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UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 859

Contribution from the Bureau of Plant Industry
WM. A. TAYLOR, Chief

Washington, D. C. | September 7, 1920

THE PROCESS OF RIPENING IN THE TOMATO, CONSIDERED ESPECIALLY FROM THE COMMERCIAL STANDPOINT

By

CHARLES E. SANDO
Formerly Junior Chemist, Horticultural and Pomological Investigations

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SHIPMENTS OF EARLY TOMATOES TO NORTHERN MARKETS.

The shipping of tomatoes grown in Florida to northern markets during the winter and spring months is an exceedingly important industry. In Table I are presented statistics prepared by the Bureau of Crop Estimates and the Bureau of Markets of the United States Department of Agriculture, showing the production and car-lot shipments of the seven States where the early-tomato crop is chiefly grown.

From the figures shown in Table I it can be seen that Florida ships annually more than half of the total quantity of early tomatoes forwarded from the seven States specified. Statistics show that

[1] This bulletin gives the results of a portion of the work carried on under the project "Factors affecting the storage life of vegetables". The paper was completed after the writer was transferred to the Office of Drug-Plant, Poisonous-Plant, Physiological, and Fermentation Investigations of the Bureau of Plant Industry.

The writer wishes to express his special indebtedness to Mr. Thomas J. Peters, of Miami, Fla., for providing facilities for the field work and for cooperating in other ways. He desires also to express his thanks and appreciation to Mr. H. H. Bartlett, of the botanical department of the University of Michigan, for counsel and suggestions during the progress of the work.

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the industry in Florida is very largely concentrated in Dade and Broward Counties, at the southern tip of the State.

TABLE I.—*Production of early tomatoes in the principal producing States of the United States, showing also car-lot shipments, for the 5-year period from 1915 to 1919, inclusive.*

State.	Crop production (tons).					Car-lot shipments.[a]				
	1919	1918	1917	1916	1915	1919	1918	1917	1916	1915
California	17,380	11,880	17,390	20,170	18,750	139	1,513	518	1,169	871
Florida	58,520	46,800	77,480	101,170	91,390	4,478	3,695	4,493	6,184	4,692
Louisiana	....	600	1,810	2,209	2,524	2	10	14	58	58
Mississippi	18,400	21,150	15,680	25,250	20,100	[b]1,388	[b]1,379	[b]1,063	[b]1,663	[b]1,690
Tennessee	6,000	10,500	13,020	29,320	24,010	366	654	947	590	529
Texas	17,700	16,000	16,430	10,770	11,260	1,198	1,123	1,276	1,153	1,318
Virginia	....	69,108	75,540	85,285	62,212	....	97	173	192	121
Total	118,000	176,038	217,350	274,174	230,246	7,571	8,471	8,484	11,009	9,279

[a] Estimated at 13 tons per car except in Mississippi, where the average is 10½ tons per car.
[b] Carloads of 10½ tons.

In spite of the fact that thousands of cars of Florida tomatoes are shipped to the North each year, the quality of a large percentage that reaches the consumer is admittedly inferior in many respects to vine-ripened or greenhouse tomatoes. Tracy (52)[1] makes the following statements in regard to the inferiority of shipped fruit:

> The tomato never acquires its full and most perfect flavor except when ripened on the vine and in full sunlight. Vine and sun ripened tomatoes, like tree-ripened peaches, are vastly better flavored than those artificially ripened. This is the chief reason why tomatoes grown in hothouses in the vicinity are so much superior to those shipped in from farther south.

It is the custom to pick the fruit when grass green and allow it to ripen and color in ripening rooms before shipment, while in transit, and after arrival at the market. Numerous complaints have been made by commission men and others that a large proportion of the tomato crop from the east coast of Florida is picked and shipped too green. When this is done, the fruit ripens very slowly, has a tendency to wrinkle, colors abnormally, and has a bad taste and flavor. Moreover, for quite different reasons, the growers prefer, when shipping their tomatoes, to have the fruit arrive in a slightly colored condition. The arrival of green fruit at the terminal often has the effect of glutting the market. The buyer is compelled to hold the fruit while ripening and consequently assumes a risk of losing a portion, whereas if the shipment is colored when it arrives he is able to dispose of it immediately.

Since the difficulties just enumerated bear a close relationship to field practice and to packing and shipping operations, the writer was stationed at Miami during the growing seasons from 1917 to 1919 in order to gain first-hand knowledge of the industry and to

[1] The serial numbers in parentheses refer to "Literature cited" at the end of this bulletin.

conduct experimental work with material grown under the conditions peculiar to Florida.

The quality of a tomato is largely determined by the amount and kind of sugars, plant acids, and vitamins which are present. It was obvious, therefore, that the method of approaching the problem would be a chemical one. If the chemical composition of vine-ripened tomatoes were known for a number of stages in the process of ripening, the data would afford a criterion for judging commercially ripened fruit.

GROWING AND HANDLING TOMATOES IN THE FIELD.

In the region about Miami, Fla., the seed beds are prepared as early as the middle of September and are planted at intervals until the early part of February in order to insure a steady supply of seedlings. In transplanting seedlings they are placed full length in the furrow, the roots are covered with a handful of moist well-rotted stable manure, and finally the whole stem, but not the leaves, is covered with loose soil. Commercial fertilizer is often used with the manure.

The soil upon which tomatoes are grown is essentially of an everglade type and is covered with water during a portion of the summer. For the past few years the moist soil and the danger of frost have been serious handicaps to very early planting. To insure a crop of tomatoes in case of frost many growers plant a portion of their fields in hills. The seeds are planted over stable manure and commercial fertilizer. After the seedlings appear the hills are thinned to one plant, which is allowed to grow to 6 inches or more in height and then bent down and covered with soil. The plants are 2 to 3 feet apart in rows 6 feet apart.

Commercial fertilizers are applied throughout the growing season up to picking time. Where only one side of the row is cultivated and the other allowed to grow in weeds, upon which the plants later lean, the fertilizer is applied in furrows on the side which is cultivated. About a week or 10 days after the plants are set out a small handful of the fertilizer is placed on one side of each plant. Sometimes it is covered with soil, but generally it is left uncovered. Ten days or two weeks after the first application, more fertilizer is applied between the plants in the original planting furrow. A shallow furrow is then turned to cover this fertilizer and also to support the plants better. The third application is placed in the furrow made when the second application was covered. The quantity is generally larger than the first and second applications and is covered by a new furrow. The fourth and final application is made in the same way. Where the fertilizer is applied at one side only, two rows are planted close together and between them weeds are allowed to grow. Where fertilizer is applied to both sides of the plants the rows are 6 feet apart. The procedure is the same. The usual practice is to fertilize at the rate of 1 to 1½ tons per acre, the last application being made several weeks before picking. The interval between applications varies with weather conditions and the growth of the plants. The custom is to locate the position of the rootlets along the side of the furrow made at the preceding application and to keep a quantity of fertilizer just ahead of these rootlets, so that a constant supply is available for the plant.

The time of picking the tomatoes of course depends upon the age and condition of the fruit. Many growers believe that it is an easy matter to determine the maturity by the character of the darkened area around the stem end. Toward the last stages of maturation the chlorophyll gradually disappears, especially around the stem end,

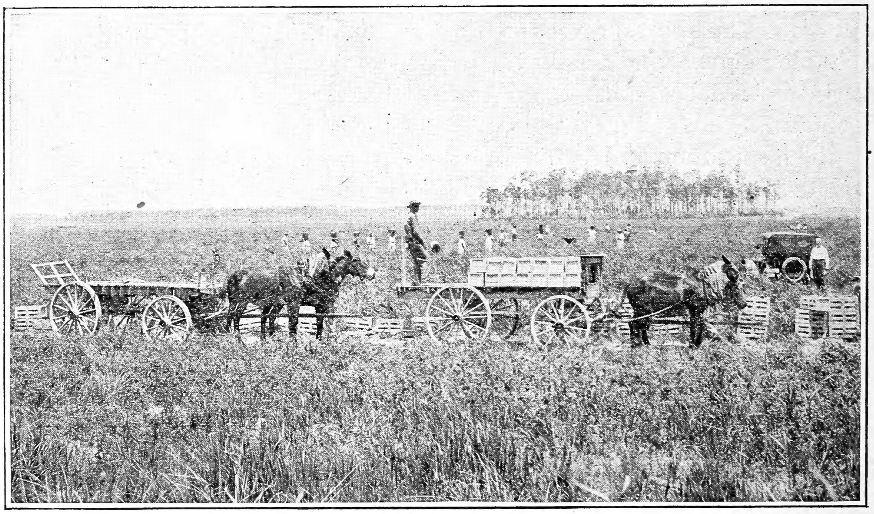

FIG. 1.—A tomato field in Florida.

where a whitened area is left. Fields are gone over once a week by the pickers, who collect the fruit in baskets or tin buckets. (Fig. 1.) In general the pickers (Nassau negroes) do not pay much attention to the color of the tomatoes, but gather those that appear large enough to ship. The tomatoes are dumped into field boxes at the ends of the rows and carried by wagon to the ripening house or packing house. The fruit is generally handled carefully, but often it is dropped from the gathering bucket to the field crate without the picker even bending over.

PACKING AND SHIPPING OPERATIONS.

Until recently the fruit was sorted, packed, and shipped immediately upon its arrival at the packing house, but the loss through disease and bruising was so great that it became necessary to adopt the ripening house as a means of culling out undesirable fruit before shipping. In the ripening house the fruit is stored at a temperature of 75° to 85° F. for a variable period, depending upon the uniformity and maturity of the tomatoes at the time of picking. When most of them show a very slight red coloration they are removed and carefully sorted; all diseased fruits are discarded and the colored ones are graded, wrapped, and packed for shipment. Green fruit goes back to the ripening room. Improper conditions of ventilation, humidity, and temperature in the ripening room often increase the amount of disease, since such conditions favor the germination of fungous spores and the spread of infections brought from the field. Nevertheless, this method of allowing diseases to develop and then culling the fruit before shipping saves paying transportation charges on spoiled fruit, as well as additional loss in transit through the spreading of infection to healthy fruit.

The use of the ripening room is restricted to the early months of shipping, when the weather conditions are such as to allow the fruit to be shipped in a colored condition. The temperature is generally low enough to prevent too rapid ripening, and when the fruit reaches the North the temperature is still colder, thus allowing the fruit to be kept for a considerable length of time before it becomes too ripe. Later in the season, however, it is inadvisable with the present methods of handling to ship colored fruit. The tomatoes are kept in the ripening room for two or three days, to allow infections to develop, and are then sorted and shipped. In general, after warmer weather sets in the green fruit goes directly to the packing house from the field and is graded and shipped at once. Sometimes it ripens in transit, but more often it arrives green and has to be ripened at the terminal. Frequently the fruit is packed in such an immature state that it never attains its normal color. In such instances the grower loses both in reputation and in financial return.

When the tomatoes arrive at the packing shed they are dumped into bins, which usually are large enough to hold several crates. From these bins the grader culls all undesirable fruit and throws the good fruit into other bins, assorting according to size. Packers standing directly in front of the bins wrap the fruits individually in special tomato paper and pack them in 4-quart baskets. Each basket requires smaller fruit at the bottom layer than at the top, where the basket is wider, but in every basket the fruit is packed very tightly; in some cases quite a little squeezing is necessary. Six baskets are placed in each crate. The top is considerably bulged, owing to the close packing of the baskets. Crates in various stages of packing are shown in figure 2.

The method of packing crates for shipment just described is unfortunately the one generally used at the present time, but there is another method that deserves careful consideration, in which the fruit after it is picked is washed and handled by means of a machine.

The field crates used in connection with the machine, and also by many growers who do not use a machine, are made of hardwood mill edgings that have been carefully planed and smoothed, especially where the tomato is likely to come in contact with them. The crate is open, so that all sand and dirt fall through and do not injure the tomatoes during hauling.

When the tomatoes arrive at the packing shed they are dumped into a large tank at the end of the machine, which contains a special washing solution kept at as high a temperature as the fruit will stand.

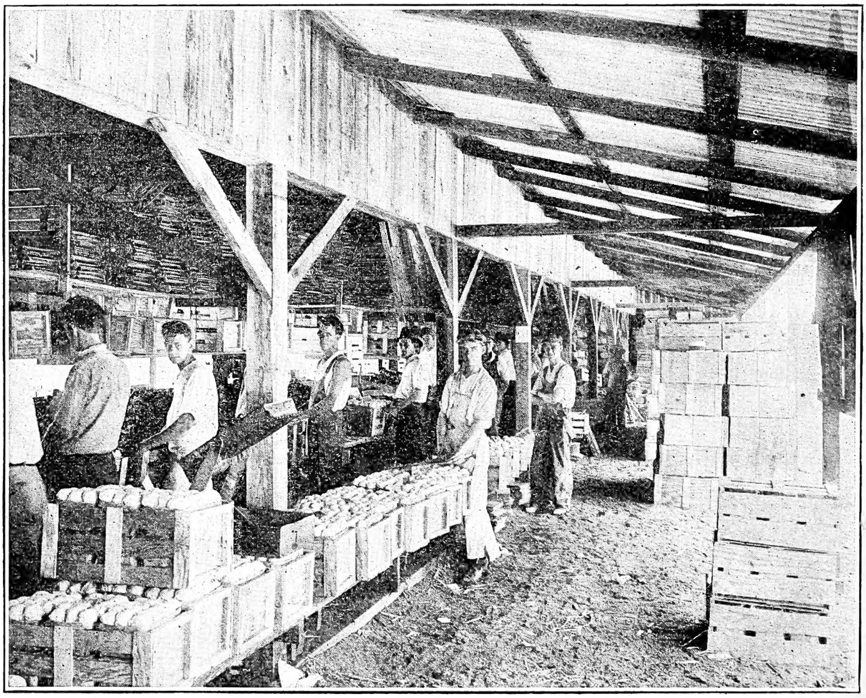

FIG. 2.—Scene in a Florida tomato packing house.

