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- *Methods of Determining the Optimum*
- *Stage of Maturity for Picking*
- *Green-wrap Tomatoes*

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SUMMARY

An objective method of determining the mature green stage of a tomato would be useful to the tomato industry. Such a method should be based on external physical or visual factors that can be judged rapidly without injury to the fruit.

Three approaches to finding a suitable method were considered in this experiment.

SPECIFIC GRAVITY. As the tomato matures, the seed cavities develop a jelly-like substance and the weight increases. With increase in weight the specific gravity increases. The increase in specific gravity may be used to indicate a point or rather a range at which the tomatoes could be separated into groups which would ripen within a given time.

COLOR. A second method concerned a change in skin color and flesh from green to red as the tomato matures. The fruit ripens from the center outward with the blossom end ripening first. Color was measured on the tomato at picking time at the blossom end, the middle section and the stem end.

MATURITY CLASSES. The variability of maturity of the green-wrap tomatoes at harvest accounts largely for the great difference in the time required to ripen a given lot. Variability in maturity necessitates handling many tomatoes several times. Each time the ripe and green tomatoes are separated, the green ones are returned to the ripening rooms. This operation is repeated until all the tomatoes are ripened or spoiled.

Analysis of the data indicates a high correlation between specific gravity and the width of the tomatoes. Specific gravity was related to relative humidity in which the fruit was grown, except for the earliest of the four tagging dates. The length and width of the tomato were related. There was a multiple correlation of $r = 0.95$ among specific gravity, width, length and weight of the tomatoes tested.

The average specific gravity of tomatoes increased as the days from tagging increased and the specific gravity decreased as the days of storage increased. Tomatoes with a specific gravity above 0.949 were 33 days or more from tagging and could be expected to ripen within 15 days. This indicates that there may be a physiological state of maturity at about 33 days from tagging which the tomato should reach to reduce the time required for ripening under the conditions of this experiment. This idea seemed to be substantiated throughout the work by specific gravity, length, width and weight—all indicating that the average tomato should be approximately 33 days from fruit set to be expected to ripen within 15 days.

The average width data indicate the greater the diameter the better the maturity of the fruit. A tomato with an average diameter of $2\frac{1}{8}$ inches or more should ripen in 15 to 18 days. This conclusion was substantiated by data compiled from actual operation of a ripening room of a tomato repack plant. The repack plant data consisted of 19 lots of tomatoes totaling 331,922 pounds which could be identified by sizes. Eleven of these 19 lots, or 264,187 pounds of fruit, were in the grade size grouping of 6×6 or larger with a minimum fruit diameter of $2\frac{1}{8}$ inches. The remaining 8 lots of 67,735 pounds were in the grade size grouping of 6×7 or smaller with maximum fruit diameter of $2\frac{1}{8}$ inches.

Ninety percent of the larger tomatoes ripened in less than 12 days, while 70 percent of the smaller tomatoes required 16 days to ripen. The difference between the time of ripening for the experimental tomatoes and those from the ripening room of the tomato repack plant was due to the difference in the method used to assess the degree of ripeness.

The industry by refusing to buy the small tomatoes, sometimes referred to as tube size tomatoes, would benefit through handling only the larger size tomatoes which are more mature, and needing 25 percent less time to ripen 20 percent more of the larger tomatoes.

The data on 655,480 pounds of tomatoes passed through the ripening room of a tomato repack plant showed that 50 percent were removed the first time over the grading belt. The second and third times over the grading belt, 23 and 7 percent were removed. The remaining 20 percent required four or more times over the grading belt.

Methods of Determining the Optimum Stage of Maturity for Picking Green-wrap Tomatoes

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THE FRESH TOMATO CROP IN TEXAS IS VALUED AT over 12 million dollars annually. The industry started about 1890 near Jacksonville in East Texas and has expanded to almost all sections of the State. Until about 1915, tomatoes were shipped in a "pink" or "turning" stage. With high prices early in the season and a good demand for tomatoes, farmers started picking their tomatoes a little greener each year. Most tomatoes in Texas are now marketed in the "green-wrap" stage.

The tomato fruit is considered mature while still in a green stage; it will ripen to a red color after removal from the plant. The maturity of a green-wrap tomato cannot always be determined accurately through observation of external characteristics, but an experienced person usually can determine "green mature" fruits. The maturity of a lot is determined by cutting a representative sample. By U. S. Standards for fresh tomatoes, "Mature means that the contents of the seed cavity have begun to develop a jelly or glue-like consistency and the seeds are well developed." Cutting and checking the contents of the seed cavity of a few fruits results in spoilage because of the cut tomatoes, and leaves doubtful the maturity status of the entire lot.

An objective method of determining the mature green stage would help in clearing the market of immature green-wrap tomatoes. Such a method should be based on external physical or visual factors that can be judged rapidly without injury to the fruit. An experiment was conducted to develop a method for determining stages of maturity of tomatoes by objective methods and to find a relationship of repacking time to maturity at harvest.

Three approaches were considered:

As the tomato matures the seed cavities develop a jelly-like substance and the weight increases. With increase in weight the specific gravity increases. The increase in specific gravity may be used to indicate a point or range at which the tomatoes can be separated into groups which will ripen within a given time.

The second approach deals with change in skin color and flesh from green to red as the tomato matures. The tomato ripens from the center outward with the blossom end ripening first. Color was measured on the tomato at picking time

at three points: the blossom end, the middle section and the stem end.

The variability of maturity of the green-wrap tomato at harvest accounts in large measure for the great difference in the time required to ripen a given lot. Variability in maturity necessitates handling many tomatoes several times. Each time the ripe and green tomatoes are separated, the green ones are returned to the ripening rooms. This operation is repeated until all the tomatoes are ripened or spoiled.

REVIEW OF LITERATURE

Development of a Tomato

The tomato, *Lycopersicon esculentum*, is native to the tropical regions of the Americas. Early explorers carried the seed to Europe about 1500, where the tomato was used first as a novelty, later for medicinal purposes, and in about 1800, for culinary purposes. By 1840, it was accepted for fresh-eating purposes in America (11).

