	------	------	------	64	30	90	------	0
Turning	------	------	------	------	------	------	------	------	60
Mature green	------	------	------	------	------	------	------	------	0
Green	------	------	------	------	------	------	------	------	0
Decayed	------	------	------	------	36	61	10	------	40

In Table 12 are shown the ripening results of tomatoes previously held at 50° and 40° for 15, 20, 25, and 44 days. Those held at 60° had so far ripened by this time that they were discarded. Of the turning lot, a maximum of 90 per cent of those from 50° had ripened after six days in 70° and the rest decayed, while of those from 40° only 18 per cent had ripened. This percentage was found after six days, and at this time 69 per cent were decayed. From 40°, 78 per cent of the mature green finally ripened in 15 days, but with poor color and quality, while those remaining were decayed. Tomatoes in the green stage stored at 50° and 40° had so deteriorated that they were discarded and not used in this experiment.

TABLE 12.—*Rate of ripening of tomatoes picked in the turning and mature green stages, at 70° F., after previous storage of 15, 20, 25, and 44 days at temperatures of 50° and 40°F., as determined by successive inspections*

Ripening period at 70° F. and stage of maturity when inspected	Condition when transferred to ripening room (70° F.) from temperature shown, period of previous storage, and percentage at each stage															
	Turning								Mature green							
	50° F.				40° F.				50° F.				40° F.			
	15 days	20 days	25 days	44 days	15 days	20 days	25 days	44 days	15 days	20 days	25 days	44 days	15 days	20 days	25 days	44 days
	Per cent	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
3 days:																
Ripe	60	40	40	-----	0	20	10	-----	0	10	0	----	0	0	0	-----
Turning	40	40	40	-----	90	10	10	-----	30	30	60	-----	0	20	10	-----
Green	----	----	----	-----	----	----	----	-----	70	60	40	-----	90	60	20	-----
Decayed	0	20	20	-----	10	70	80	-----	0	10	0	-----	10	20	70	-----
5 days:																
Ripe	----	----	----	80	----	----	----	0	----	----	----	-----	----	----	----	0
Turning	----	----	----	10	----	----	----	0	----	----	----	-----	----	----	----	0
Green	----	----	----	----	----	----	----	-----	----	----	----	-----	----	----	----	20
Decayed	----	----	----	10	----	----	----	100	----	----	----	-----	----	----	----	80
6 days:																
Ripe	90	80	80	-----	18	9	10	-----	50	67	100	-----	0	11	12	-----
Turning	0	0	0	-----	13	0	10	-----	30	23	0	-----	31	11	13	-----
Green	----	----	----	-----	----	----	----	-----	20	0	0	-----	59	48	0	-----
Decayed	10	20	20	-----	69	91	80	-----	0	10	0	-----	10	30	75	-----
9 days:																
Ripe	90	68	72	90	9	0	20	-----	90	90	90	-----	76	49	12	0
Turning	0	0	0	0	0	0	0	-----	10	0	0	-----	14	10	13	20
Green	----	----	----	----	----	----	----	-----	0	0	0	-----	0	0	0	0
Decayed	10	32	28	10	91	100	80	-----	0	10	10	-----	10	41	75	80
15 days:																
Ripe	----	49	----	----	----	0	----	-----	90	77	----	-----	78	59	----	-----
Turning	----	0	----	----	----	0	----	-----	0	0	----	-----	0	0	----	-----
Green	----	----	----	----	----	----	----	-----	0	0	----	-----	0	0	----	-----
Decayed	100	51	----	----	100	0	----	-----	10	23	----	-----	22	41	----	-----

Of the turning group after 20 days' storage, a maximum of 80 per cent of those from 50° storage ripened in six days. Of those from 40° storage, only 20 per cent ripened, whereas 70 per cent had decayed after three days in the ripening room at 70°. Of the mature green lot, 90 per cent of those from 50° storage ripened after 9 days at a temperature of 70°, whereas 59 per cent of those from 40° storage ripened after 15 days but had poor color. The greater number of tomatoes of the mature green stage from 40° preliminary storage that ripened at 70°, as shown in Tables 11, 12, and 13, seems to indicate a less injurious effect from low-temperature exposure on tomatoes at this stage of maturity than on those classed as in the turning stage.

Of the tomatoes in the turning stage after 25 days preliminary storage at 50° F., 80 per cent ripened after six days, while of those from the 40° storage a maximum of 20 per cent ripened in nine days, but with poor color, and 80 per cent were decayed. Of the mature green tomatoes, all those from 50° storage ripened in six days, while of those from 40° storage only 12 per cent ripened. The color of all the tomatoes of this lot from 50° storage that ripened was somewhat pale, whereas the color of those from 40° storage was very pale and unattractive.

The tomatoes that still remained sound after 44 days' storage at the different temperatures were ripened at 70° as in the previous

tests. The results are shown in Table 12. Of those in the turning grade from 50° storage 80 per cent were ripe after five days, though the color was pale, and 90 per cent were ripe after nine days, 10 per cent being decayed. Those from 40° storage when put in the ripening room did not appear to be in first-class condition, being somewhat shriveled and of a pale color, although no evidence of decay was apparent. However, after five days in the ripening room they had all decayed. Only in 40° storage were there any remaining in the mature green stage that were apparently sutiable for a ripening test. None of these ripened, however, and 80 per cent were decayed after five days.

In reviewing this experiment it is apparent that tomatoes in neither the turning, mature green, nor green condition can be held as long as 15 days at 40° and be expected to ripen satisfactorily. Those that did color up—and they were mostly those in the mature green stage—colored unsatisfactorily and were of poor quality, and decay developed before all could ripen. When held at 40° for 20 days and then transferred to 70°, only 59 per cent of the mature green ones eventually could be classed as ripened, and this was after 15 days of ripening. Only 20 per cent of the turning group ripened after 20 days at 40°, and this was after three days at 70°. Following this, decay developed rapidly. When stored at 50° for as long as 44 days, 90 per cent of the tomatoes in the turning stage ripened fully after 9 days at 70°, but the color and quality were not so satisfactory as those obtained with the tomatoes stored at 60°. Of the mature green tomatoes, those held at 50° for 25 days, 90 per cent were ripe and sound after 9 days in the ripening room, but after 44 days at 50° no sound specimens remained to test in the ripening room.

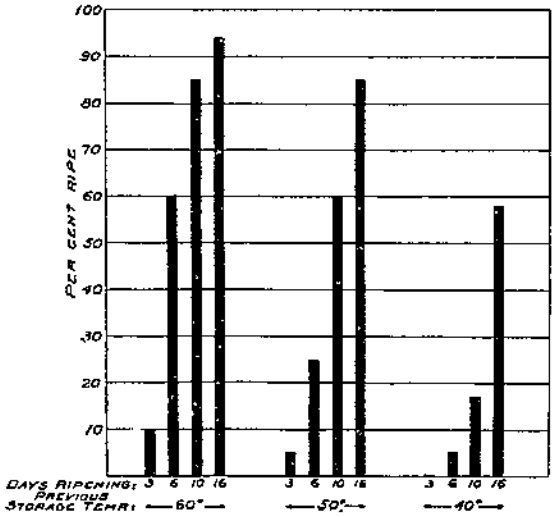


FIGURE 4.—Ripening of Marglobe tomatoes at 70° F., after 12-days' storage at 60°, 50°, and 40°; picked mature green

The tomatoes that were stored at 60° ripened rapidly at 70°, and the color and quality were practically as good in most cases as those of field-ripened tomatoes. After 12 days' storage at 60°, ripening at this temperature had progressed so far that no specimens of the desired unripened stages were available for further study.