Were the solution with which the tomatoes are washed nothing more than hot water, it can hardly be doubted that the thorough removal of adhering sand, dirt, and fungous spores would be beneficial. The tomatoes remain in this supposedly disinfectant solution for about half a minute, constantly revolving, and are pushed toward an endless chain which carries them up an incline, where a spray of cold water rinses off the washing mixture. Drying is accomplished by passing the fruit between two layers of sponges. As it passes over the rollers, cullers are able to pick out the undesirable fruit without handling the remainder. It then passes over a special sizer, from which the several grades drop on tightly spread duck inclined planes and roll down into pockets. The tomatoes are not jarred or bruised in any way in traveling from the tank to the packer.

Careful handling is essential in the successful production and shipping of tomatoes, and machine handling in the packing house is therefore to be highly recommended. Any device which will prevent bruising and cutting will reduce the opportunities for fungous infection and subsequent loss.

Refrigerator cars without ice are preferred by the growers for shipping, since these cars are fitted with ventilators which can be opened and closed as weather conditions require. Ventilated cars are used also when there is a shortage of refrigerator cars, but owing to their poor construction there is likelihood in the colder regions of the fruit freezing. When the cars first leave the South the custom is to have the ventilators open, but as they move farther north these are closed to prevent frost injury. When the cars are billed through to Canada some shippers close the ventilators as soon as the cars are filled. Each car contains an average of 500 crates, or approximately 13 tons of fruit. With so large a volume of respiring fruit in a confined space it is obvious that a condition of oxygen deficiency may easily come about.

PREVIOUS CHEMICAL INVESTIGATIONS OF THE TOMATO.

The earliest important chemical investigations of the tomato seem to have been those of J. F. John and C. Bertagnini, cited by Peckolt (37, p. 197). The latter author states that John probably made the first analysis of the tomato in 1814. Bertagnini, according to Palmeri (34), isolated citric acid from this fruit in 1850 and identified it by means of its silver salt.

In 1873, Kennedy (27) first isolated the alkaloid solanin from the tomato. His method was to macerate with dilute sulphuric acid for 48 hours. The expressed liquid was then treated with aqueous ammonia (sp. gr., 0.96) in excess. The precipitate which separated was filtered and dried at 120° F., after which it was extracted with hot alcohol. On cooling, the alcoholic solution deposited solanin as small feathery crystals.

The first quantitative analysis of the whole tomato fruit was that of Dahlen (16), who reported the amounts of water, protein, fat, glucose, crude fiber, ash, nitrogen, and phosphoric acid.

Since the work of Dahlen, various chemists have published analyses of the tomato. Palmeri (34) in 1885 reported on the constituents of various portions of the fruit and also included an ash analysis. Various later attempts were made to show the amounts of nitrogen, phosphoric acid, and potash which the tomato removed from the soil and also the effect of different fertilizer treatments on the composition of the fruit. The most important work along this line was performed by Patterson (36), Bishop and Patterson (12), Voorhees (55), Alwood (3), Alwood and Bowman (4), Bailey and Lodeman (8), Bailey (7), and Jenkins and Britton (26).

There has been no little difference of opinion concerning the kind of acid occurring in the tomato. As before stated, Bertagnini (37) isolated and identified the acid as citric, while McElhenie (30) believed that oxalic, citric, and malic acids were present. Patterson (36) makes the following statement:

On following the schemes for the detection of organic acids as given in Fresenius's Qualitative Analysis, paragraph 193, page 342, and Prescott's Organic Analysis, page 336, the following acids were found to be present in the concentrated juice of the tomato, viz, malic, tartaric, benzoic, and formic. Malic acid predominated and the others appeared to be present in very small quantities, and as there has been no time for a further investigation as to the relative amounts of these, the whole of the free acids has been calculated as malic acid.

Passerini (35) claims that the acidity is due chiefly to citric acid and makes the statement: [1]

Il sapore dolce é dovuto a glucosi, i quali hanno azione resultante levogira sulla luce polarizzata; l'acidita per la massima parte ad acido citrico, come dimostrammo in altra nota.

Briosi and Gigli (13) also confirm the presence of citric acid: [2]

Queste esperienze provano nel liquido giallo la presenza dell'acido citrico; e siccome isaggi con l'acqua di calce e col cloruro di calcio, ed altri che per brevitá non riferiamo, escludono l'acido tartarico, possimao credere che l'acidita stessa sia, almeno per la massima parte dovuta a esso acido citrico, già riconosciuto nel pomodoro per la prima volta da Bertagnini.

Alwood and Bowman (4) make the following statement:

A qualitative examination showed the presence of citric, malic, tartaric, formic, and succinic acids. Of these the citric acid was by far the most abundant, so that in the quantitative determinations the whole acid was calculated as citric acid.

Stüber (50) reports that apparently all the acid present was citric, and in no case was tartaric, malic, or succinic acid found.

Formenti and Scipiotti (19) claim that salicylic acid occurs naturally in the tomato to the extent of 15 to 25 milligrams per kilogram of fresh fruit juice.

Albahary (1) gives the following acids as occurring in the tomato: Malic, 0.48 per cent; citric, 0.09 per cent; oxalic, 0.001 per cent; tartaric and succinic, traces. He also reports the presence of an amino acid (2).

Bacon and Dunbar (6) state that—

the acid of tomatoes has been called by various authors malic, citric, tartaric, and oxalic. The acid is actually citric, as shown. * * *

[1] Translated as follows: The sweet taste is due to glucose, which has a resulting levorotatory action upon polarized light; the greatest part of the acidity is due to citric acid, as we have shown in a previous note.

[2] Translated as follows: These experiments prove the presence of citric acid in the yellow liquid; experiments with lime water and calcium chlorid and others which we do not mention for the sake of brevity exclude tartaric acid. We may believe that this same acidity is due, at least for the most part, to that citric acid already recognized in the tomato for the first time by Bertagnini.

Congdon (15) differs from Bacon and Dunbar (6) and claims that the acids are oxalic, citric, and a very slight amount of malic. Oxalic acid is supposed to predominate.

The preponderance of opinion seems to be that the chief acid in the tomato is citric.

With regard to the kind of sugar occurring in the tomato there is more uniformity of opinion. Patterson (36) says:

> A few samples of tomatoes were examined for both classes of sugars, the glucose being determined in solutions made up without application of heat; and then a portion of this solution was made up in the usual manner for the cane-sugar determinations. The amount of increase indicating cane sugar was so small that it was thought to be probably due to substances of a gummy or pectose nature, which are well understood to form sugars which act on Fehling's solution when treated with mineral acids. And from the amount of free acid in the tomato, cane sugar would not be likely to exist to any extent.

Briosi and Gigli (13) believe that levulose is the sugar to which the sweetness of the yellow juice is chiefly due.

Alwood and Bowman (4) say that "it is very probable that no other sugars than those of the glucose kind exist in tomatoes."

Snyder (46), however, reports the presence of reducing and non-reducing sugars.

Stüber (50) finds no change in the sugar content of sugar samples before and after inversion.

Albahary (2) presents data showing the presence of cane sugar.

Bacon and Dunbar (6) make the following statement:

> A number of experiments have shown that the sugar of tomatoes is usually invert sugar, with at times a slight excess of levulose.

Thompson and Whittier (51) were unable to find sucrose in either green or ripe fruits, but reported approximately equal quantities of levulose and dextrose, concluding that in the classification of fruits according to the kind of sugar present the tomato falls in the invert-sugar group. One of the more recent investigators, Bigelow (11), shows that sucrose is probably absent. He states:

> It is probable that the sugar in tomatoes is all invert sugar. This was indicated by some samples which were examined, in which the determination of sugar before and after inversion gave the same results.

The work herein reported supports the contention of most scientific workers that little or no cane sugar is present in the tomato. It is very probable that where small amounts of sucrose are indicated by the increased reduction of Fehling's solution after acid hydrolysis that the increased reduction is due to other substances than invert sugar.

Since the data of the present investigation concern the percentage composition of the entire fruit, the comparable results of previous analyses of the whole tomato have been assembled in Table II.

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TABLE II.—*Summary of the more important analyses of the whole tomato fruit.*

[An asterisk (*) indicates that the figure was obtained by the writer, using data given by the particular author. All others are original.]

Author and condition.	Variety.	Number of determinations.	Water.	Total solids.	Sugar-free solids.	H_2O soluble solids.	Cane sugar.	Reducing sugar.	Starch.	Crude fiber.	Total acidity.	Total N.	Protein.	N-free extract.	Fat, etc.	Ash.	K_2O.	P_2O_5.
Dahlen (16):																		
Wet		1	92.87	*7.13	*4.60			a2.53		0.84		0.200	1.25	*4.07	0.33	0.633		0.081
Dry		1			*64.51			35.42		11.82		2.81	17.59	*57.09	4.64	8.89		1.14
Babcock (5):																		
Wet	Early Acme	3	91.26	*8.74	*5.28			a3.46		.70	b0.57	*.16	1.00	*5.84	.47	.73		
Dry	do	3			*60.41			39.54		8.03	6.52	*1.83	11.25	*66.82	5.35	8.32		
Voorhees (55):																		
Wet	Best crossed	12	94.00	6.00						.54		*.124	.78	3.78	.41	.49	0.258	.067
Dry	do	12								9.0		*2.06	13.00	63.00	6.83	8.17	*4.30	*1.11
Patterson (36):																		
Wet	60 varieties	612	95.61	*4.39	*1.47	3.85		*2.92		.62	b.45	*.144	.90	2.07	.40	.40	.269	.046
Dry	do	612			*33.48	*87.69		c66.52		14.12	*10.25	*3.27	*20.50	*47.15	*.91	*9.11	*6.13	*1.05
Passerini (35): d																		
Wet	Nostrali		93.02	*6.98				e3.73		f1.07	g.815	h.165	h1.03		f.696	{i.726, j.790}	}h.432	.094
Dry	do	5						53.50		15.33	11.68	1.83	14.79		9.97		6.19	1.347
Wet	Napoletani	2	93.60	6.39				k*2.67			l*3.61					.79		
Dry																12.36		
Briosi and Gigli (13): m																		
Wet			*95.54	*4.46												*.355		
Dry																.796		
Alwood and Bowman (4):																		
Wet	Trophy	2	93.34	*6.66						1.158		*.167	1.044	3.649	.469	.337		
Dry	do	2								17.40		*2.51	15.68	54.80	7.05	5.07		
Wet	Common	{ 9	93.63	6.37														
		11				3.82		a2.09			n.71							
Bailey and Lodeman (8):																		
Wet	Ignotum	8	*94.17	5.83	*.96		o4.87				b.72							
Dry	do	8			16.49		*83.53				*12.33							
Bailey (7):																		
Wet	do		p94.33	p5.67			q1.01				.46							
Dry	do						*17.70				*8.30							
Caldwell (14):																		
Wet			s*94.33	s5.67	*4.44		o.97				b.57							
Dry					t*82.07		t*17.93				s*10.05							
Handbook Exp. Sta. (53):																		
Wet			93.64	*6.36	*3.31		o3.05			.75	b.46	.16	u.91	v3.80	.43	.47	.27	.05
Dry					*52.54		*47.96			11.79	*7.23	*2.51	*15.72	*58.33	6.71	*7.39	*4.24	*.78

Jenkins and Britton (26):																		
Wet	Acme and Ignotum	8	94.28	*5.72								.109					.325	.058
Dry		8										1.90					*5.68	1.009
Snyder (46):																		
Wet	Acme, Livingston, and Aristocrat	3	93.77	6.23	*2.40		1.65	(w)			b.42	x.17	y.476	h*4.22	h.05	.59		
Dry	do	3			*38.52		26.48	(z)			*6.74	*2.72	*7.64	*66.31	*7.86	*9.45		
Huston and Bryan (25):																		
Wet	Lorillard and Stone	2	93.54	6.46	*3.93		.13	aa2.40		.59	b.50	*.201	1.26	3.44	.35	.82		
Dry		2			*60.83		*2.01	*37.16		*9.14	*7.74	*3.12	*19.50	*53.25	*5.57	*12.69		
Van Slyke, Taylor, and Andrews (54):																		
Wet		2	94.46	*5.54								.176					.331	.065
Dry		2										*3.18					*5.97	1.17
Stüber (50): bb																		
Wet		2	94.82	5.18	*2.33		None.	c2.87			.475	.138	.859			.56	h.346	.051
Dry		2			*44.98			55.41			*.917	*2.66	*16.58			*10.81		*.98
Formenti and Scipiotti (19):																		
		2										*.18	*1.125					
Wet		4														*.61		
		6	94.06	*5.94														
Albahary (1):																		
Wet			93.50	*6.50	*2.90		3.60				cc.57	*.152	.95		.20	.74		
Dry					*44.62		*55.38				*8.77	*2.34	*14.62		3.07	*11.38		
Albahary (2):																		
Wet			94.39	5.56	*1.84		dd1.60	2.12	0.36	.27	ee.42	*.076	ff.48		.11	.57		
Dry					*33.05		28.77	38.12	6.40	4.85	7.65	1.36	*8.62		1.98	10.08		
Street (49):																		
Wet			95.63	*4.37		2.93				.46		*.136	.85	2.37	.27	.42		
Dry						67.05				10.53		*3.112	19.45	54.23	6.18	9.61		
Congdon (15): gg																		
Wet		8									*.528							

a As glucose. *b* As malic acid. *c* As invert.