Experiments with the Gulf State Market variety showed that the fruits reach the mature green

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stage about 27 days after fertilization. As a tomato matures it increases in almost all quantitative and qualitative measurements, including size, weight and specific gravity. Lutz (6) reported that specific gravity, total acidity and hydrogen-ion concentration increase and resistance to puncture decreases with stage of maturity, with variations in each item. He also reported that a picked immature tomato ripens only 1 day earlier than a vine-ripened tomato.

Use of Specific Gravity

Specific gravity is an indirect means of determining the dry-matter content of a substance. One method of determining specific gravity is the ratio of the weight in air of a substance times the known specific gravity of the liquid used to the weight in air of the substance minus the weight of the substance when submerged in the liquid.

Lutz (6) and Nettles (7) determined the specific gravity of tomatoes by placing them in successive alcohol-water mixtures of known specific gravity and noting the most dense mixture in which the fruit sank. Nettles (7) later used the method in which the weight of the fruit in air is divided by the volume of the fruit as it displaces its volume in water.

Kunkel *et al.* (5) reported the use of specific gravity to separate potatoes into different cooking quality groups. The potatoes were separated into the various cooking classifications by floating them in solutions of known specific gravity. The floaters of the lowest specific gravity were conveyed to a tank with a solution of a higher specific gravity. The floaters from the second solution were separated from the sinkers and the sinkers in each solution were kept separate. In this way, the potatoes were placed in three grades based upon specific gravity. Nylund (9) found a direct relationship between hollow heart and the specific gravity of potatoes. Nichols and Reed (8) found that flesh texture and color are correlated with specific gravity of prunes.

Kelly and Smith (4) suggested in 1944 that specific gravity could be used conveniently for determining the maturity of fruits and vegetables such as apples, pears, peaches, plums, cherries, grapes, citrus fruits, potatoes, tomatoes, cucumbers, cabbage, melons and peas.

Separation of Tomatoes by Skin Color

Skin color may be a means of determining maturity of green-wrap tomatoes. Desrosier *et al.* (1) reported that color grading is used successfully on red apple varieties and canning tomatoes. Francis (13) reported that the ratio of red to green in the skin of McIntosh apples showed a marked variation with the size of the apple.

Little is known about the color of a green-wrap tomato. Visual observations show that as the tomato increases in maturity it changes in shade from a green immature to a mature green-wrap. It might be possible to use a color indicator

to separate immature from mature tomatoes with some variability because of some fruit being shaded.

Pressure or Compressibility of Tomatoes

It is believed that the more mature tomatoes will not ship satisfactorily because they cannot withstand the pressure of the package without bruising. Lutz (6) found that resistance to puncture decreased slightly after the mature green stage was reached. He added that the pressure test showed no consistent relation between maturity and pressure readings of tomatoes.

Hamson (3) stated that pressure tests may be used to obtain a rapid, accurate evaluation of differences in firmness of tomatoes. He also reported that an increase in firmness results largely from a greater content of pectin in fleshy tissue of firm fruits.

Ripening Operation

Differences in the degree of maturity of green-wrap tomatoes at harvest time account in large measure for the great variability in the time required to ripen a given lot.

Wright and Gorman (13) found that "Under average market conditions, tomatoes are usually ripened at about 68°, 4 or 5 days being required for mature green tomatoes."

According to Sorensen (10), tomatoes are first graded in the ripening room when 60 percent are ready for sale as indicated by color. The green and pink tomatoes are separated so that the "pinks" can be processed the next day. The green tomatoes are replaced in the ripening room until about 70 percent show enough color to justify being handled again.

MATERIALS AND METHODS

The tomatoes used in these studies were grown on Lufkin fine sandy loam at College Station in the spring of 1954. Samples were taken during the growing season for specific gravity, length, width and weight measurements. Skin color readings were made with a photo volt reflection meter on the stem, blossom end and middle section of tomato fruits. Compressibility of the tomato fruit after ripening, percent moisture and loss of weight in storage also were recorded. The effect of weather on each of these conditions for each stage of maturity and the four dates of tagging of blossoms was recorded. The experiment was designed to correlate seasons of production and varieties of tomatoes, but this phase was eliminated after the spring and fall of 1953 because of uncontrolled weather conditions and the variability among varieties.

The Rutgers variety was used for the spring growing season of 1954. With the specific gravity, length, width, weight, weather and tagging and picking dates, an attempt was made to find an objective method for determining when a tomato has reached the mature green stage and will ripen within a given time.

Tagging of Tomato Blossoms

To measure the maturity of the tomatoes in days from fruit set, day-old open blossoms were marked with identifying tags and fruits were picked at varied stages of maturity of 24, 27, 30, 33, 36, 39 and 42 days from tagging.

The tagging operation covered four different days, April 21, 23, 27, and May 3, when 600, 800, 1200 and 800 flowers were tagged.

A cardboard container, 12 $\frac{5}{8}$ inches wide by 16 inches long by 3 $\frac{1}{2}$ inches deep with crossed dividers, giving 20 compartments 3 × 3 × 3 $\frac{1}{2}$ inches, was used to maintain individual fruit records. The dividers were arranged to provide four rows with five compartments per row, Figure 1. A sample of 20 tagged tomatoes represented each stage of maturity for each tagging date.

The front end of the box was labeled. The tomatoes were numbered from left to right and front to back. The number assigned to the cell or compartment of the box was the number assigned to the tomato.

A "cross" was placed in the bottom of each cell as the tomato was eliminated.

Specific Gravity

To determine the specific gravity of a whole tomato fruit the following measurements are needed.