RESULTS IN 1927

For the experiments of the season of 1927 the Marglobe variety was again grown. The seed was sown during the first week in June and the plants set in the field on July 8. On October 17, when a killing frost seemed near, the entire planting was gone over, and all

fruits except those too small or immature were picked. The entire picking was then divided into the same four grades as in 1926—firm ripe, turning, mature green, and green. With differences in some details, the tests were carried on much the same as in 1926.

RIPENING IN STORAGE

In the first experiment, half-bushel hampers of approximately 85 fruits each, representing tomatoes of the different stages of maturity when picked, were put in storage. Those in the turning stage were stored at 55°, 50°, 40°, and 36° F. The mature green stage was stored at 60°, 55°, 50°, and 40°, and the green stage at 70°, 60°, 55°, and 40°. Since previous investigations showed evidence of breakdown due to low temperature at 50°, it was decided to add 55° as an intermediate ripening and storage temperature between 50° and 60°; and since some ripening of tomatoes in the turning stage at 40° had been previously noted, it was decided to add 36° as a still lower storage temperature. Since rapid decay developed at the higher temperature, tomatoes in the turning and mature green stages were not stored at 70°. The various lots were held for periodic inspection to determine the progress of ripening and decay. The results of the inspections are given in Tables 13 and 14.

TABLE 13.—*Condition of tomatoes picked in the turning stage after storage for different periods at various temperatures*

Period in storage and holding temperature (° F.)	Percentage in each condition or stage of maturity			Remarks
	Ripe	Turning	Decayed	
After 8 days:				
55°	100	0	34	Color and quality good.
50°	81	19	0	Do.
40°	15	85	2	Color yellowish; flavor not good.
36°	14	86	0	Pale color; soft; flavor not good.
After 17 days:				
55°	100	0	46	Color and flavor good.
50°	100	0	26	Do.
40°	15	85	29	Ripe and pale-pink color; soft; flavor not good.
36°	0	0	100	
After 28 days:				
55°	100	0	95	Color and flavor fair.
50°	100	0	88	Color and flavor not good.
40°	100	0	100	Pale color; flavor not good.
36°				

In Table 13 are given the results of the inspections, while in storage, of tomatoes in the turning stage when picked. After eight days in storage all of those stored at 55° had fully ripened with good color and quality, while 34 per cent showed decay; of those stored at 50°, 81 per cent were ripe with no decay; of those stored at 40° only 15 per cent were ripe; and of those stored at 36°, 14 per cent were ripe. The color and quality of those in 40° and 36° storage were not good. After 17 days all of those in 50° storage had ripened, but 46 per cent were decayed. At 40° and 36° there was no increase in the number of ripened fruits, whereas the decay at 40° had increased to a total of 29 per cent; at 36° all specimens had decayed. After 28 days the decay in 55° storage had increased to a total of 95 per cent. In 50° storage all the tomatoes had developed full color, but 88 per cent of

these showed decay. Of those held at 40° all specimens had fully colored, but the color was pale and unattractive, and all showed some decay. The quality of these was poor.

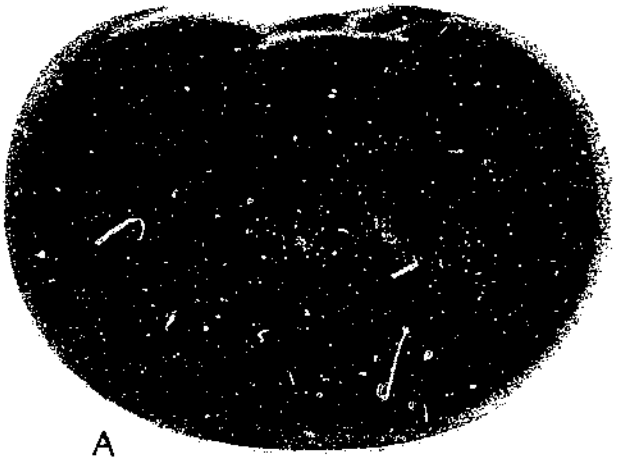
TABLE 14.—*Condition of tomatoes picked in the mature green stage after storage for different periods at various temperatures*

Period in storage and holding temperature (°F.)	Percentage in each condition or stage of maturity				Remarks
	Ripe	Turning	Green	Decayed	
After 8 days:					
60°	52	39	9	0	Color and quality very good.
55°	62	17	20	0	Do.
50°	10	61	29	0	Color not good; yellowish.
40°	0	51	49	0	Color yellowish; flavor not good.
After 17 days:					
60°	92	8	0	4	Color and quality very good.
55°	94	3	3	0	Do.
50°	87	8	5	0	Color not good; flavor fair.
40°	0	78	22	5	Color pale; flavor poor.
After 28 days:					
60°	100	0	0	39	Color good; fruit soft; flavor good.
55°	100	0	0	37	Color good; fruit firm; flavor good.
50°	95	5	0	39	Color pale; flavor fair.
40°	79	0	21	75	Color very pale pink; flavor not good.
After 36 days:					
60°					
55°	100	0	0	66	16 per cent still firm; flavor good.
50°	0	0	0	100	
40°	0	0	0	100	
After 42 days:					
60°					
55°	100	0	0	83	17 per cent still sound, but soft.
50°					
40°					

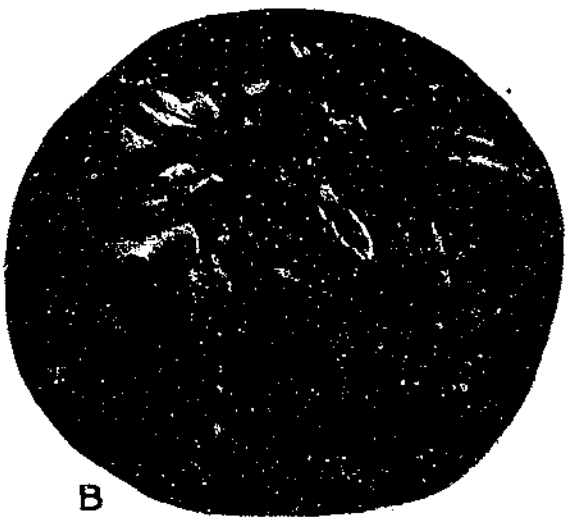
In Table 14 are shown the results from the storage of mature green tomatoes. After eight days at 60°, 52 per cent were fully ripe, and 62 per cent of those held at 55° were ripe, with color and quality practically as good as in field-ripened fruit. Only 10 per cent of those held at 50° were ripe, and they had unsatisfactory color; none of those held at 40° were fully colored. After 28 days all at 60° and 55° were fully ripe, and the sound fruits in 60° storage were becoming soft, while those in 55° storage were still firm. Only 39 and 37 per cent, respectively, of decayed fruits were found in those stored at these temperatures. At 50° coloring progressed, but at this and the lower temperatures the color that developed was not satisfactory.

