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Introduction

During recent years, the consumption of tomatoes has increased at a tremendous rate. The supply, however, has kept pace with the demand and at the peak of the season the markets, in many sections, are glutted to such an extent that the price received by the grower does not cover the cost of production.

By nature, the tomato plant has the capacity to produce an indeterminate and progressive yield but is curtailed by even the lightest frost. In most sections, there is some variation in the occurrence of early frosts in the fall. Good growers plan their operations accordingly. Immediately following the first fall frost, the supply of native tomatoes on the market is sharply reduced. This results in a rapid upward trend in the price received.

The problem of short time storage is, therefore, an important factor to be considered by the grower not only in holding over a surplus until the market is cleared, but also in lengthening his season of marketing in the fall.

It has been shown by numerous investigators that, while tomatoes may be classed as a highly perishable product, they may be held under some storage conditions

for a period of several weeks without the loss of a desirable appearance in a majority of the fruits. Were it possible to lengthen the storage period, the market gardener could harvest fruits during the period of high productivity and low price and place them in storage until the glutted condition of the market was relieved. In any case, the price usually rises after the first frost.

Although considerable work has been done to show that tomatoes can be stored, on a practical basis, for a short time, comparatively few investigations have dealt with chemical and nutritional changes of the fruit during storage. For the most part, knowledge is lacking concerning the effect of waxing, washing, and wrapping fruits that are stored.

The main purpose of the investigation thus was to determine the marketable storage life of tomatoes, and what effect the use of washes, waxes, and various types of wrappers have on the keeping quality of such stored fruits considered from a chemical, physiological, and pathological viewpoint. Studies reported herein deal with the effect of storage on green mature fruits as well as on ripe fruits.

Review of Literature

In the brief review of literature which follows, no attempt will be made to study reports concerned either

with the storage of other vegetables or with other phases of tomato production. Only the material which is pertinent to the storage of tomatoes or to the distinct phases of the experiment as herein described, was considered of sufficient importance to be included in such a review.

Although the tomato, Lycopersicum esculentum Mill., is a native of Central and South America and was used for food by the Indians in these regions, it was not generally recognized or grown as a commercial crop until the latter half of the last century.

The earliest references to the tomato are concerned with a description of the plant, its culture, and the characteristics of the fruit. Later, when the tomato became more popular as an edible product, chemical analyses were made to determine the composition of the fruits as related to quality. Studies were also made to relate the effect which varying environmental factors might have on composition and hence quality.

Before 1915, recommendations were made as to the storage conditions best adapted for tomatoes, but these were based on general observations rather than on actual experimental evidence.

The first work of importance, and the most referred to is that of Sando (52), who studied the effect

of various conditions on ripening. His results showed that during ripening there is an increase in moisture, acids, and sugars, and a decrease in solids, ash, total nitrogen, starch, pentosans, and crude fiber. He concluded from his results that the wrapping of green mature fruits was harmful in that it decreased ventilation causing an accumulation of the products of respiration, and, consequently, that it modified the ripening processes to such an extent that the fruit never attained the full quality of the vine ripened product.

In 1923, Adam (1), working with half-, three-quarters-, and fully-ripe fruit, stored at 31, 33, and 35°F., found that the more mature fruit softened more rapidly, while the green remained firm the longest. Mold growth seemed to be the initial cause of softening and the limiting factor in determining the length of the storage period.

In the same year, Rosa (49) made recommendations as to the stage of maturity at which tomatoes should be harvested, and the conditions for storage. These were in accord with Sando's recommendations, and were probably based on his work.

Diehl (19), the following year, reported the effect of low temperatures for varying periods of time on the subsequent ripening of tomatoes. He found that

temperatures of 30 to 31°F., for one day or 32°F. for four days had no ill effects on the further ripening at higher temperatures, but, following eight days exposure at 32°F., decay resulted before ripening could take place. Under cooling as much as 40°F. below the freezing point was not harmful, and the treated fruits ripened normally as to color and condition.

Rosa (50) stated that the softening of ripe fruits leading to breakdown and decay is thought to be due to an increase in soluble solids and the conversion of calcium pectate of the middle lamella to pectic acid. With a day temperature of 70°F. and a night temperature of 55°F., softening proceeded at a slower rate when ripened in air or ethylene than when ripened on the vine.

In a later experiment concerning the effect of temperature, Rosa (51) found over 90 per cent ripening of green mature fruits in 16 days at 16 to 18°C and 100 per cent ripening at both 25 and 30°C in 8 and 11 days respectively. Green mature fruits, held for 25 days at 4°C, showed no red pigment formation and decayed on removal to 25°C, but after 20 days at 12°C, sound fruits ripened in eight days at the higher temperature. Tomatoes at the turning stage of maturity ripened in 18 days at 8°C, but were subject to breakdown upon removal to higher temperatures. In general, his results

showed a retardation in the development of red pigment and an increase in the extent of breakdown as the storage period was lenthened and as the temperature was lowered.

MacGillivray (31) the same year, in a report of his studies dealing with the effect of storage temperature on loss in weight of whole and injured fruits, found that the loss in weight and volume is directly proportional to the temperature and length of the storage period, and is less for whole than for injured fruits. His results showed also that losses in organic constituents, especially sugars and acids which greatly impair flavor, are directly proportional to storage temperature and are, as with loss in weight, greater for damaged than for whole fruits.

Substantiating the results of Rosa (50), Brown (15) found an increase in total scluble solids and a decrease in acidity during ripening in storage. Fruits wrapped with waxed paper were lower in total soluble solids than those not wrapped. They also developed a flat taste and poor color. Paraffin coated tomatoes remained firm, and ripening was completely inhibited, while paraffin placed on the stem scar delayed the attack of storage rots. Although the flavor improved during ripening, it never equalled that of vine ripened fruits.

Observations at the Indiana Experiment Station (3) are in accord with previous results (31), namely,

that in ripe tomatoes there is a continuous loss in weight and organic constituents. These losses are proportional to the temperature and length of storage, and are also dependent on the condition of the fruit. Losses occurred more rapidly in acids than in sugars at low temperatures, resulting in an insipid tasting product.

Considering both ripening and quality of the product, 54 to 59°F. was found the most beneficial for tomato storage at the California Experiment Station (3).

Loss in weight, as a result of respiration and transpiration, is greatest in the early period of storage, and may be reduced by lowering the temperature. Overholser and Moses (40), observing the rates of temperature change at various positions in the refrigerator cars, in the containers, in the air spaces between the fruits, and in the fruits, found that, by precooling for five hours, it was possible to lower the temperature of the fruit to 55 to 64°F. The temperature attained depended on the relative position of the fruit in the car, and whether the fruit was in the center or near the outside of the containers.

Wright et al. (65) further confirmed the results of Diehl (19) and Adam (1) that low temperatures did not inhibit ripening. He was able to hold mature green fruits at 25°F. for 18 to 21 hours, or at 32°F. for four days

without ill effects on ripening. These results are opposed to those reported by Rosa (51), who found that low temperatures inhibited ripening. Field results, however, would not lead one to follow the practical application inferred from such experimental results, since the authors found that mature green tomatoes harvested the evening before the first fall frost ripened more rapidly and developed less decay during storage than those harvested the morning after exposure to the frost. They also reported that ripening in darkness produced a more evenly colored fruit than when ripened in daylight.

Ramsey and Link (47), in describing market diseases of tomatoes, recommended a low humidity in the refrigerator car and ripening room for the control of certain transit and storage diseases.

Wardlaw and McGuire (64), in studying the effect of fertilizers on the keeping quality of tomatoes, obtained no consistent results as to the influence of fertilizers. They did find, however, that green mature fruits, stored at 47.5°F. for 17 days, and ripened at 70°F. would keep well for an additional 17 days.