d Passerini (35) gives the following additional data: Skin (wet), 1.3; seed, 2.5; pulp and juice, 96.2; specific gravity of juice, 1.0183 at 15° C. Ash constituents (percentage of wet weight): Na_2O, 0.043; CaO, 0.010; MgO, 0.022; Fe_2O_3, 0.002; SiO_2, 0.002; SO_3, 0.025; Cl, 0.139. Referred to total dry weight: Na_2O, 0.616; CaO, 0.143; MgO, 0.315; Fe_2O_3, 0.029; SiO_2, 0.029; SO_3, 0.358; Cl, 1.99.

e As glucose, 1 determination. *i* Pure, 1 determination.

f Determinations, 2. *j* Crude, 5 determinations.

g As citric acid, 1 determination. *k* As glucose, 20 varieties.

h One determination. *l* As citric acid, 20 varieties.

m Briosi and Gigli (13) give additional data as follows: Skin (wet), 3.73; seed (wet), **10.92**; pulp and juice, 85.35; specific gravity of juice (mean of 4 determinations), **1.0217**.

n As citric acid.

o As sugar.

p Determinations, 24.

q As sugar, 22 determinations.

r As malic acid, 13 determinations.

s Determinations, 13.

t Determinations, 8.

u Should be 1.00.

v Should be 3.71.

w Levulose, 1.09; dextrose, 1.09.

x Protein, N=0.076; nonprotein, N=0.003.

y Protein, 0.476 (0.0×6.25).

z Levulose, *17.49; dextrose, ×17.49.

aa As dextrose.

bb Stüber (50) also gives the following ash constituents, referred to wet weight of the whole fruit: Na_2O, 0.013; CaO, 0.013; MgO, 0.021; Fe and Al phosphates, 0.004; SiO_2, 0.005; SO_3, 0.032; Cl, 0.034; CO_2, 0.121.

cc Malic acid, 0.48; citric acid, 0.09.

dd Sugar after hydrolysis.

ee As organic acids.

ff Protein=0.39, amid=0.09; **total, 0.48.**

gg Congdon (15) gives 1.0216 as the specific gravity of the juice.

Relatively few investigations have been reported showing the progressive changes in composition of the tomato. Differences in composition between green and ripe fruit are given in several instances, but the researches of Albahary (2) and Bigelow (11) seem to be the only systematic studies of the changes occurring during development.

Passerini (35) reports a partial analysis of both green and ripe fruits of two varieties. The data, which are expressed in terms of wet weight, seem to indicate that as the tomato matures there is an increase in water and sugar and a decrease in total solids and acid. Formenti and Scipiotti (19) found that the water content of the entire fruit was greater in the ripe fruit than in that half ripe. Thompson and Whittier (51) reported a slightly larger percentage of total sugar in ripe than in green tomatoes.

Congdon (15) reported the specific gravity of ripe and green tomatoes as 1.0216 (average of eight) and 1.0230, respectively; also the citric acid content as 0.528 (average of eight) for ripe and 0.990 for green fruit. Bigelow (11) studied the composition of tomatoes (expressed juice) at different stages of maturity, but did not arrive at any very definite conclusions. He states that in general the percentage of solids and sugars increases and the percentage of acid decreases as the tomato becomes more mature.

Albahary (2) has given the most complete account of the chemical transformations in tomatoes during ripening. He used three successive stages of ripening: (1) Green fruit before seed development, (2) green fruit at the time seeds were completely formed, and (3) fruit which was fully ripe, and he concluded that with ripening there is a progressive increase in acids, sugars, starch, and nitrogenous nonprotein constituents, while proteins and cellulose diminish greatly, remaining practically stationary toward the end of ripening.

From the preceding résumé of former work on the chemical composition of the tomato at different stages of its growth, it is seen that there is little consistency in the results obtained.

The red pigment of the tomato is not estimated in any of the routine analyses. It has been isolated by several workers, who found that the amount recoverable was 0.2 per cent of the dry weight of the fruit or less. Its preparation in pure crystalline condition was first accomplished in 1876 by Millardet (31), who named it solanorubin. After it had passed into the synonymy of carotin, it was again isolated, in 1903, by Schunck (45), who renamed it lycopin. Montanari (32) made the first analysis and proved that it was a hydrocarbon. The final identification of lycopin as an isomer of carotin was made by Willstätter and Escher (58). In 1913 Duggar (17) studied the effect of conditions upon the development of the tomato pigmentation and found the color of the ripe fruit to depend (1) upon the presence or absence of lycopin in the flesh (in the absence of red lycopin the flesh is yellow, due to carotin and possibly xanthophyll, which are masked in the red fruit) and (2) upon the presence or absence in the epidermal walls of a yellow pigment. In the presence of the latter the red flesh is seen through a yellow screen, giving a more or less orange effect, but if it is absent the skin is transparent and the color a clear red.

EXPERIMENTAL MATERIAL.

The fruit for all the analytical work herein reported (with the exception of the "puffy" fruit discussed in the appendix) was obtained from plants of the Livingston Globe variety grown at Peters, Dade County, Fla. This variety is almost exclusively used for winter shipping to northern markets. For the life-history work the plants were grown in a field where the soil conditions represented the average of the entire acreage planted in tomatoes. These plants had the same treatment as the commercial plantings. They were set in the field in January and, following the local practice, were given four applications of commercial fertilizer and the usual quantities of compost.

In the former studies of the progressive changes in composition during ripening the tomatoes for sampling were classified by size and were usually picked at one time. This method of sampling was not deemed sufficiently accurate to be used in the present investigation, for ripe tomatoes have a great range of variation in size, which fact alone should enable one to conclude that it is not the size that determines the degree of maturity. In order to establish a basis for selecting fruits of comparable maturity, blossoms were tagged and observations made as to the time of ripening. In a series of observations made during the summer of 1918 at Arlington, Va., several hundred blossoms of Livingston Globe plants were tagged, and part of the fruit was picked every week, weighed, and measured. The important fact brought out by the experiment (Table III, Sec. A) is that the maturity of a tomato fruit depends upon age and not upon size. In the latitude of Washington, D. C. (at Arlington, Va.), 49 days were required to bring the fruit to maturity, starting with the blossom. Of the 20 fruits left upon the vines, all colored at the same time regardless of size or weight. The experiment was repeated with plants grown in Florida, and the same results were obtained. (Table III, Sec. B). In this case 200 tomatoes remained on the vines at the end of 56 days, 181 of which were colored (turning to red) and 19 green. The variations in size and weight were as great as at Arlington, if not greater. It was impossible to judge to the day the age of the blossoms which were tagged, but the variation among blossoms was hardly more than one or two days.

This method of obtaining tomatoes of known relative maturity is a fairly accurate procedure and is certainly to be preferred to that used by other investigators, who selected fruit according to size.

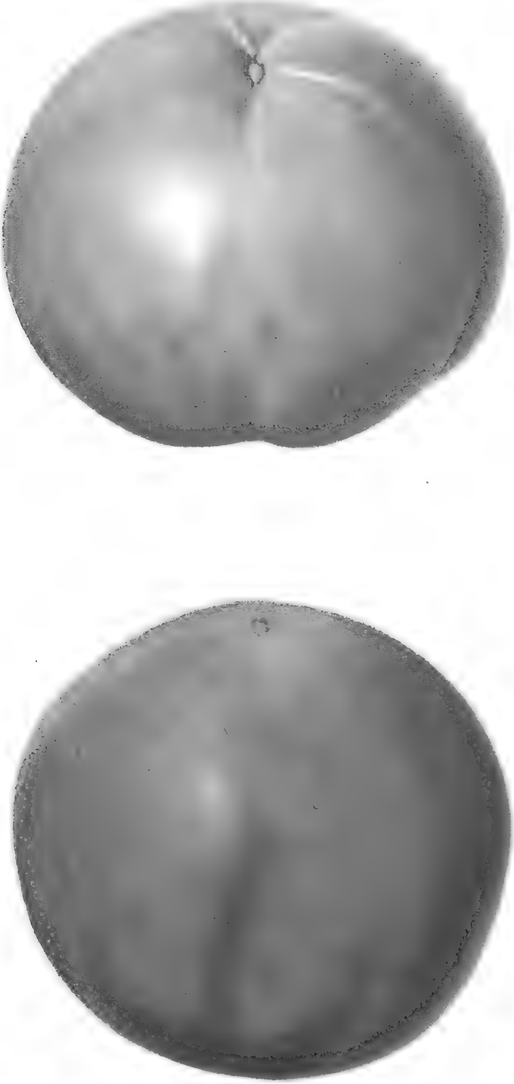
TABLE III.—*Weights and equatorial diameters of individual tomatoes grown at Arlington, Va., in the summer of 1918, and at Peters, Fla., in the winter of 1918, picked at intervals from blossoming time until the fruits were ripe.*

Locality and descriptive data.	Color of fruit.	Individual tomatoes.										Average.
		No. 1.	No. 2.	No. 3.	No. 4.	No. 5.	No. 6.	No. 7.	No. 8.	No. 9.	No. 10	
SEC. A.—Arlington, Va.:												
Weight (grams)—												
Age 7 days.....	Green...	0.30	0.50	0.70	0.90	1.50	1.60	1.70	1.80	3.00	3.40	1.54
Age 13 days	...do....	1.40	2.00	3.60	5.30	6.10	13.90	14.60	17.50	20.80	21.60	10.68
Age 21 days	...do....	39.60	40.70	42.20	45.00	50.50	82.60	85.70	87.60	90.00	93.60	65.75
Age 30 days	...do....	52.90	57.10	71.50	79.80	83.40	109.50	114.30	115.70	128.60	135.40	94.82
Age 38 days	...do....	34.30	49.40	64.40	76.50	81.90	155.10	169.90	190.30	276.70	284.00	135.25
Age 49 days	Turning to red.	55.80	94.10	98.80	122.80	137.20	164.00	180.70	197.60	234.50	247.90	153.34
Diameter (cm.)—												
Age 7 days.....	Green...	.45	.60	.65	.80	1.05	1.10	1.15	1.15	1.40	1.55	1.14
Age 13 days	...do....	1.00	1.20	1.60	1.80	1.80	2.60	2.70	2.70	2.70	2.80	2.10
Age 21 days	...do....	3.80	3.80	3.90	4.00	4.10	4.80	4.90	4.90	4.90	5.00	4.41
Age 30 days	...do....	4.20	4.30	4.60	4.70	4.80	5.40	5.40	5.50	5.60	5.70	5.02
Age 38 days	...do....	3.80	4.10	4.40	4.80	4.90	6.00	6.10	6.40	6.70	7.30	5.45
Age 49 days	Turning to red.	4.60	4.90	5.20	5.40	5.70	5.90	6.30	6.70	6.90	7.30	5.49
SEC. B.—Peters, Fla.:												
Weight (grams)—												
Age 7 days.....	Green...	.07	.08	.08	.08	.09	.11	.52	.55	.67	1.13	.33
Age 15 days	...do....	1.68	1.75	1.84	2.27	2.32	9.40	10.63	11.95	12.39	13.19	6.74
Age 21 days	...do....	40.78	44.67	45.12	46.57	46.67	57.03	68.02	86.35	86.42	124.72	63.65
Age 28 days	...do....	43.79	62.60	63.53	67.12	69.18	75.35	77.48	91.85	111.97	160.84	82.37
Age 35 days	...do....	53.32	64.37	73.40	76.31	94.92	95.25	97.92	100.12	118.95	177.48	95.10
Age 42 days	...do....	78.60	95.45	95.82	99.81	100.78	126.66	151.23	195.36	222.11	313.33	147.91
Age 56 days	Turning to red.	79.18	110.18	127.72	131.52	139.97	157.42	170.54	179.69	185.18	346.79	162.81
Diameter (cm.)—												
Age 7 days.....	Green...	.43	.45	.45	.45	.45	.55	.85	.95	1.05	1.30	.69
Age 15 days	...do....	1.60	1.60	1.60	1.70	1.75	2.80	2.85	2.90	3.10	3.25	2.31
Age 21 days	...do....	4.50	4.55	4.60	4.60	4.65	4.85	5.65	5.80	6.00	6.60	5.18
Age 28 days	...do....	4.50	5.00	5.00	5.05	5.20	5.50	5.50	5.80	6.20	7.00	5.47
Age 35 days	...do....	4.45	4.70	4.75	5.15	5.45	5.45	5.60	6.05	6.15	7.00	5.47
Age 42 days	...do....	5.00	5.45	5.50	5.60	5.75	6.25	7.25	7.25	7.25	7.35	6.37
Age 56 days	Turning to red.	5.25	5.65	5.70	5.80	5.90	6.40	6.60	6.75	6.85	8.85	6.38

Plates I and II show in color four stages in ripening, which are referred to later in this bulletin as green, i. e., with no red present (*A*); turning, i. e., mostly green, with a trace of color at the style end (*B*); pink, i. e., slightly colored over most of the fruit, with little or no green except at the stem end, but not yet a good full red (*C*); and red ripe, i. e., completely mature as far as color change is concerned (*D*).