In Table 15 are shown the results of the ripening of green tomatoes at temperatures of 70°, 60°, 55°, 50°, and 40°. Ripening developed much as with the mature green tomatoes, the rate of ripening decreasing with the temperature. Although those in 70° storage ripened faster, they did not remain in good condition after ripening as long as those stored at 60° or 55°. Those that ripened at temperatures below 55° did not develop good color or quality.

The rate of ripening was almost as rapid at 55° as at 60° or 70°, whereas the rate of decay after ripening was markedly slower. At 50°, although ripening took place, the color did not develop to so dark a shade of red as at the higher temperatures, and the quality of the fruit was only fair, while the fruit usually was very soft by the time it was entirely colored. It was also noted in addition that there was a tendency of the fruit to split between the segments near the



A



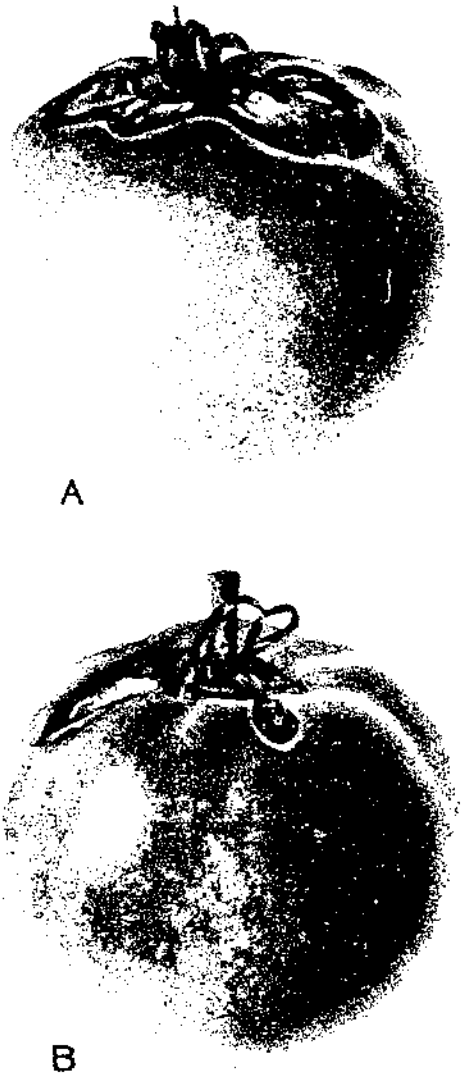
B

A.—Mature green Globe tomato held at 25° F. for 21 hours and subsequently ripened at 70°. Localized freezing injury is apparent but most of the fruit ripened normally

(Color drawing by R. C. Steadman)

B.—Marglobe tomato ripened at 50° in three weeks from original pink or turning stage when picked. This shows typical severe breakdown around the stem as well as lesions on the side

(Color drawing by M. P. Arnold)



A.—Mature green Marglobe tomato after six weeks storage at 40° F.;

B.—Mature green Marglobe tomato after four weeks storage at 40° and then two weeks in the 60° ripening room

Color drawings by R. C. Steadman

stem end, and often soft dark spots from one-sixteenth to one-half inch in diameter appeared scattered over the fruit. (Pl. 1, B.) In these lesions fungous growth, *Macrosporium solani*, was usually found. At temperatures below 50° this fungus was seldom noted, but the fruit softened and decayed because of other organisms. At 40° and 36° little or no ripening took place. The fruit soon became yellowish green to white, and soft. (Pl. 2.)

TABLE 15.—*Condition of tomatoes picked in the green stage after storage for different periods at various temperatures*

Period in storage and holding temperature (° F.)	Percentage in each condition or stage of maturity				Remarks
	Ripe	Turning	Green	Decayed	
After 8 days:					
70°	5	24	22	1	
60°	10	45	45	0	
55°	8	15	77	0	
50°	0	13	87	0	
40°	0	0	100	0	
After 17 days:					
70°	100	0	0	11	Soft.
60°	75	17	8	1	Color and flavor good.
55°	65	10	26	0	Do.
50°	38	31	31	0	Color yellowish; flavor fair.
40°	0	17	83	2	Color yellowish; flavor poor.
After 28 days:					
70°	100	0	0	100	All decayed.
60°	100		0	31	Firm; color good; flavor good.
55°	86	14	0	14	Do.
50°	90	0	10	1	All very soft; color pale; flavor fair.
40°		15	85	35	All very soft; color pale; flavor poor.
After 36 days:					
70°					
60°	100	0	0	100	
55°	100	0	0	20	65 per cent firm; flavor good.
50°	0	0	0	100	Breakdown identified as Macrosporium solani.
40°	0	0	100	12	Pale yellow; no breakdown as at 50°; flavor poor.
After 42 days:					
70°					
60°					
55°	100			78	
50°					
40°	0	0	0	100	All nearly white and breaking down.

STORAGE OF RIPE TOMATOES

In the next experiment, a holding test, half-bushel hamper lots of firm ripe tomatoes were stored at 50°, 40°, and 36° F.; the results are shown in Table 16. After eight days in storage, 95 per cent of those held at 50° had become soft, and 5 per cent were showing decay, whereas all the specimens held at 40° and 36° were still firm and in good condition. After 17 days at 50°, 36 per cent were still classed as sound but soft, while the decay had increased to 64 per cent. At 40°, 50 per cent of the tomatoes were soft and 50 per cent decayed, and at 36° all were classed as sound but soft. After 28 days, tomatoes at all the storage temperatures were found to be decayed.

In a further test of the influence of temperature on the holding of ripe tomatoes, firm ripe fruits that had been held at 55°, 50°, and 36° were transferred in lots of 10 each to 60° after 8 and 18 days in storage. After 8 days in storage and 10 days at 60°, as shown in Table 17, those from 55° storage were still firm and in good condition, while those from 50° storage were somewhat soft. The quality in those from both 55° and 50° was good. Those from 36° storage

were faded in color and their flavor was somewhat impaired. After 18 days in storage the next lot was exposed to a temperature of 60°, and inspections were made after 5, 10, and 15 days. After 15 days at 60° those from 55° storage were still in good condition and firm, while those from 50° storage were soft but of good color. All of those from 36° storage were beginning to decay after five days at 60°. The color of these had changed to a pale yellowish pink.

