THE EFFECT OF CRACKED ICE IN PRESERVING

THE

NUTRITIVE VALUE OF FRESH FRUITS

AND

VEGETABLES

THE EFFECT OF CRACKED ICE IN PRESERVING THE NUTRITIVE VALUE OF FRESH FRUITS AND VEGETABLES

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INTRODUCTION

Preserving the nutritive value of fresh fruits and vegetables is of national importance. Great progress has been made in determination of nutritional values of food, in methods of cooking and processing to preserve these values. There are few published papers concerning the retention of quality of fresh fruits and vegetables utilizing crushed ice display as compared with room temperature display. The desirability of a method of retaining quality in fresh fruits and vegetables is quite evident from observation of the produce displayed in most retail grocery stores.

The retention of quality must be considered from the time of harvest until the product reaches the consumer. Present methods of handling, due to carelessness and lack of knowledge, result in heavy losses of food nutrients prior to reaching the consumer. Local market gardeners and fruit growers provide little protection from time of harvest to sale. Grocers in most instances do not provide sufficient protection of the produce while it is displayed for sale to the consumer. Shippers in some states, particularly California, have recognized that special methods must be used if produce is to be acceptable when it reaches its destination. Extensive use is made of cracked ice on produce shipped in trucks and refrigerator cars. Protection is provided at the time of loading and maintained to the destination point. However, it is not customary to ice prior to final packing in the truck or car. As a result, there are serious losses in quality before grading and packing occur. This is particularly noticeable when there is a delay in handling after harvest. In a like manner, serious losses may also occur when the products are not kept properly refrigerated after delivery to the terminal market.

REVIEW OF LITERATURE

Factors Affecting the Nutritive Values of Fresh Fruits and Vegetables

Fresh fruits and vegetables are the principal natural sources of ascorbic acid (Vitamin C) (29). Since Vitamin C is unstable and quickly disappears from fresh fruits and vegetables when stored and displayed under average conditions (air temperature) (16), the development of a practical method of retaining the Vitamin C content would contribute to the conservation of nutritional values. The present methods of handling fruits and vegetables, which expose them to the effects of warm dry air, result in a decrease in Vitamin C content, change of texture, change of flavor, change of color, dehydration, and decay.

In a report by Hauck (21) it is stated that authorities agree that about one-fourth of the food produced is discarded before it reaches the consumer. He also quoted Robert T. Oliver of Syracuse University at follows:

> "What agricultural economists have tended to call normal wastage is draining away twenty to thirty per cent of all the food our farmers produce. One pound of food in every four that is grown is destined for the garbage dump. Two hours out of eight worked by our farmers, food processors, and distributors is time thrown away. Twenty-five acres of every one hundred acres are ploughed, planted, cultivated, and harvested with the produce to be finally discarded as waste."

Rough percentage estimates made by the War Food Administration indicated (21) that losses in leafy, green and yellow vegetables were forty-three per cent, tomatoes and citrus fruits thirty-three per cent and deciduous fruits twenty-six per cent. This indicates the necessity for reducing waste and preserving quality of fresh fruits and vegetables.

Index of Quality

In order to measure quality a means of evaluation is required. As stated by Fenton (16):

> "Vitamin C may be used on this general basis as a criterion of quality in vegetables. If it is retained, all other attributes known as quality, that is aroma, color, flavor, texture, and nutrients will be retained. Of all the vitamins, Vitamin C is most easily destroyed, and no other vitamin or mineral is dissolved from vegetables more easily."

Tressler (38) concluded that the Vitamin C content noticeably decreased as vegetables became overmature. The Vitamin C content is fairly well retained in fresh vegetables under refrigeration but at room temperatures (70 Degrees Fahrenheit or above) the vitamin is rapidly lost. He states that the Vitamin C content may be used as an index of quality in frozen vegetables. As a result of these findings, Vitamin C content is to be used as the index of quality in this study.

Factors Causing Variation of Vitamin C

in Fresh Fruits and Vegetables

In England, Olliver (29) determined that the Vitamin C content of asparagus varied in the proportion of 1:3:6, in white stem, green stem, and tips respectively. Feener et. al. (15) report that the greatest amount of Vitamin C in asparagus is found in the green portion and that mature stalks were slightly lower than immature stalks in Vitamin C content.

Tressler et. al. (39) report that variety was a factor of considerable importance in the Vitamin C content of Green Snap beans, tomato and spinach. The soil and growing conditions affect the Vitamin C content of spinach. The Vitamin C content of tomatoes increases as they ripen. Wade and Kanapaux (41), in a study of the ascorbic acid content of Snap beans, concluded that the stage of maturity made only slight differences in the ascorbic acid content. Tressler et. al. (39) supports the same view in work with Snap beans.

Olliver (29) found the distribution of ascorbic acid to be fairly even throughout a single leaf of spinach but there were differences between the leaves of the same plant. Feener et. al. (15), in the Boston area, found the Vitamin C content of spinach varied more throughout the year than that of any other vegetable, being higher in Spring and Fall and lower in Winter and Summer. Spinach stored at room temperature lost Vitamin C rapidly, while that under refrigeration held up well. They found the center leaves higher in Vitamin content than the outer leaves and that crushed or broken leaves lost Vitamin C rapidly, as much as 60 per cent was lost as compared with the loss from unbroken leaves. Kifer and Munsell (22) report a variety difference in the Vitamin C content of spinach and that the Princess Juliana variety with heavily savoyed, bluish-green leaves, seemed slightly less potent in Vitamin C than Virginia Savoy and Viroflay varieties. Tressler et. al. (39) report that in New York, Fall spinach was slightly higher in Vitamin C content than Spring spinach. The content was also greater in spinach from upland soils than that grown on muck. Witwer et. al. (43) present evidence that the amount of Vitamin C in leafy green vegetables increases as fertility of the soil with respect to nitrogen decreases.

Clow and Marlatt (8) studied the effect of allowing field mature green tomatoes to ripen at 70 Degrees Fahrenheit for three to four weeks and found them to be as potent a source of Vitamin C as those allowed to ripen in the field. Tressler et. al. (39) report that fully ripe tomatoes contained twice as much Vitamin C as green ones. Tressler et. al. (39) indicate that variety is a factor of considerable importance in determining the ascorbic acid content of tomatoes. The Vitamin C content of the tomato increases as it ripens (39). Maclinn et. al. (27) found considerable variation in the ascorbic acid content of the varieties of tomatoes tested but found no correlation between size and Vitamin C content. McCollum (26) reports a variation in the amount of Vitamin C between varieties, the amount of defoliation of the plant or exposure of fruits to sunlight. The lighted side of the tomato was higher in Vitamin C content. Tripp et. al. (40) found no consistent relationship between size of the tomato and its Vitamin C value but did find a difference between varieties. Currence (10) concludes that environmental factors rather than the variety causes the difference in the ascorbic acid content of tomatoes.

Smith et. al. (35) found that the ascorbic acid content of the cantaloupe increases with ripening. Mosley and Satterfield (28) show that overripe melons have a lower Vitamin C content than ripe melons. They found no definite relationship between size of the cantaloupe and the ascorbic acid content. Some variation between varieties was noted. There were large variations in the amount of Vitamin C between cantaloupe of the same variety (28). Wheeler et. al. (42) found variation between the ascorbic acid content of varieties and that ripe cantaloupes were higher in ascorbic acid than green cantaloupes.

Schrader et. al. (34) report that in the peach the ascorbic acid concentration was found highest in the skin, lower in the flesh just under the skin, and lowest in the flesh around the pit. The ascorbic acid content increases as the peach ripens being highest in the fully ripe fruit. The Vitamin C content of the peach is not as high as that of citrus fruits or tomatoes.

Mayfield and Richardson (25) report a seasonal variation of the ascorbic acid content of the strawberry with the content decreasing as the season progresses. A variation also occurred from year to year. Satterfield and Yarbrough (33) found differences in the ascorbic acid content between seven varieties produced under the same conditions. Lineberry and Burkhart (23) report that the Vitamin C content of the Klondike strawberry was markedly affected by the environment, (sunshine and field location). Burkhart and Lineberry (6) found the ascorbic acid content of sun-ripened strawberry to be greater than that of the shade-ripened berry. They also found that the Vitamin C content of ripe berries was greater than that of green berries.

Effects of Storage Temperature

Many aspects of the problem of fruit and vegetable handling from the field to the consumer have been thoroughly investigated but only limited study has been made on the storage of fresh fruits and vegetables in cracked ice. Gordon et. al. (20) compared the effects of snow ice and room temperature handling on the retention of Vitamin C in fresh vegetables displayed in a retail market. They found that ascorbic acid (Vitamin C) was rapidly lost from leaf lettuce 21.7%, green beans 11%, and spinach 44.8% at room temperature after an eight hour period. Ascorbic acid retention was much better when the vegetables were displayed on snow ice. The appearance and quality of vegetables on snow ice (display) was better than that of vegetables held at room temperature. Zepplin and Elvehjem (45) came to the conclusion in their study of effects of refrigeration on Vitamin C (ascorbic acid) retention on chard, lettuce, spinach, broccoli and green beans, that packing fresh vegetables in crushed ice is a practical and effective means of preventing quality deterioration during transportation and storage. This type of storage combines the factors of humidity and low temperature. When vegetables were handled in this manner they retained their characteristic color, weight, and freshness. Tressler et. al. (39) found that spinach, snap beans and green peas stored at $1^{o}C.$ to $3^{o}C.$ ($34^{o}F.$ to $38^{o}F.$) lost little ascorbic acid within three days, whereas those kept at room temperature lost approximately fifty per cent in the same period of time. Burrell and Elbright (7) in a comparison of (1) freshly harvested and (2) market fruits and vegetables found that garden fresh fruits and vegetables contained considerably larger quantities of ascorbic acid than those obtained from the open market. Proctor and Greenlie (32) who studied the effect of temperature on the Vitamin C content of spinach found that spinach when held at temperatures below 40°F. retained Vitamin C quite well, while at ordinary room temperatures it deteriorated rapidly. Thus, they came to the conclusion that low storage temperature, high humidity, combined with moderate air velocities, were desirable for retention of Vitamin C and the quality of fresh vegetables. Platenius (30) in his study of effect of temperature on rate of deterioration of fresh vegetables stated that, "The holding of vegetables at 35 F. had no noticeable effect on the subsequent rate of breakdown when these vegetables were later transferred to higher temperatures". The rate of visible breakdown and rate of deterioration of eating quality were not necessarily the same (30). Work at Michigan State (1) indicated that the loss of ascorbic acid in leaf lettuce, green beans and spinach at room temperature in a period of eight hours was 22, 11, and 45 per cent respectively, while similar lots on snow ice lost only 0, 3, and 4 per cent respectively, of their ascorbic acid content. (1) Dunker and Fellers (13) found that spinach stored at 1°C to 3°C. (34°F. to 38°F.) lost but little ascorbic acid in three days but when at room temperature it lost 50 per cent in three and almost all, in seven days. Dunker et. al. (12) report that sweet corn at room temperature lost very little ascorbic acid the first day, at the end of the third day 20%, and 50% after four days. They found little loss in Vitamin C occurred in corn after harvest and refrigerated storage in the husk for a few days. From studies in Wisconsin (14) the ascorbic acid losses from vegetables in 48 hours were as follows: Spinach 70%, Lettuce 70%, Broccoli (flowers) 65%, Green Bean 25%, and Swiss Chard 60%. All losses were greatly reduced by refrigeration (14). Fitzgerald and Fellers (18) found that a storage temperature of 34°F. allowed a retention of 50 to 100% of the original ascorbic acid content of fresh fruits and vegetables. Spiers et. al.