Material for analysis was obtained by tagging blossoms (other than those of the "crown hand")[3] soon after opening and then collecting tomatoes at the different stages in numbers large enough for sampling. An attempt was made to pick all the tagged fruit from an entire row in order to eliminate the error that possibly otherwise might have occurred of unconsciously selecting large or small fruit. Samples were taken at the end of the second, third, fourth, fifth, and sixth weeks, and after the tomatoes had barely started to color (designated as turning), and finally when fully colored or ripe. At the time of carrying on the work the weather conditions were such that eight weeks were required to bring the tomato to maturity (red ripeness).

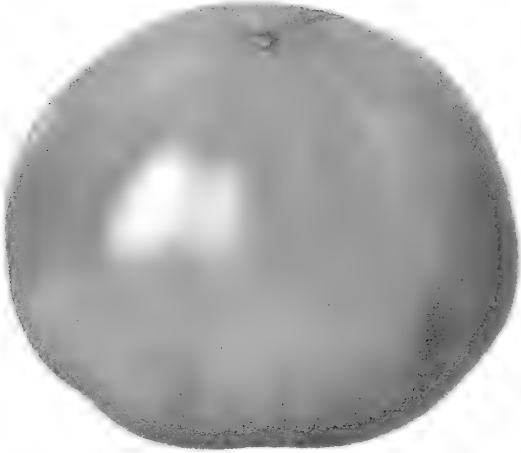
[3] Growers are accustomed to refer to all the fruit developing from a single inflorescence as a "hand." The "crown hand" is the lowest inflorescence on the stem. It frequently fails to set fruit.

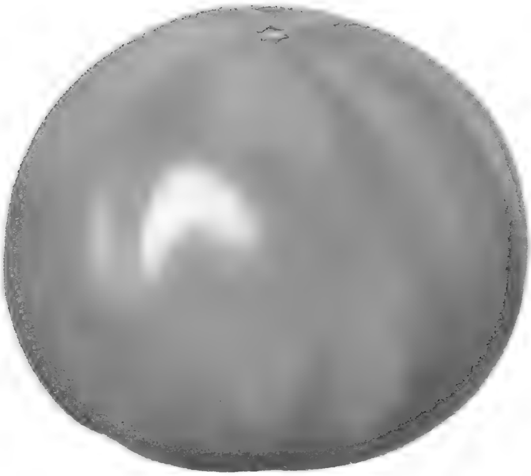


R. C. STEADMAN, del.

COLOR STAGES IN THE RIPENING OF THE TOMATO.

Green, *A*; turning, *B*.





R. C. STEADMAN del.
5-20-3

A. HOEN & CO. BALTIMORE

COLOR STAGES IN THE RIPENING OF THE TOMATO.

Pink, *C*: red ripe, *D*.

METHODS OF ANALYSIS.

Sampling and preservation.—In order to obtain representative samples at each stage of ripening and to avoid the necessity of analyzing a large number of individual fruits to determine existing variations, composite samples were resorted to. These composite samples were taken from approximately 20 tomatoes. To eliminate error due to possible correlations between size and chemical composition, tomatoes were chosen so that each composite sample was obtained from fruits of all sizes, with the exception of abnormally large or small fruit which were discarded. The method of collecting the samples was uniform throughout. Where the fruits were small (e. g., those 14 days old) a 200-gram lot was made by using entire tomatoes, but with larger fruit samples of 200 grams were made up by removing a cylinder from each tomato with a half-inch cork borer. The cylinders were taken through the equator perpendicularly to the axis. A fairly representative sample was obtained in this manner, for the portion removed from each tomato was roughly proportional to the size of the whole fruit. The method of preserving samples for analysis was similar to that used by Hasselbring and Hawkins (21) in their studies of sweet potatoes and identical with the procedure of Kraus and Kraybill (28) with tomatoes. The material was heated with 80 per cent alcohol for 1 hour at 70° to 75° C., with the addition of calcium carbonate ($CaCO_3$) to insure the neutralization of acids. Two-quart glass-top jars were used, and approximately 1,065 c. c. of 95 per cent alcohol and 0.5 gram of precipitated $CaCO_3$ were added, after which the heating was carried out on a boiling water bath. Moisture and ash samples were merely covered with 95 per cent alcohol without subsequent heating.

In preparing the samples for analysis (with the exception of certain moisture, dry-weight, and ash samples) the alcohol was removed from the insoluble residue by filtering into a 2-liter volumetric flask. The residue was thoroughly extracted with warm 80 per cent alcohol, which was cooled, filtered, and added to the original filtrate. The volume of the flask was then made up to mark at 20° C. (referred to later as the original extract) and one-tenth and three-twentieths aliquots pipetted off and placed in separate Florence flasks, which were stoppered, labeled, and set aside. The residue was dried at 80° C. in an air oven for a few days and then allowed to come to air-dry weight, after which it was weighed and finely ground in a drug mill (referred to later as the original residue). One-tenth and three-twentieths portions were weighed and stored in small stoppered vials.

Moisture, dry weight, and ash.—An entire 200-gram sample covered with 95 per cent alcohol was placed in a large beaker and evaporated nearly to dryness on a steam bath. It was then transferred to a

250 cubic-centimeter tared beaker and dried at 60° to 70° C. to apparent dryness, after which it was dried in vacuo at 80° C. until the loss between two successive weighings was negligible. For ash the residue was ground in a mortar, then placed in the vacuum oven over night and approximately one-half of the total sample used for the crude-ash determination.

Acidity.—All acid determinations were made with fresh material. Two hundred grams of tomatoes were pulped and placed in a liter volumetric flask, made up to volume with cold distilled water, and toluol was added to prevent the growth of organisms. After standing three days, 50 c. c. aliquots were titrated against approximately a tenth normal sodium-hydroxid solution (N/10 NaOH), using phenolphthalein as the indicator. No trouble was experienced in determining the end point. Separate determinations were made until the duplicates checked. In order to determine the effect of enzyms on acid content, a sample treated with boiling water was titrated three days later and the results compared with one using cold water. For the former, 200 grams of material required 14.28 c. c. N/10 NaOH, and for the same quantity of material employing cold water, 14.18 c. c. N/10 NaOH were required for neutralization.

Free reducing substances.—One-tenth of the original alcoholic extract was evaporated nearly to dryness while the same part of the residue was being extracted on a filter paper with warm water (35° C.). Very little reducing substance remained after extracting the original residue with alcohol, as described under "Sampling and preservation," but the warm-water extraction was performed to insure the removal of final traces. The aqueous extract was combined with the residue from the alcoholic portion and filtered into a 250 c. c. volumetric flask, after which the filter paper was thoroughly washed. One cubic centimeter of lead-acetate solution (a saturated solution of the normal salt) was added and the solution made up to volume at 20° C. The whole was filtered immediately and the excess of lead removed by adding approximately 0.5 gram of sodium oxalate. After standing a short time the mixture was filtered through dry filter paper and 10 c. c. of the clear solution used for the sugar determination. The method used for determining reducing sugars was a combination of that of Bertrand (10), and that of Munson and Walker (33, 56). In this method the cuprous oxid is determined by titration, as in the Bertrand method, Fehling's solution and the time of heating are as specified by Munson and Walker. The Munson and Walker tables were used for the sugar equivalents.

Total sugars.—Fifty cubic centimeters of the solution used for free reducing sugars were transferred to a 100 c. c. volumetric flask and 5 c. c. of HCl (sp. gr., 1.19) added. The mixture was set aside over night and the flask made to volume at 20° C. the following morning. The solution was then neutralized and filtered and 20 c. c. used for reduction.

Starch.—The residue from the water extraction of the sample used for reducing substances was placed in an Erlenmeyer flask and heated immersed in a boiling water bath for 2½ hours with 150 c. c. of water and 15 c. c. of HCl (sp. gr., 1.125). After cooling and neutralizing to phenolphthalein with NaOH, the mixture was made to 250 c. c. volume at 20° C. and filtered through a dry filter paper; 20 and 50 c. c. aliquots of this solution were used for reduction.

Pentosans.—A quantity of the original alcoholic extract representing one-tenth of the total extract was evaporated nearly to dryness in an Erlenmeyer flask and one-tenth of the original residue added to this. Pentosans were determined by the furfural-phloroglucid precipitate method. The usual procedure is to distill over 360 c. c. and then to make up to 400 c. c. with a phloroglucin solution. It required 480 c. c. of distillate to obtain all of the furfural present, and 40 c. c. of phloroglucin solution were added to this. No correction was made for the additional 120 c. c. distilled over. Kröber's formulæ were used in calculating the pentosan equivalents, as given in the Official and Provisional Methods of Analysis (57).

Total nitrogen.—Two hundred cubic centimeters of the original alcoholic extract, representing one-tenth of the sample, were introduced into a Kjeldahl flask and evaported to dryness on the steam bath, and to this residue one-tenth of the original residue from the original sample was added. The total nitrogen in the aliquot was determined by the Kjeldahl method.[1]

Crude fiber.—A quantity of the residue representing three-twentieths of the sample was used for crude-fiber determination, which was made in the usual manner.

ANALYTICAL DATA CONCERNING PROGRESSIVE CHANGES IN COMPOSITION DURING RIPENING.

The data showing progressive changes in composition during the process of ripening are assembled in Table IV. In section A of this table the percentages are referred to the weight of the entire fruit; in section B they are reduced to a basis of dry weight. Each entry in this table is a mean of two determinations, except as indicated by an asterisk (*), which shows that duplicate determinations were not made.

Although the method of sampling has been described, it may not be amiss to emphasize the fact that each sample was a composite of fruits of the same maturity but of greatly varying sizes. The data with regard to average size and average weight at the various ages are found in Table III.

[1] All determinations of nitrogen reported in this investigation were carried out by the Nitrogen Laboratory, Bureau of Chemistry, United States Department of Agriculture.

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TABLE IV.—*Progressive changes in the composition of Livingston Globe tomatoes during the process of ripening.*

[The asterisk (*) indicates that the given result is based upon a single determination; results not thus marked are the mean of two determinations.]

Constituents.	Age and color of fruit.						
	14 days, green.	21 days, green.	28 days, green.	35 days, green.	42 days, green.	56 days, turning.	56 days, red.
SEC. A.—Percentage of entire fruit:							
Moisture	*93.250	*94.140	*94.140	*94.540	*94.240	*94.450	*94.490
Total solids	*6.750	*5.860	*5.860	*5.560	*5.760	*5.550	*5.510
Sugar-free solids	5.006	3.824	3.753	3.416	3.385	2.994	2.847
Ash, crude	*.634	*.562	*.533	*.509	*.497	*.484	*.504
Acidity (as citric acid)	.320	.585	.352	.883	.640	.397	.420
Total nitrogen	.1999	.150	.1365	.1305	.140	.1225	.116
Protein (=N × 6.25)	1.247	.938	.853	.8156	.875	.766	.725
Total sugar (as invert)	1.743	2.006	2.106	2.143	2.375	2.556	2.667
Cane sugar	.018	.041	0	.018	.070	.018	.024
Reducing sugar (as invert)	1.724	1.962	2.112	2.125	2.300	2.537	2.637
Starch	1.068	.830	.616	.544	.555	.222	.146
Pentosans	.332	.276	.247	.273	.264	.228	.238
Crude fiber	*.503	*.464	*.447	*.484	*.433	*.423	*.394
Ratio (sugar ÷ acid)	5.450	3.420	5.980	2.430	3.710	6.430	6.340
Carbohydrates—							
Total	3.647	3.576	3.415	3.443	3.628	3.429	3.441
Soluble	1.743	2.006	2.106	2.143	2.375	2.556	2.667
Insoluble	1.903	1.570	1.309	1.300	1.253	.873	.774
Determined constituents	99.100	99.801	99.294	100.192	99.870	99.526	99.580
SEC. B.—Percentage of dry matter:							
Sugar-free solids	74.120	65.250	64.050	61.440	58.760	53.940	51.670
Ash, crude	*9.390	*9.590	*9.090	*9.150	*8.620	*8.720	*9.140
Acidity (as citric acid)	4.740	9.980	6.000	15.880	11.110	7.150	7.620
Total nitrogen	2.960	2.560	2.330	2.340	2.440	2.200	2.100
Protein (=N × 6.25.)	18.500	16.000	14.550	14.660	15.250	13.780	13.130
Total sugar (as invert)	25.830	34.240	35.930	38.550	42.230	46.030	48.320
Cane sugar	.264	.708	0	.323	1.215	.324	.435
Reducing sugar (as invert)	25.560	33.490	36.040	38.200	39.930	45.710	47.850
Starch	15.840	14.220	10.500	9.770	9.630	4.000	2.650
Pentosans	4.920	4.700	4.210	4.890	4.580	4.120	4.320
Crude fiber	*7.450	*7.920	*7.630	*8.710	*7.510	*7.620	*7.150
Ratio (sugar ÷ acid)	5.450	3.420	5.980	2.430	3.710	6.430	6.340
Carbohydrates—							
Total	54.030	61.030	58.270	61.920	63.970	61.720	62.450
Soluble	25.830	34.240	35.930	38.550	42.230	46.030	48.320
Insoluble	28.200	26.790	22.340	23.370	21.740	15.690	14.130

From Table IV it may be seen that the tomato contains a comparatively small amount of solid matter and that a considerable portion of this consists of acids and sugars, especially in the ripe fruit. In fruit 14 days old there are relatively small percentages of acids and sugars, but as the tomato matures these increase perceptibly in the case of acids and markedly in the case of sugars. In general, throughout the ripening period there is an increase in moisture, acids, and sugars and a decrease in solids, total nitrogen, starch, pentosans, crude fiber, and ash. Some of these losses are probably not absolute, but attributable to changes in the proportion of the constituents. Tracing the figures for moisture content from the first column, concerning tomatoes 14 days old, across to the last column for ripe fruit, it will be seen that there is a gradual and progressive increase in total moisture. The only irregularity is that noticed in the fourth column (for 35 days). The moisture content here is greater than it should be if the change followed a regular curve of increasing water, being greater than in fruit when fully ripe.