1. Liquid weight is the weight of the tomato when it is placed in a solution with a specific gravity less than that of the tomato. The tomato will not float and the weight can be determined. In these experiments the tomato was placed in a wire basket that was attached to a scale. The weight of the tomato in the liquid was recorded. The equipment used for determining specific gravity of the tomatoes is shown in Figure 2.
2. Specific gravity of the liquid used. Ninety-five percent ethyl alcohol was used for

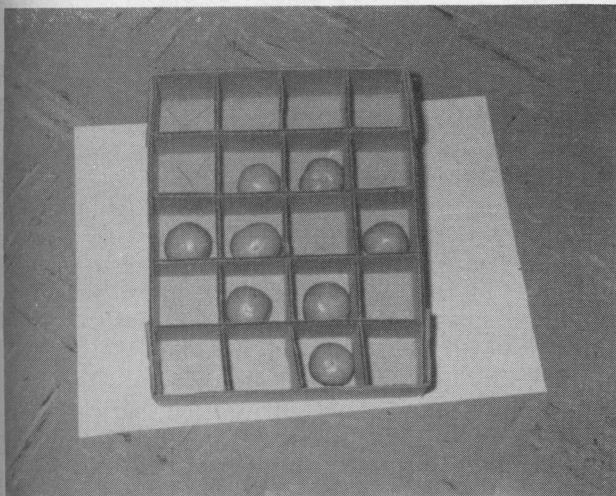


Figure 1. Cardboard container used to maintain identity of tomatoes in the experiment.

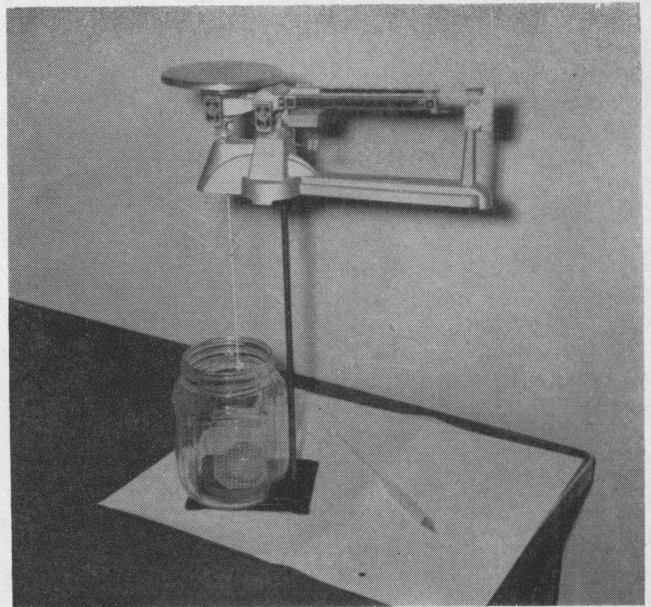


Figure 2. Equipment used to determine specific gravity.

this experiment because it has a specific gravity of approximately .800. The specific gravity of the liquid was determined at the start of each lot of 20 tomatoes by the use of hydrometers.

The formula used for determining the specific gravity of each tomato was:

$$\text{Specific gravity} = \frac{\text{Weight in air} \times \text{specific gravity of liquid}}{\text{weight in air} - \text{weight in liquid}}$$

Color Test

There is a visual change in the skin color of tomatoes as they mature. Color tests were made to determine if they could be used to measure the stage of maturity of green-wrap tomatoes.

To determine the change of color of the tomato during the ripening process, the color of the tomato skin and the flesh underneath the skin were recorded numerically by photoelectric determinations made with a photo volt reflection meter No. 610, Figure 3.

The color of the tomato fruit was measured at the stem end, the middle area and the blossom end. Three readings were taken at each location and averaged.

Ripening Storage Period

After physical and color tests were completed, the tomatoes were placed in storage and allowed to ripen at 64° F. with a relative humidity of 58 to 60 percent. The storage facilities consisted of the chilled rooms operated by the Department of Agricultural Engineering. The boxes of tomatoes were placed on racks in the room to allow good circulation of air.

The storage period varied from 6 to 30 days, but as the tomatoes ripened they were checked at 3-day intervals until all had ripened.

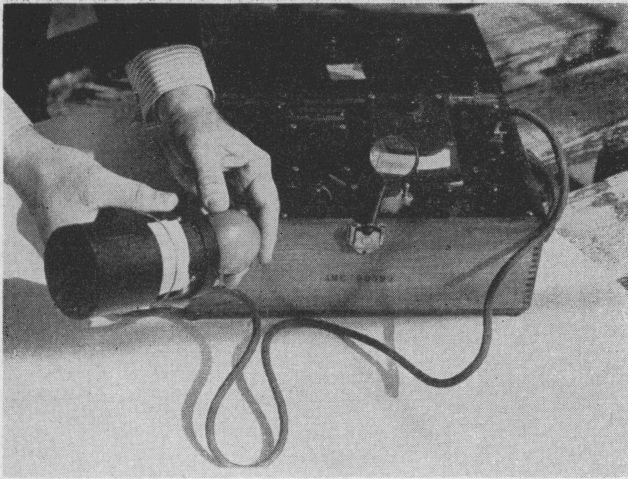


Figure 3. Photo volt reflection meter used to record color.

Pressure or Compressibility Tests

Pressure-testing equipment indicated the amount of penetration a tomato would stand before breaking, Figure 4. The pressure area was constant for the entire experiment. At the completion of the ripening period, the following data were recorded for the pressure-test phase:

1. Diameter of tomato in centimeters.
2. Grams of weight used. This usually held constant, but when the condition of the tomato indicated that it would not withstand the normal weight used, less weight was applied.
3. Pressure-test reading. The formula for measuring the resistance of the tomato to the pressure test was:

$$\text{Resistance} = \frac{\text{pressure test reading}}{\text{diameter of tomato} \times \text{grams of weight used}} = \text{centimeters per gram.}$$

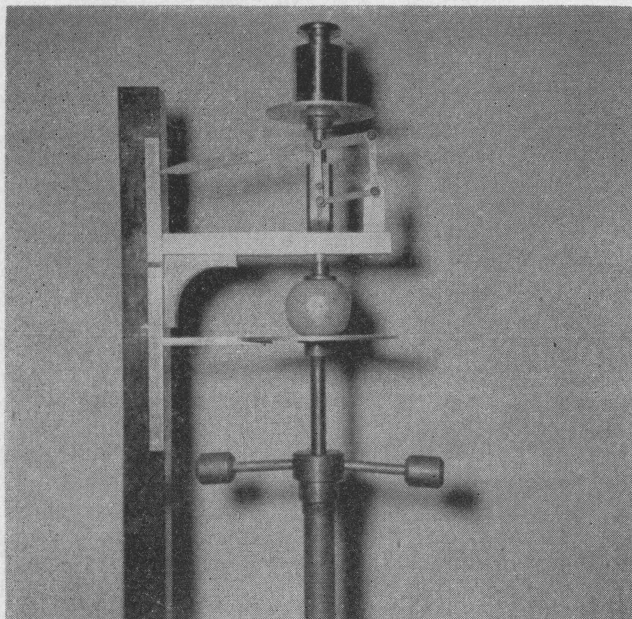


Figure 4. Equipment used to determine compressibility of the tomatoes.