(36) using the Mary Washington variety of asparagus in refrigeration tests, (with moderate or heavy icing around the butts) found that the quality was maintained in excellent condition for a week with very little moisture loss. At the same time, asparagus held at room temperature deteriorated and was in poor condition after three days. When heavily iced, the asparagus retained 81% of its original ascorbic acid content at the end of five days (36). Brasher et. al. (4) found that the freshly harvested appearance of corn, tomatoes, cantaloupes, and kale was well preserved by the use of cracked ice and by ice refrigeration. A similar condition for tomatoes resulted in deterioration after the fourth day. The palatability of produce was better in these vegetables held in snow or cracked ice than in those stored at room temperature. Sweet corn and cantaloupes at room temperature were unfit for food after two days, and tomatoes at the end of four days. Their results indicated that the use of cracked ice or ice refrigeration offers a way to reduce losses due to shrinkage and spoilage and to allow greater retention of Vitamin C, freshness, and palatability (4). Gilligan and Woodmansee (19) in their experiment found that even though the destruction of ascorbic acid in the cantaloupe was delayed by the use of chopped ice or refrigeration there was no significant loss at room temperature in four days. Olliver (29) in England reported that with vegetables stored at room temperature, under conditions approximating those in retail shops, as much as 78% of the Vitamin C of spinach was destroyed in two days, with an 80% loss from the tips of asparagus in four days. The results of Feener et. al. (15) with vegetables held at 1-3°C. (34° F. to 38° F.) indicate very little Vitamin C loss for long periods of storage, while that held at 21° C. to 22° C. (70° F. to 72° F.) lost from 50 to 90% and was not marketable after 72 hours. Their data suggests that by proper refrigeration throughout the marketing period the Vitamin C content could be retained during the normal marketing

period (15). Similar results were obtained by Yaroshenko (44). Brown and Morse (5) report no loss of ascorbic acid when tomatoes were held as long as eighteen days either at refrigerator temperature (44° F.) or at laboratory temperatures (75° F. to 88° F.).

Lineberry and Burkhart (23) found no loss of ascorbic acid from strawberries stored at 5° C. (41° F.) for two days and concluded that strawberries free of mechanical injury and under good shipping conditions do not lose an appreciable amount of Vitamin C (ascorbic acid) within forty-eight to seventy-two hours after harvest. Mayfield and Richardson (25) report no appreciable loss in ascorbic acid content of fresh strawberries when held either for five days in a mechanical refrigerator (40° F.) or for two days at room temperature (75° F.).

It is apparent from the variability of the reports on the use of refrigeration and of cracked ice that an investigation to obtain data under Oklahoma conditions is desirable. The condition of vegetables sold in most produce markets and the general high temperatures prevailing during the Oklahoma marketing season further indicate study of quality retention would be of value to the public. A method that would allow for higher Vitamin C retention, for palatability, and for better appearance in fresh fruits and vegetables would be desirable from the standpoint of the producer, the grocer, and the consumer. The reports of the amount of food wasted due to trimming and spoilage that occur on the farms, in the markets, and in the consumer's home prior to its ultimate use presents a challenge to investigate and devise means to reduce the losses from these factors.

METHOD OF STUDY

In this study the following horticultural crops were used; Mary Washington asparagus, Hale's No. 36 cantaloupe, Burpee's Stringless Greenpod bean, Tendermost sweet corn, Southern Giant Curled mustard, Elberta peach, Bloomsdale spinach, Blakemore strawberry, and Stokesdale tomato.

The method of determination of ascorbic acid content was essentially that of Bessy and King (3) modified to the extent of using three per cent metaphosphoric acid for extraction recommended by Bessy (2) and use of the Waring Blendor recommended by Davis (11). Analyses were made to determine the Vitamin C content at six hour intervals for the first day and then daily. At each analysis, samples were also taken to determine dry weight. Changes in texture, flavor, and color were noted at each time interval and herein reported. Texture evaluations were made by the bite test, that is, biting with the teeth to determine if the produce is firm, soft, crisp, or tough. Flavor evaluations were made on the basis of odor and taste as described by Crocker (9). Color was determined by matching with color gradient plates of Maerz and Paul (24).

Following harvest or purchase the vegetables and fruits were brought into the laboratory and treated as indicated.

(a) Freshly harvested material obtained in the field.

  (1) Iced at harvest, maintained in cracked ice display case.

  (2) Uniced at harvest, maintained in regular (room temperature) display case.

(b) Material obtained from Local Retail Markets or handled by ordinary methods prior to test.

  (3) Iced in laboratory and maintained in cracked ice.

  (4) Uniced in laboratory in regular display.

In sampling, a relatively large amount of material was prepared, and a twenty-five gram sample weighed for analysis. Dry weight determination was also made using a similar sample. Three per cent metaphosphoric acid solution was used in the extraction of ascorbic acid from the tissues. Maceration was accomplished by use of Waring Blendor operating for two or three minutes depending on the type of material. The Blendor breaks the cellular structure thus making it possible for the metaphosphoric acid to dissolve the Vitamin C. The blended material was filtered through a number twelve Whatman folded filter and a five cubic centimeter portion of the filtrate withdrawn and pipetted into a white porcelain evaporating dish. The filtrate in the evaporating dish was titrated with a standardized Sodium, 2, 6 - Dichloro-benzenoneindophenol dye (Eastman). The dye was admitted from an automatic Zero burette until a faint pink endpoint was reached and the reading was recorded. The dye was standardized daily with United States Pharmacopoeia Reference Standard Ascorbic acid.

The dry weight of each twenty-five (25) gram sample was determined by drying in a Thelco Thermostatic Controlled Oven. The material remained in the oven twenty-four hours at a temperature of 200° F. The beakers were then removed from the oven and placed in a desiccator until weighed. Dry weight is equal to the weight of the tared beaker and dried material minus the weight of the tared beaker.

Calculations of ascorbic acid content were made on the dry weight basis as herewith indicated:

$$\frac{\text{Known dye concentration}}{\text{Known ascorbic acid strength}} : \frac{\text{Known dye concentration}}{\text{Unknown ascorbic acid solution}}$$

= ascorbic acid expressed as milligrams per cubic centimeter.

Total weight of sample and solution minus dry weight (sample) times milligrams of ascorbic acid per cubic centimeter of test solution divided by dry weight of sample = Milligrams of ascorbic acid per gram (dry weight basis).

Calculation procedure for formulation of graphs and tables:
The averages of the ascorbic acid values per time interval (0, 6, 12, 18, 24, 48 hours, etc.) per treatment were determined. Expressing the average zero reading of ascorbic acid content as one hundred per cent, determined the percentage change per time interval. The graphs as prepared, indicate the average cumulative loss, the average rate of loss, and the average room temperature for each treatment of the respective fruit or vegetable. Data are recorded in chart form and so used in reporting results of these experiments.

RESULTS OF STUDY

Losses in the Ascorbic Acid (Vitamin C) content of the fruits and vegetables were greatest when displayed at room temperature. Freshly harvested mustard and asparagus, at room temperature, lost 85 and 83% of their original ascorbic acid content in six days. That stored in cracked ice lost only 31 and 41%, respectively, in the same period of time. Spinach at room temperature lost 62% of its original ascorbic acid content in five days, while that on crushed ice lost only 24% in five days and 26% in six days.

The data in Tables I, II, III, and IV show the average changes in Vitamin C and moisture content. The graphs, numbers 1 to 18, chart each of the following factors:

(a) Average room temperature.

(b) Cumulative average loss of Ascorbic Acid at room temperature.

(c) Cumulative average loss of Ascorbic Acid on cracked ice.

(d) Average rate of loss at six-hour intervals at room temperature. (Red dashed line).

(e) Average rate of loss at six hour intervals for cracked ice. (Black dashed line).

TABLE I

THE EFFECT OF TIME AND TEMPERATURE ON CHANGES IN ASCORBIC ACID CONTENT OF FRESHLY HARVESTED FRUITS AND VEGETABLES*

	Holding Condition	No. of Tests	Ave. Ascorbic Acid Mg/gram (Dry Weight Basis)									
			Hours				Days					
VEGETABLE			0	6	12	18	1	2	3	4	5	6
Asparagus	iced	3	5.27	5.26	5.11	4.80	4.54	4.10	3.80	3.47	3.34	3.08
	uniced	3	5.27	4.51	4.11	3.52	3.10	2.52	1.60	1.42	0.92	0.86
Green Snap Bean	iced	6	1.97	1.95	1.88	1.84	1.79	1.74	1.63	1.59	1.50	1.35
	uniced	6	1.97	1.80	1.68	1.62	1.49	1.22	1.01	0.84	0.76	0.66
Green Sweet Corn	iced	6	0.46	0.45	0.43	0.40	0.38	0.37	0.34	0.27	0.27	0.26
	uniced	6	0.46	0.42	0.40	0.39	0.36	0.33	0.27	0.21	0.16	0.11
Mustard	iced	3	8.94	8.55	8.24	7.88	7.69	7.40	7.20	6.66	6.24	6.16
	uniced	3	8.94	7.31	6.94	6.74	6.46	5.14	3.28	2.61	2.32	1.25
Spinach	iced	3	5.25	5.10	5.10	4.87	4.78	4.93	4.50	4.24	4.02	3.82
	uniced	3	5.25	4.17	4.00	3.67	3.62	3.53	2.98	2.67	2.07	-
Tomato	iced	6	4.34	4.30	4.12	4.04	3.91	3.85	3.51	3.34	3.11	3.02
	uniced	6	4.34	3.88	3.65	3.49	3.39	3.20	3.05	3.00	2.86	2.68
Cantaloupe	iced	4	3.31	3.28	3.15	3.11	3.01	2.82	2.62	2.82	2.78	2.63
	uniced	4	3.31	3.10	2.96	2.92	2.88	2.82	2.73	2.42	-	-
FRUIT												
Peach	iced	6	0.91	0.90	0.87	0.82	0.79	0.75	0.73	0.68	0.65	0.60
	uniced	6	0.91	0.88	0.81	0.74	0.66	0.62	0.59	0.54	0.51	-
Strawberry	iced	4	5.81	5.63	5.38	5.27	5.17	4.95	4.72	4.38	4.03	3.82
	uniced	4	5.81	5.45	5.18	4.99	4.82	4.45	4.27	-	-	-

* Such material is herein referred to as "Field Samples", expressed as F.S.