An instance was reported to the staff of the Agricultural Experiment Station of New South Wales (4), in which tomatoes, picked green, had been kept for two months at 50°F. and had ripened slowly, without excessive

losses. With the suggestion that at a lower temperature, the length of storage might be increased, experiments were conducted storing green fruits at 34°F. For three weeks there was no change, but, after another week, the green color was not as intense and there appeared a slight shrivelling of the skin, which was quite noticeable around the stem end. After the sixth week, complete breakdown occurred and mildew appeared, while abnormal ripening had resulted in the production of a yellow-green color. They conclude that four weeks is the limit of storage at 32°F.

In 1934, results were reported by Platenius, Jamison, and Thompson (43) which show that the most suitable condition for storage is 50 to 60°F. for a period of 30 days. Fruits stored at this temperature sometimes remained marketable for 40 to 50 days. At 40°F, fruits did not ripen in 28 days, and when transferred to 70°, decay took place rapidly and none ripened.

Wardlaw, Leonard, and Baker (63) studied ripening in stored fruits that had been harvested from plants receiving different fertilizer treatments. Though the results were not consistant, they tend to show that with a combination of phosphorus and potassium, the rate of ripening of fruits stored at 45°F., was increased throughout the season, while with phosphorus, potassium, and

nitrogen the rate of ripening was decreased.

Raleigh (45) stated that ripe tomatoes will remain marketable for ten days when stored at 40°F., and mature green fruits for one month at 50 to 60°F. The relative humidity was 95 per cent in both cases.

Platenius (42) recommended wax emulsions as a means of protection of tomatoes against loss of moisture. He stated that the wax film had no effect on chemical changes within the fruit, nor did it affect the spread of disease.

In an article in the Market Growers Journal (5), tomatoes were reported to remain marketable for a longer period of time when treated with a wax emulsion. Waxed tomatoes were said to ripen in one to two weeks when stored at 70°F. Vine ripened tomatoes may be kept for as long as eight weeks when waxed and stored at 35 to 45°F.

Materials and Methods

The tomatoes used in these experiments were of an English type known as the variety Comet. Two different lots were stored; the first, in November, and the second in January. These are hereafter referred to as Experiment I and Experiment II.

The tomatoes of Experiment I consisted of

the Waltham Forcing strain of Comet grown at the Massachusetts State College. On July 1, 1937, they were seeded thickly in flats and on July 15 the seedlings were pricked out into other flats 2 x 2 inches apart. Two weeks later they were transplanted into four inch pots. The plants were about 12 inches high on August 20, when they were planted in the greenhouse bed which had been steam sterilized for control of nematodes and soil bearing diseases. An application of fertilizer analyzing 5 per cent nitrogen, 8 per cent phosphorus, 7 per cent potassium was made to the soil at the rate of 2600 pounds per acre a few days previous to planting. The plants were pruned and trained to a single stem and topped when they had attained a height of six feet. Special attention was given to see that the plants were watered properly, and that the houses were fumigated with hydrocyanic acid gas when there were indications of infestation from aphids and the greenhouse white fly. From general appearance, the plants made a vigorous growth and for all practical purposes were characteristic of the variety Comet.

The tomatoes used in Experiment II were obtained from a commercial grower, in Sudbury, Massachusetts. They were grown under similar cultural conditions to those of Experiment I but were harvested from a later planting.

The tomatoes for Experiment I were picked November 15, removed immediately to the laboratory, prepared for, and placed in storage the morning of November 17. Those for the second experiment were picked January 17, and taken to the laboratory the same day. The fruits were properly prepared and placed in storage January 18.

The fruits of Experiment I were taken to the laboratory and were sorted into two groups of eight lots each. There were 30 fruits in each lot or 480 fruits in all. Eight of the lots were composed of fruit which, according to the standards of the United States Department of Agriculture were in the pink stage of ripeness. By inspection all the lots were very nearly alike in regard to maturity, considering color, size, and condition of fruit. These are referred to in the discussion as the green lots. The other eight lots were composed of fruits in the firm ripe stage of maturity,and also were as nearly alike as could be secured.

Color was evaluated by comparison to the color standards of Maerz and Paul (36). Readings were always taken at the blossom end as the color was found to be the most uniform in that region.

The two groups of eight lots each were treated exactly alike. One control lot from each of the two

groups was used immediately for analytical work. The remaining lots were stored after receiving the following treatments: untreated, wrapped in cellophane, wrapped in parchment, wrapped in tissue, dipped in sodium borate solution, dipped in formaldehyde solution, and coated with paraffin over the stem scar.

Each individual fruit of all the lots, except the controls not stored, was weighed. The fruits to be wrapped were weighed and then wrapped, with the blossom end of the fruit in the center of the wrapper. The weight of each fruit was marked on the wrapper so that individual losses in weight could be obtained. The fruits of the washed, the paraffined, and the control lots were weighed after the treatment. Small gummed labels were stuck on these fruits so as to identify them and to provide a record of their individual weights.

The tomatoes of Experiment II were all of the firm, ripe stage of maturity and fully colored. They were sorted into 14 lots of 15 fruits each, except the control, which contained 12, and the control with calyx attached, which contained 13. No unstored control was used in this experiment as the analyses of chemical changes were not to be studied after storage. The lots were treated as follows: control, control with calyx, borax washed, formaldehyde washed; and the following one

lot of each washed with formaldehyde before the treatment, and one lot with the treatment alone: cellophane, parchment, and tissue wrapped, paraffined at the stem end, and wax coated. This group was weighed and treated in a similar manner as Experiment I.

The parchment used was a white vegetable paper of 20-pound basis weight, cut to 9 x 9 inch size.

The cellophane, or transparent cellulose paper, used in these experiments was colorless, No. 300 P:H:T: grade, cut to 9 x 9 inch size.

The tissue was of the type commonly used to wrap apples, and green in color.

The borax wash was a 5 per cent sodium borate solution, with 0.5 per cent tar soap included as a wetting agent, and was used at a temperature of 40°C.

The formaldehyde solution was a 1:300 dilution of commercial 37 per cent grade. This was used at a temperature of 20°C.

The waxed tip treatment consisted of an application of pure paraffin sufficient to cover the stem scar.

A wax emulsion, formulated by the Franklin Research Company, formula number 489-A, was used in coating the entire fruit.

For the sake of simplicity and clarity, the des-

cription of the treatment shall be used throughout the discussion to indicate the lot treated in such a manner. For example, cellophane washed indicates the lot washed with formaldehyde and wrapped in cellophane; formaldehyde indicates the lot washed with formaldehyde.

After treatment, each lot was placed in a wooden flat, 20 x 15 x 3 inches. The bottom of the flat was covered with paper toweling to prevent bruising of the fruits by the wood. The fruits were packed in one layer, stem end down, and with sufficient room to allow for ventilation and with little or no crowding.

The flats were stacked in one pile in the southeast corner of the storage room. Wooden blocks one inch thick were placed below the bottom flat, and between the flats to allow for ventilation.

During Experiment I, the temperature of the storage room was recorded from time to time and was found to vary from about 45 to 55°F. Humidity was not determined during the period of storage of Experiment I. While the tomatoes of Experiment II were in storage, the temperature and humidity were recorded at intervals of every two or three days. The temperature was read from a dry bulb thermometer and ranged from 45 to 49°F., averaging 46.7°. The relative humidity was taken with a wet and dry bulb thermometer and ranged from 45 to 48

per cent.

In both experiments, the lots were inspected frequently and were removed when it appeared that the maximum length of storage had been reached without excessive losses due to decay and disease. The ripe lots of Experiment I were taken out of storage on December 6, and the green lots on December 16. The lots of Experiment II were removed from storage on February 16.

After removal from the storage room, the fruits were taken to the laboratory and color was again determined. The fruits were weighed and examined individually for disease, softening, decay, and any other visible physiological breakdown. They were then tested for firmness with a penetrometer (manufactured by Chatillon). The area of the needle used to puncture the skin and flesh was .02065 square centimeters and the apparatus recorded the pressure in grams. Each fruit was punctured about 1/2 inch from the blossom end. The epidermis was then carefully removed from around the blossom end, and the flesh was punctured on the side opposite to the first puncture.