The percentage moisture was determined for each tomato after all other measurements were completed. The formula used was the oven-dry material weight divided by the wet material weight.

Visual Inspection Rating

An attempt was made to correlate the specific gravity of the tomato with a visual observation by cutting and inspecting the tomatoes.

A number of tomatoes of unknown stage of maturity were used in the visual inspection rating. Each tomato was cut across the middle section and rated according to one of the four classifications used in the visual inspection rating.

Very (green) immature tomatoes—no seed or very immature. No glue or jelly-like consistency in the cavities.

Immature—immature seed, white and easily cut by the knife. A jelly-like substance starting to form.

Mature—seed not easily cut by the knife. The glue or jelly-like substance formed. This classification determines the maturity of tomatoes under the present system.

Good maturity—seed well filled and not easily cut by the knife. Jelly-like substance well formed in the locules.

At the time of visual inspection, puffiness in the tomato was recorded each time it was noted.

RESULTS AND DISCUSSION

Specific Gravity of the Tomatoes

Table 1 indicates that the few tomatoes with a very low specific gravity greatly influenced the average of the group. The extremely low ones cannot be separated from those below the average without a further specific gravity separation.

Considerable variation of specific gravity was found within each maturity date.

No correlations were found between specific gravity at each maturity date and the three color readings, or between length and air weight of the tomatoes. There was a correlation of .67 between specific gravity and minimum temperature, .68 for maximum temperature, and .70 for differences in temperature.

Table 2 shows very high correlations between specific gravity and the width of the tomato. The good correlation may be accounted for by the fact that as the tomato increases in maturity and the cavities or locules become filled with the jelly or glue-like substance, the width of the tomato increases.

There was a good correlation between specific gravity and the sum of the relative humidity for three of the four tagging dates, April 23, April 27 and May 3. The correlations were .90, .80 and .98, respectively. The other tagging date, April 21, showed no correlation.

TABLE 1. PERCENT OF TOMATOES ABOVE AND BELOW THE AVERAGE FOR EACH MATURITY DATE

Maturity in days	Percent above and below the average specific gravity	
	Above	Below
24	67.5	32.5
27	59.3	40.7
30	65.8	34.2
33	60.0	40.0
36	60.0	40.0
39	63.7	36.3
42	64.4	35.6

Length, Width and Weight of Tomatoes

The outstanding characteristic of the Rutgers tomato is its flat shape. Of the 1,040 tomatoes measured in 1954, 84 percent were 2 to 3 inches wide, 14 percent were 3 or more inches wide and the rest were less than 2 inches; 12.8 percent were 1 inch long and 87.2 percent were 2 to 3 inches long.

Figure 5 shows a good correlation between the length and width of the tomatoes for each stage of maturity. The most rapid gain in length and width is up to approximately 33 days from tagging of 1-day-old flowers. This is the period of most rapid development and the tomato cannot be considered a mature green-wrap at 33 days of age.

Weather definitely affected the length of the tomato. Table 3 shows that the weather factors had a fair correlation with three of the dates of tagging; April 21 showed no correlation. The weather may have been too cool at the time of the first tagging date (April 21) to have any recognizable effect on the tomato. Only the tagging date April 23 had a correlation between length and humidity and maximum and minimum temperature.

There was a good correlation between the width and the weight of the tomato. The correlation between the weight and length was less, Table 4.

There was a definite relation between specific gravity and width of the tomato, also between the size (width and length) and weight. The multiple correlation coefficient measured the combined effect of the three independent variables on the average specific gravity of the tomatoes for each stage of maturity. The importance of the three

TABLE 2. CORRELATIONS BETWEEN SPECIFIC GRAVITY AND WIDTH OF EACH LOT OF TOMATOES FOR EACH MATURITY

Maturity in days	Average specific gravity	Average width in inches	Correlation (R ²)
24	.93595	2.4	.99
27	.93811	2.5	.98
30	.94206	2.7	.99
33	.94950	2.7	.99
36	.95113	2.6	.98
39	.95503	2.7	.99
42	.96752	2.8	.99

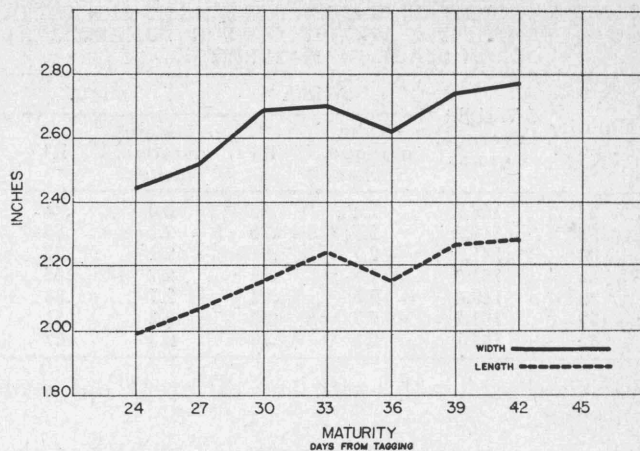


Figure 5. Average length and width of tomatoes by days of maturity.

independent variables on the average specific gravity is shown in the simple correlations in Tables 2 and 4. The multiple correlation coefficient, $R 1.234 = 0.95$, indicates a high degree of association between the average specific gravity of the tomatoes for each stage of maturity and average width, length and weight.

The square of the coefficient, $R 1.234 = 0.90$, indicated the proportion of the squared variability in the average specific gravity of the tomatoes for each stage of maturity explained by these three factors. The coefficient of determination is 0.90, or 90.0 percent.

The unaccounted for variability is expressed by the coefficient of nondetermination, 0.10 ($1-0.900 = 0.10$). The coefficient of nondetermination is the proportion of the squared variability in the average specific gravity of the tomatoes for each stage of maturity not explained by the three other factors. This unaccounted for variability may be due to error, or some other unexplained factors.