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TABLE II

THE EFFECT OF TIME AND TEMPERATURE ON CHANGES IN MOISTURE CONTENT OF FRESHLY HARVESTED FRUITS AND VEGETABLES*

VEGETABLE	Holding Condition	No. of Tests	Ave. Moisture Content in Per Cent: Hours 0	6	12	18	Days 1	2	3	4	5	6
Asparagus	iced	3	92.1	92.3	92.5	92.3	92.7	92.9	93.0	92.1	92.1	92.7
	uniced	3	92.1	92.6	92.2	92.8	92.3	92.4	92.3	91.2	90.4	89.9
Green Snap Bean	iced	6	88.5	88.5	88.2	88.3	88.4	88.8	89.2	89.8	89.1	89.0
	uniced	6	88.5	88.3	88.0	88.1	86.6	87.1	85.1	85.4	86.2	84.0
Green Sweet Corn	iced	6	71.4	70.9	70.2	70.1	69.8	69.8	69.2	69.1	69.4	69.0
	uniced	6	71.4	69.8	69.6	69.2	68.7	67.0	65.5	64.2	61.6	58.5
Mustard	iced	3	87.8	87.6	87.2	86.9	86.7	87.1	87.2	87.2	87.3	87.5
	uniced	3	87.8	86.4	85.8	85.5	85.6	85.1	79.8	79.4	78.2	78.2
Spinach	iced	3	89.2	89.1	89.7	89.1	89.0	88.9	88.9	88.8	88.9	88.8
	uniced	3	89.2	87.7	87.4	86.7	86.6	86.6	85.4	85.2	81.6	-
Tomato	iced	6	93.9	93.8	93.7	93.7	93.6	93.4	93.6	93.4	93.3	93.3
	uniced	6	93.9	93.7	93.4	93.3	93.3	93.4	93.5	93.4	93.2	93.2
Cantaloupe	iced	4	92.2	92.4	92.7	92.7	92.6	92.3	92.5	92.4	91.9	92.1
	uniced	4	92.2	92.1	92.3	92.2	92.4	92.0	92.6	92.7	-	-
FRUIT												
Peach	iced	6	86.6	86.6	86.5	86.2	86.0	86.2	85.1	85.8	85.6	85.2
	uniced	6	86.6	86.5	86.0	85.8	85.4	85.4	85.4	84.6	84.5	-
Strawberry	iced	4	90.1	90.0	90.1	89.8	89.8	90.3	89.4	89.5	89.8	89.7
	uniced	4	90.1	90.0	89.7	89.7	89.5	89.9	90.2	-	-	-

* Such material is herein referred to as "Field Samples", expressed as F.S.

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TABLE III

THE EFFECT OF TIME AND TEMPERATURE ON CHANGES IN ASCORBIC ACID CONTENT OF FRUITS AND VEGETABLES SECURED FROM LOCAL PRODUCE MARKETS*

VEGETABLE	Holding Condition	No. of Tests	Ave. Ascorbic Acid Mg/gram (Dry Weight Basis)									
			Hours				Days					
			0	6	12	18	1	2	3	4	5	6
Asparagus	iced	3	3.05	2.86	2.76	2.62	2.24	2.04	2.14	2.11	2.08	1.95
	uniced	3	3.05	2.32	2.07	1.98	1.83	1.43	1.21	1.06	0.92	0.69
Green Snap Bean	iced	6	1.58	1.56	1.50	1.44	1.43	1.32	1.18	1.10	0.97	0.94
	uniced	6	1.58	1.44	1.38	1.26	1.17	0.88	0.76	0.71	0.63	0.53
Green Sweet Corn	iced	6	0.41	0.41	0.40	0.40	0.38	0.34	0.31	0.27	0.24	0.23
	uniced	6	0.41	0.40	0.40	0.38	0.35	0.32	0.24	0.17	0.13	0.09
Mustard	iced	3	5.77	5.15	4.44	4.73	4.26	4.18	4.05	3.88	3.54	3.38
	uniced	3	5.77	4.62	4.45	3.42	3.20	2.09	1.27	0.61	-	-
Spinach	iced	3	3.90	3.57	3.42	3.39	3.07	2.85	2.60	2.22	2.07	1.77
	uniced	3	3.90	2.73	2.63	2.23	2.38	1.51	1.36	-	-	-
Tomato	iced	6	3.52	3.45	3.34	3.22	3.08	2.99	2.93	2.88	2.77	2.68
	uniced	6	3.52	3.26	3.10	2.96	2.93	2.86	2.78	2.69	2.65	2.49
Cantaloupe	iced	4	3.02	3.00	2.90	2.83	2.85	2.70	2.55	2.49	2.53	2.43
	uniced	4	3.02	2.85	2.72	2.72	2.54	2.39	2.30	2.08	-	-
FRUIT												
Peach	iced	6	0.80	0.80	0.78	0.71	0.66	0.62	0.64	0.57	0.55	0.51
	uniced	6	0.80	0.73	0.67	0.62	0.58	0.54	0.54	0.46	-	-
Strawberry	iced	4	5.70	5.68	5.35	5.19	5.11	5.03	4.54	4.40	3.90	3.78
	uniced	4	5.70	5.45	5.18	5.08	4.88	4.35	4.12	-	-	-

* Such material is herein referred to as "Store Samples", expressed as S.S.

TABLE IV

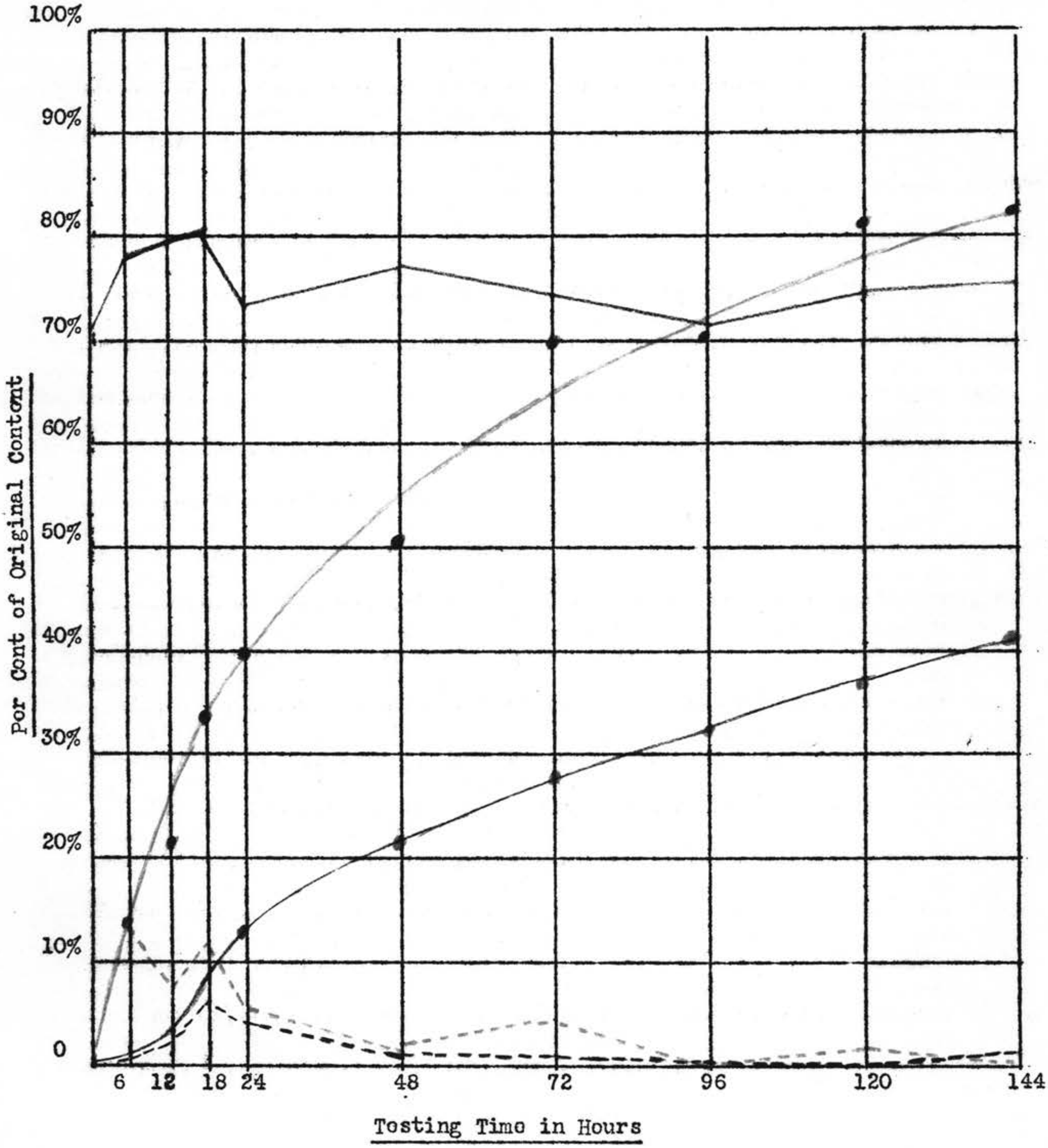
THE EFFECT OF TIME AND TEMPERATURE ON CHANGES IN MOISTURE CONTENT OF FRUITS AND VEGETABLES SECURED FROM LOCAL PRODUCE MARKETS*