TABLE 16.—*Condition of tomatoes picked in the firm ripe stage and stored at temperatures and for periods shown*

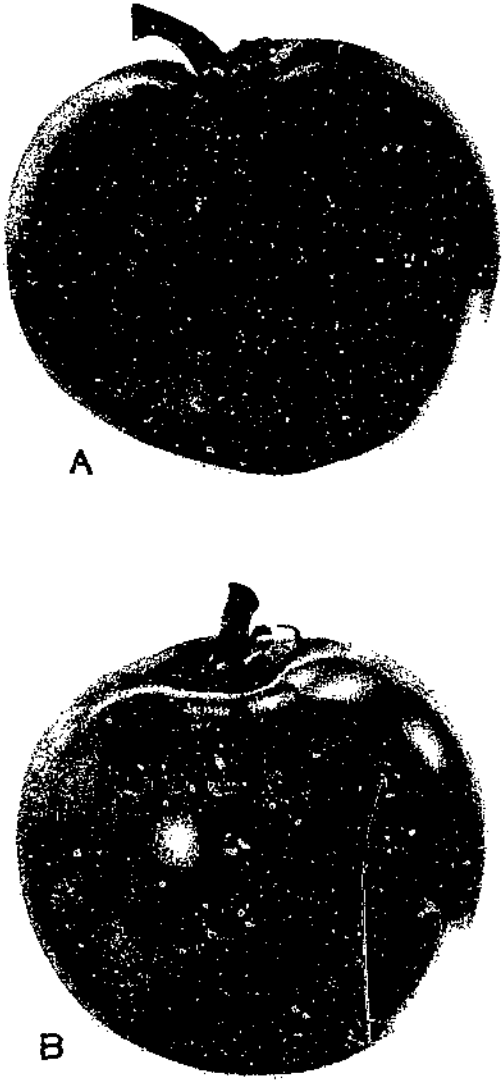
Period in storage and holding temperature (° F.)	Percentage in each condition or stage of maturity			Remarks
	Firm	Soft	Decayed	
After 8 days:				
50°	0	95	5	Soft ones were sound and in good condition, with good flavor.
40°	100	0	0	Flavor good.
36°	100	0	0	Do.
After 17 days:				
50°	0	36	64	Decay consisted of soft, round, brown spots, ¼ to ½ inch, caused by Macrosporium solani.
40°	0	50	50	Flavor of soft ones insipid.
36°	0	100	0	Very soft and ready to break down about the stem ends; flavor insipid.
After 28 days:				
50°	0	0	100	Discarded.
40°	0	0	100	Do.
36°	0	0	100	Do.

TABLE 17.—*Condition of tomatoes picked in the firm ripe stage after 8 and 18 days each in storage at 55°, 50°, and 36° F., as determined by successive inspections in the ripening room at 60°*

Preliminary holding period and storage temperature (° F.)	Development of decay in ripening room—			Remarks
	After 5 days	After 10 days	After 15 days	
Held for 8 days:	*Per cent*	*Per cent*	*Per cent*	
55°	-------	0	-------	Firm; color and quality good.
50°	-------	4	-------	Soft; color and quality good.
36°	-------	8	-------	Soft; color faded; quality poor.
Held for 18 days:				
55°	0	0	0	Firm; color and quality good.
50°	0	0	0	Soft; color and quality good.
36°	10	100	100	Color poor when put in ripening room; soon became soft, and rapid decay developed.

RESULTS IN 1928

During 1928 the work was largely a repetition of that of previous years, and was done with a view to verifying the results previously obtained. For this reason the work was not carried out in such detail as in the previous years. Two plantings of Marglobe tomatoes were made in the field the last of April and the 1st of July.



A.—Normal Marglobe tomato picked mature green and ripened at 60° F.;
B.—Marglobe tomato picked mature green two days after a hard frost and ripened at 60°. Mottled area apparently due to frost injury

(Color drawings by R. C. Steadman)

RIPENING IN STORAGE

For the first experiment a lot of mature green tomatoes from the first planting was picked on August 1, and half-bushel hamper lots were stored at 60°, 50°, and 40° F., so that the rate of ripening and the keeping quality at these temperatures might be studied and compared with the results obtained during the previous seasons. Inspections were made at these temperatures after 7, 14, 21, and 29 days in storage, with the results shown in Table 18. After seven days in storage 12 per cent of those in 60° storage were ripe; 3 per cent of those in 50° storage were ripe; and none of those stored at 40° were ripe. After 14 days 23 per cent of those in 60° storage were ripe, 3 per cent of those in 50° storage, and 1 per cent of those in 40° storage. After 21 days 33 per cent of those in 60° storage were ripe, 18 per cent of those in 50° storage, and 2 per cent of those in 40° storage. After 29 days all of those stored at 60° were ripe and in good sound condition, with color and quality practically equal to that of field-ripe tomatoes. Only 31 per cent of those stored at 50° were ripe and 10 per cent were decayed. The ripe tomatoes stored at this temperature were of a pale color, soft in texture, and not so attractive as those stored at 60°. (Pl. 3, A.) Only 2 per cent of those stored at 40° were ripe, while 25 per cent were decayed.

TABLE 18.—*Rate of ripening and development of decay in tomatoes picked in the mature green stage, after storage at temperatures and for periods shown*

Storage temperature (° F.)	Days in storage	Percentage in each condition or stage of maturity				Storage temperature (° F.)	Days in storage	Percentage in each condition or stage of maturity			
		Ripe	Turning	Green	Decayed			Ripe	Turning	Green	Decayed
60	7	12	9	79	0	60	21	33	17	13	0
50	7	3	7	90	0	50	21	18	12	70	0
40	7	0	1	99	0	40	21	2	0	98	0
60	14	23	6	61	0	60	29	100	0	0	0
50	14	3	9	88	0	50	29	31	19	40	10
40	14	1	0	99	0	40	29	2	0	73	25

In another experiment undertaken to study the rate of ripening in storage, half-bushel lots of mature green tomatoes picked October 11 were stored at 60°, 55°, and 50°. Periodic inspections were made more frequently than in the former experiment and continued until 47 days after picking, as shown in Table 19. After 30 days at 60°, 90 per cent had ripened and 9 per cent were decayed. After 47 days at 55°, 90 per cent were ripe and 10 per cent were decayed. The quality and color of those ripened at 60° and 55° were very good. After 47 days at 50°, however, only 65 per cent had ripened, and these displayed a pale and unattractive color with poor quality, while 19 per cent were decayed.

In this and the preceding experiments the most satisfactory storage temperatures again proved to be 60° and 55°. The rate of ripening at 60° was more rapid, whereas at 55° the tomatoes kept 17 days longer before the same amount of ripening had developed as at 60°. At 50° some ripening took place, but the color was unsatisfactory. At 40° little or no ripening occurred. At 50° and 40° the rate of decay was more rapid than at the higher temperatures.