From each lot portions of the fresh fruit were removed for the determination of acidity and the vitamin C content. Diseased portions of fruits, and fruits which had failed to ripen, were discarded from the

samples which were to be dried. The remainder of each lot was weighed, placed in a large shallow glass dish and dried in an oven at from 50 to 60° C. under a current of air for four to five days when about 90 per cent of the moisture had been removed. The lots were again weighed, and ground in a mill to pass a millimeter sieve.

The following analyses were made: titrable acidity, hydrogen-ion concentration, vitamin C content, total solids, ash, nitrogen, reducing sugars, ether extract, crude fiber and total soluble solids, nitrogen, and ash. All analyses were made in duplicate.

Titrable acidity and hydrogen-ion concentration were determined on the extracted juice of the fresh sample with a glass electrode.

Ascorbic acid content was determined, on fresh samples, by the Tillmans method as modified by Bessey and King. Each sample consisted of a composite of representative portions of five tomatoes. According to Maclinn, Fellers, and Buck (35), a second extraction increased the ascorbic acid content by 10 per cent. This amount was added to the value determined to be present in each sample.

Total solids were calculated on the basis of 2-gram samples dried in a vacuum oven for 24 hours at 65°C.

Total ash was determined from 2-gram samples ignited in a muffle furnace.

Total nitrogen, ether extract, and crude fiber were determined according to the methods of the Association of the Official Agricultural Chemists (6).

Reducing sugars were calculated by the Munson Walker method (6).

In making the calculations for Table I, the means were computed arithmetically, and the probable errors were computed by Bessel's formula, $P.E._m = \pm .6745\sqrt{\frac{\Sigma D^2}{N(N-1)}}$ in which ΣD^2 is the sum of the squares of the individual deviations from the mean, and N is the number of individuals concerned. In computing the probable error of difference, the formula $P.E._{diff} = \pm\sqrt{E_1^2 + E_2^2}$, in which E_1^2 is the square of the probable error of one mean, and E_2^2 is the square of the probable error of the other mean. The probable error of the sum was computed by following the formula $P.E._{sum} = \pm\sqrt{\frac{\Sigma E^2}{N}}$ where ΣE^2 is the sum of the squares of the probable errors of the means, and N is the number of means.

When the difference divided by the probable error of the difference was equal to 3.2 or more, the difference was considered significant, since the probability against obtaining such a difference due to chance is over 31:1. While odds of 30:1 has generally been used as the standard of significance, Fisher has stated

odds of 20:1 to be of some significance.

Presentation and Discussion of Data

Temperature and Humidity

The tomatoes of Experiment I which were stored ripe remained in cold storage a total of 19 days. Those which were stored green were in cold storage 31 days. All the lots of Experiment II remained in cold storage 30 days. During the storage period of Experiment I, the temperature of the storage room was observed to vary from 45 to 55°F, but for the greater part of the time, it remained rather constant at approximately 48 to 50°F. In Experiment II the temperature and humidity of the storage room was taken twice weekly. The temperature was found to vary from 45 to 49°F with an average of 46.7°F. With the exception of one reading, the relative humidity varied directly with the temperature, and ranged from 44 to 48 per cent and averaged 46 per cent.

Color of Fruit

The color of the green lots before storage ranged according to the charts of Maerz and Paul (36) from a pale grey-green (12E1-12J1) to a somewhat brighter shade (12E2-12J2). The color of the firm ripe lots (of both Experiment I and II) when stored varied from a dull orange (12E11-12L11) through burnt orange (3C12) to a

tomato red (3G12). When the various lots of the green mature fruit were removed from storage, five fruits of the lot covered with paraffin at the stem end, and one fruit of the lot wrapped with parchment had not ripened. The failure of these fruits to ripen was not considered due to any effect of the treatment but was thought due to the possibility of the fruit being harvested while still immature. All other fruits in the green lots had ripened to a color ranging from Rose Amber (12B9) to Amberglow (12H11), and Brazil Red (4K12) and are thus variations of orange-red combinations. The fruits of the ripe lots of Experiment I and Experiment II ranged in color from a Bittersweet (3B12) to a Brazil Red (4K12). These are also combinations of orange and red. Though some of the fruits of the green lots of Experiment I attained a full red ripe color equal to the ripest of the ripe lots, the color of most of the fruits was somewhat more orange-red and of a lighter shade.

Pressure Tests

The means of the readings from the penetrometer with their respective probable errors, of all the lots after storage are given in Table I. In Experiment I, the range in the readings of the pressure test, taken with the skin on, is from 352 ± 9.0 to 410 ± 7.7 with an average of 376 ± 2.9 in the lots stored green, and from

261 ± 9.6 to 301 ± 8.6 with an average of 279 ± 3.4 in the lots stored ripe. In Experiment II, the mean pressure test readings range from 256 ± 6.9 to 323 ± 9.1 with an average of 284 ± 2.3. Comparing the averages of the lots stored ripe with the average of the lots stored green, there is, in both cases, a considerable difference in firmness of fruit as measured by the penetrometer. The difference between group 1 and group 2 of Experiment I is 97 ± 4.5.

TABLE I
Pressure Test

Treatment	Skin on			Skin off		
Experiment I	M gms.	PE gms.	CV* per cent	M gms.	PE gms.	CV per cent
Control Green	373	±6.3	13.4	104	±8.1	65.7
Cellophane Green	381	±8.1	16.9	128	±8.2	51.2
Parchment Green	376	±8.0	16.9	139	±9.4	53.8
Tissue Green	371	±6.3	13.1	262	±7.7	49.5
Waxed Tip Green	410	±7.7	14.5	158	±11.0	53.6
Formaldehyde Green	352	±9.0	20.5	102	±9.4	73.5
Borax Green	372	±7.2	15.1	121	±6.5	42.4
Control Ripe	275	±6.3	18.3	95	±6.7	56.2
Cellophane Ripe	275	±10.8	31.2	117	±7.5	50.9
Parchment Ripe	261	±9.6	28.8	99	±7.9	62.3
Tissue Ripe	262	±9.0	27.0	105	±7.9	58.9
Waxed Tip Ripe	301	±8.6	22.8	112	±8.0	57.3
Formaldehyde Ripe	285	±9.7	27.2	87	±6.8	62.1
Borax Ripe	295	±8.1	21.9	90	±7.2	63.5
Experiment II						
Control	258	±5.4	10.2	34	±3.0	43.8
Control with Calyx	300	±5.5	9.3	57	±7.6	68.6
Cellophane	323	±9.1	15.6	35	±2.9	43.1
Cellophane washed	316	±14.4	25.4	61	±5.8	52.6
Parchment	273	±6.4	13.0	47	±4.5	52.9
Parchment washed	261	±5.9	12.6	60	±5.9	55.6
Tissue	256	±6.9	14.9	31	±1.9	34.2
Tissue washed	291	±8.7	16.6	33	±2.5	42.1
Waxed Tip	291	±11.0	20.9	35	±3.7	58.8
Waxed Tip Washed	265	±7.5	15.7	49	±3.0	34.1
Waxed	279	±9.0	16.8	33	±4.7	78.5
Waxed Washed	299	±8.2	15.3	35	±3.7	58.0
Formaldehyde	295	±9.8	18.3	37	±2.5	37.0
Borax	266	±8.2	17.0	29	±2.2	42.4

TABLE II

Differences in Pressure Test - Experiment I
(in grams)