	Holding Condition	No. of Tests	Ave. Moisture Content in Per Cent									
			Hours				Days					
VEGETABLE			0	6	12	18	1	2	3	4	5	6
	iced	3	92.7	93.3	93.3	93.6	93.5	93.4	93.3	93.1	93.1	92.9
Asparagus	uniced	3	92.7	92.4	93.2	93.0	92.9	92.6	92.3	92.0	92.4	90.0
	iced	6	89.5	89.4	88.8	89.2	89.2	88.9	90.0	89.4	89.4	89.2
Green Snap Bean	uniced	6	89.5	89.2	89.1	88.7	88.4	86.9	86.2	82.2	84.5	84.2
	iced	6	71.5	71.4	70.7	70.2	70.2	69.8	70.8	70.5	70.2	70.5
Green Sweet Corn	uniced	6	71.5	71.2	70.5	70.0	69.0	68.1	65.6	62.4	60.6	55.4
	iced	3	89.4	88.9	89.0	88.4	88.6	89.2	89.3	89.7	89.6	89.5
Mustard	uniced	3	89.4	88.2	87.5	85.4	85.3	81.9	78.6	76.0	-	-
	iced	3	90.0	89.9	89.6	89.5	89.8	88.7	88.6	88.7	88.6	88.4
Spinach	uniced	3	90.0	89.2	88.3	87.5	87.9	85.9	86.0	-	-	-
	iced	6	93.6	93.7	93.6	93.4	93.3	93.3	93.4	93.4	93.3	93.3
Tomato	uniced	6	93.6	93.7	93.5	93.2	93.4	93.6	93.5	93.4	93.4	93.3
	iced	4	92.6	92.6	92.5	92.4	92.4	92.2	92.4	92.5	92.6	92.7
Cantaloupe	uniced	4	92.6	92.5	92.5	92.3	92.2	92.5	92.5	92.6	-	-
FRUIT												
	iced	6	86.4	86.4	86.0	85.5	85.0	84.7	84.7	84.8	84.7	84.5
Peach	uniced	6	86.4	86.5	85.2	84.8	84.7	83.7	83.5	82.9	-	-
	iced	4	91.1	91.0	90.5	90.7	90.6	90.5	90.8	90.5	90.0	90.0
Strawberry	uniced	4	91.1	90.7	90.6	90.6	90.5	90.3	90.4	-	-	-

* Such material is herein referred to as "Store Samples", expressed as S.S.

17

Percentage of Ascorbic Acid Loss in Iced and Un-Iced Produce



Curves showing loss of ascorbic acid in per cent from starting content

BLACK	= Ice Packed Produce
RED	= Produce at room temperature, not ice packed
BLUE	**= Average room temperature °F.**

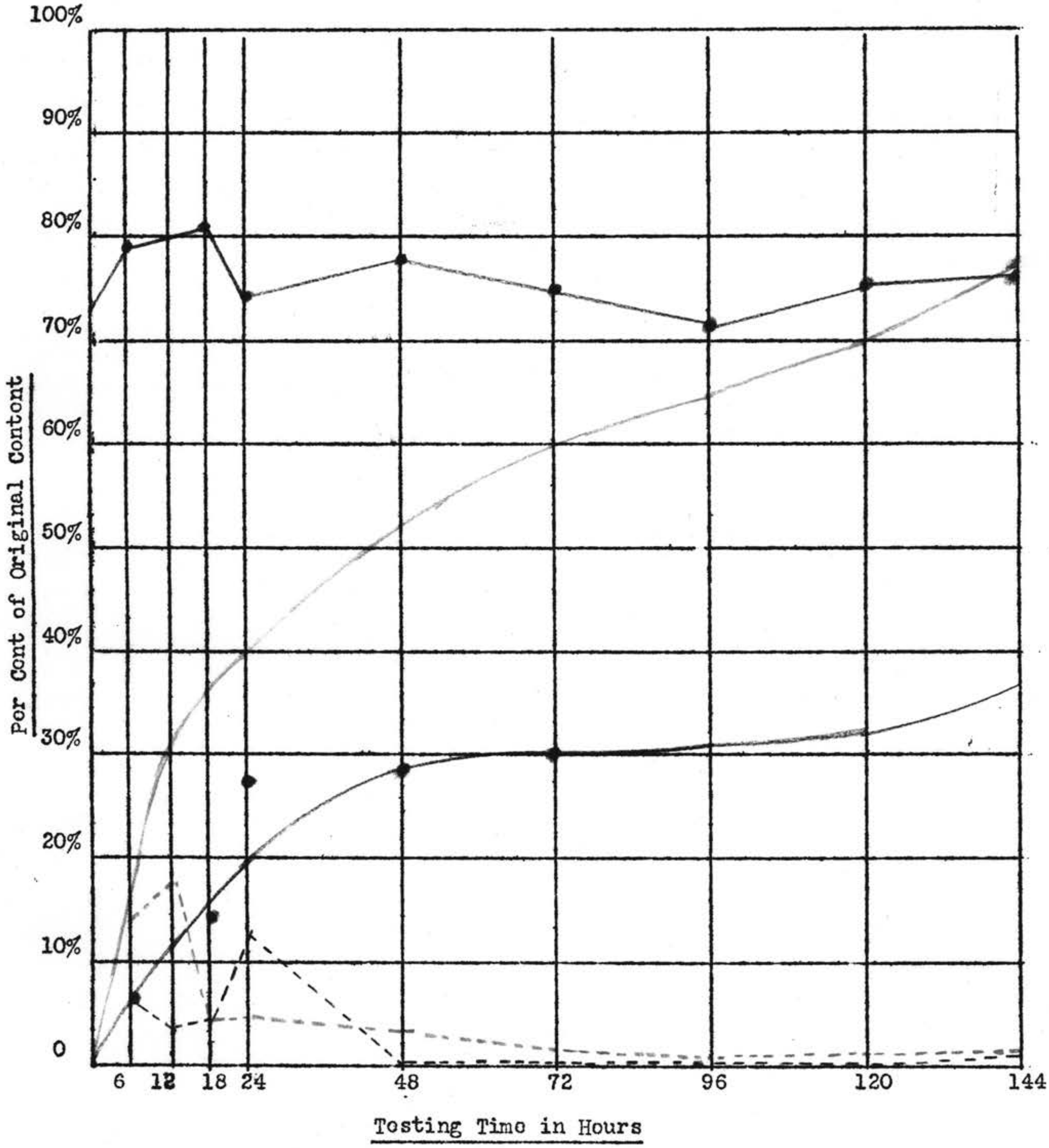
Kind of Produce

P.S. Mary Washington Asparagus

Chart No. 1

From Tests No. **Average of 3 tests**

Percentage of Ascorbic Acid Loss in Iced and Un-Iced Produce



Curves showing loss of ascorbic acid in per cent from starting content

BLACK	=	Ice Packed Produce
RED	=	Produce at room temperature, not ice packed
BLUE	=	**Average room temperature °F.**