It seems that a clue to the reason for this irregularity is afforded by Table V, showing weather conditions for the period previous to picking the samples. Just before picking this particular sample there was a rainfall of 9.10 inches within 36 hours. This precipitation was as unusual for the locality as it was injurious. Not only was the actual rainfall excessive, but the overflow from the Everglades still further complicated the situation. In some places a total loss resulted, and everywhere some damage was reported. At Peters, Fla., where the fruit for this investigation was grown, the loss was comparatively small, but the ground was saturated for more than a week. In view of the fact that the only anomalous moisture content was found in the 35-day fruit, it seems justifiable to correlate it with the excessive rainfall. It would hardly be warranted, however, to conclude from this one instance that the moisture content is higher after a heavy rain than normally. The coincidence is merely pointed out and should be of some interest in view of the widespread opinion in the canning industry that a heavy rainfall increases the amount of water in tomatoes. Bigelow (11) was recently unable to draw any definite conclusions with regard to this matter.

TABLE V.—*Weight and equatorial diameter of tomatoes at dates when samples were taken, together with mean temperature and total precipitation for the period (usually seven days) preceding sampling.*

Time of sampling.	Color of fruit.	Average weight (grams).	Average diameter (cm.).	Meteorological data.	
				Temperature (° F.).	Precipitation (inches).
Age 14 days	Green	6.74	2.31	66	0.83
Age 21 days	do	63.65	5.18	73	.24
Age 28 days	do	82.37	5.47	77	.01
Age 35 days	do	95.10	5.47	62	9.42
Age 42 days	do	147.91	6.37	68	.27
Age 56 days	Turning to red	162.81	6.38	76	.09
Mean				70	
Total					10.85

Inversely with moisture, total solids show a gradual decrease as the tomato matures. Turning to section B of Table IV, which gives the same data as those of section A of the same table, but reduced to a dry-weight basis, the sugar-free solids are seen to decrease considerably, while soluble carbohydrates increase and insoluble carbohydrates decrease regularly. Total carbohydrates vary somewhat, but in general seem to show an increase.

Regarding the changes in acidity, there is considerable fluctuation, but when we consider the changes in a general way there is an increase in quantity from the second week to the fifth and then a gradual decrease during the last three weeks of ripening. The total quantity of acid found in the red-ripe fruit is, however, still greater than in the first stage analyzed. The possibility should be borne in mind that the ripe tomato may contain relatively more acid salts and less free acid than the green fruit. Since the acid content was determined throughout by titration to neutrality, with phenolphthalein as the indicator, it is obvious that the presence of acid salts might cause the analytical results to show more acid than the taste would indicate. As will be seen later, the change in the ratio of acid to sugar is in the direction to account for the sweetening that takes place during ripening. Nevertheless it is not impossible that the ratio of free-acid salts is likewise of importance.

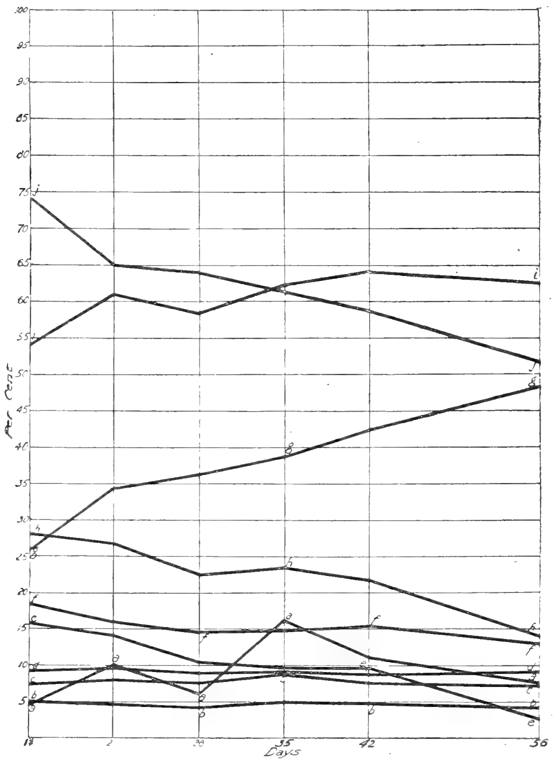


FIG. 3.—Diagram showing the progressive changes in the composition of Livingston Globe tomatoes during ripening. The percentages are based upon dry weight. Curve *a–a*, acid; *b–b*, pentosans; *c–c*, crude fiber; *d–d*, crude ash; *e–e*, starch; *f–f*, protein; *g–g*, soluble carbohydrates (total sugar); *h–h*, insoluble carbohydrates; *i–i*, total carbohydrates; *j–j*, sugar-free solids.

It is believed that rainfall and other factors influence the quantity of acid in tomatoes, although there are few analytical data at hand to indicate this. In the fourth column of figures of Table IV (sec. B), concerning the tomatoes that received the highest rainfall, the acidity is 15.88 per cent, and in the fifth column, where the tomato would no doubt be still affected, there is a decrease to 11.11 per cent, but this figure is higher than the remaining ones.

In this connection it may be worth while to suggest that a tomato with excessive water content may have the intercellular spaces sufficiently diminished so that gas exchange is impeded. Under such conditions a deficiency of oxygen might result in an accumulation of acid, due to incomplete oxidation of carbohydrates to carbon dioxid.

The most striking change during ripening is that undergone by carbohydrates. In the first stage analyzed it was noticed particularly that insoluble carbohydrates composed 52.1 per cent of the total carbohydrates present, while in the last stage, that of ripe fruit, soluble carbohydrates were in excess, amounting to 77.3 per cent of the total. Nearly all of the total sugar in the tomato fruit is apparently invert sugar, and this increases from 25.56 per cent in the case of 14-day-old fruit to 48.32 per cent in ripe fruit, an increase of nearly 89 per cent. Starch decreases during maturation from 15.84 to 2.65 per cent. The most marked decrease, as would be expected, is noticed during the period of transition from green to red. The progressive decrease in starch during ripening is in striking contrast to the increase in starch noticed by Albahary (2).

Pentosans decrease during ripening, but only to a comparatively slight extent.

Total nitrogen decreases gradually during ripening and this fact is rather interesting and important in the light of some recent investigations of Kraus and Kraybill (28). They make the following statements:

> On account of the wide differences in composition of different parts of any plant grown under a given set of conditions, only similar portions are compared. With but few exceptions, increased amounts of total nitrogen are associated with decreased amounts of total carbohydrates. This condition holds fairly uniformly throughout the plant with the exception of the lower leaves.

Examination of Table IV (sec. B) shows that increased total nitrogen in the tomato fruit under the conditions used for the material in this investigation is associated with decreased total carbohydrates. The above investigators analyzed leaves and stems of the tomato plant, while the data presented in the present paper furnish analytical figures for the fruit, thus yielding complete analyses of the entire plant. The correlation between total nitrogen and total carbohydrates holds with respect to the fruit as well as to the other parts of the plant (excluding the lower leaves).

All of the changes during ripening are represented in the diagram shown as figure 3.

COMPARISON OF THE COMPOSITION OF COMMERCIALLY PICKED TOMATOES WITH TURNING AND VINE-RIPENED FRUIT.

It is conceded by many commission men and by some of the growers themselves that the tomatoes shipped to the North differ very noticeably in flavor and palatability from normal fruit. The chemical composition of Florida-grown tomatoes compares favorably with the various analyses reported of such fruit grown in other localities, so the inferiority of the former can not be attributed to the kind of soil or climatic conditions prevailing in Florida. Elimination of these possibilities led the writer to look for other causes of the trouble. It will be seen from the analytical data which follow that tomatoes picked green and allowed to ripen exposed to air and light differ slightly in composition from vine-ripened fruit. They contain more sugar-free solids, slightly more acid, and less total sugar than vine-ripened tomatoes, but these differences hardly explain the great difference in taste. In tracing the trouble to lack of ventilation it is believed that a proper explanation is presented. The analytical data upon which these conclusions are based are presented in Tables VI and VII.

TABLE VI.—*Composition of artificially ripened and vine-ripened Livingston Globe tomatoes.*

[The asterisk (*) indicates that the given result is based upon a single determination: results not thus marked are the mean of two determinations.]

Constituents.	Commercially picked; green.		Turning fruit.		Vine-ripened fruit; red ripe.
	As picked.	Ripened at room temperature.	As picked.	Ripened at room temperature.	
SEC. A.—Percentage of entire fruit:					
Moisture	*93.800	*94.310	*94.450	*94.540	*94.490
Total solids	*6.200	*5.690	*5.550	*5.460	*5.510
Sugar-free solids	3.975	3.059	2.994	2.916	2.847
Acidity (as citric acid)	.508	.475	.397	.375	.420
Total nitrogen	.138	.1335	.1225	.1265	.116
Protein (=N × 6.25)	.831	.834	.766	.791	.725
Total sugar (as invert)	2.225	2.631	2.556	2.543	2.667
Cane sugar	.060	.012	.018	.024	.024
Reducing sugar (as invert)	2.175	2.628	2.537	2.518	2.637
Starch	*.855	.095	.222	.101	.146
Pentosans	.258	.214	.227	.251	.238
Crude fiber	*.404	*.462	*.423	*.438	*.394
Ratio (sugar ÷ acid)	4.380	5.540	6.430	6.780	6.340
Carbohydrates—					
Total	3.742	3.403	3.429	3.334	3.441
Soluble	2.225	2.631	2.556	2.543	2.667
Insoluble	1.517	.772	.873	.791	.774
SEC. B.—Percentage of dry matter:					
Sugar-free solids	64.110	53.770	53.940	53.410	51.670
Acidity (as citric acid)	8.190	8.340	7.150	6.860	7.620
Total nitrogen	2.140	2.340	2.200	2.320	2.100
Protein (=N × 6.25)	14.370	14.630	13.780	14.500	13.130
Total sugar (as invert)	35.880	46.230	46.030	46.580	48.320
Cane sugar	.821	.210	.324	.430	.435
Reducing sugar (as invert)	34.970	46.010	45.710	46.120	47.850
Starch	*13.790	1.680	4.000	1.850	2.650
Pentosans	4.170	3.770	4.120	4.600	4.320
Crude fiber	*6.520	*8.120	*7.620	*8.020	*7.150
Ratio (sugar ÷ acid)	4.380	5.540	6.430	6.780	6.340
Carbohydrates—					
Total	60.870	59.800	61.720	61.050	62.450
Soluble	35.880	46.230	46.030	46.580	48.320
Insoluble	24.990	13.670	15.690	14.470	14.130

The percentage composition of samples of commercially picked green fruit (Pl. I, *A*), of the same after being ripened at room temperature, of turning fruit as picked (Pl. I, *B*) and after being ripened, and of vine-ripened fruit (Pl. II, *C*) is given in Table VI. All the fruit for the different samples was collected at the same time, in order that a comparison might be made. In the case of commercially picked green tomatoes, four crates were taken at random in one of the largest packing houses of the South. The fruit had just been picked and brought into the packing shed. The sample for analysis was taken from as representative a lot as could be obtained, portions of approximately 20 tomatoes being used. These had been ripened by exposure to air and light in the laboratory until they assumed a characteristic ripe appearance, as judged by the color. They were sampled 13 days later. Turning tomatoes were taken to the laboratory after being picked and one lot sampled; another lot was set aside to ripen. Four days later they showed a red color and were therefore sampled. Vine-ripened fruit was, of course, sampled as soon as it was brought into the laboratory. Table VI summarizes the analytical results obtained. Comparing the analyses of commercially picked green tomatoes with those given in Table IV, it will be seen that green fruits are not mature, for the chemical transformations of ripening have not been completed. The sugar-free solids are comparatively high, while the sugars are correspondingly low. The total amount of carbohydrates is still low compared with that in mature fruit. Taking composition as a criterion of maturity, one must conclude that commercially picked green fruits are immature and therefore inferior. When green fruit is commercially ripened, however, changes take place, which, although corresponding in general trend to those of normal vine ripening, nevertheless fail to bring the fruit to the same degree of ripeness attained normally. The artificially ripened tomato is lower in total sugar than vine-ripened fruit (46.23 per cent of the dry weight in the former, as contrasted with 48.32 per cent in the latter) and higher in acid (8.34 per cent, as contrasted with 7.62 per cent). The ratio of sugar to acid in the former is 5.54, while in the latter it is 6.34. In other words, the artificially ripened fruit is different in taste, due to the lack of one constituent and an excess of the other. In spite of these differences, however, the taste is not as bad as that of fruit which reaches the market. If some way could be devised to place on the market fruit having substantially the same flavor as that found in tomatoes ripened like the samples used, there would be little likelihood of complaint.