The size of the tomato seems to affect the specific gravity. A higher average specific gravity was recorded with the larger size (above 2.5 inches) and decreased as the size decreased (below 2.25 inches).

There were high correlations between the weight and size of the tomato. There was a good correlation between weight of the tomatoes at picking and one tagging date (April 23) and weather (humidity and temperature), but this

TABLE 3. CORRELATION BETWEEN WEATHER AND LENGTH OF THE TOMATO AT DIFFERENT TAGGING DATES

Weather factor	Tagging dates			
	April 21	April 23	April 27	May 3
Maximum temperature	.17	.59	.64	.65
Minimum temperature	.02	.59	.64	.63
Difference ¹	.12	.07	.65	.09
Relative humidity	.02	.81	.83	.66

¹ Difference between daily maximum and minimum temperatures.

TABLE 4. CORRELATION BETWEEN LENGTH AND WIDTH WITH THE WEIGHT OF THE TOMATOES AT EACH STAGE OF MATURITY

Maturity in days	Weight average, grams	Width		Length	
		Width average, inches	R ²	Length average, inches	R ²
24	106.7	2.4	.89	2.0	.74
27	119.9	2.5	.79	2.1	.53
30	141.9	2.7	.91	2.1	.72
33	152.3	2.7	.86	2.2	.85
36	140.4	2.6	.92	2.1	.68
39	161.2	2.7	.90	2.2	.51
42	165.1	2.8	.86	2.3	.67

varied considerably with the different dates of tagging.

The ratio between length and width and the weight of the tomato is very high when compared with the specific gravity for the average of the lot of tomatoes that are 24 and 27 days from tagging. By 30 days from tagging the ratio had decreased rapidly, indicating that the length and width growth has slowed down and the weight of the tomato has increased.

Color of Tomatoes

The skin color and flesh of the tomato change from dark to light green during the ripening pro-

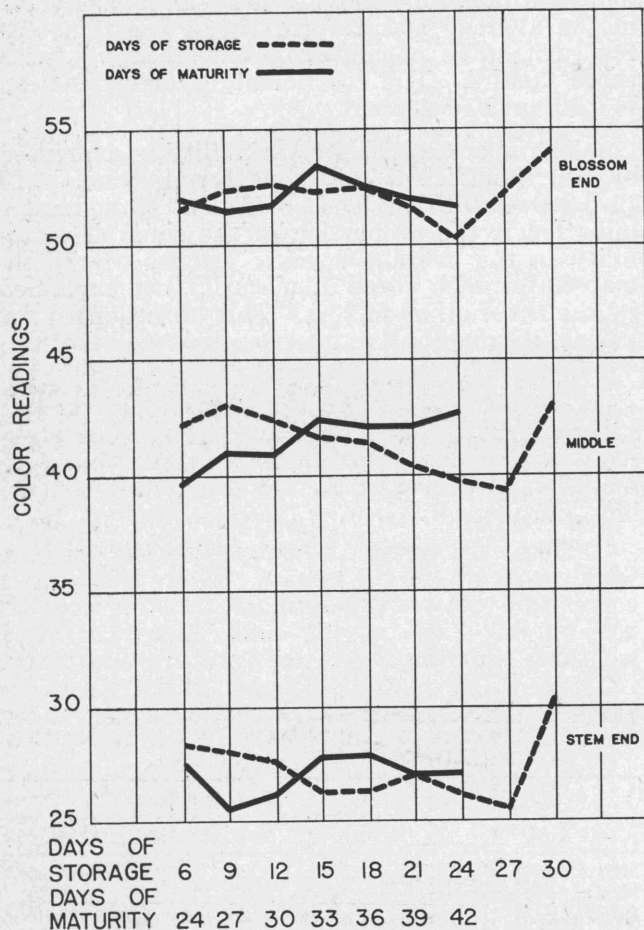


Figure 6. Average blossom, middle and stem end color reading on a photo volt reflection meter on tomatoes by days of maturity and storage.

TABLE 5. CORRELATION BETWEEN WEIGHT OF THE TOMATO AT TAGGING DATES AND TEMPERATURE AND HUMIDITY

Tagging dates	Humidity	Maximum temperature	Minimum temperature	Difference between max. and min. temp.
April 21	.34	.32	.30	.37
April 23	.81	.81	.81	.83
April 27	.57	.56	.56	.54
May 3	.66	.66	.67	.65

cess. The color change starts at the blossom end and spreads towards the stem end. About the time the stem end becomes lighter in color the blossom end shows pink. The pink develops to red and spreads to the stem end.

Figures 6 and 7 give the average color of each maturity group and the average color of the tomatoes with time during ripening in storage. The blossom-end color reading is highest at 33 days from tagging, but this would not be a good measure for determining maturity as the color is lower for the 6 to 9 days of storage. The middle, stem end and total average color readings may be used to indicate maturity. The average color reading decreases with the number of days in storage. The charts indicate that the color readings are higher when the tomatoes are more than 30 days from tagging and were in storage less than 15 days.

The color of the tomatoes that were visually inspected was constant. The very immature tomatoes had a slightly higher color reading but this would not be a reliable measure for separating the immature from the mature tomatoes.

The average color for blossom, middle and stem end of all the tomatoes at the end of the storage period when the tomatoes were ripe is shown in Figure 8. The tomatoes that required 12 to 15 days to ripen had a uniform color and as the days of storage increased the color uniformity decreased. This also may indicate that the most physiologically mature tomatoes are the ones that ripen in about 12 days of storage.

When the tomatoes were separated into three size groups of above 2.5 inches, 2.25 to 2.5 inches and below 2.25 inches, the average color reading increased as the size of the tomato increased. This indicates that size may have a relation to the color readings of the tomatoes.

Maturity of Tomatoes

The number of days it takes to ripen a green-wrap tomato is very important. In 1954, 76.3 percent of the tomatoes ripened in 18 days or less. The remaining 23.7 percent required up to an additional 12 days under the conditions of these tests. If the tomatoes had been grown under different environmental conditions, such as temperature, the days from blooming to ripening might have been different. Elimination of this group of approximately 24 percent would reduce the cost, time and effort in the ripening of the tomatoes.