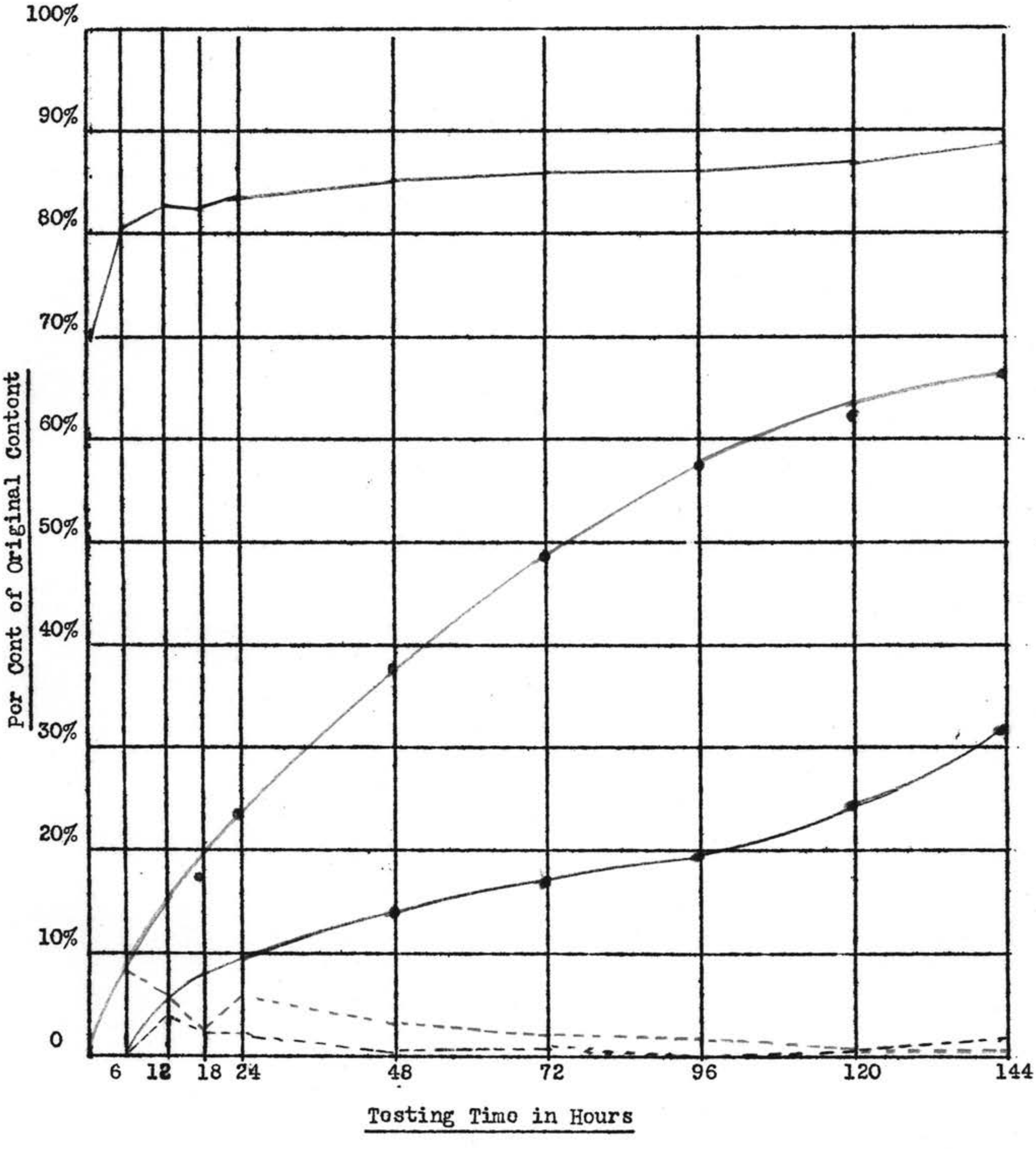
Kind of Produce

S.S. Mary Washington Asparagus

Chart No. 2

From Tests No. **Average of 3 tests**

Percentage of Ascorbic Acid Loss in Iced and Un-Iced Produce



Curves showing loss of ascorbic acid in per cent from starting content

BLACK = Ice Packed Produce

RED = Produce at room temperature, not ice packed

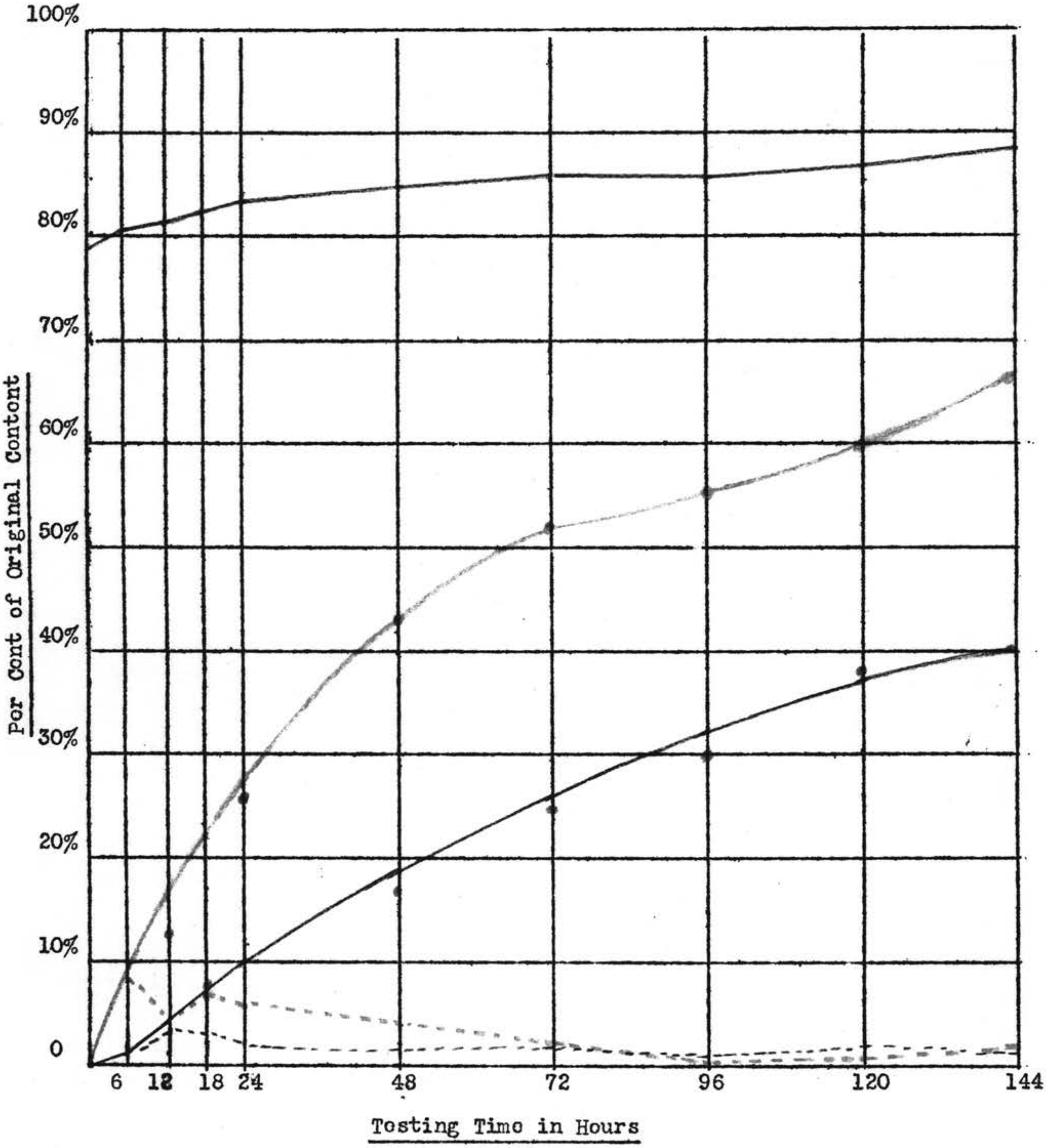
BLUE = Average room temperature °F.

Kind of Produce Burpee's Stringless Greenpod F.S. Green Snap Bean

Chart No. 3

From Tests No. Average of 6 tests

Percentage of Ascorbic Acid Loss in Iced and Un-Iced Produce



Curves showing loss of ascorbic acid in per cent from starting content

BLACK = Ice Packed Produce

RED = Produce at room temperature, not ice packed

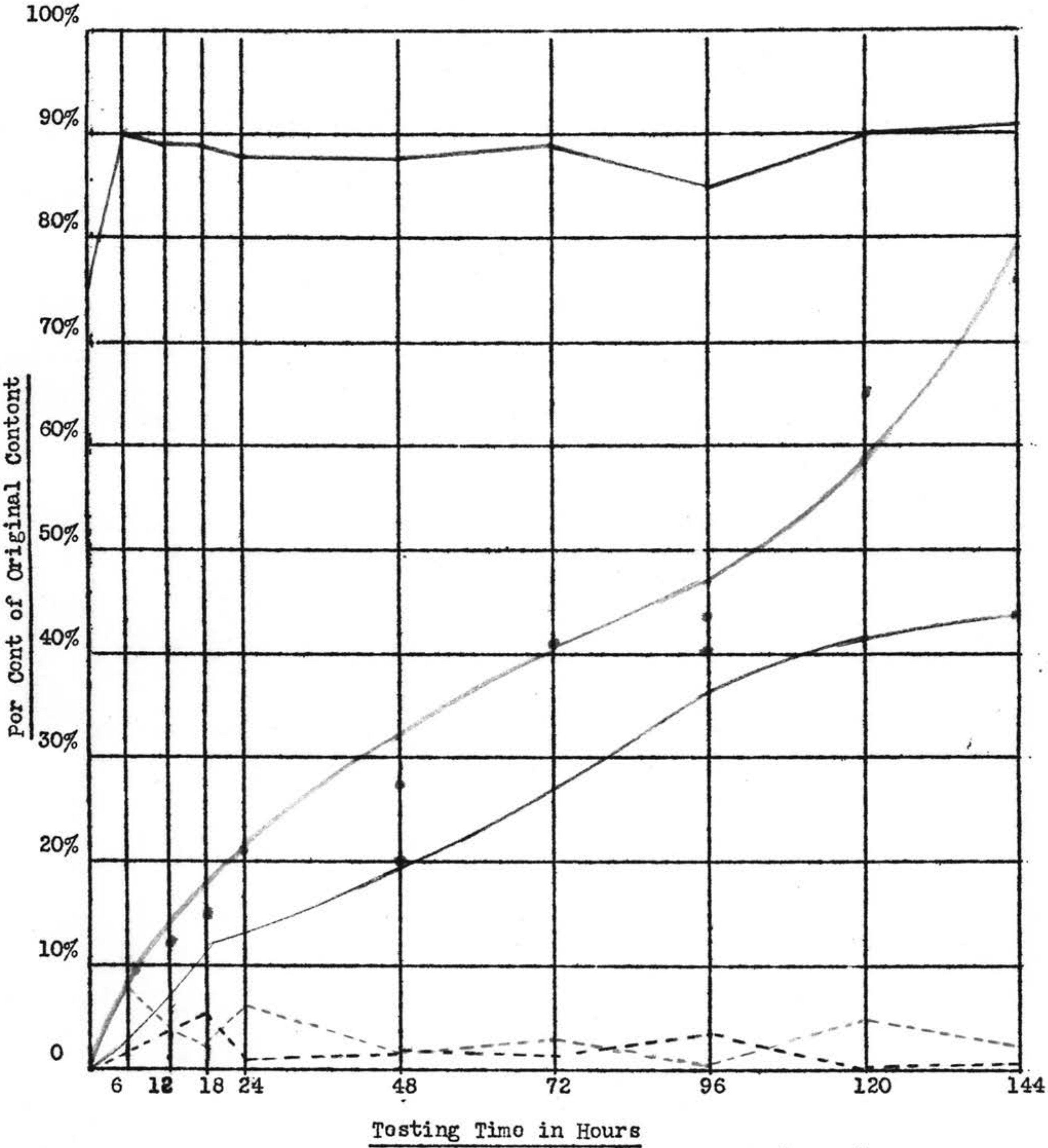
BLUE = Average room temperature °F.

Kind of Produce: Burpee's Stringless Greenpod ~~S.S. Green Snap Bean~~

Chart No. 4

From Tests No. Average of 6 tests

Percentage of Ascorbic Acid Loss in Iced and Un-Iced Produce



Curves showing loss of ascorbic acid in per cent from starting content

Kind of Product Tendermost Fla. Sweet Corn

BLACK = Ice Packed Produce

5

Chart No.