When the data for turning tomatoes (Table VI) are examined, it is found that they compare more favorably with vine-ripened mature fruit than the commercially picked green fruits. In the interval between the time when green tomatoes are picked in commercial practice and the time of turning red on the plant, sugar-free solids normally decrease considerably, while sugars increase in proportion. Since in turning tomatoes there is very little starch present which can be converted into sugar, it is seen that there is not so marked an increase of soluble carbohydrates in further ripening as in the artificial ripening of green-picked fruit. The acid content changed from 7.15 to 6.86 per cent during ripening, but the latter figure is below that of normal fruit. The total amount of sugar is also below normal, but not as much so as in artificially ripened green tomatoes. The ratio in the case of ripened turnings is 6.78, compared with 6.34 in vine-ripened fruit. This signified that the former should be comparatively sweet and less pronouncedly acid, as was indeed true. The facts brought out indicate that there is less chemical difference between turning and vine-ripened fruit than there is between commercially ripened green fruits and the latter. Differences in chemical composition between vine-ripened fruit and commercially picked green tomatoes ripened in the laboratory, exposed to air and light, are not sufficient to account for the marked differences in flavor and palatability between commercially ripened fruit and normal fruit. This conclusion was confirmed by taste comparisons.

EFFECT OF LACK OF VENTILATION ON RIPENING.

Since the differences due to ripening after picking with normal exposure to the air were obviously insufficient to account for the inferiority of Florida tomatoes after shipment, it seemed to be clearly indicated that the cause of the difficulty might well be lack of ventilation during commercial ripening. As already stated, the fruits are wrapped before packing for shipment, and it seemed not unlikely that the paper used might appreciably retard gas exchange and thus modify the course of ripening.

In order to test the hypothesis that wrapping plays an important part in influencing the composition and flavor of tomatoes, it was deemed necessary to analyze tomatoes which were ripened in a nonventilated chamber and to compare the results with those obtained with wrapped fruit. Comparisons were made between (1) tomatoes commercially picked and ripened without ventilation, (2) commercially picked and ripened, wrapped with one paper, (3) commercially picked and wrapped with three papers, (4) commercially picked and ripened unwrapped at room temperature, (5) turnings ripened unwrapped at room temperature, and (6) vine-ripened fruit. All of the fruit used for the above comparisons was obtained at the same time. A box for the green fruit ripened with no ventilation was made of composition board about a quarter of an inch thick. The approximate size was a little less than 1 cubic yard. All corners were sealed with adhesive tape and the door was made by cutting it from the board and hinging it on. The total exclusion of air from the interior of the chamber of course was not secured, but the degree of nonventilation obtained was complete enough for the experiment, as shown by the fact that at times the oxygen content of the chamber would not support an alcohol flame. Six baskets of tomatoes (approximately 125 fruits) were allowed to remain in this chamber, which was heated with one electric bulb, until they showed a red color. They were then removed and sampled by taking portions from 15 to 20 fruits. It required 11 days for the color to appear. Other fruits were wrapped with one and three papers and set aside at room temperature until they also attained a red color. These were sampled 11 days later. Summaries of the analyses are given in Table VII.

TABLE VII.—*Composition of commercially picked green Livingston Globe tomatoes allowed to ripen under different conditions as compared with artificially ripened turnings and vine-ripened red fruits.*

[The asterisk (*) indicates that the given result is based upon a single determination; results not thus marked are the mean of two determinations.]

Constituents.	Commercially picked; ripening— No ventilation.	One paper wrapping.	Three paper wrappings.	At room temperature.	Turning fruit; ripened at room temperature.	Vine-ripened fruit; red ripe.
SEC. A.—Percentage of entire fruit:						
Moisture	*93.930	*94.500	*94.430	*94.310	*94.540	*94.490
Total solids	*6.070	*5.500	*5.570	*5.690	*5.460	*5.510
Sugar-free solids	3.745	3.037	3.039	3.059	2.916	2.847
Acidity (as citric acid)	1.104	.850	.673	.475	.375	.420
Total nitrogen	*.134	.131	.1265	.1335	.1265	.116
Protein (=N × 6.25)	*.838	.818	.791	.834	.791	.725
Total sugar (as invert)	2.325	2.462	2.531	2.631	2.543	2.667
Cane sugar	.048	.012	.077	.012	.024	.024
Reducing sugar (as invert)	2.275	2.450	2.450	2.628	2.518	2.637
Starch	.079	.084	.139	.095	.101	.146
Pentosans	.255	.224	.238	.214	.251	.238
Crude fiber	*.482	*.482	*.473	*.462	*.438	*.394
Ratio (sugar ÷ acid)	2.110	3.010	3.760	5.540	6.780	6.340
Carbohydrates—						
Total	3.140	3.253	3.381	3.403	3.334	3.441
Soluble	2.325	2.463	2.531	2.631	2.543	2.667
Insoluble	.815	.790	.850	.772	.791	.774
SEC. B.—Percentage of dry matter:						
Sugar-free solids	61.700	55.050	54.550	53.770	53.410	51.670
Acidity (as citric acid)	18.180	15.450	12.080	8.340	6.860	7.620
Total nitrogen	*2.210	2.380	2.270	2.340	2.320	2.100
Protein (=N × 6.25)	*13.810	14.670	14.190	14.630	14.500	13.130
Total sugar (as invert)	38.290	45.950	45.440	46.230	46.580	48.130
Cane sugar	.791	.218	1.382	.210	.430	.435
Reducing sugar (as invert)	37.450	44.540	43.980	46.010	46.120	47.850
Starch	1.301	1.620	2.500	1.680	1.850	2.650
Pentosans	4.190	4.080	4.270	3.770	4.600	4.320
Crude fiber	*7.940	*8.760	*8.490	*8.120	*8.020	*7.150
Ratio (sugar ÷ acid)	2.110	3.010	3.760	5.540	6.780	6.340
Carbohydrates—						
Total	51.730	60.400	60.700	59.800	61.050	62.450
Soluble	38.290	45.950	45.440	46.230	46.580	48.320
Insoluble	13.440	14.450	15.260	13.670	14.470	14.130

There are striking differences in the analyses between the acid and carbohydrate content of tomatoes commercially picked and ripened without ventilation and the same fruit ripened when exposed to the air. Without ventilation the acids are very high and the soluble carbohydrates (sugars) are low. These facts indicate incomplete oxidation of carbohydrates to carbon dixoid (CO_2) with the consequent accumulation of acid. The connection of these changes in composition with the flavor is very obvious. The nonventilated fruit was markedly inferior. Although the reaction was decidedly acid, the general flavor was insipid. While the same effect was not produced to as great an extent in fruit ripened when wrapped with paper, it nevertheless takes place. Fruit wrapped with one paper had a noticeably inferior flavor; it was not as poor as the sample ripened without ventilation, but it was worse than that of green fruit ripened without wrapping. The acid content of fruit ripened without ventilation shows an increase of approximately 138 per cent over that of vine-ripened fruit; that of fruit ripened while wrapped with one paper, an increase of approximately 102 per cent; and that of fruit ripened while wrapped with three papers, an increase of about 58 per cent. The soluble carbohydrate content for fruit ripened without ventilation shows a decrease of nearly 21 per cent compared with normal fruit; that of fruit ripened while wrapped with one paper, a decrease of nearly 5 per cent; and that of fruit ripened while wrapped with three papers, a decrease of nearly 6 per cent.

The data presented also bring out the fact that green tomatoes ripened when exposed to air and unwrapped are superior in taste and chemical composition to the same fruit ripened when wrapped with paper.

Several experiments were carried out in order to determine what effect lack of ventilation produced on the normal color of the tomato. Since they all yielded the same results, it will suffice to present the figures from one. Two large glass jars were filled with green fruit and cardboard covers placed over each. Unwrapped fruits were placed in baskets as checks. Both lots were held at room temperature and examined at the same time. (Table VIII.)

TABLE VIII.—*Effect of lack of ventilation on the normal coloring of tomatoes held at room temperature.*

Time of examination.	21 fruits in bottles (no ventilation).		31 fruits in baskets (ventilated).				
	Green.	Turning.	Green.	Colored.			
				Turning.	Pink.	Red.	Total.
After 6 days	21		6	10	6	9	25
After 12 days		21			5	[a] 26	31

[a] 14 soft.

These results would seem to indicate that lack of ventilation retards ripening and the consequent formation of pigment in the tomato. It was noticed that the tomatoes kept in jars were firmer than those left exposed to the air. Hill (24) records a similar condition in the case of peaches held in an atmosphere of carbon dioxid (CO_2). His explanation is that CO_2 evidently prevents the hydrolysis of the pectin to which peaches owe their hardness. This may also be the case with tomatoes. An attempt was made to duplicate the results presented above by using a larger closed chamber and also by wrapping the fruit in paper, but no concordant data were obtained. There are hardly sufficient data to justify making any statement as to the effect of wrapping on the color formation. It is often noticed that tomatoes picked green and ripened artificially acquire a much better color than vine-ripened fruit. The color is deeper and more even.

Investigation has been made by Duggar (17) of the effect of various conditions on the development of the tomato pigment (called by this author lycopersicin). He studied the effect of light and temperature on its development and concluded that high color is independent of any direct effect of light and that fruit will redden perfectly in darkness at a temperature of even 20° to 25° C. He also states that "when half-grown varieties are employed a temperature of 30° C. is sufficient to suppress lycopersicin development to a marked extent. Fruits nearer maturity, that is, those showing a blush of color, permit a stronger lycopersicin development at all temperatures employed." Duggar (17) also studied the relation of oxygen to pigment production in the tomato and concluded that lack of oxygen inhibited lycopersicin development.

From a consideration of all the data it appears that wrapping is harmful to the tomato and that lack of ventilation is probably the main cause of inferiority in taste and keeping quality.

In 1913 Hill (24) reported on the respiration of fruits and growing plant tissues in certain gases with reference to ventilation and fruit storage. He found that apples and peaches ripened poorly when oxygen was withheld from them. It was also pointed out that an accumulation of carbon dioxid within paper wrappers in which peaches are shipped and an insufficient supply of oxygen cause "ice scald."

Fischer and Nelson (18) recently came to a similar conclusion with regard to wrapping cantaloupes, maintaining that "wrapped cantaloupes do not refrigerate so well in transit nor do they reach the consumer in as good condition as do cantaloupes not wrapped." In both of these investigations similar conditions were found to be the result of wrapping, namely, that wrapped fruits were firmer but of poorer quality than those unwrapped.

Another serious disadvantage of the present method of picking and shipping green tomatoes lies in the fact that it is practically impossible to determine comparable stages of maturity in picking. In spite of the fact that the fruit of individual baskets is all approximately of the same size, the coloring of the fruit does not occur at the same time. The explanation for this fact has already been given. The maturity of a tomato depends on its age and not on its size; consequently fruits of the same size do not necessarily ripen and turn red simultaneously. The most obvious disadvantage of the inability to determine comparable stages of maturity is the fact that when the fruit does ripen, either in transit or after reaching the market, it colors up so irregularly that many sortings become necessary before the dealer is able to dispose of it. The more uniform in size and color a package is the more salable it is, so naturally the dealer sorts the fruit to insure a quick sale. In consequence of many handlings the fruit becomes soft and injured and is more liable to fungous attacks through the germination of adhering spores. It is clear that, if possible, only fruit of the same age should be packed in a single container. No criterion for determining age exists except at the time of turning from green to pink. If turning tomatoes could be packed instead of green ones, this particular commercial difficulty would be solved. Since it has been shown, moreover, that Florida tomatoes are lacking in certain fundamental qualities as to taste, which would likewise be remedied by picking more mature fruit, the writer turned his attention to determining the feasibility of shipping "turnings." It was found, as would of course be expected, that the riper the tomatoes the shorter the time it is possible to hold them, but the fact was ascertained that "turnings" can be kept in good condition at a temperature approximating that obtained in refrigerator cars (50° to 55° F.) long enough to ship them and to sell them to the consumer. Turning tomatoes held in the refrigerator for 10 days and then kept at a temperature of approximately 75° F. for 5 days longer were found to be in an excellent condition. Other fruits remaining at the lower temperature for 15 days were still firm enough to be held at room temperature for a few days. At lower temperatures than those used it is possible to hold tomatoes even longer than 15 days. Iced shipments in pony refrigerators sent by express from Miami, Fla., to Washington, D. C., arrived in excellent condition. One commission man who has been shipping fruit under ice for a number of years states that these tomatoes reach the market in excellent condition and bring higher prices than uniced fruit. The above statements are not offered as recommendations for picking and shipping turning tomatoes under ice. There are, however, many good reasons for suggesting that turning fruit may be picked and shipped under an initial icing. One of these reasons has already been mentioned, namely, that it would be possible to pick fruit at the same stage of maturity which would ripen uniformly and save considerable of the loss which is at present experienced. Furthermore, chemical analysis has shown that turning fruit compares favorably with normal or vine-ripened fruit in composition, taste, and palatability. Other investigators, Powell (38), Ramsey (39, 40, 41), Stevens and Wilcox (47, 48), Ridley (42), and others, have shown that fruits are more liable to fungous infection when they are wounded than when uninjured. This is what one would expect in the light of some recent investigations which show a high correlation between susceptibility to infection and the resistance offered by the fruit to mechanical puncture.