The ripening period decreases as the age of the fruit increases. Tomatoes when harvested at

24 days from tagging 1-day-old blossoms plus 23 days required for ripening are available for the market in 47 days. This is about the same number of days required for tomato fruits harvested at 30 days of age and which ripen in 17 days. Tomatoes harvested at 24 days from fruit set do not ripen more than half a day earlier than tomatoes harvested at 30 days. Six days less storage time were required for the more mature tomatoes. Thirty-day-old tomatoes were larger, heavier and were more uniform in color on ripening. This may indicate that the tomato should reach a physiologically mature green stage to decrease the ripening period.

Figure 9 shows that as the number of days of storage increases the average specific gravity of each group decreases. This verified the belief that the more mature tomatoes have a higher specific gravity and mature tomatoes will ripen more quickly. The fact that specific gravity for ripened tomatoes was higher than the average indicates there is less variability between the specific gravity of the ripened tomatoes than at stages of maturity.

At the start of this experiment, it was hoped that a definite point on the specific gravity scale could be used to separate the tomatoes into lots that required different storage periods. It appears now that a range rather than a specific point must be used.

Figure 9 shows that, with a specific gravity of .949, tomatoes are over 33 days from the tagging of 1-day-old open flowers and the tomatoes above this point will ripen in 6 to 15 days. Lutz (6) in Mississippi indicated that with Gulf State Market tomatoes the mature-green stage was reached about 27 days after fruit set. This experiment does not attempt to define the number of days from fruit set to a mature-green stage; it attempts to indicate the point on the specific gravity scale at which the average tomato would ripen, which may be approximately 33 days or more from tagging and the tomatoes would ripen in 6 to 15 days.

The size of the tomato seems to indicate in some respects its maturity. Figures 10, 11 and

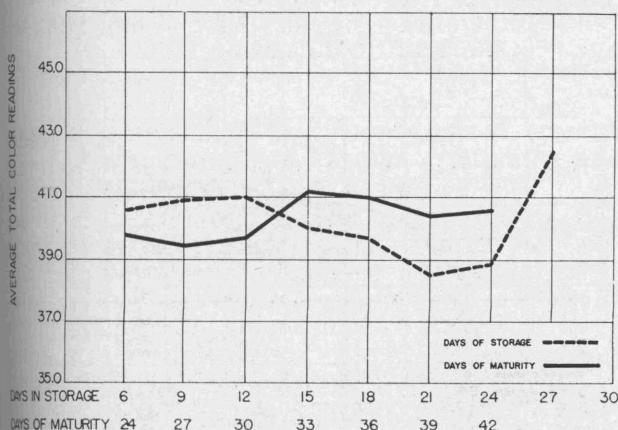


Figure 7. Average color reading on a photo volt reflection meter on tomatoes by days of maturity and storage.

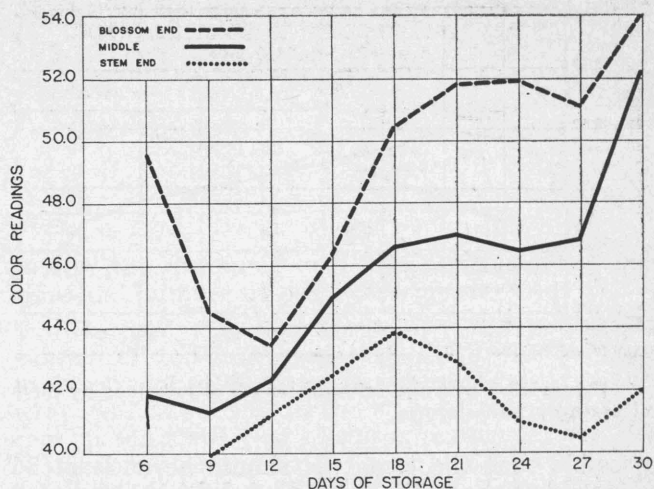


Figure 8. Average color reading on a photo volt reflection meter for blossom, middle and stem end of tomatoes on ripening by days of storage.

12 show the average length, width and weight of the tomato at each stage of maturity and the average original length, width and weight of the tomatoes that ripened in each storage period.

The length data indicate that the average tomato of 2 2/16 inches or more will ripen in 15 to 18 days. Below this length the time of ripening increases. The average tomato does not reach the desired length until about 33 days from tagging of 1-day-old flowers.

The average width data show that the greater the diameter, the better the maturity. The diameter decreases with each increase in storage up to 15 days, tapers off to 21 days of storage and then drops rapidly. The average width indicates that there may have been a period of 15 to 21 days of storage. The actual ripening operation supports this information and is presented in a later section.

The weight of the tomato also shows to some extent the maturity. The average weight of the tomato increases with the increase in days from fruit set. The average weight of the tomatoes that ripened in 6 days was high and as the number of days required to ripen increased the average weight decreased. Figure 13 shows that it is

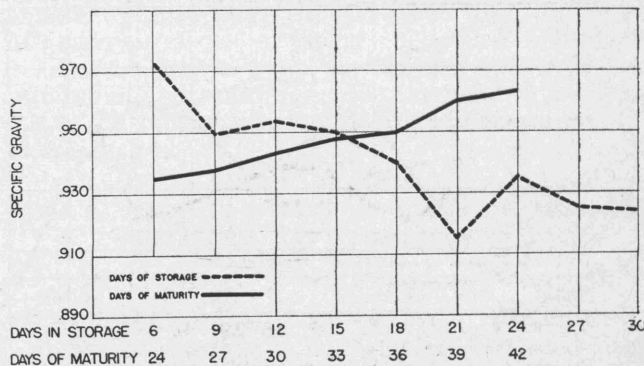


Figure 9. Average specific gravity of tomatoes by days of maturity and storage.