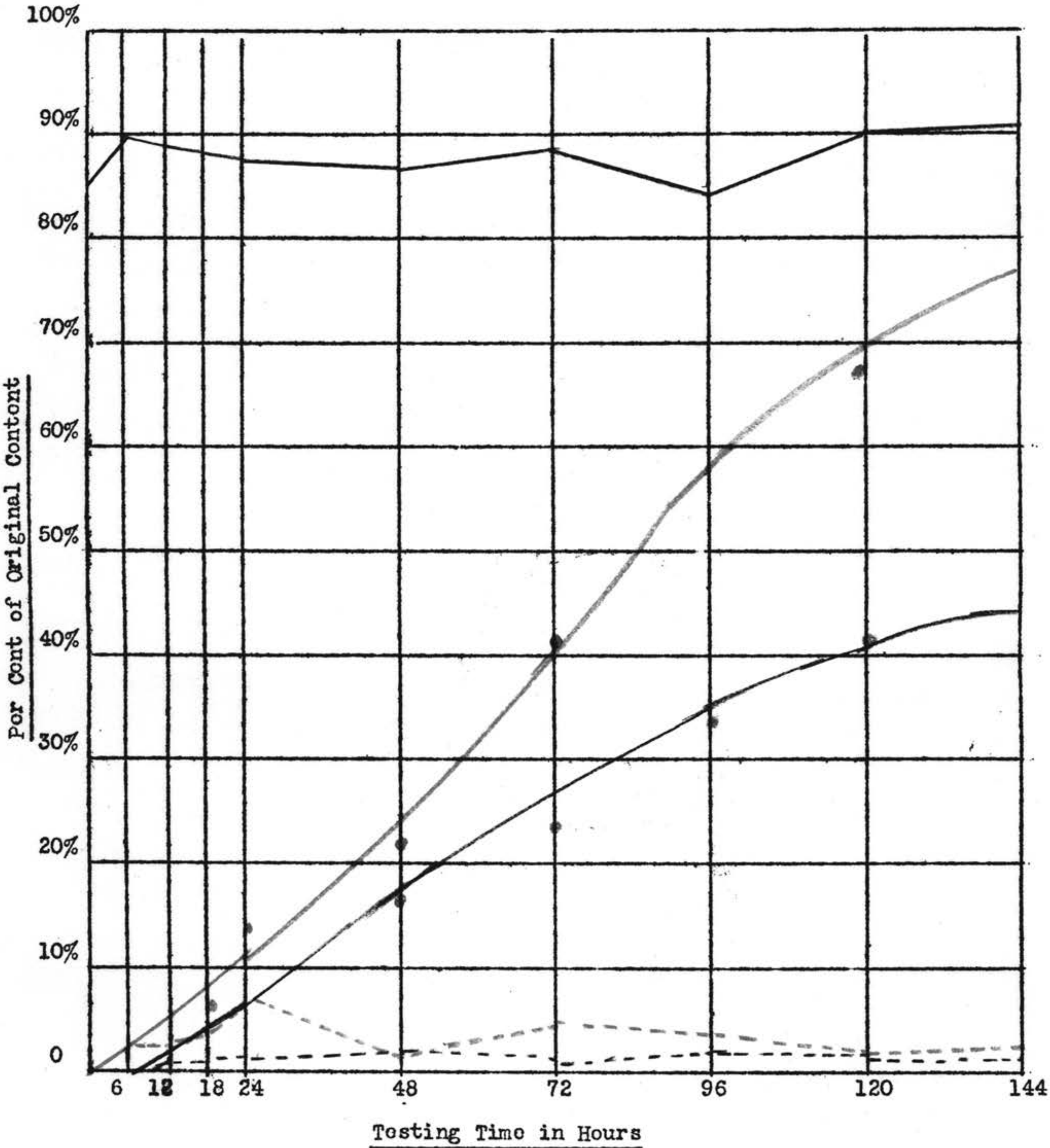
Average of 6 tests

RED = Produce at room temperature, not ice packed

BLUE = Average room temperature °F.

From Tests No.

Percentage of Ascorbic Acid Loss in Iced and Un-Iced Produce



Curves showing loss of ascorbic acid in per cent from starting content

BLACK = Ice Packed Produce

RED = Produce at room temperature, not ice packed

BLUE = Average room temperature °F.

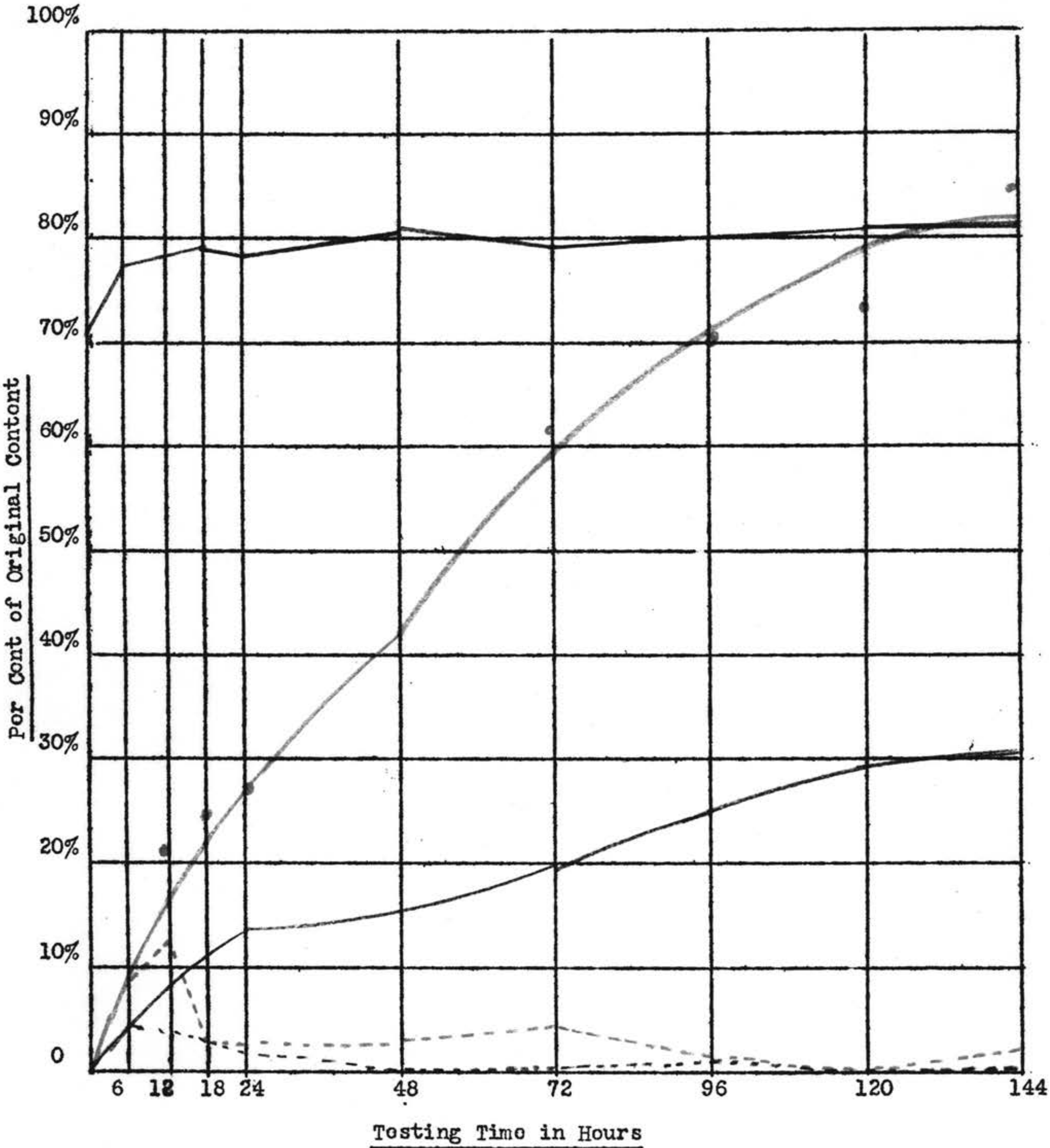
Kind of Produce: Tendermost S.S. Sweet Corn

Chart No.

From Tests No. 6

Average of 6 tests

Percentage of Ascorbic Acid Loss in Iced and Un-Iced Produce



Curves showing loss of ascorbic acid in per cent from starting content

BLACK = Ice Packed Produce

RED = Produce at room temperature, not ice packed

BLUE = Average room temperature °F.

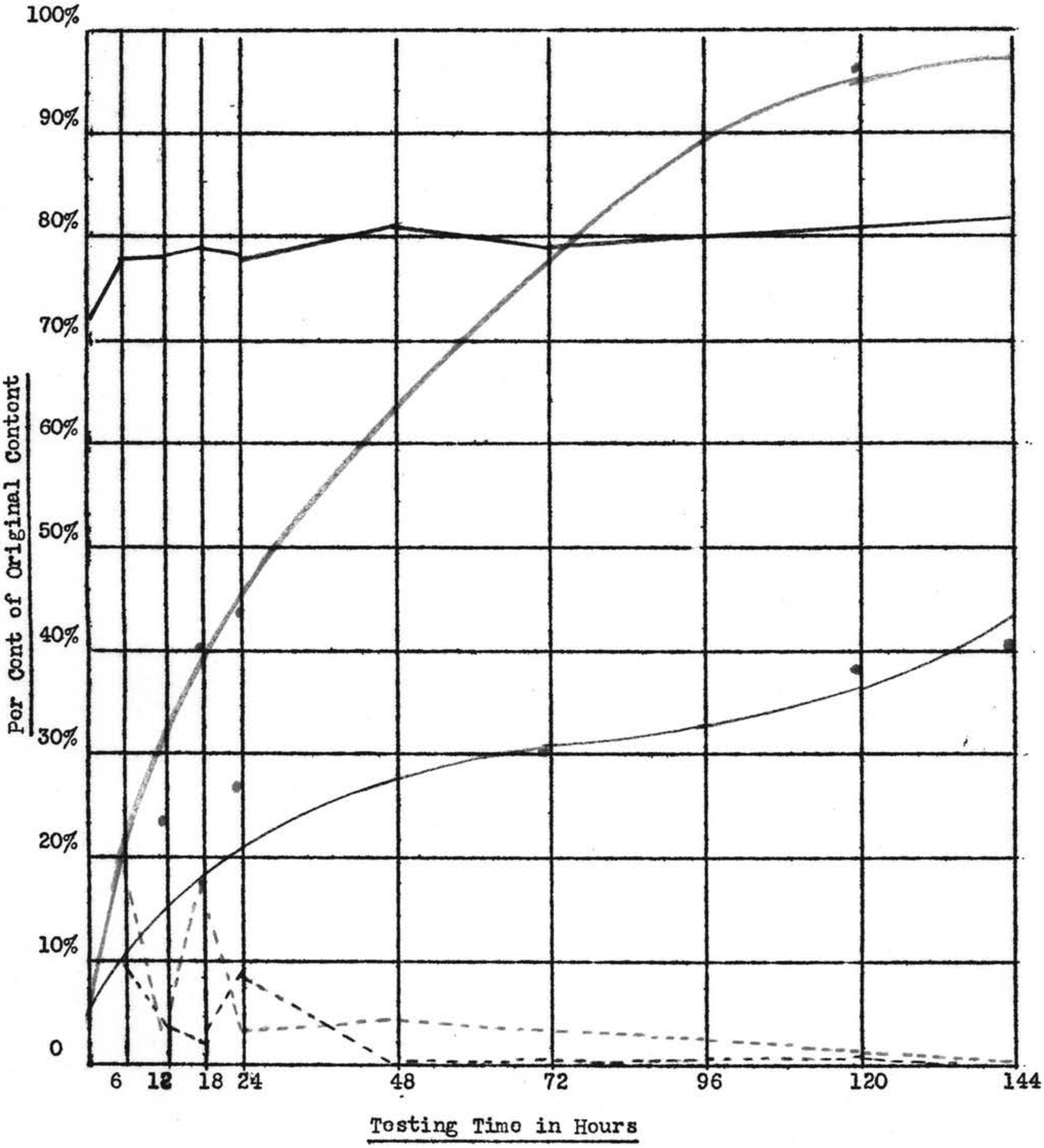
Kind of Produce Southern Giant Curled F.S. Mustard

7

Chart No. Average of 3 tests

From Tests No.