Treatment		Difference	Probable Error of Difference
Greater Value	Lesser Value		
Skin On			
Control Green	Control Ripe	98	± 8.9
Cellophane Green	Cellophane Ripe	106	±13.5
Parchment Green	Parchment Ripe	115	±12.5
Tissue Green	Tissue Ripe	109	±11.0
Waxed Tip Green	Waxed Tip Ripe	109	±11.6
Formaldehyde Green	Formaldehyde Ripe	67	±13.3
Borax Green	Borax Ripe	77	±10.8
Waxed Tip Green	Control Green	37	± 9.9
Waxed Tip Green	Tissue Green	39	±10.0
Skin Off			
Parchment Green	Parchment Ripe	40	±12.2
Tissue Green	Tissue Ripe	157	±11.0
Waxed Tip Green	Waxed Tip Ripe	46	±13.6
Borax Green	Borax Ripe	31	± 3.1
Waxed Tip Green	Control Green	54	±13.7
Tissue Green	Control Green	158	±11.1
Tissue Green	Waxed Tip Green	104	±13.4
Tissue Green	Parchment Green	123	±12.2
Tissue Green	Cellophane Green	134	±11.2
Tissue Green	Borax Green	141	±10.1
Tissue Green	Formaldehyde Green	160	±12.1

TABLE III

Differences in Pressure Test - Experiment II
(in grams)

Treatment		Difference	Probable Error of Difference
Greater Value	Lesser Value		
Skin On			
Tissue Washed	Tissue	35*	± 11.1
Control with Calyx	Control	42	± 7.7
Cellophane	Waxed	44	± 12.8
Cellophane	Parchment	50	± 11.1
Cellophane	Borax	57	± 12.2
Cellophane	Control	65	± 10.6
Cellophane Washed	Waxed Tip Washed	51*	± 16.3
Cellophane Washed	Parchment Washed	55	± 15.6
Cellophane Washed	Control	58	± 15.4
Waxed Washed	Parchment Washed	38	± 10.2
Waxed Washed	Control	41	± 9.8
Formaldehyde	Control	37	± 11.1
Formaldehyde	Tissue	39	± 12.0
Tissue Washed	Control	33	± 10.3
Skin Off			
Cellophane Washed	Formaldehyde	24	± 6.3
Cellophane Washed	Waxed Washed	26	± 6.7
Cellophane Washed	Cellophane	26	± 6.5
Cellophane Washed	Control	27	± 6.6
Cellophane Washed	Tissue Washed	28	± 6.3
Parchment Washed	Formaldehyde	23	± 6.4
Parchment Washed	Waxed Washed	25	± 7.0
Parchment Washed	Control	26	± 6.7
Parchment Washed	Tissue Washed	27	± 6.4
Waxed Tip Washed	Control	15	± 4.3
Waxed Tip Washed	Tissue Washed	16	± 3.9
Parchment	Tissue	16	± 4.9
Parchment	Borax	18	± 5.0

*Odds only 29 to 1 that difference is not due to chance.

The difference between group I and Experiment II are 92 ± 3.7 (odds in both cases over 15,000,000 to 1 against the difference being due to chance).

Differences in pressure test are given in Table II. All comparisons that appear in the table are Significantly different.

From Table II it may be seen that there is a significant difference in pressure test with the skin on between green and ripe lots of the same treatment, the green lots being firmer than the corresponding ripe lots. The difference was as great as 115 grams pressure in the case of the parchment wrapped fruits. Among the green lots the differences between the waxed tip and the control, and the waxed tip and the tissue were the only ones that were significant. The waxed tip was the highest of the group. Within the ripe lots of Experiment I, no significant differences were found from the results of the pressure test with the skin on, but, as with the green lots, the waxed was higher than the other lots.

With the skin removed, the means of the green lots ranged from 102 ± 9.4 to 262 ± 7.7 and averaged 145 ± 3.3; the ripe lots varied from 87 ± 6.8 to 117 ± 7.5 with an average of 101 ± 2.8. In Experiment II, the range in pressure test with the skin off is from 29 ± 2.2 to 61 ± 5.8, with an average of 33 ± 1.1.

Comparing this with the green lots of Experiment I there is a difference of 84 ± 6.7 (odds of over 15,000,000, to 1 that the difference is not due to chance). The difference between the two groups of Experiment I is 34 ± 4.3 (odds over 2,000,000 to 1 that the difference is not due to chance).

With the skin removed, the greatest pressure recorded on the green fruits was in the lot wrapped in tissue paper, and the next greatest was in the waxed tip lot. From a statistical viewpoint, the tissue wrapped lot was significantly greater than all the other lots, while the waxed tip lot was significantly greater than only the control. Grouping the borax, formaldehyde, and control, lots which were not wrapped, and tissue, parchment, cellophane, and waxed tip, lots which were protected, and comparing the two groups, a difference of 69 ± 6.58 grams is found (odds over 15,000,000, to 1 that the difference is not due to chance).

In Experiment II the lot showing the highest pressure test with the skin on was the cellophane wrapped lot, with the cellophane washed, control with calyx, waxed washed, formaldehyde, waxed tip and tissue, next in the order given. The last two lots were not significantly different. In comparing the various lots statistically, no washed lots were compared with unwashed unless

they received the same treatment after washing, excepting comparisons with the control. The control with calyx was compared with only the control.

The control with calyx, cellophane, cellophane washed, waxed washed, formaldehyde, and tissue washed were significantly greater in pressure test than the control. The cellophane wrapped lot was significantly greater in pressure test than the waxed, parchment and borax; the cellophane washed was greater than the waxed tip washed and parchment washed; waxed washed was greater than parchment washed; and formaldehyde was greater than tissue. The only treatment that showed significantly greater firmness when washed than when not washed was the tissue wrapped lot.

With the skin removed, the highest mean pressure test was the cellophane washed lot, with parchment washed, control with calyx, waxed tip washed, and parchment next highest. The control was significantly lower in pressure test than cellophane washed, parchment washed, and waxed tip washed. The cellophane washed lot was significantly higher than the formaldehyde, waxed washed, and tissue washed; parchment washed was significantly greater than the formaldehyde, waxed washed, and tissue washed; waxed tip washed was greater than tissue washed; and parchment was greater than tissue and borax. With the skin removed

the pressure test was significantly greater in the washed than in the unwashed lot of the cellophane wrapped lots.

A test for correlation was made in the green and ripe groups of Experiment I and in Experiment II between the pressure recorded with the skin on and with the skin removed. In the green lots, the correlation between the firmness with the skin on and the firmness of the same fruits with the skin removed was found to be 5.25 ± .034, a highly significant value according to the test of Fisher. Its squared value indicates that 27.6 per cent of the firmness of the fruit with the skin on is due to the firmness of the flesh.

The correlation coefficient of the ripe lots of Experiment I was found to be .33 ± .043, and though this group does not show as high an "r" value, it is greater than six times its probable error, and its squared value shows that 10.9 per cent of the pressure required to puncture the fruit is due to the firmness of the flesh. The correlation coefficient for Experiment II is .278 ± .044 which again is highly significant, though only 7.3 per cent of the firmness of the fruit with the skin on is due to the firmness of the flesh.

The coefficients of variability in the pressure test of the lots of both experiments are given in Table I together with the means and their probable errors.

The range in the coefficient of variability with the skin on was 13.1 to 20.5 per cent with an average of 15.8 per cent for the green lots, 18.3 to 31.2 per cent, averaging 25.3 per cent for the ripe lots, and 10.2 to 20.9 per cent, averaging 15.8 per cent for the lots of Experiment II. With the skin removed the range was 42.4 to 73.5 per cent with an average of 55.7 per cent for the green lots, 50.9 to 63.5 per cent, averaging 58.7 for the ripe lots, and 34.1 to 78.5 per cent, averaging 50.1 per cent for the lots of Experiment II. The variability is consistantly higher in the fruit with the skin removed than in the whole fruit. The ripe lots with the skin on were also consistantly higher in variability than the corresponding green lots, though no such relationship was found between the two groups with the skin removed.

The coefficients of variability of the controls with the skin on were consistantly low in both experiments. The control with calyx with the skin on showed a high uniformity in pressure test when compared with other treatments. This would seem to indicate that, in the whole fruit, any of the treatments used tend to increase the variability of the results, whether the results show greater or less degree of firmness in the treated lots over the untreated.