TABLE 19.—*Rate of ripening and development of decay in tomatoes picked in the mature green stage and stored at ripening temperatures of 60°, 55°, and 50° F.*

Inspection in ripening rooms after—	Percentage in each condition or stage of maturity when stored at the temperature indicated											
	Ripe			Turning			Green			Decayed		
	60°	55°	50°	60°	55°	50°	60°	55°	50°	60°	55°	50°
6 days	0	0	0	2	3	0	98	97	100	0	0	0
8 days	1	0	0	2	6	1	96	94	98	1	0	1
11 days	2	1	0	5	8	1	92	90	98	1	1	1
14 days	6	0	0	12	9	1	78	84	98	4	1	1
18 days	20	9	1	17	16	4	57	73	93	6	2	2
21 days	35	11	1	26	22	6	32	65	90	7	2	3
25 days	64	26	2	24	28	9	4	44	85	8	2	4
30 days	90	37	6	0	31	22	1	27	61	9	5	11
33 days	------	52	10	------	31	27	------	8	48	------	9	15
43 days	------	83	37	------	7	33	------	1	11	------	9	19
47 days	------	90	65	------	0	11	------	0	5	------	10	19

EFFECTS OF STORAGE TEMPERATURE ON SUBSEQUENT RIPENING

In the next experiment half-bushel lots of mature green tomatoes picked August 1 were stored at 50° and 40°. After 7, 14, and 21 days, 20 specimens from each lot were removed to the 60° ripening room, and subsequent inspections were made with the object of determining how long tomatoes can be held at these lower temperatures and still be expected to ripen satisfactorily when put under optimum ripening conditions. The results are shown in Table 20.

TABLE 20.—*Rate of ripening and development of decay in tomatoes picked in the mature green stage, stored for different periods at 50° and 40° F., and transferred to a 60° ripening room*

Duration of previous storage and time in ripening room	Percentage in each condition or stage of maturity when inspected in ripening room after previous storage at temperature shown							
	Ripe		Turning		Green		Decayed	
	50°	40°	50°	40°	50°	40°	50°	40°
Previous storage 7 days:								
7 days	35	5	5	10	50	85	10	0
14 days	60	40	10	15	20	45	10	0
22 days	85	100	0	0	5	0	10	0
Previous storage 14 days:								
7 days	15	5	15	0	70	90	0	5
14 days	100	55	0	25	0	15	0	5
Previous storage 21 days:								
7 days	50	0	30	0	20	35	0	65
14 days	100	0	0	0	0	0	0	100

After seven days' storage at 50° and 40° and seven days in the ripening room, 35 per cent of the tomatoes from 50° storage were ripe and 10 per cent were decayed, while 5 per cent of those from 40° storage were ripe. After 22 days of ripening, 85 per cent of those from 50° and 100 per cent of those from 40° storage were ripe. The ripened tomatoes from both 50° and 40° storage were of good color and quality. After 14 days of storage at the lower temperatures and 7 days at 60°, 15 per cent of those from 50° and 5 per cent from 40° storage were ripe, with 5 per cent decay in the latter. After 14 days of ripening at 60°, all of those from 50° storage were ripe and 55 per cent of those from 40° storage, with no further development of decay.

After 21 days' storage at 50° and 40° and 7 days of ripening at 60°, 50 per cent of those from 50° storage were ripe, whereas none from 40° storage were ripe, and 65 per cent were decayed. After 14 days of ripening, all the tomatoes from 50° storage were colored but were somewhat pale and of fair quality, while all of those from 40° storage had decayed. In this experiment tomatoes stored 14 days at 50° subsequently ripened at 60°, although their color was pale and unattractive. Tomatoes stored at 40° for 14 days colored very slowly and unsatisfactorily at 60°, but when stored for 21 days at this temperature they failed to ripen at all and quickly decayed when transferred to a suitable ripening temperature.

In another lot of tomatoes picked on August 22 and stored under the same conditions as in the former experiment, seven days' exposure to 40° F. apparently had a deleterious effect on the subsequent ripening at 60°, as shown in Table 21. After seven days' storage and seven days in the ripening room at 60°, 5 per cent of those from 50° storage were ripe, while none of those from 40° storage were ripe. After 14 days at 60°, 40 per cent of those from 50° storage were ripe, while only 10 per cent of those from 40° storage were ripe and 15 per cent had decayed. When stored for 14 days and ripened for 7 days at 60°, 5 per cent of those from 50° storage were ripe and 50 per cent turning, while none of those from 40° storage were ripe or turning and 35 per cent were decayed. After 14 days all those from 50° storage were ripe and sound, while all of those from 40° storage were decayed. Perhaps one reason that the tomatoes in the latter experiment did not hold so well as before is that this lot was not in such good condition when picked, being more tender and watery because of excessive rainfall.

TABLE 21.—*Rate of ripening and development of decay in tomatoes picked in the mature green stage, stored for 7 and 14 days at 50° and 40° F., and transferred to a 60° ripening room*

Duration of previous storage and time in ripening room	Percentage in each condition or stage of maturity when inspected in ripening room after previous storage at temperature shown							
	Ripe		Turning		Green		Decayed	
	50°	40°	50°	40°	50°	40°	50°	40°
Previous storage 7 days:								
7 days	5	0	5	5	90	95	0	0
14 days	40	10	0	15	60	60	0	15
Previous storage 14 days:								
7 days	5	0	50	0	45	65	0	35
14 days	100	0	0	0	0	0	0	100

A series of tests with varying exposures of 3, 4, 8, 11, 14, and 21 days to unfavorable storage temperatures was made with tomatoes picked October 11. Inspections of all lots usually terminated when the accumulated decay became too large for commercial-storage practice. In the first experiment, half-bushel lots of mature green tomatoes were stored at 50°, 40°, and 32° F. for three days, after which they were all transferred to the 60° ripening room and inspected periodically, as shown in Table 22.

TABLE 22.—*Rate of ripening and development of decay in tomatoes picked in the mature green stage, stored three days at 50°, 40°, and 32° F., and transferred to a 60° ripening room*

Inspection in ripening room after—	Percentage in each condition or stage of maturity after storage at temperature indicated											
	Ripe			Turning			Green			Decayed		
	50°	40°	32°	50°	40°	32°	50°	40°	32°	50°	40°	32°
3 days	0	0	0	0	5	0	100	95	100	0	0	0
5 days	0	0	0	10	10	0	90	90	100	0	0	0
7 days	0	0	0	10	5	0	90	90	100	0	5	0
10 days	10	5	0	50	15	20	40	80	80	0	5	0
12 days	30	10	0	50	20	40	20	65	60	0	5	0
14 days	60	25	20	30	15	40	10	60	40	0	10	0

TABLE 23.—*Rate of ripening and development of decay in tomatoes picked in the mature green stage stored 4, 8, 11, 14, and 21 days at 40°, 36°, and 32° F., and transferred to the 60° ripening room*