Percentage of Ascorbic Acid Loss in Iced and Un-Iced Produce



Curves showing loss of ascorbic acid in per cent from starting content

Kind of Produce

Southern Giant Curled S.S. Mustard

BLACK = Ice Packed Produce

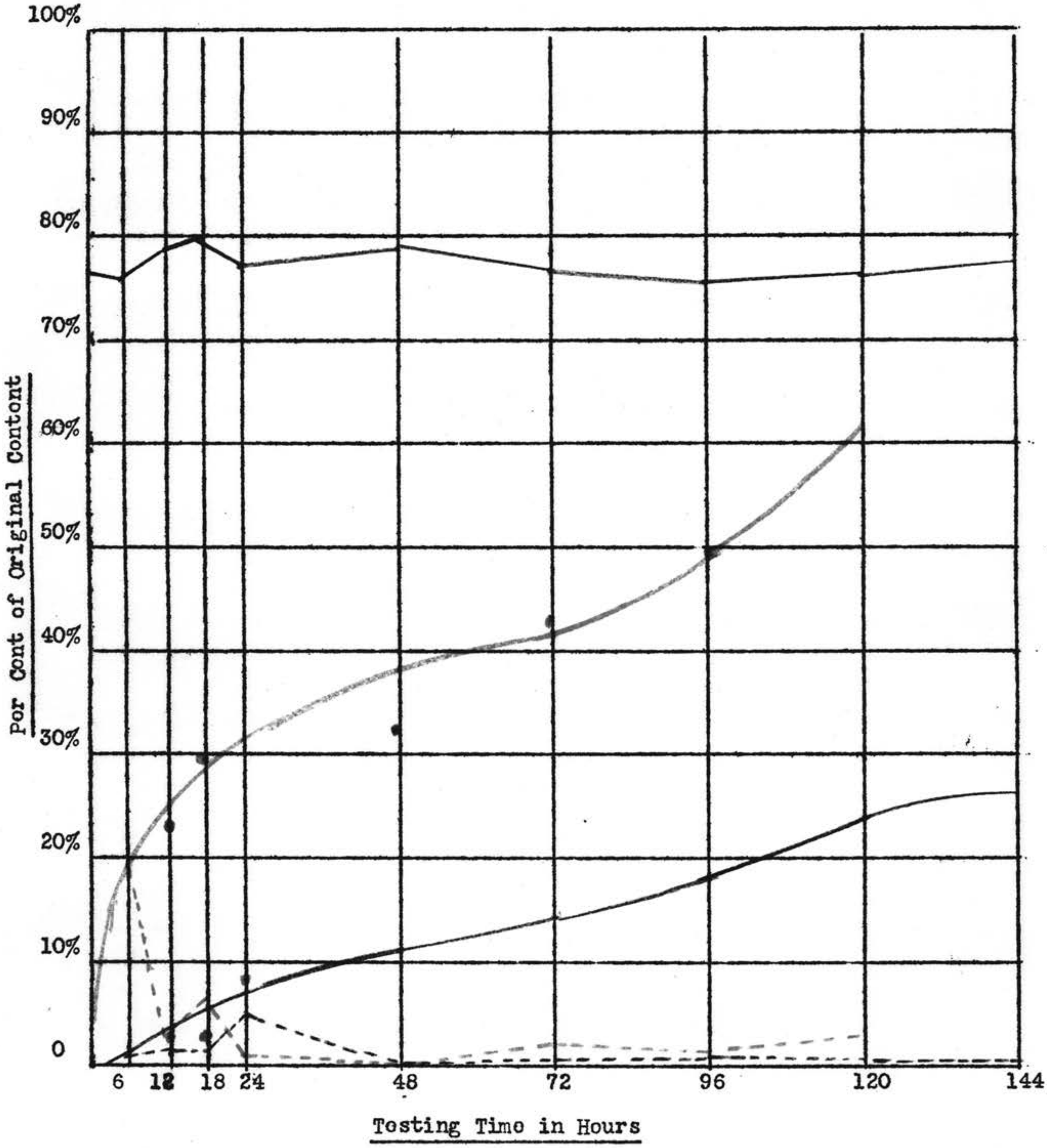
RED = Produce at room temperature, not ice packed

Chart No. 8

From Tests No. Average of 3 tests

BLUE = Average room temperature °F.

Percentage of Ascorbic Acid Loss in Iced and Un-Iced Produce



Curves showing loss of ascorbic acid in per cent from starting content

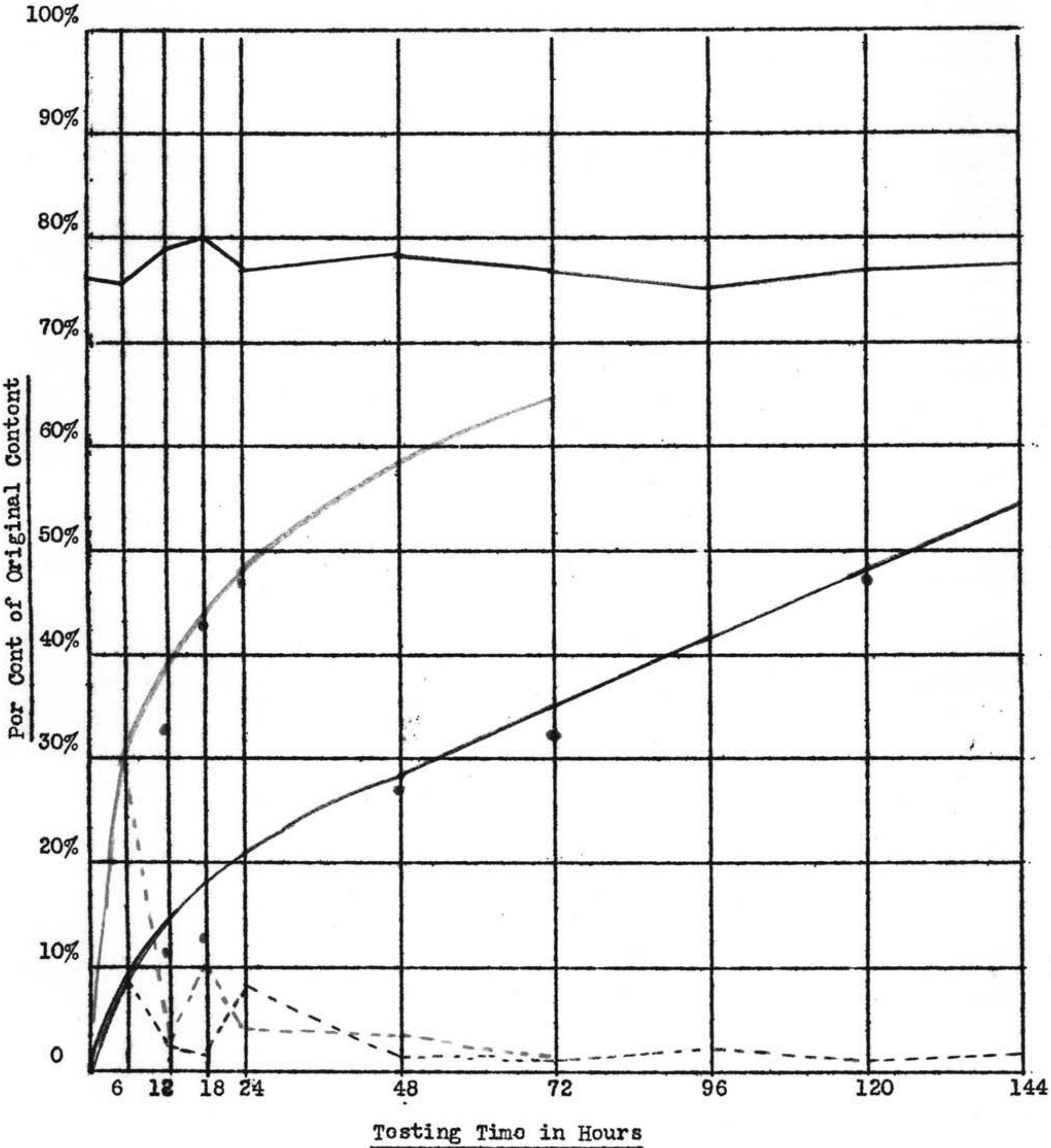
Kind of Produce **Bloomsdale Longstanding F.S. Spinach**

BLACK	= Ice Packed Produce
RED	= Produce at room temperature, not ice packed
BLUE	**= Average room temperature °F.**