Loss in Weight

The mean per cent loss in weight with the probable error for each lot of tomatoes in both experiments is given in Table IV. The range of the loss in weight of the lots stored green was from 4.62 ± .25 per cent to 6.04 ± .28 per cent, while the range for the lots stored ripe was somewhat greater, 3.38 ± .35 to 6.04 ± .40.

The green lots had a higher percentage loss in weight than the ripe lots in five of the seven treatments, and in one treatment there was an equal loss in both green and ripe lots. On a statistical basis, tissue wrapping was the only treatment in which there was a significantly greater loss in weight in the lot stored green than in the lot stored ripe. Within the green lots, the treatment with borax wash lost significantly more weight than the control. The waxed tip lot lost significantly less weight than the cellophane wrapped, parchment wrapped, and borax. The greatest loss in weight of both the green and the ripe fruits was in the parchment wrapped lot, and the least loss in weight was in the waxed tip.

In the ripe lots, there was a greater range in the means of the percentage loss in weight, and there were also greater statistical differences between the various combinations. The control, cellophane, parchment, and borax had significantly greater losses in

weight than the tissue and the waxed tip, and the parchment also had a greater loss in weight than the formaldehyde. It is seen from this that tissue and waxed tip showed significantly less loss in weight than any of the other treatments except formaldehyde. Formaldehyde showed greater loss in weight than tissue and waxed tip, but the odds were only 2.2 to 1, and 4.7 to 1, respectively, against a greater loss in weight in formaldehyde treatment being due to chance.

In Experiment II the range in percentage loss in weight is from 5.42 ± .18 to 7.64 ± .55. The least loss in weight was with the waxed treatment, and the greatest loss with the control. The control differed significantly from the waxed tip and the waxed, while the control with calyx, having a slightly lower mean loss in weight, but on the other hand a very much lower probable error, showed significantly greater loss in weight than the cellophane, parchment, waxed tip, waxed, and waxed washed samples. These differences as well as those which follow are found in Table V. Of the five pairs of treatments which were, in one case, washed with formaldehyde before the treatment and, in the other case, received the treatment alone, the washed lots were consistently higher in loss in weight than the corresponding lots not washed; the cellophane wrapped, however, was the only one in which

Table IV

Per Cent Loss in Weight

Treatment	Mean	Probable Error of the Mean	Coefficient of Variability
Experiment I			
Control Green	4.91	±.24	39.3
Cellophane Green	5.76	±.25	34.9
Parchment Green	6.04	±.28	36.2
Tissue Green	5.16	±.19	29.1
Waxed Tip Green	4.62	±.25	42.8
Formaldehyde Green	5.47	±.27	37.1
Borax Green	5.88	±.13	17.5
Control Ripe	5.49	±.40	57.9
Cellophane Ripe	5.62	±.23	33.2
Parchment Ripe	6.04	±.40	52.8
Tissue Ripe	3.78	±.18	38.9
Waxed Tip Ripe	3.38	±.35	82.8
Formaldehyde Ripe	4.35	±.33	60.9
Borax Ripe	5.25	±.31	47.4
Experiment II			
Control	7.64	±.55	35.6
Control with Calyx	7.37	±.19	13.3
Cellophane	5.92	±.12	11.6
Cellophane Washed	7.04	±.24	18.6
Parchment	6.42	±.18	15.9
Parchment Washed	6.68	±.16	13.3
Tissue	6.53	±.30	25.0
Tissue Washed	6.96	±.28	22.3
Waxed Tip	5.65	±.16	16.1
Waxed Tip Washed	6.61	±.27	22.2
Waxed	5.42	±.18	18.5
Waxed Washed	6.21	±.20	18.3
Formaldehyde	7.05	±.15	11.6
Borax	6.97	±.40	32.1

TABLE V

Differences in Per Cent Loss in Weight

Treatment		Difference	Probable Error of Difference
Greater Value	Lesser Value		
Experiment I			
Tissue Green	Tissue Ripe	1.38	±.26
Borax Green	Control Green	.97	±.27
Cellophane Green	Waxed Tip Green	1.14	±.35
Parchment Green	Waxed Tip Green	1.42	±.37
Borax Green	Waxed Tip Green	1.26	±.28
Control Ripe	Tissue Ripe	1.71	±.44
Control Ripe	Waxed Tip Ripe	2.11	±.53
Cellophane Ripe	Tissue Ripe	1.84	±.30
Cellophane Ripe	Waxed Tip Ripe	2.24	±.42
Parchment Ripe	Tissue Ripe	2.26	±.44
Parchment Ripe	Waxed Tip Ripe	2.66	±.53
Parchment Ripe	Formaldehyde Ripe	1.69	±.52
Borax Ripe	Tissue Ripe	1.47	±.36
Borax Ripe	Waxed Tip Ripe	1.87	±.47
Experiment II			
Control	Waxed Tip	1.99	±.57
Control	Waxed	2.22	±.58
Control with Calyx	Cellophane	1.45	±.23
Control with Calyx	Parchment	.95	±.27
Control with Calyx	Waxed Tip	1.72	±.26
Control with Calyx	Waxed Washed	1.16	±.28
Control with Calyx	Waxed	1.95	±.26
Cellophane Washed	Cellophane	1.12	±.27
Cellophane Washed	Waxed Tip	1.39	±.29
Cellophane Washed	Waxed	1.62	±.30
Parchment Washed	Cellophane	.76	±.20
Parchment Washed	Waxed	1.26	±.24
Parchment Washed	Waxed Tip	1.03	±.23
Parchment	Waxed	1.00	±.26
Tissue Washed	Cellophane	1.04	±.31
Tissue Washed	Waxed Tip	1.31	±.32
Tissue Washed	Waxed	1.54	±.33
Tissue	Waxed	1.11	±.35
Waxed Tip Washed	Waxed	1.19	±.32
Formaldehyde	Waxed Tip	1.40	±.22
Formaldehyde	Cellophane	1.13	±.19
Formaldehyde	Waxed Washed	.84	±.25
Formaldehyde	Waxed	1.63	±.23
Borax	Waxed	1.55	±.44

the washed was significantly greater in loss in weight than the unwashed. Formaldehyde treatment had a greater loss in weight than all other treatments except the control and the control with calyx, but the differences were significant in only the waxed, waxed washed, waxed tip, and cellophane. Waxed had significantly smaller losses in weight than borax, tissue, and parchment.

Other lots were compared, some of which were found to be significantly different, and these are also reported in Table V. Those not specifically mentioned above, however, are not considered as fair comparisons. For instance, cellophane showed less loss in weight than tissue washed, but the latter is a combination of two treatments both different from the single treatment of the former.

The coefficient of variability was computed on all samples and this is also reported in Table IV. The mean coefficient of variability of the green lots 33.8 per cent, and the range was from 17.5 per cent with the borax lot to 42.8 per cent with the waxed tip. The ripe lots had a much higher average coefficient of variability, it being 49.6 per cent, or 15.8 per cent higher than the green lots. The lowest value in the ripe lots, 33.2 per cent was the cellophane wrapped lot, and the highest value, 82.8 per cent, was in the waxed tip lot,

which was also the highest of the green lots. With the ripe fruits, the waxed tip was over 20 per cent higher than the next highest value, but if one fruit which had a particularly high loss in weight was not included in the computation, the coefficient of variability was only 57.3 per cent. Other lots did not contain one fruit which alone so greatly altered the coefficient of variability. Comparing lots treated alike in the green and ripe groups, there was a larger variability in the ripe lots than in the green in all cases excepting the cellophane wrapped.

In Experiment II, the range in coefficient of variability was from 11.6 per cent with the formaldehyde treatment to 35.6 per cent in the control. The average for all the lots was 19.6 per cent. No consistent differences were found between the washed and unwashed lots of a treatment. The control had a coefficient of variability nearly three times that of the control with calyx. This would indicate that much of the variability in the loss in weight was due to evaporation which takes place through the stem scar.