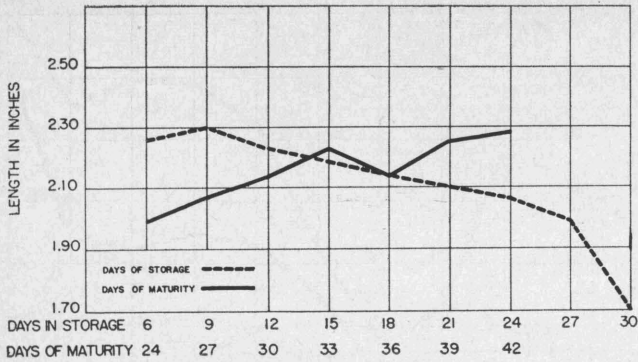


Figure 10. Average original length of tomatoes by days of maturity and storage.

possible that the tomatoes should be at least 36 days old to reach the average weight that ripened in 18 days of storage.

Figures 9 (specific gravity), 10 (length), 11 (width) and 12 (weight) indicate that the average tomato should be approximately 33 days from fruit set to ripen in 15 days.

Tomatoes steadily lose weight as the number of days of storage increases and the percent moisture changes. Table 6 shows that the tomatoes requiring only 6 days of storage may not have had as much moisture as others. After 9 days of storage, the amount of moisture decreases with increasing length of storage. The compressibility or resistance to pressure of a tomato increases with the storage period. It is possible that with the loss of weight (mainly as loss of moisture) the compressibility increases up to a point.

Pressure or Compressibility of Tomatoes

After 30-33 days of age, the pressure the tomato fruit will stand decreases as maturity and the length, width, weight, and specific gravity increase, Table 7.

This verifies the generally accepted idea that as the tomato approaches maturity the size of fruit increases and the fruit tends to become softer. When the tomatoes are about 33 days of age they have a resiliency similar to that of rubber.

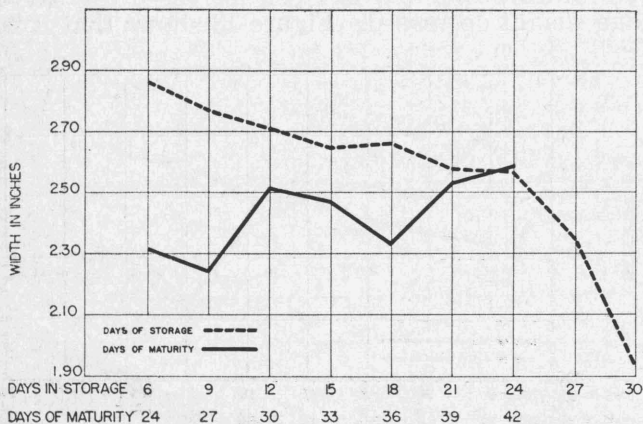


Figure 11. Average original width of tomatoes by days of maturity and storage.

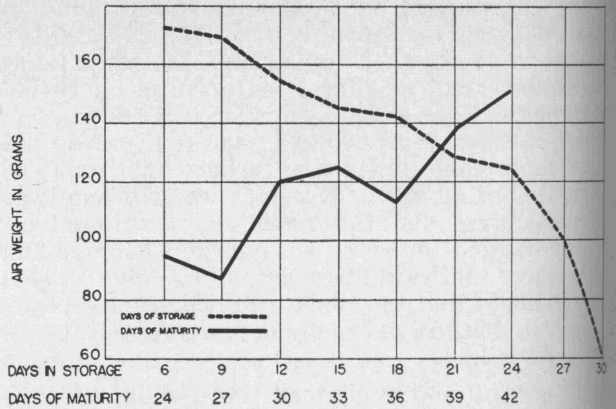


Figure 12. Average original weight of tomatoes by days of maturity and storage.

The smaller the tomato, the higher the pressure or compressibility will be for tomatoes below 2.25 inches, as compared with 2.25 to 2.5, and above 2.5 inches. Figure 13 indicates that average pressure in 1,000 grams per cm. is high at 24 days from fruit set and decreases until the tomato reaches approximately 33 days from fruit set.

The amount of pressure a tomato will stand decreases as the tomato increases in age from fruit set. Pressure test determinations also were made after the storage period. The amount of pressure a tomato will stand increases as the number of days in storage increases.

The amount of pressure a tomato will withstand increases from 6 up to 12 or 15 days of storage, at which time it reaches approximately the same pressure as that of the tomatoes that are 30-33 days of age.

Visual Inspection Rating

Five hundred fifty-four tomatoes of unknown maturity were inspected visually after the specific gravity, weight, length and width measurements had been recorded. The percentage of tomatoes in each classification was very immature, 2.9; immature, 36.8; mature 43.1; and good maturity, 17.1.

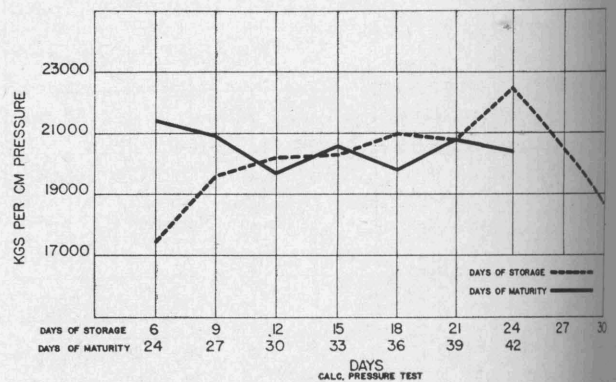


Figure 13. Compressibility of tomatoes by days of maturity and storage.

TABLE 6. AVERAGE PERCENT MOISTURE AND LOSS OF MOISTURE AND PRESSURE TEST FOR DAYS IN STORAGE.

Days in storage	Moisture	Loss of weight	Calc. pressure ¹
6	91.9	1.6	.174
9	94.2	3.9	.197
12	94.3	3.5	.203
15	93.4	4.4	.203
18	93.1	6.5	.210
21	93.9	7.1	.209
24	93.9	8.1	.225
27	92.3	9.4	.205
30	92.1	13.4	.199

¹1,000 grams per cm.

About 40 percent were placed in the immature group and the rest were classified as mature tomatoes.

During the inspection, the tomatoes also were classified as puffy and nonpuffy. The percent of puffy tomatoes for the four classification groups was 62.5, 39.7, 23.8 and 15.8, respectively.

The specific gravity for all tomatoes and for those nonpuffy and puffy is shown in Table 8. Puffy tomatoes lower the specific gravity of each group of tomatoes.