Previous storage and inspection in ripening room after—	Percentage in each condition or stage of maturity after storage at temperature indicated											
	Ripe			Turning			Green			Decayed		
	40°	36°	32°	40°	36°	32°	40°	36°	32°	40°	36°	32°
	Per cent	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
4 days' previous storage:												
2 days	0	0	0	0	3	0	100	97	100	0	0	0
4 days	0	0	0	0	3	0	100	97	100	0	0	0
7 days	0	0	0	0	3	2	95	97	95	5	0	3
10 days	0	0	0	5	3	2	90	97	90	5	0	8
14 days	3	3	0	5	5	8	85	90	80	7	2	12
17 days	8	5	12	10	15	15	75	78	58	7	2	15
21 days	15	20	12	33	27	42	35	43	23	17	10	23
26 days	58	60	60	2	22	5	8	8	8	32	10	27
8 days' previous storage:												
2 days	0	0	0	0	0	0	100	100	98	0	0	2
4 days	0	0	0	10	0	5	88	100	93	2	0	2
7 days	3	0	0	5	5	5	85	90	90	7	5	5
10 days	7	2	5	20	5	0	63	88	90	10	5	5
14 days	32	5	5	28	22	10	25	63	63	15	10	17
11 days' previous storage:												
3 days	0	0	0	0	0	0	100	100	100	0	0	0
7 days	0	0	0	2	2	2	98	98	98	0	0	0
10 days	0	13	0	2	2	0	95	85	90	3	0	10
14 days	2	15	0	10	5	7	80	75	65	8	5	28
19 days	15	15	0	37	0	0	28	0	0	10	85	100
22 days	55			25			5			15		
26 days	80			5			0			15		
14 days' previous storage:												
4 days	0	0	0	0	0	0	100	100	100	0	0	0
7 days	0	0	0	2	0	0	98	98	98	0	0	2
11 days	0	0	0	5	8	0	88	75	55	7	17	45
16 days	2	0	0	22	27	10	58	28	13	18	45	77
19 days	13	7		47	25		15	10		25	58	
23 days	50	25		17	10		0	0		33	65	
26 days	67	35		0	0		0	0		33	65	
21 days' previous storage:												
4 days	0	0	0	0	0	0	80	100	100	20	0	0
9 days	0	0	0	0	0	0	30	0	0	70	100	100
12 days	0			0			30			70		
16 days	0			0			25			75		
19 days	0			20			5			75		
22 days	10			13			0			77		
26 days	23			0			0			77		

In the next and succeeding experiments of this series the tomatoes were stored before ripening at 40°, 36°, and 32°, 36° being substituted for the 50° used in the preceding test. The tomatoes were exposed to these temperatures for increasing periods of time before being put in the 60° ripening room. Inspections in the ripening room were made at frequent intervals. The results as shown in Table 23 are practically in accord with results of experiments already discussed and need not be again considered in detail.

Summing up the results of this group of experiments, it may be stated that mature green tomatoes stored at 50° for periods up to 14 days subsequently ripened normally at 60°, but if they were stored longer at 50° the color developed on ripening at 60° was somewhat pale and not attractive. When tomatoes were stored at 40° for 11 days or less and later transferred to 60°, most of the fruits ripened, but the color was poor. If the tomatoes were left for a longer time at 40°, few of the fruits subsequently ripened. If tomatoes were left at 32° and 36° for from 8 to 11 days, the color of the ripened fruit was pale and unattractive and the quality poor. If the period of preliminary storage was longer than this, most of the fruits failed to ripen.

One holding test was made with both firm ripe tomatoes and tomatoes in the turning stage. Half-bushel lots of those at each stage were stored at 50°, 40°, and 36° for 14 days and then held in the laboratory at about 75°, and inspected after 2 and 5 days. The high temperature of the laboratory made this a rather severe test, and 5 days proved to be about the limit of time any of the lots could be held. As shown in Table 24, after 2 days in the laboratory the originally firm ripe tomatoes from preliminary storage of 14 days at 50° were all somewhat soft but in good sound condition. Those from 40° storage were soft and had small dark soft spots indicative of low-temperature breakdown. Fruits from 36° storage were quite soft and of a yellowish cast, but without spots such as those from 40° storage showed. Of the lots in the original turning stage, those from 50° and 40° storage were well colored, firm, and in good condition. Tomatoes from 36° storage were pale yellowish pink and somewhat soft. After five days in the laboratory all of the originally firm ripe lots were decaying, while of the turning lots 83 per cent of those from 50° storage were sound, of those from 40° storage 65 per cent were sound, and of those from 36° storage all were decaying.

TABLE 24.—*Condition of tomatoes picked in the firm ripe and turning stages, stored 14 days at 50°, 40°, and 36° F., and transferred to ordinary room temperature (about 70°)*

Holding period and preliminary storage temperature (°F.)	Condition at room temperature	
	Picked in firm ripe stage	Picked in turning stage
2 days:		
50°	All soft, ripe; condition good	All fully colored and firm.
40°	All showing small, dark, soft spots	Do.
36°	All soft; yellowish color	All soft; pale yellowish color.
5 days:		
50°	All showing decay	83 per cent still sound.
40°	do	65 per cent still sound.
36°	do	All decaying.

EFFECT OF FIELD FROST ON RIPENING OF MATURE GREEN TOMATOES

Late in October, 1928, an attempt was made to determine the effect of field frost on the subsequent ripening of mature green tomatoes. On the evening of October 26, when a heavy frost seemed imminent, a half-bushel lot of mature green tomatoes from the late planting was picked and placed in an unheated room. Previous to this time no frost had occurred. The tomatoes in the field were still in excellent condition and the vines in their prime. The frost occurred during the night as expected and proved to be a heavy one that killed all the vines. The following morning an equivalent lot was picked, each tomato of this lot still showing hoarfrost when picked. The two lots were then put into the 60° ripening room, and periodic inspections were made to record the progress of ripening. The results are shown in Table 25. The rate of ripening was more rapid in the tomatoes picked before the frost, and in addition the progress of decay was less rapid. At the termination of the experiment after 38 days in the ripening room, 91 per cent of those picked before the frost were ripe and in good condition, whereas the remainder, 9 per cent, were decayed. Of those picked after the frost, 79 per cent were ripe and 21 per cent were decayed. The appearance and quality of the ripe tomatoes of both lots were apparently equal.

TABLE 25.—*Comparative rate of ripening of unfrosted and frosted mature green tomatoes picked the evening before and the morning following a heavy field frost, October 26–27, 1928, as determined by successive inspections in a 60° F., ripening room*

Time of picking and period in ripening room	Percentage at each stage of maturity when inspected				Time of picking and period in ripening room	Percentage at each stage of maturity when inspected			
	Ripe	Turning	Green	Decayed		Ripe	Turning	Green	Decayed
Evening before frost:	*Per cent*	*Per cent*	*Per cent*	*Per cent*	Morning after frost:	*Per cent*	*Per cent*	*Per cent*	*Per cent*
15 days	2	24	68	6	15 days	3	14	73	10
18 days	24	18	51	7	18 days	9	20	55	16
22 days	39	23	31	7	22 days	29	19	33	19
25 days	58	12	23	9	25 days	43	15	21	21
32 days	75	6	10	9	32 days	67	9	3	21
38 days	91	0	0	9	38 days	79	0	0	21

Two days following the frost just described, another experiment on the effect of frost or frost injury in the field on the ripening of tomatoes was started. At this time the effect of frost on the tomatoes could be seen as marked by a previously unnoted mottled appearance in certain areas on the exposed sides of the fruits as they remained in the field. Transparent watery tissue was noted within the affected areas of the outer tissue, as shown in Plate 3, B.[6] Two lots of a half bushel each of mature green tomatoes were picked. One lot consisted of specimens all of which showed the mottling described, whereas the other showed no apparent injury. Those that did not show injury were usually found nearest the ground or in more or less sheltered positions on the plant that the frost had not reached.