Except for a few cases, the coefficient of variability followed the trend of the probable errors of the means in both experiments.

Ascorbic Acid

Vitamin C or ascorbic acid was found to be present in least amount in the green lot not stored, .1300

milligrams per gram of fresh fruit. The ripe unstored lot was calculated to have .1675 milligrams per gram of fresh material. Group 1 was found to have an average of .1794 milligrams, and group 2 an average of .1779 milligrams per gram of fresh fruit. Maclinn, Fellers, and Buck (35) found that storage at room temperature up to ten days resulted in no loss in vitamin C. They also noted that Florida grown tomatoes picked green in January, showed no difference in vitamin C content whether they were wrapped in parchment or unwrapped, or whether partly or fully ripe, though the amount was less than in native grown fruits.

Acidity

Hydrogen-ion concentration showed little variation among the samples, the range being from pH 4.3 to 4.6, the two groups averaging practically the same. Titrable acidity is reported on the basis of the milliliters of N/10 sodium hydroxide required to neutralize one gram of fresh material. In the samples not stored, this amount was .52 ml. for the green lot and .64 ml. in the ripe lot. This is in agreement with the results of Sando (52), namely that during the ripening period there is an increase in titrable acidity. The range in the green stored lots was from .21 to .52 ml. with an average of .38 ml., and in the ripe stored lots from .35

to .56 with an average of .44 ml.

Chemical Analysis

In Tables VI, VII, VIII and IX are given the results of the chemical analyses of the lots of Experiment I. In Tables VI and VIII, the results are reported on the basis of the air dry sample, and in Tables VII and IX, they are calculated to the fresh basis.

According to Table VII, the total solids ranged from 4.6 to 5.4 per cent, and averaged 5.2 per cent in the lots stored green, and from 4.3 to 5.5, with an average of 4.8 per cent in the lots stored ripe. Rosa (51) found a decrease in total solids from 7.29 to 6.05 per cent during artificial ripening in air. The parchment wrapped lots contained the greatest amount of total solids in both groups.

On the basis of the fresh weight, total ash ranged from .38 to .44 per cent in the lots stored green, and from .36 to .52 per cent in the lots stored ripe, with averages of .41 and .44 per cent respectively. Though the averages showed a slight difference, there were no consistent differences between corresponding lots of the two groups. As with total solids, parchment wrapped was the highest in ash content.

In the tomatoes stored green, there was a variation in the nitrogen content from .15 to .25 per cent with an avetage of .20 per cent, and in the tomatoes

TABLE VI

Analysis of the Air Dry Sample
(in per cent)

	Moisture	Ash	Protein*	Ether Extract	Crude Fiber°	N-Free Extract	Reducing Sugars+
Fruits Stored Green							
Control	6.00	8.91	20.25	3.44	9.98	51.42	31.80
Cellophane	5.54	10.11	28.75	2.98	11.10	41.52	23.14
Parchment	6.31	10.02	21.50	3.18	11.25	47.74	23.43
Tissue	5.19	8.94	20.81	3.06	9.83	52.17	29.41
Waxed Tip	5.21	10.03	28.81	3.38	11.23	41.34	23.90
Formaldehyde	4.90	10.09	21.63	3.18	11.18	49.02	24.67
Borax	5.00	10.14	22.85	3.32	10.73	47.96	23.80
Fruits Stored Ripe							
Control	4.33	8.53	30.11	3.02	9.98	44.03	20.07
Cellophane	5.80	7.88	18.35	2.85	9.13	55.99	38.52
Parchment	5.19	8.34	19.44	3.31	9.83	53.89	34.52
Tissue	6.10	8.80	31.09	3.31	10.10	40.60	28.40
Waxed Tip	5.97	8.51	31.13	3.26	9.43	41.70	32.66
Formaldehyde	4.96	8.24	19.10	3.08	9.58	55.04	34.44
Borax	4.69	8.57	31.08	3.29	10.25	42.12	31.56
Fruits Not Stored							
Green	3.56	7.94	19.13	3.90	9.55	55.92	31.28
Ripe	3.71	9.23	19.38	3.03	9.50	55.05	32.18

*Total nitrogen X 6.25
+Calculated as glucose
°Determined by Mr. Phil. Smith of the Experiment Station.

TABLE VII

Analysis of the Sample (fresh basis)

	Moisture	Total Solids	Ash	Protein#	Reducing+ Sugars	Ether Extract	Crude° Fiber	Ascorbic Acid mg/gm	pH	cc N/10* NaOH
Fruit Stored Green										
Control	94.6	5.4	.44	1.56	1.04	.16	.52	.179	4.6	.40
Cellophane	94.5	5.5	.41	.94	2.00	.15	.47	.194	4.4	.56
Parchment	94.4	5.6	.44	1.06	1.83	.18	.53	.223	4.6	.37
Tissue	95.4	4.6	.38	1.31	1.23	.14	.44	.201	4.6	.42
Waxed Tip	94.7	5.3	.42	1.56	1.63	.16	.47	.136	4.6	.35
Formaldehyde	94.6	5.4	.42	1.00	1.77	.16	.49	.179	-	-
Borax	95.2	4.8	.38	1.44	1.44	.15	.47	.144	4.6	.55
Fruits Stored Ripe										
Control	95.7	4.3	.36	.81	1.29	.14	.40	.172	4.6	.40
Cellophane	95.4	4.6	.44	1.25	1.01	.13	.48	.168	4.5	.21
Parchment	94.5	5.5	.52	1.13	1.21	.16	.58	.187	4.5	.40
Tissue	94.9	5.1	.43	1.00	1.42	.15	.48	.172	4.6	.32
Waxed Tip	95.6	4.4	.42	1.31	1.00	.14	.47	.172	4.5	.40
Formaldehyde	95.6	4.4	.42	.88	1.03	.13	.47	.203	4.5	.40
Borax	94.6	5.4	.52	1.19	1.22	.17	.55	.172	4.3	.52
Controls Not Stored										
Green	96.4	3.6	.28	.69	1.09	.10	.43	.130	4.6	.52
Ripe	94.2	5.8	.71	1.06	2.48	.17	.53	.168	4.5	.64

#Total nitrogen X6.25
*ccN/10 NaOH to neutralize 1 gm. fresh material
+Calculated as glucose
°Determinations made by Mr. Phil. Smith of the Experiment Station

TABLE VIII

Analysis of the Air Dry Sample
(in per cent)

Soluble solids, ash, and nitrogen.*

		Green		Ripe	
		Not Stored	Stored	Not Stored	Stored
Water	Solids	73.17	78.97	78.77	79.39
	Ash	99.02	98.89	99.26	99.54
	Nitrogen	.447	.430	.505	.525
Hydrochloric Acid	Solids	72.65	77.05	77.08	79.14
	Ash	99.47	99.39	99.69	99.38
	Nitrogen	.488	.440	.515	.508
Sodium Carbonate	Solids	77.28	80.66	81.67	81.71
	Ash	98.64	99.11	99.11	99.15
	Nitrogen	.519	.474	.525	.617
Hydrochloric Acid+Pepsin	Solids	76.46	78.87	80.55	80.74
	Ash	99.58	99.41	99.47	99.51
	Nitrogen	.623	.549	.661	.671
Sodium Carbonate +Trypsin	Solids	74.86	82.87	72.01	83.16
	Ash	97.48	98.93	96.88	98.76
	Nitrogen	.711	.664	.623	.728

*Figures represent soluble constituents in relation to totals.