The weight of the tomato increases with maturity principally because the locules become filled with a jelly-like substance as it matures. Table 9 gives the average weight of the tomatoes in each rating group and shows the variability of the weight of the tomatoes. Puffy tomatoes weighed more than nonpuffy tomatoes only in the extreme immature and mature groups.

Table 10 gives the average length and width of tomatoes for each visual inspection group. This table indicates that there is little difference in size between puffy and nonpuffy tomatoes. Weight and size are not a good means of separating the puffy tomatoes from the group.

Relationship of Maturity to Repacking Costs

A load of tomatoes does not ripen uniformly. Data were obtained in 1953 from the ripening rooms of the E. A. Brown Tomato Company, San Antonio, Texas. This information was obtained by actual timing of each load, recording the volume, amount removed, number of times required

TABLE 7. COMPARISON OF THE PRESSURE A TOMATO WILL STAND FOR VARIOUS CONDITIONS AND STAGES OF MATURITY

Maturity in days	Average weight, grams	Average width, inches	Average length, inches	Average calc. pressure ¹	Average specific gravity
24	107.3	2.4	2.0	.215	.936
27	118.9	2.5	2.1	.210	.938
30	141.9	2.7	2.1	.197	.942
33	151.7	2.7	2.2	.207	.949
36	144.0	2.6	2.1	.198	.951
39	162.0	2.7	2.2	.209	.955
42	166.0	2.8	2.3	.206	.967

¹1,000 grams per cm.

TABLE 8. AVERAGE SPECIFIC GRAVITY OF ALL, NON-PUFFY AND PUFFY TOMATOES IN EACH VISUAL INSPECTION RATING

Rating	All	Nonpuffy	Puffy
1	.91987	.94167	.9068
2	.93170	.93917	.92036
3	.94207	.94405	.93575
4	.95621	.95861	.94340

to run the tomatoes over the grading belt, and time and number of employees used.

During the experimental work, 655,480 pounds of tomatoes were checked. An average of 50 percent of the tomatoes were removed in the first run, 23 percent in the second run and 7 percent in the third run. Approximately 20 percent of the tomatoes were still green and not ready for retail sale. The number of days of storage increased with each succeeding run or reworking of the tomatoes.

Considerable variation was noted in checking the number of days in storage in the ripening operation. Nineteen lots with 331,922 pounds of tomatoes were designated by size. There were 11 lots with 264,187 pounds in the grade-size grouping of 6 × 6 or larger (6 × 6 refers to arrangement of tomatoes by size), and 8 lots with 67,735 pounds in the grade-size grouping of 6 × 7 or smaller. There were 6 tomatoes along the width and length of the lower layer in the container. There was an apparent difference in the amount of time required to ripen the tomatoes in each group.

The 6 × 6 or larger tomatoes required an average of 12.2 days from shipping to ripen 89.9 percent of the group. An average of 15.9 days was needed to ripen 69.3 percent of the smaller tomatoes (6 × 7 or smaller).

The number of times required to handle the tomatoes varied with the two groups, Table 11.

The size of the tomato was a fair indication of maturity. With an average length of 2.15 (U. S. Standard 2 2/16 inches and larger the average tomato could be expected to ripen in 6 to 15 days. The average width of approximately 2.6 (2 10/16) inches and longer could be expected to ripen in about 6 to 21 days. The data presented in this section show that tomatoes of 6 × 7 or smaller require more time to ripen than tomatoes of grade size 6 × 6 or larger. The U. S. Standard grades for green-wrap tomatoes (11) give the minimum and maximum diameter for 6 × 6 as 2.5 to 2.9 inches and 6 × 7 size tomatoes as 2.25 to 2.6 inches.

TABLE 9. AVERAGE WEIGHT IN GRAMS OF ALL, NON-PUFFY AND PUFFY TOMATOES IN EACH VISUAL INSPECTION RATING

Rating	All	Nonpuffy	Puffy
1	100.3	119.3	88.9
2	119.7	119.3	120.3
3	133.9	132.5	138.5
4	173.8	175.7	163.4

TABLE 10. AVERAGE WIDTH AND LENGTH OF ALL, NON-PUFFY AND PUFFY TOMATOES IN EACH VISUAL INSPECTION RATING

Rating	Width, inches			Length, inches		
	All	Nonpuffy	Puffy	All	Nonpuffy	Puffy
1	2.34	2.46	2.27	1.99	2.01	1.98
2	2.53	2.52	2.55	2.09	2.06	2.12
3	2.63	2.62	2.67	2.16	2.14	2.21
4	2.89	2.90	2.86	2.34	2.31	2.33

The U. S. size of 6 × 6 or larger has a minimum diameter 2.5 inches and a maximum of 2.9 inches. For the 6 × 7 or smaller tomato, the U. S. diameters are 2.25 to 2.6 inches. The overlapping of these two sizes should be noted. Using the maximum size of 2.625 inches, the width size in Figure 11 showed that the average tomatoes above this size ripened in 6 to approximately 15 days. This corresponds to the 12.2 days as the average time required to ripen 89.9 percent of 6 × 6 or larger tomatoes. The 6 × 7, or smaller size, averaged 15.9 days to ripen 69.3 percent of the tomatoes.

There is a slight difference in ripening time between the experimental data and the data from the tomato repack plant. This is mainly because of the difference in classification of ripeness. In the repack plant a tomato was classified as ripe when it still had some green color; in the experiment, a tomato had to be uniformly red to be classified ripe.

Other data previously presented indicated that the shape of the Rutgers tomato is flat, causing the width to be the larger dimension. It also was shown that the tomato increased in size as the number of days from fruit set increased. The average size of 2.50 inches was found when the tomato was 30 or more days from fruit set.

TABLE 11. NUMBER OF TIMES TOMATOES WERE HANDLED AND PERCENT REMOVED IN EACH OPERATION

No. of times handled	6 × 6 or larger size		6 × 7 or smaller size	
	Percent removed	No. of days to ripen	Percent removed	No. of days to ripen
Run No. 1	49.0		69.3	
Run No. 2	37.0		—	
Run No. 3	3.6		—	
Total runs	89.9	12.2	69.3	15.9
Remainder ¹	10.1		30.7	
Total	100.0		100.0	

¹ Individual lots were small and mixed together, causing the lots to lose their identity.

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