The investigations of Rosenbaum (43) on the origin and spread of tomato fruit rots in transit have demonstrated that overripeness, bruises, and other injuries favor the appearance of these rots. Since the resistance of the epidermis shows the relative ease with which a fruit may become infected by means of a mechanical entrance of the spore tube, tables are presented showing these data in connection with tomatoes. Table IX (sec. A) shows the pressure necessary to penetrate the epidermis of fruit of different ages. The epidermis of colored fruit is softer than that of green tomatoes 38 days old, yet the difference is too small to justify the conclusion that green fruits are preferable on this account. Table IX (sec. B) also shows the effect of temperature on the resistance of the epidermis to wounding. These results indicate that tomatoes are less liable to injury when cooled than when they are warm and consequently are less liable to fungous infection. It is generally known also that respiration decreases considerably with the lowering of temperature. The products causing the inferior taste and flavor in tomatoes probably result from intramolecular respiration as a result of withholding free oxygen from the tissues. Under the present methods of shipping tomatoes from the South it would be impossible to allow cars to remain open throughout the entire journey. The initial icing of cars at the warm end of the trip would have the effect of preventing the harmful result of lack of ventilation by reducing respiration to a minimum.

TABLE IX.—*Effect of age and temperature upon the resistance to wounding of the epidermis of Livingston Globe tomatoes, showing also color conditions.*[1]

Descriptive data.	Sec. A.—Age of tomatoes. With needle having a diameter of 68 microns.						Sec. B.—Temperature effects. With needle having a diameter of—			
	7 days; green.	13 days; green.	21 days; green.	30 days; green.	38 days; green.	49 days; turning.	68 microns; turning.		78 microns; red ripe.	
Temperature of penetration (°C.)	30	29	29	30	33	30.5	24	9	25	14
Average of 10 scale readings at which penetration occurred for individual tomatoes:										
No. 1	41.3	38.3	23.6	14.4	32.4	33.8	23.91	15.75	32.48	30.92
No. 2	40.9	36.3	27.8	23.2	33.3	31.6	32.81	28.54	30.87	31.21
No. 3	38.4	37.1	32.6	21.3	28.2	29.5	21.40	16.70	32.16	28.64
No. 4	40.6	37.3	33.9	20.4	24.8	30.7	22.97	18.66	26.36	24.65
No. 5	41.2	40.3	32.1	23.7	30.5	32.0	25.35	20.60	28.91	22.63
No. 6	41.0	40.3	31.5	24.8	32.6	32.6	27.38	23.54	27.95	27.84
No. 7	39.6	36.6	29.3	24.9	25.8	32.3	25.38	23.36	31.32	29.32
No. 8	41.3	37.6	34.7	25.6	18.6	26.1	18.47	16.27	31.86	29.42
No. 9	41.7	36.6	31.5	25.1	32.2	37.0	24.35	20.38	23.66	23.79
No. 10	41.9	37.5	34.2	25.5	30.5	30.2	27.80	25.08	26.61	28.46
No. 11	......	39.8	32.1	27.7	27.5	32.6	29.19	25.72	......	......
No. 12	......	39.3	30.5	25.0	28.8	30.5	......	......	......	......
No. 13	......	37.4	26.3	21.6	30.0	29.1	......	......	......	......
No. 14	......	37.1	31.3	28.1	31.5	30.1	......	......	......	......
No. 15	......	38.8	22.6	25.4	33.9	28.7	......	......	......	......
No. 16	......	36.8	29.8	25.6	30.4	......	......	......	......	......
No. 17	......	38.4	29.5	......	27.8	......	......	......	......	......
No. 18	......	39.3	32.3	......	......	......	......	......	......	......
No. 19	......	39.5	24.9	......	......	......	......	......	......	......
No. 20	......	36.4	28.9	......	......	......	......	......	......	......
Average scale reading for entire lot of fruit	40.8	38.0	30.5	23.8	29.3	31.1	25.35	21.33	29.32	27.6
Due to tension of spring..grams	11.75	10.86	8.49	6.38	8.11	8.67	13.20	11.80	6.96	6.46
Weight of needle and rod...do..	14.63	14.63	14.63	14.63	18.91	18.91	23.48	23.48	12.04	12.04
Pressure necessary to puncture..grams.	2.88	3.77	6.14	8.25	10.80	10.24	10.28	11.68	5.08	5.58

[1] For detailed information as to the apparatus and methods used to obtain the data presented in this table, see the following references: Hawkins and Harvey (22); Hawkins and Sando (23); Rosenbaum and Sando (44).

Against the arguments in favor of picking and shipping turning fruit one must consider the advantages of present practices. The picking of turning fruit would require that the fields be gone over more frequently than at present and that the pickers exercise much more judgment and care. The writer had planned to make commercial shipments of tomatoes picked at the turning stage in order to get dependable information which might serve as a basis for recommending to the growers changes in the current practice, but the discontinuance of this work for the present has prevented the carrying out of the plan. It is of very great importance to the growers that these shipments be made. It is felt that the work reported upon in this bulletin supports the chemical explanation offered of the inferiority of tomatoes shipped from the east coast of Florida during the winter and spring months. It remains to be determined whether the changes in current practice suggested in these pages can be put into effect. If they can be, the result of these investigations will be to insure the consumer a better product in the future than in the past.

SUMMARY AND CONCLUSIONS.

With the particular object of discovering the chemical basis for the inferiority of commercially picked and ripened Florida tomatoes marketed in the North during the winter and spring, a series of analyses has been made of tomatoes of several degrees of maturity and of tomatoes ripened artificially under various conditions of ventilation.

It was found that the only way to secure samples of comparable maturity for analysis was to tag the blossoms and pick the fruit at a definite age. There is a wide range of variation in the size of the tomatoes within the same variety, but ripening proceeds at a uniform rate regardless of size. Maturity is dependent upon age, not upon size.

Using fruit of known age, therefore, analyses were made which indicate that in general throughout the ripening period there is an increase in moisture, acids, and sugars and a decrease in solids, total nitrogen, starch, pentosans, crude fiber, and ash.

The most striking change which occurs during ripening is that undergone by carbohydrates. Sugars increase from 25.66 per cent in fruit 14 days old to 48.32 per cent in ripe fruit.

Starch decreases in the same interval from 15.84 to 2.65 per cent. The most marked decrease takes place during the period of transition from green to red.

The percentage composition of fruit picked green but ripened with free access of air compared with analyses of turning and vine-ripened fruit did not show enough variation to account for the great differences in taste found in commercially shipped fruit. Turning tomatoes showed less difference from vine-ripened fruit than did the green fruit and compared favorably with normal tomatoes not only in composition but also in taste.

The effect of lack of ventilation on ripening was to increase the acid content approximately 138 per cent over that of vine-ripened fruit. The flavor of tomatoes ripened without ventilation was very inferior. The soluble carbohydrate content showed a decrease of nearly 21 per cent. Commercially ripened green fruit, wrapped with one paper, showed an increase in acid of approximately 102 per cent and a sugar decrease of nearly 5 per cent compared with corresponding tests of vine-ripened tomatoes. The results of wrapping with three papers were less marked and are difficult to explain.

The data seem to justify the conclusion that wrapping probably modifies the course of ripening to such an extent as to account for marked changes in taste and flavor. The combined results of picking fruit green, of wrapping, and of closing the cars in transit probably account for the total differences existing in quality between commercially shipped and vine-ripened tomatoes.

LITERATURE CITED.

ALBAHARY, J. M.

(1) 1907. Analyse complète du fruit du Lycopersicum esculentum ou tomate. *In* Compt. Rend. Acad. Sci. [Paris], t. 145, no. 2, p. 131–133.

(2) 1908. Étude chimique de la maturation du Lycopersicum esculentum (tomate). *In* Compt. Rend. Acad. Sci. [Paris], t. 147, no. 2, p. 146–147.

(3) ALWOOD, W. B.
1891. Tomatoes. Va. Agr. Exp. Sta. Bul. 9, 18 p.

(4) ——— and BOWMAN, WALKER.
1890. A study of tomatoes. Va. Agr. Exp. Sta. Bul. 4, 18 p.

(5) BABCOCK, S. M.
1883. [Analysis of the] tomato. *In* N. Y. State Agr. Exp. Sta. 1st Ann. Rpt. 1882, p. 24.

(6) BACON, R. F., and DUNBAR, P. B.
1911. Changes taking place during the spoilage of tomatoes, with methods for detecting spoilage in tomato products. U. S. Dept. Agr., Bur. Chem. Cir. 78, 15 p.

(7) BAILEY, L. H.
1892. Do fertilizers affect the quality of tomatoes? *In* N. Y. Cornell Agr. Exp. Sta. Bul. 49, p. 456–458.

(8) ——— and LODEMAN, E. G.
1891. Notes on tomatoes. N. Y. Cornell Agr. Exp. Sta. Bul. 32, p. 143–189.

(9) BÉRARD, M.
1821. Suite du mémoire sur la maturation des fruits. Ann. Chim. et Phys., t. 16, p. 225–251.

(10) BERTRAND, GABRIEL.
1906. Le dosage des sucres réducteurs. Bul. Soc. Chim. Paris, s. 3, t. 35, p. 1285–1299.

(11) BIGELOW, W. D.
1917. Report on canned vegetables. *In* Jour. Assoc. Off. Agr. Chem., v. 3, no. 1, p. 1–21.

(12) BISHOP, W. H., and PATTERSON, H. J.
1890. Experiments with tomatoes. Md. Agr. Exp. Sta. Bul. 11, p. 47–74.

(13) BRIOSI, GIOVANNI, and GIGLI, TORQUATO.
1890. Su la composizione chimica e la struttura anatomica del frutto del pomodro (Lycopersicum esculentum Mill.). *In* Staz. Sper. Agr. Ital., v. 18, fasc. 1, p. 5–34.

(14) CALDWELL, G. C.
1892. The determination of sugar in the tomato. N. Y. Cornell Agr. Exp. Sta. Bul. 49, p. 399–400.

(15) CONGDON, L. A.
1912. A further study of the tomato with special reference to canned tomatoes. *In* N. Dak. Agr. Exp. Sta. 23d Ann. Rpt., 1912, pt. II, p. 216–242.

(16) DAHLEN, H. W.
1875. Beiträge zur chemischen Kenntniss der Gemüsepflanzen. *In* Landw. Jahrb., Bd. 4, p. 613–721.

(17) DUGGAR, B. M.
1913. Lycopersicin, the red pigment of the tomato, and the effect of conditions upon its development. *In* Wash. Univ. Studies, v. 1, pt. 1, no. 1, p. 22–45. Literature, p. 44–45.

(18) FISCHER, G. L., and NELSON, A. E.
1918. More care is needed in handling western cantaloupes. U. S. Dept. Agr., Bur. Markets Doc. 9, 11 p., 4 fig.

(19) FORMENTI, CARLO, and SCIPIOTTI, ARISTIDE.
1906. Zusammensetzung italienscher Tomatensäfte. *In* Ztschr. Untersuch. Nahr. u. Genussmtl., Bd. 12, Heft 5, p. 283–295.

(20) GORE, H. C., and FAIRCHILD, DAVID.
1911. Experiments on the processing of persimmons to render them nonastringent. U. S. Dept. Agr., Bur. Chem. Bul. 141, 31 p., 5 fig., 3 pl.

(21) HASSELBRING, HEINRICH, and HAWKINS, L. A.
1915. Pysiological changes in sweet potatoes during storage. *In* Jour. Agr. Research, v. 3, no. 4, p. 331–342. Literature cited, p. 341–342.

(22) HAWKINS, L. A., and HARVEY, R. B.
1919. Physiological study of the parasitism of Pythium debaryanum Hesse on the potato tuber. *In* Jour. Agr. Research, v. 18, no. 5, p. 275–297, 2 fig., pl. 35–37. Literature cited, p. 295–297.