TABLE IX

Analysis of the Sample (in Per Cent)
(Fresh Basis)

Soluble solids, ash, and nitrogen*

		Green		Ripe	
		Not Stored	Stored	Not Stored	Stored
Water	Solids	2.63	4.26	4.57	3.41
	Ash	.28	.44	.71	.36
	Nitrogen	.049	.108	.086	.068
Hydrochloric Acid	Solids	2.62	4.16	4.47	3.40
	Ash	.28	.44	.71	.36
	Nitrogen	.054	.110	.088	.066
Sodium Carbonate	Solids	2.78	4.36	4.74	3.51
	Ash	.28	.44	.70	.36
	Nitrogen	.057	.119	.089	.080
Hydrochloric Acid+Pepsin	Solids	2.75	4.26	4.67	3.57
	Ash	.28	.44	.71	.36
	Nitrogen	.069	.137	.112	.087
Sodium Carbonate +Trypsin	Solids	2.69	4.47	4.18	3.58
	Ash	.27	.45	.69	.36
	Nitrogen	.078	.166	.106	.095

*Figures represent soluble constituents in relation to totals.

stored ripe, there was a variation of from .13 to .21 per cent with an average of .17 per cent. Nitrogen in the unstored green control was less in amount than in any of the stored lots or the ripe control not stored. Rosa (50) found a steady increase in total nitrogen as the fruit ripened.

On the basis of the fresh weight reducing sugar calculated as glucose varied in the green lots from 1.04 to 2.00 per cent, averaging 1.56 per cent, and in the ripe lots from 1.00 to 1.42 per cent, averaging 1.17 per cent. Alwood and Bowman (2) stated that the only sugar which exists in the tomato is of the "glucose kind", and reported a range of from 1.59 to 2.71 per cent and an average of 2.09 per cent glucose in ripe tomatoes. According to Table VII the highest value of all the lots was in the ripe control not stored, a result which is in agreement with that reported by Rosa (50), and Sando (52). The green control not stored was lower in reducing sugars than the average of either of the stored groups and lower than the ripe control, not stored, though it was not consistently lower than all the lots when compared with each of the lots individually.

Ether soluble material varied in group I from .14 to .18 per cent with an average of .16 per cent and in group 2 from .13 to .17 per cent with an average of

.15 per cent. The green control, not stored, contained the least amount of ether soluble material and the ripe control, not stored, was equalled or exceeded by only two lots in the stored groups, though these changes may have been due to differences in the proportion of other materials.

In the green control, not stored, crude fiber was found to be .43 per cent, in the green lots stored it averaged .48 per cent, in the ripe lots stored, .49 per cent, and in the ripe control not stored, .53 per cent.

Total soluble solids, ash and nitrogen, for the four controls are given in Tables VIII and IX. The amounts soluble in water, in N/10 hydrochloric acid solution, in .5 per cent sodium carbonate solution in N/10 hydrochloric acid and .05 per cent pepsin solution, in .5 per cent sodium carbonate and .125 per cent trypsin solution are all reported. The same relationship exists among the lots in regard to solubility in the various solutions. Examination of the table shows that the least amount of soluble material was in the green lot not stored, with the ripe stored lot, green stored, and ripe not stored higher in the order named. Solubility did not vary greatly in water and dilute hydrochloric acid.

In all cases, there was more soluble material in sodium carbonate solution than in the water or hydrochloric acid. The total solids soluble in the solutions containing enzymes would be expected to be greater than in the solutions without enzymes. This was true except in the controls not stored, which, when digested with sodium carbonate, yielded more soluble material than when digested with trypsin and sodium carbonate. This was probably due to poor filtering.

Soluble ash was lowest in all solutions in the green lot not stored, next lowest in the ripe stored, then in the green stored, and highest in the ripe not stored. There was little variation in the solubility of the ash in the different solutions.

As with ash and total solids, soluble nitrogen was least in amount in the unstored green lot, and increased in the lots in the following order: ripe stored, ripe unstored, and green stored. The same order was followed in all the solutions, and except for two small deviations, the amount soluble in the five solutions increased in order from water, hydrochloric acid, sodium carbonate, hydrochloric acid and pepsin, to sodium carbonate and trypsin.

Disease and Total Shrinkage

The percentage of fruits marketable, of

fruits showing disease, and total shrinkage is given in Table X. Total shrinkages as reported in the table, includes total loss in weight of marketable fruits and total wastage because of unmarketability of fruits. An average of the groups of Experiment I indicates that the incidence of disease was over twice as large in the ripe lots as in the green lots. The lots treated with disinfectant and the controls showed a smaller number of diseased fruits than any of the other lots of Experiment I. The greatest number of diseased fruits was found in the cellophane and parchment wrapped lots.

In Experiment II, the occurrence of disease was lowest in the cellophane washed lot, with waxed washed, and tissue washed next. The greatest occurence of disease was in the waxed tip and waxed lots. The average percentage of diseased fruits of the control, cellophane, parchment, tissue, waxed tip, and waxed lots was 68.9 per cent, while the average of lots washed with formaldehyde and then treated as the above was 33.3 per cent, showing a reduction to half the incidence of disease in the washed lots. Occurrence of disease was consistently lower in the washed lots than in those not washed.

TABLE X.

Per Cent of Fruits Marketable and Diseased, and
Per Cent Total Shrinkage

Treatment	Marketable	Diseased	Total Shrinkage
Experiment I			
Control Green	93.3	3.3	8.9
Cellophane Green	83.3	20.0	20.9
Parchment Green	83.3	20.0	21.0
Tissue Green	86.7	16.7	17.8
Waxed Tip Green	80.0	16.7	25.7
Formaldehyde Green	100.0	3.3	5.4
Borax Green	86.7	6.7	19.0
Control Ripe	86.7	16.7	16.0
Cellophane Ripe	66.7	43.3	39.6
Parchment Ripe	63.3	43.3	38.8
Tissue Ripe	80.0	33.3	22.0
Waxed Tip Ripe	83.3	23.3	19.5
Formaldehyde Ripe	86.7	13.3	14.0
Borax Ripe	76.7	16.7	26.1
Experiment II			
Control	73.4	60.0	7.9
Control with Calyx	93.4	66.6	13.6
Cellophane	86.6	53.4	15.6
Cellophane Washed	80.0	20.0	25.4
Parchment	60.0	66.6	38.9
Parchment Washed	86.6	46.6	18.1
Tissue	53.4	66.6	45.8
Tissue Washed	80.0	26.6	27.0
Waxed Tip	46.6	80.0	48.7
Waxed Tip Washed	80.0	33.4	33.2
Waxed	33.4	86.6	63.0
Waxed Washed	86.6	26.6	18.0
Formaldehyde	66.7	46.6	34.4
Borax	60.0	46.6	40.2

The average percentage of marketable fruits in group 1 was 87.6 per cent and of group 2 was 66.2 per cent, or a reduction of 20% marketable fruits in the ripe lots.

In Experiment II, the percent of marketable fruits was greater in the washed than in the unwashed lots, averages being 82.6 and 56.0 per cent respectively. In other words, washing increased the per cent of marketable fruits by 25 per cent.

Total shrinkage as reported in Table X averaged 17.0 per cent for the green lots and 25.1 per cent for the ripe lots in Experiment I, and for Experiment II, 30.7 per cent. Comparing the unwashed lots with the similarly treated washed lots of Experiment II, the average for the former is 42.4 per cent and for the latter 25.3 per cent.

The disease which caused the greatest loss in the stored fruits was Phoma rot, Phoma destructiva, Plowr. Anthracnose, Colletotrichum phomoides (Sacc.) Chester, and Cladosporium or green mold rot, Cladosporium fulvum Cke. were also present but caused comparatively small losses. Several other molds were present but seemed to be secondary infections and not the initial cause of any decay.

A form of physiological breakdown (see plates) was noted

particularly in the lots of Experiment II. On the outside of the fruit, it appeared as a mottling of the flesh with lighter colored areas. The mottling was not distinct, but appeared as a diffused wide whitish veination. When the epidermis was removed, it was seen that the whitish areas followed the vascular system. A cross section of the fruit showed that the cells of these areas have a silvery white appearance, which Weber and Ramsey (61) explained as signifying a lack of moisture. The entire flesh of the outer wall did not show the breakdown, but only the portion nearest the epidermis and in the region of the vascular bundles, though the width of the area in cross section varied considerably. Occassionally the breakdown followed the vascular bundles a slight distance into the inner walls.