[6] The mottled and netted condition described, has apparently been previously noted in other tomatoes grown under different conditions, including greenhouse-grown tomatoes. This may possibly be a condition brought about by an unbalanced physiological environment and not necessarily connected alone with frost injury.

Since the tomato plants were not staked or supported but were allowed to lie on the ground, which was mulched with straw, there should have been no difference between the frosted and the unfrosted tomatoes with reference to their relative locations on the vines. The two lots were ripened at 60° F., as in the foregoing experiment. The results are shown in Table 26. On the last inspection, after 43 days in the ripening room, 92 per cent of the fruits showing no frost injury ripened, while 73 per cent of those actually showing frost injury ripened and were of good color and quality, with, however, a trace of the netting still apparent after ripening.

TABLE 26.—*Comparative rate of ripening of lots of mature green tomatoes showing frost injury and those showing no apparent injury, both picked two days after a heavy field frost occurring October 26–27, 1928, as determined by successive inspections in a 60° F. ripening room*

Condition and period in ripening room	Percentage in each stage of maturity when inspected				Condition and period in ripening room	Percentage in each stage of maturity when inspected			
	Ripe	Turning	Green	Decayed		Ripe	Turning	Green	Decayed
Lot not showing frost injury:	*Per cent*	*Per cent*	*Per cent*	*Per cent*	Lot showing frost injury:	*Per cent*	*Per cent*	*Per cent*	*Per cent*
19 days	0	15	83	2	19 days	0	7	78	15
25 days	20	15	60	5	25 days	5	10	60	25
29 days	37	18	40	5	29 days	17	10	48	25
32 days	55	8	30	7	32 days	22	25	28	25
38 days	80	0	12	8	38 days	60	10	5	25
43 days	92	0	0	8	43 days	73	2	0	25

RIPENING OF SHIPPED TOMATOES

After the preparation of the results already given, it was decided to carry on ripening tests following low-temperature exposure with tomatoes shipped from the South, in order to compare the results with those already obtained. Therefore, on April 17, 1930, a lot of newly arrived tomatoes of the Marglobe variety from near Miami, Fla., was purchased on the market in Washington, D. C. These were packed in the ordinary 6-basket carriers and arrived mostly in the mature green stage, only a few having ripened or nearly ripened. They were unwrapped and sorted into unit 4-quart basket lots of mature green and turning specimens, the latter including those that had from a trace of pink to less than one-half of their areas colored. Duplicate basket lots of mature green tomatoes were put in storage at 32°, 36°, 40°, 50°, 60°, and 70° F., to determine the rate of ripening at these temperatures; additional lots were put at 32°, 36°, 40°, and 50°, and basket lots were periodically transferred to 60° to ripen. Practically the same procedure was followed with turning tomatoes, except that since the supply of these was limited they were left to ripen only at 40°, 50°, and 60° and other lots were periodically transferred from 32°, 36°, and 40° to the 60° ripening room.

The results from this test in general were much the same as those obtained with tomatoes grown at the Arlington Experiment Farm. These tomatoes ripened much more rapidly, since they had been picked six to eight days before arriving at the laboratory. The mature green tomatoes, as shown in Table 27, did not ripen during the test at either 32°, 36°, or 40°. Although no decay developed at these

temperatures, the fruits became soft and pale yellow-green in color and somewhat shriveled. At 50°, although most of the fruits ripened, the color that developed was somewhat pale and blotched. At 60° and 70° the color development and quality were very satisfactory. Of the tomatoes in the turning stage left to ripen at 40°, nearly all were classed as ripe, but they were soft and their color pale and quality poor. At 50° all ripened (Table 27), but the color was slightly pale. At 60° ripening was, as usual, normal, and the quality good; at 40° and 50° the color was pale and the quality fair to good.

The turning tomatoes, exposed to temperatures of 32°, 36°, and 40° for increasing periods of time, as shown in Table 28, all eventually ripened after exposures of up to 11 days. After 8 days' exposure those from 32° and 36° storage developed a color that could not be classed as normal, since it was somewhat pale and yellowish, and the flavor was poor, being rather acid and lacking sweetness. In those from 40° storage, after exposure of 11 days, the color that developed was pale and yellowish, and the quality was considered as only fair.

TABLE 27.—*Progressive ripening and decay of mature green and turning Florida Marglobe tomatoes stored at Washington, D. C., at various temperatures, as determined by successive inspections*

[The general quality of the tomatoes ripened at 60° and 70° F. was good; the quality of those ripened at lower temperatures was fair to poor]

Condition when stored and period of storage	Condition when inspected	Percentage ripe or decayed at each storage temperature (°F.)					
		32° [1]	36° [1]	40° [2]	50° [2]	60° [3]	70° [3]
Mature green:							
4 days	Ripe	0	0	0	2	30	77
	Decayed	0	0	0	0	0	5
6 days	Ripe	0	0	0	8	75	80
	Decayed	0	0	0	2	0	7
8 days	Ripe	0	0	0	12	85	87
	Decayed	0	0	0	2	0	7
11 days	Ripe	0	0	0	22	93	93
	Decayed	0	0	0	2	0	7
13 days	Ripe	0	0	0	48	93	-------
	Decayed	0	0	0	2	0	-------
15 days	Ripe	-------	0	0	68	95	-------
	Decayed	-------	0	0	2	0	-------
18 days	Ripe	-------	-------	0	80	97	-------
	Decayed	-------	-------	0	3	0	-------
Turning:							
4 days	Ripe	-------	-------	50	70	100	-------
	Decayed	-------	-------	70	0	0	-------
6 days	Ripe	-------	-------	-------	90	-------	-------
	Decayed	-------	-------	-------	0	-------	-------
8 days	Ripe	-------	-------	-------	100	-------	-------
	Decayed	-------	-------	-------	0	-------	-------

[1] Fruits became soft and pale yellow; quality fair to poor.

[2] In the mature green group those that ripened were somewhat pale and mottled in color, with rather poor quality; in the turning group those that ripened were also somewhat pale in color, but with fair to good quality.

[3] Color and quality of ripe tomatoes good.