(23) ——— and SANDO, C. E.
1920. Effect of temperature on the resistance to wounding of certain small fruits and cherries. U. S. Dept. Agr. Bul. 830, 6 p., 1 fig.

(24) HILL, G. R., jr.
1913. Respiration of fruits and growing plant tissues in certain gases, with reference to ventilation and fruit storage. N. Y. Cornell Agr. Exp. Sta. Bul. 330, p. 377–408. Bibliography, p. 407–408.

(25) HUSTON, H. A., and BRYAN, A. H.
1901. The chemical composition of materials. *In* Ind. Agr. Exp. Sta. 13th Ann. Rpt., [1899]/1900, p. 80–88.

(26) JENKINS, E. H., and BRITTON, W. E.
1896. On the use of commercial fertilizers for forcing-house crops. Experiments with tomatoes. *In* Conn. Agr. Exp. Sta. 19th Ann. Rpt., 1895, p. 75–90.

(27) KENNEDY, C. W.
1873. Solania in Solanum lycopersicum. Amer. Jour. Pharm., v. 45 (s. 4, v. 3), p. 8–9.

(28) KRAUS, E. J., and KRAYBILL, H. R.
1918. Vegetation and reproduction with special reference to the tomato. Oreg. Agr. Exp. Sta. Bul. 149, 90 p., 22 fig. Literature cited, p. 87–90.

(29) LLOYD, F. E.
1911. Carbon dioxide at high pressure and the artificial ripening of persimmons. *In* Science, n. s., v. 34, no. 887, p. 924–928. Citations, p. 928.

(30) MCELHENIE, T. D.
1872. Lycopersicum esculentum.—Tomato. *In* Amer. Jour. Pharm., v. 44, p. 197–200.

(31) MILLARDET, A.
1876. Note sur une substance colorante nouvelle (Solanorubine) découverte dans la tomate. Nancy, 1876. (Abstract.) *In* Just's Bot. Jahresber., Jahrg. 4, p. 783–784. 1876. Original not seen.

(32) MONTANARI, CARLO.
1904. Materia colorante rossa del pomodoro. *In* Staz. Sper. Agr. Ital., v. 37, fasc. 10, p. 909–919.

(33) MUNSON, L. S., and WALKER, P. H.
1906. The unification of reducing sugar methods. *In* Jour. Amer. Chem. Soc., v. 28, no. 6, p. 663–686.

(34) PALMERI, P.
1885. Sul pomodoro. *In* Ann. R. Scuola Sup. Agr. Portici, v. 5, p. 67–83.

(35) PASSERINI, N.
1890. Sulla composizione chimica del frutto del pomodoro. (Solanum lycopersicum L.) *In* Staz. Sper. Agr. Ital., v. 18, fasc. 5, p. 545–572.

(36) PATTERSON, J.
1889. Report of the chemist. *In* Md. Agr. Exp. Sta. 2d Ann. Rpt., 1889, p. 67–93.

(37) PECKOLT, TH.
1909. Heil- und Nutzpflanzen Brasiliens. *In* Ber. Deut. Pharm. Gesell., Jahrg. 19, Heft 3, p. 180–207.
Cites early analyses of John and Bertagnini.

(38) POWELL, G. H., et al.
1908. The decay of oranges while in transit from California. U. S. Dept. Agr., Bur. Plant Indus. Bul. 123, 79 p., 26 fig., 9 pl. (2 col.).

RAMSEY, H. J.
(39) 1915. Factors governing the successful shipment of red raspberries from the Puyallup Valley. U. S. Dept. Agr. Bul. 274, 37 p., 26 fig.

(40) 1915. Handling and shipping citrus fruits in the Gulf States. U. S. Dept. Agr., Farmers' Bul. 696, 28 p., 10 fig.

(41) 1916. The handling and shipping of fresh cherries and prunes from the Willamette Valley. U. S. Dept. Agr. Bul. 331, 28 p., 11 fig.

(42) RIDLEY, V. W.
1918. Factors in transportation of strawberries from the Ozark region. U. S. Dept. Agr., Bur. Markets Doc. 8, 10 p., 6 fig.

(43) ROSENBAUM, JOSEPH.
1918. The origin and spread of tomato fruit rots in transit. *In* Phytopathology, v. 8, no. 11, p. 572–580, 1 fig., pl. 4.

(44) ——— and SANDO, C. E.
1920. Correlation between the size of the fruit and the resistance of the tomato skin to puncture and its relation to infection with Macrosporium tomato Cooke. *In* Amer. Jour. Bot., v. 7, no. 2, p. 78–82.

(45) SCHUNCK, C. A.
1903. The xanthophyll group of yellow colouring matters. *In* Proc. Roy. Soc. London, v. 72, no. 479, p. 165–176, pl. 6–7.

(46) SNYDER, HARRY.
1899. Tomatoes. Composition and food value. *In* Minn. Agr. Exp. Sta. Bul. 63, p. 513–517.

STEVENS, N. E., and WILCOX, R. B.
(47) 1917. Rhizopus rot of strawberries in transit. U. S. Dept. Agr. Bul. 531, 22 p., 1 fig. Literature cited, p. 21–22.

(48) 1918. Further studies on the rot of strawberry fruits. U. S. Dept. Agr. Bul. 686, 14 p.

(49) Street, J. P.
1911. Report on vegetables. *In* U. S. Dept. Agr., Bur. Chem. Bul. 137, p. 122–134.

(50) Stüber, W.
1906. Über die Zusammensetzung der Tomate und des Tomatensaftes. *In* Ztschr. Untersuch. Nahr. u. Genussmtl., Bd. 11, Heft 10, p. 578–581.

(51) Thompson, Firman, and Whittier, A. C.
1913. Forms of sugar found in common fruits. Proc. Soc. Hort. Sci., 9th Ann. Meeting, 1912, p. 16–22.

(52) Tracy, W. W.
1907. Tomato culture . . . , 150 p., illus. New York.

(53) U. S. Department of Agriculture. Office of Experiment Stations.
1893. Composition of vegetables. *In* U. S. Dept. Agr. Off. Exp. Stas. Bul. 15, p. 401.

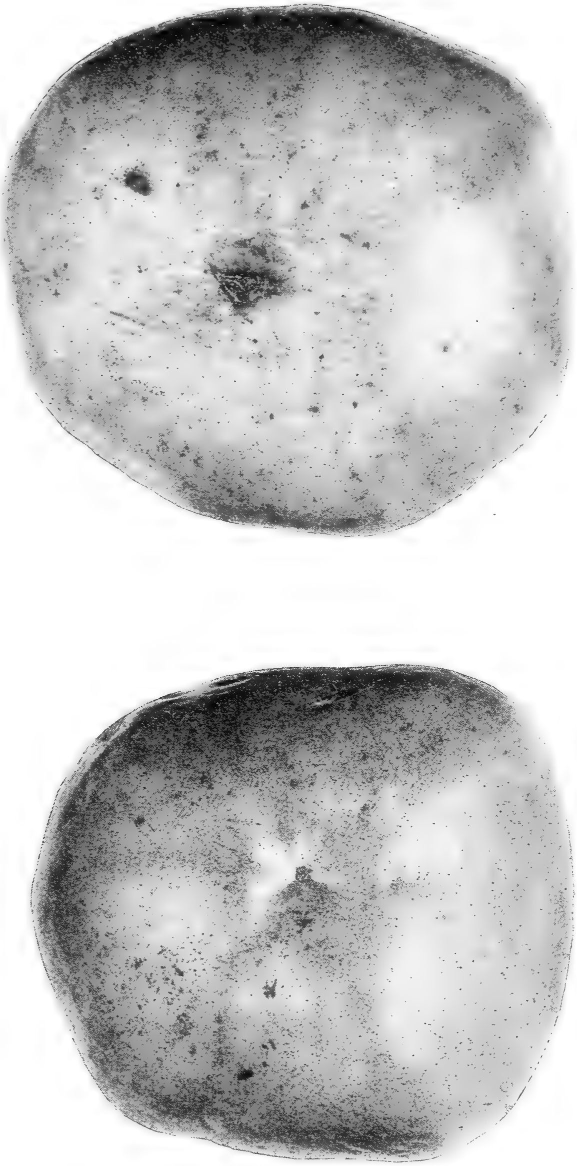
(54) Van Slyke, L. L., Taylor, O. M., and Andrews, W. H.
1905. Tabulated analyses showing amounts of plant-food constituents in fruits, vegetables, etc. *In* N. Y. Agr. Exp. Sta. Bul. 265, p. 223–230.

(55) Voorhees, E. B.
1889. Experiments on tomatoes. N. J. Agr. Exp. Sta. Bul. 63, 27 p.

(56) Walker, P. H.
1907. The unification of reducing sugar methods. *In* Jour. Amer. Chem. Soc., v. 29, no. 4, p. 541–554.

(57) Wiley, H. W., ed.
1908. Official and provisional methods of analysis, Association of Official Agricultural Chemists. As compiled by the committee on revision of methods. U. S. Dept. Agr., Bur. Chem. Bul. 107 (rev.), 272 p., 13 fig. Reprinted in 1912.

(58) Willstätter, Richard, and Escher, H. H.
1910. Über den Farbstoffe der Tomate. *In* Ztschr. Physiol. Chem., Bd. 64, Heft 1, p. 47–61, pl. 2 (col.).



EXTERIOR OF A NORMAL AND OF A "PUFFY" TOMATO.

INTERIOR OF A NORMAL AND OF A "PUFFY" TOMATO.

APPENDIX.

COMPARISON OF THE COMPOSITION OF "PUFFY" AND NORMAL LIVINGSTON GLOBE TOMATOES.

The abnormality in tomatoes called puffiness is one in which the seed cavities are affected. The fruit sounds hollow when it is patted with the hand and shows external angular irregularities. Plates III and IV show the angular appearance of the exterior and also the characteristic appearance of the interior of the fruit. In a locality where the trouble was especially pronounced one crate of tomatoes was taken at random from a packing house and the number of hollow and normal fruits estimated. The figures follow: Estimated by the sound before cutting, normal 58, hollow 95; estimated by cutting the fruit in two, normal 32, partly hollow 56, pronouncedly hollow 66.

Counts were made in order to determine whether certain plants produced fruits that were all hollow and other plants produced normal fruit. It appears that a single plant may produce both normal and hollow fruit. There is no stage in the life history of the tomato at which puffiness is a natural occurrence, but it may occur on small as well as large fruit. It does not seem to affect the amount of color or the time of ripening. Table X shows that although there are some differences in chemical composition between normal and "puffy" fruit there are no possible explanations to be gained from this standpoint.

Various fertilizer plats were arranged to determine the effect of different amounts of nitrogen, potash, and phosphoric acid upon the production of "puffy" fruit. Seven plats were set out and the fertilizer mixtures were given in four applications at the rate of 1 ton to the acre. The fertilizer ingredients consisted of acid phosphate, sodium nitrate, and potassium sulphate, and the following ratios were used on the various plats: 1 : 5 : 3; 1 : 10 : 8; 3 : 5 : 3; 3 : 10 : 8; 3 : 6 : 0; 7 : 5 : 3; and 7 : 10 : 8.

TABLE X.—*Composition of normal and "puffy" Livingston Globe tomatoes. Both samples picked green, but fairly mature.*

Constituents.	Normal fruit.		"Puffy" fruit.	
	Wet basis.	Dry basis.	Wet basis.	Dry basis.
Moisture	94.36	....	94.32	....
Total solids	5.64	....	5.68	....
Sugar-free solids	2.93	51.95	2.84	50.00
Total nitrogen	.140	2.48	.139	2.45
Total sugar (as invert)	2.71	48.05	2.84	50.00
Reducing sugar (as invert)	2.40	42.55	2.61	45.95
Starch	.42	7.44	.38	6.70
Alcohol-soluble pentosans	.034	.602	.033	.581
Insoluble pentosans	.190	3.54	.197	3.47
Crude fiber	.55	9.75	.54	9.51
Carbohydrates:				
Total	3.904	69.38	3.990	70.26
Soluble	2.71	48.55	2.84	50.00
Insoluble	1.19	20.83	1.15	20.26

Examination of the fruit produced in this experiment showed that both normal and hollow fruits were to be found on every plat. Complete counts could not be made, owing to the destruction of the vines by a flood before the end of the season, but enough observations were made to show that within the limits used varying quantities of fertilizer elements did not influence the production of hollow fruit.

No positive results were obtained in this study showing the cause of puffiness in tomatoes, but the evidence indicated that the condition is not correlated with any considerable differences in the chemical composition of the mature fruit. The phenomenon is probably physiological in its nature, for the same varieties which show it in Florida are said not to do so, or only to a very slight extent, when grown in Michigan. A great difference that immediately occurs to one between conditions in the two places is that in Florida the crop is produced only through heavy annual applications of commercial fertilizers, which are not used in Michigan. Puffiness may therefore be dependent upon an unbalanced soil solution, but, if so, none of the variations in the fertilizers just enumerated sufficed to restore a proper condition. It is, of course, not inconceivable that puffiness is of a genetical nature and due to somatic variation. If so, it might, in conformity with the observed facts, be much more frequent in some varieties than in others, and the same plant might show both normal and "puffy" fruit. The whole subject is one which needs investigation.

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