Weber and Ramsey referred to the condition as "cloudy spot", and stated that, though it is not common, it is found in most tomato growing areas of Florida. They stated that there is no organism associated with it, but found that it seemed to be confined to individual plants scattered here and there in the field.

No such abnormality was noted in the fruits previous to storage, but close examination of the cross sections of the tomatoes after storage showed that

nearly all of them gave some evidence of the condition, some showing it to only a slight degree and in very small areas, while in others the entire fruit showed distinct and heavy veination, which sometimes extended into the inner walls. In this experiment, the condition did not seem to be due to variations in individual plants, but to some environmental factor affecting the fruits after harvest and during storage. Though there is no known cause for the abnormality, it is possible that low temperature during storage combined with the loss of moisture might be, at least in part, the cause of the condition.

All fruits in the second experiment were rated according to arbitrary standards, on the severity of this breakdown. The results of this rating showed that the condition was most severe in the formaldehyde, borax, and control with calyx, and the least severe in parchment washed, with cellophane washed and parchment next.

Conclusions and Summary

Under the conditions of these experiments, namely a temperature of 45 to 50°F and a relative humidity of 45 per cent, 20 to 30 days was found to be the optimum length of the storage period for ripe tomatoes. Green mature and pink tomatoes can be kept for

30 days or longer under the same conditions, and will develop slowly a full red ripe normal color.

The firmness of the fruit was observed to diminish during the ripening process. Rosa (50) found that during artificial ripening in air (and ethylene), softening did not occur as rapidly as in vine ripened fruits. In the present experiment, the green fruits, after 31 days storage, were found to be much firmer as measured by the pressure tester than the ripe lots after 19 days storage. The fruits of the waxed tip treatment were the firmest of both the green and the ripe lots of Experiment I. In Experiment II, the cellophane wrapped lot was the firmest. In general, no difference was found between the washed and the unwashed lots of the same treatment.

Considering the firmness of the flesh with the skin removed, as measured by the pressure tester, the lots stored green which ripened in storage were again much firmer than the lots which were ripe when stored. As with the skin on, no difference was observed between the washed and the unwashed lots of Experiment II. With the skin removed, the lot showing the highest average pressure test for the green stored fruits was the tissue wrapped lot, and for the ripe stored fruits was the cellophane wrapped lot. In Experiment II, with

the skin removed, the cellophane formaldehyde washed lot showed the highest average pressure test.

The firmness of the tomato fruit is probably due, for the most part, to two factors, one, the actual firmness of the flesh, and the other, the toughness of the skin. The degree to which the firmness of the fruit is dependent upon the soundness of the flesh, was found to be about 15 per cent. It may be assumed, then, that 85 per cent of the differences in firmness of the whole fruit is due to toughness of the skin, experimental error, and experimental differences. How much is due to actual differences in experimental treatments cannot be stated on the basis of the data obtained and here presented.

The variability in the firmness of the whole fruits was comparatively small, being around 15 to 20 per cent. This might be explained on the basis of the following assumption: if two fruits, one with soft flesh and one with firm flesh were tested by the penetrometer, the soft fruit might resist puncture by as great a pressure as the firm fruit due to the elasticity and toughness of the skin of the soft fruit, whereas, with the firm fruit, the skin is taut and resists puncture with no greater pressure than the softer fruit.

The variability in the firmness of the flesh

was, however, considerably higher, averaging 55 per cent. On the basis of the above assumption, this would be expected because, in this case, the flesh resisted puncture solely with its own firmness and unprotected by the skin.

Losses in weight were smaller in the ripe than in the green lots of Experiment I. Normal loss in the weight of tomatoes during storage is due to respiration and evaporation. Greater losses in weight may be caused by disease. This difference in loss in weight between the green and ripe fruits might be explained by a report by Gustafson (22) concerning the ripening of fruit on the vine. He stated that during normal growth, a decrease in the rate of respiration occurs, reaching a minimum at the green mature stage of maturity; this is followed by an increase during ripening, reaching a maximum when the fruits are orange to red in color; this is then followed by another decrease in the rate of respiration.

If the same changes in the rate of respiration occur during the artificial ripening of fruit, the green fruits, respiring more rapidly than the ripe fruits, would be expected to lose more weight. This is substantiated by the results as stated above.

The smallest loss in weight in both groups of

Experiment I was in the waxed tip lots. Total shrinkage, however, was least with the formaldehyde treatment, and as these lots also showed the least number of diseased fruits, it may be assumed that greater losses are due to disease than to the normal factors of evaporation and respiration.

The results of Experiment II further substantiate the above assumption that the greatest losses occurred as a result of disease, for with a lower percent of diseased fruits, there was also a lower per cent total shrinkage. Comparing any two lots which showed large differences in the percentages of diseased fruit, it was found that the total shrinkage in most cases varied directly as the percentage of fruits diseased, while the mean percentage loss in weight, which may be greatly affected by other environmental factors than disease, may show an inverse proportion. If disease were not such a large factor in total losses, the total shrinkage should vary directly as the mean per cent loss in weight.

The percentage of fruits showing disease, and the total shrinkage were found to be reduced 50 per cent as the result of washing the fruits with formaldehyde solution previous to further treatment. Such a great reduction did not occur unless some protection against further infection was provided, either by wrapping or

by sealing the stem scar.

No single treatment seemed to show a greater uniformity in loss in weight than any of the others. All of the treatments showed some variability, though the lots stored ripe were considerably more variable in loss in weight than those stored green.

The percentage of fruits marketable was dependent almost wholly upon the percentage of disease. In Experiment I, disease was the cause of 85 per cent of the unmarketability, and in Experiment II, the percentage of fruits unmarketable, due to disease, was 82 per cent.

Phoma rot was the most common disease causing loss of marketable fruit.

Cloudy spot, a physiological disturbance, was observed after storage in nearly all the fruits used in Experiment II. In severe cases, the fruit was rendered unfit for market. In moderate cases, it detracted from the appearance of the fruit. From the observations made in this experiment, it seemed quite possible that low temperature, combined with loss of moisture, had some influence in causing the breakdown.

As the chemical analyses were made on composited samples, there was no way of testing statistically the value or significance of the results obtained. The results can, however, be assumed to show trends.

The lot harvested green and not stored, contained the least amount of solid material, and the lot ripened on the vine and not stored showed the greatest amount of solid material. The green lots apparently lost a much greater amount of moisture during storage than did the ripe lots, for after storage, the green lots contained a higher percentage of solids, and the ripe lots a lower percentage of solids than they contained before storage. The above statement may be assumed to be true since the average of the percentage losses in weight is greater for the green than for the ripe lots, together with the fact that, during storage, evaporation is a much greater cause of loss in weight than respiration.

When calculated on the basis of the fresh weight, the percentage differences in the results of the chemical analyses for the various constituents were dependent, to a large degree, upon differences in percentage of dry weight. On the basis of the air dry and oven dry samples, some rather large differences in composition were observed, but when calculated to the fresh weight basis, these differences were masked by the large amount of water present in the fresh fruit. Sugar and acid were probably the most important constituents modifying the flavor and hence the quality

of tomatoes. These varied rather widely in the different lots, but variations within the green and the ripe groups did not show any consistant differences, though the green lots retained more of their reducing sugars than the ripe lots. This might be expected on the basis of Rosa's statement that reducing sugars increase during normal ripening. He stated also that acidity increases during ripening, but no such increase was found in the present experiment.

Soluble solids were also found to increase during ripening in storage, but the amount was never as high as in the vine ripened fruit. The amount of soluble solids would affect flavor only in so far as the amount of sugars contained in the soluble solids.

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Plate I

Cloudy Spot in Tomato

Plate II

Initial and Advanced Stages of Cloudy Spot

Epidermis Removed

Plate III

Initial and Advanced Stages of Cloudy Spot

Cross Section of Tomato

Approved by

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Date June 3, 1938