TABLE 28.—*Progressive ripening and decay of turning Florida Marglobe tomatoes after varying preliminary periods of storage at Washington, D. C., at various temperatures, as determined by successive inspections in a 60° F. ripening room*

Period in ripening room at 60° F. after preliminary storage	Condition when inspected	Percentage ripe or decayed after period in ripening room following preliminary storage for periods and at temperatures shown																	
		4 days [1]			6 days [1]			8 days [3]			11 days [4]			13 days [5]			15 days [6]		
		32°	36°	40°	32°	36°	40°	32°	36°	40°	32°	36°	40°	32°	36°	40°	32°	36°	40°
0 day	Ripe	0	0	20	20	10	20	20	10	50	30	20	50	....	60	70	....	....	60
	Decayed	0	0	0	0	10	0	20	10	0	0	0	20	....	0	0	....	....	0
2 days	Ripe	70	50	50	70	50	80	50	80	90	60	100	80	....	100	90	....	....	60
	Decayed	10	10	10	0	10	20	20	10	10	0	0	20	....	0	0	....	....	40
4 days	Ripe	90	90	70	100	80	....	70	90	....	90	....	....	....	....	100	....	....	....
	Decayed	10	10	10	0	20	....	30	10	....	0	....	....	....	....	0	....	....	....
7 days	Ripe	....	....	90	....	....	....	....	....	....	100	....	....	....	....	....	....	....	....
	Decayed	....	....	10	....	....	....	....	....	....	0	....	....	....	....	....	....	....	....

[1] Color and quality good.
[2] Color good.
[3] Color fair to good, quality poor.
[4] Color pale, quality poor.
[5] Color fair.
[6] Color fair, quality poor.
[7] Color good, quality fair.

Mature green tomatoes that were held for increasing lengths of time at 32° to 50° and then ripened at 60°, as shown in Table 29, ripened satisfactorily after exposures up to and including six days. When held for eight days, most of those from 32° and 36° storage ripened, but the color was only fair and not altogether satisfactory, while the quality was poor. Exposure to 32°, 36°, and 40° for 11 days prevented most of the fruits from ripening, and considerable decay developed in the ripening room. After longer exposures little or no ripening occurred. In 50° storage some ripening began to develop in the basket units before they were transferred to the 60° ripening room.

Most of the decay that developed in these storage experiments originated around the stem end in areas of mechanical injury, apparently caused by too tight packing in the crate. This condition was noted on many of the tomatoes when removed from the crates. They were marked by rough, shriveled areas where they had chafed together during transit. Figure 5 shows two ripened tomatoes with the injury and resultant decay described.

TABLE 29.—*Progressive ripening and decay of mature green Florida Marglobe tomatoes after varying preliminary periods of storage at Washington, D. C., at various temperatures, as determined by successive inspections in the ripening room at 60° F.*

Period in ripening room at 60° F. after preliminary storage	Condition when inspected	Percentage ripe or decayed after period in ripening room following preliminary storage for periods and at temperatures shown																							
		4 days [1]				6 days [1]				8 days [2]				11 days [3]				13 days [4]				15 days [5]			
		32°	36°	40°	50°	32°	36°	40°	50°	32°	36°	40°	50°	32°	36°	40°	50°	32°	36°	40°	50°	32°	36°	40°	50°
0 day	Ripe	0	0	0	0	0	0	0	25	0	0	0	30	0	0	0	40	0	0	0	70	----	0	5	70
	Decayed	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0	0	0	0	----	0	0	0
2 days	Ripe	0	0	0	25	5	0	10	65	0	0	10	45	0	5	0	65	0	0	0	90	----	0	15	85
	Decayed	0	0	0	0	0	0	0	0	0	0	5	0	15	5	15	5	10	25	15	0	----	45	30	0
4 days	Ripe	0	15	15	40	15	25	40	75	10	15	30	65	0	5	10	80	0	5	10	90	----	----	----	----
	Decayed	0	0	0	0	5	0	0	0	0	15	20	0	15	5	15	5	40	55	35	0	----	----	----	----
7 days	Ripe	30	45	50	80	35	50	70	80	40	60	50	65	10	20	25	85	----	----	----	----	----	----	----	----
	Decayed	0	0	0	0	10	0	0	0	0	15	25	0	50	30	40	5	----	----	----	----	----	----	----	----
9 days	Ripe	55	65	85	100	45	85	85	90	65	70	60	80	----	----	----	----	----	----	----	----	----	----	----	----
	Decayed	0	0	0	0	10	0	0	0	10	15	25	0	----	----	----	----	----	----	----	----	----	----	----	----
11 days	Ripe	75	90	85	----	65	100	100	90	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----
	Decayed	0	0	0	----	10	0	0	0	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----
14 days	Ripe	80	90	100	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----
	Decayed	0	0	0	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----

[1] Color of ripened tomatoes good; quality fair to good.
[2] Color of ripened tomatoes from 32° and 36° fair, from 40° and 50° good. Quality in 50° lot was fair; at lower temperatures, poor.
[3] From 32° and 36°, color pale and blotched; from 40°, fair; from 50°, good.
[4] From 32°, 36°, and 40°, fruits mostly yellowish and soft with poor quality. Color from 50° good, quality fair.
[5] Color good from 50°, poor at lower temperatures; color yellowish, fruit soft.

SUMMARY AND CONCLUSIONS

Exposure of mature green tomatoes at temperatures of 40° F. or below did not necessarily prevent subsequent ripening. Tomatoes ripened normally when exposed for 18 to 21 hours to temperatures as

FIGURE 5.—Florida tomatoes ripened after receipt at Washington, D. C., showing injury caused by tight packing

low as 25°, which is almost 5.5 below their average freezing point, if subsequently stored at a favorable temperature. When stored at 32° and 36° for periods up to five to eight days, tomatoes later ripened to practically normal color and flavor, but the rate of ripening was slower than in fruits not so exposed. The ripening of tomatoes stored at 40° for 11 to 15 days was delayed but took place normally.

If stored at 50° for less than 14 to 18 days, the tomatoes ripened normally when placed in a favorable temperature.

Chilling storage did not slow up or prevent ripening in fully mature green tomatoes so noticeably as in less mature ones.

When stored at 50° F., tomatoes in the turning stage or beginning to show color when picked usually ripened almost normally. At 40° storage usually no ripening developed in tomatoes of any stage of immaturity.

The lowest temperature at which full ripening with good color and flavor developed was 55°. At this temperature the rate of ripening was comparatively slow, but the development of normal decay was also slow. No indications of abnormal decay or breakdown were apparent. This temperature is recommended for either storage or delayed-ripening purposes.

At 60° to 70° the rate of ripening was considerably increased. These temperatures are recommended for ripening but not for storage. For rapid ripening a temperature much higher than 70° is not desirable because of the rapid rate of decay.

Firm, fully ripe tomatoes held up most satisfactorily at 55° storage. Ripe tomatoes may be expected to keep in good condition at temperatures as low as 32° for from 8 to 10 days, but when removed to a higher temperature, as would be necessary in getting commercial lots to the consumer, they soon break down.

Tests on a commercial lot of mature green tomatoes shipped from Florida and stored and ripened under conditions similar to those for the tomatoes grown at the Arlington Experiment Farm showed similar results.

Mature green tomatoes picked the evening before the first field frost ripened in storage more rapidly and developed less decay than those picked the morning following the frost.

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