Chart No. 9

From Tests No. **Average of 3 tests**

Percentage of Ascorbic Acid Loss in Iced and Un-Iced Produce



Curves showing loss of ascorbic acid in per cent from starting content

Kind of Produce

Bloomsdale Longstanding S.S. Spinach

BLACK = Ice Packed Produce

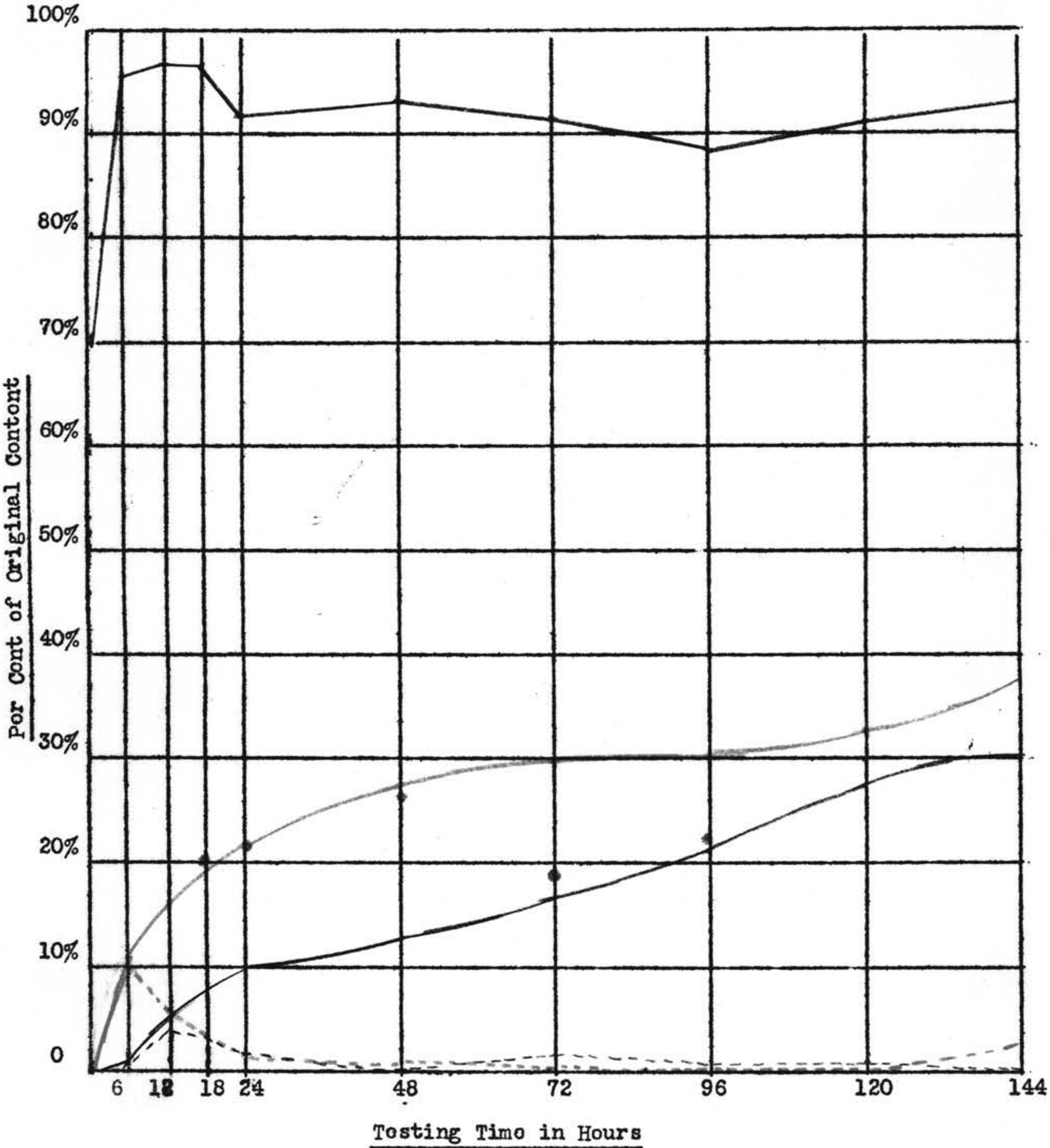
Chart No. 10

RED = Produce at room temperature, not ice packed

From Tests No. Average of 3 tests

BLUE = Average temperature room °F.

Percentage of Ascorbic Acid Loss in Iced and Un-Iced Produce



Curves showing loss of ascorbic acid in per cent from starting content

BLACK = Ice Packed Produce

RED = Produce at room temperature, not ice packed

BLUE = Average room temperature °F.

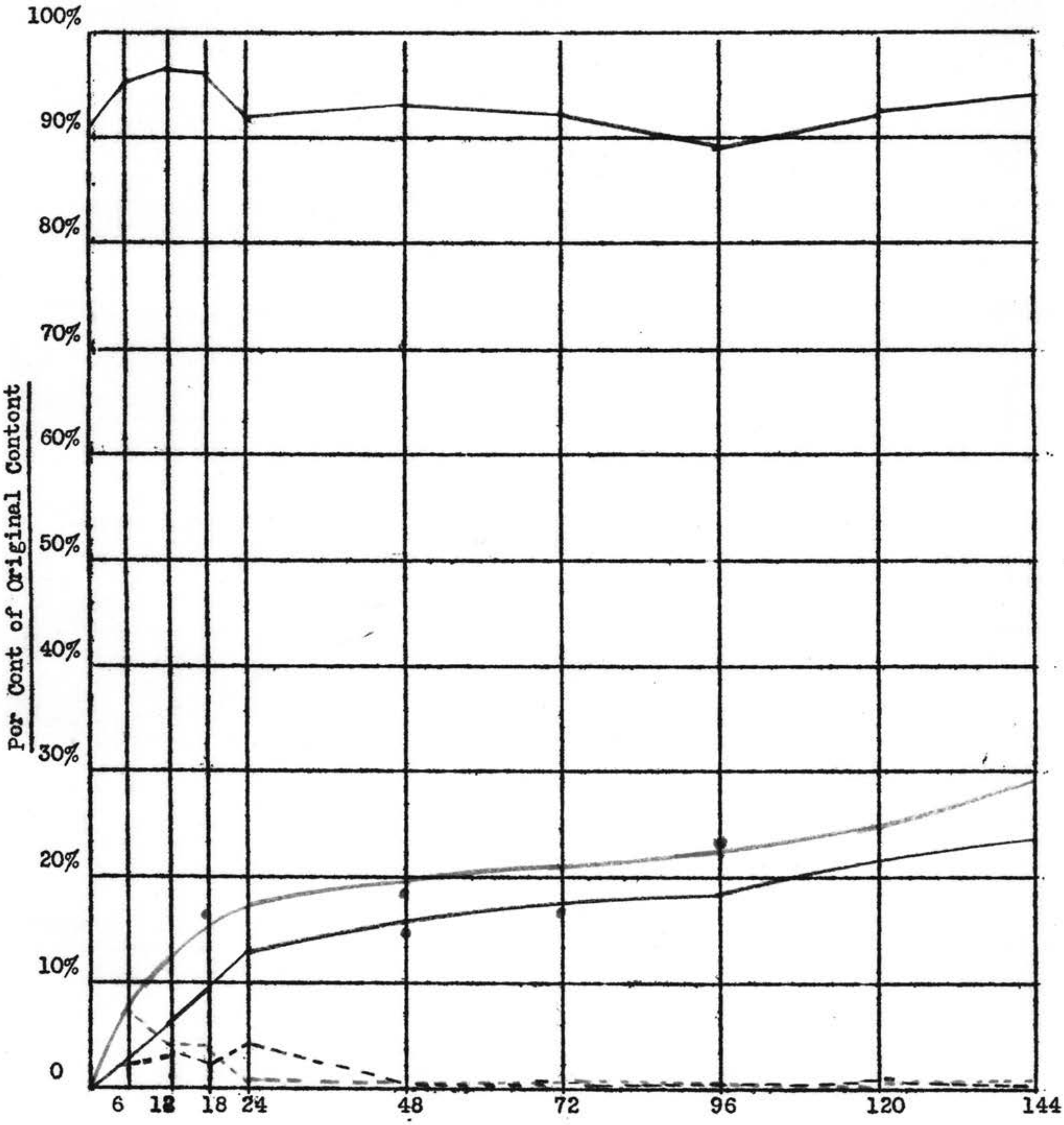
Kind of Produce

F. S. Stokesdale Tomato

Chart No. 11

From Tests No. Average of 6 tests

Percentage of Ascorbic Acid Loss in Iced and Un-Iced Produce



Testing Time in Hours

Curves showing loss of ascorbic acid in per cent from starting content

BLACK = Ice Packed Produce

RED = Produce at room temperature, not ice packed

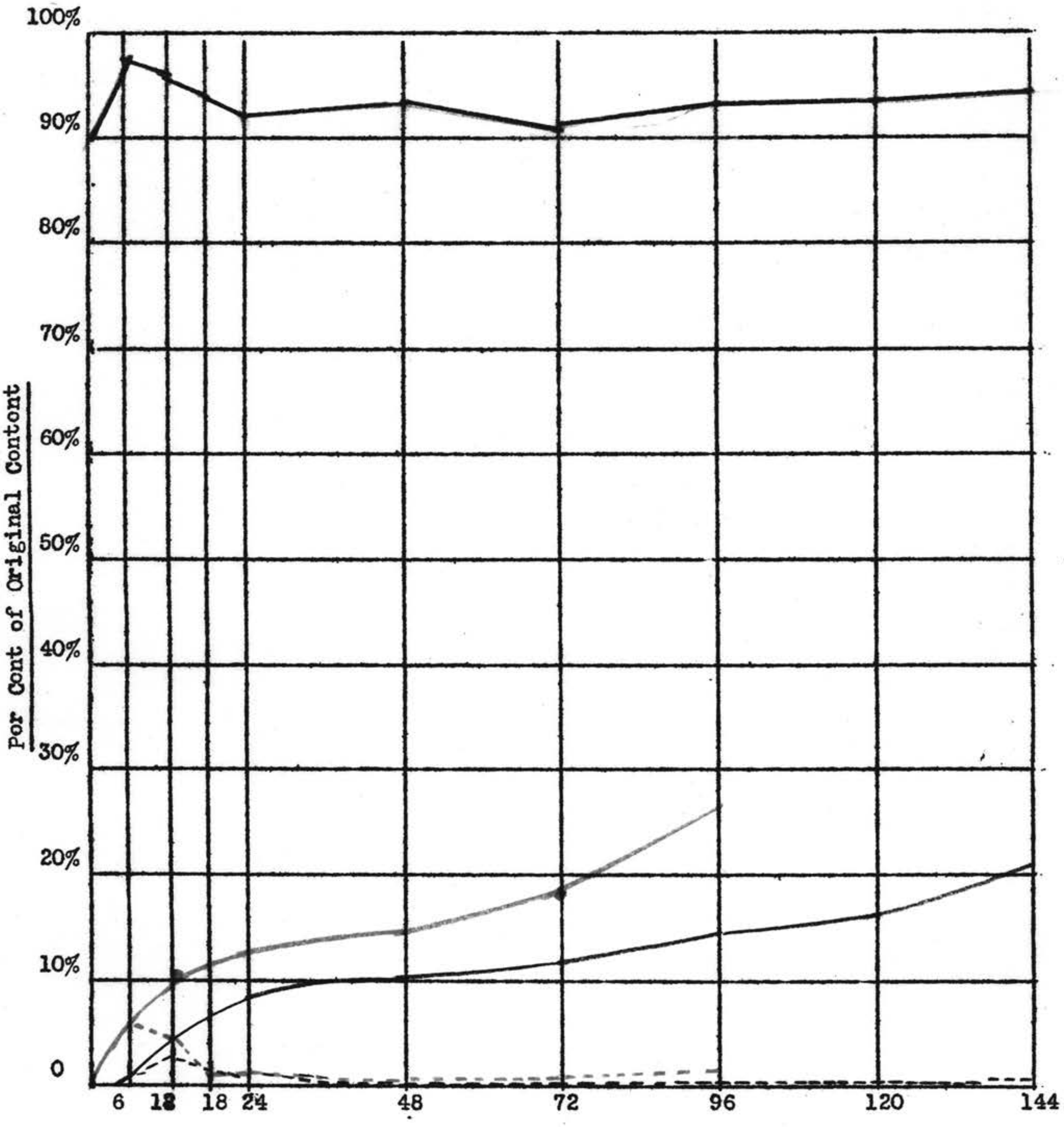
BLUE = Average room temperature °F.

Kind of Produce **S.S. Stokesdale Tomato**

Chart No. **12**

From Tests No. **Average of 6 tests**

Percentage of Ascorbic Acid Loss in Iced and Un-Iced Produce



Testing Time in Hours

Curves showing loss of ascorbic acid in per cent from starting content

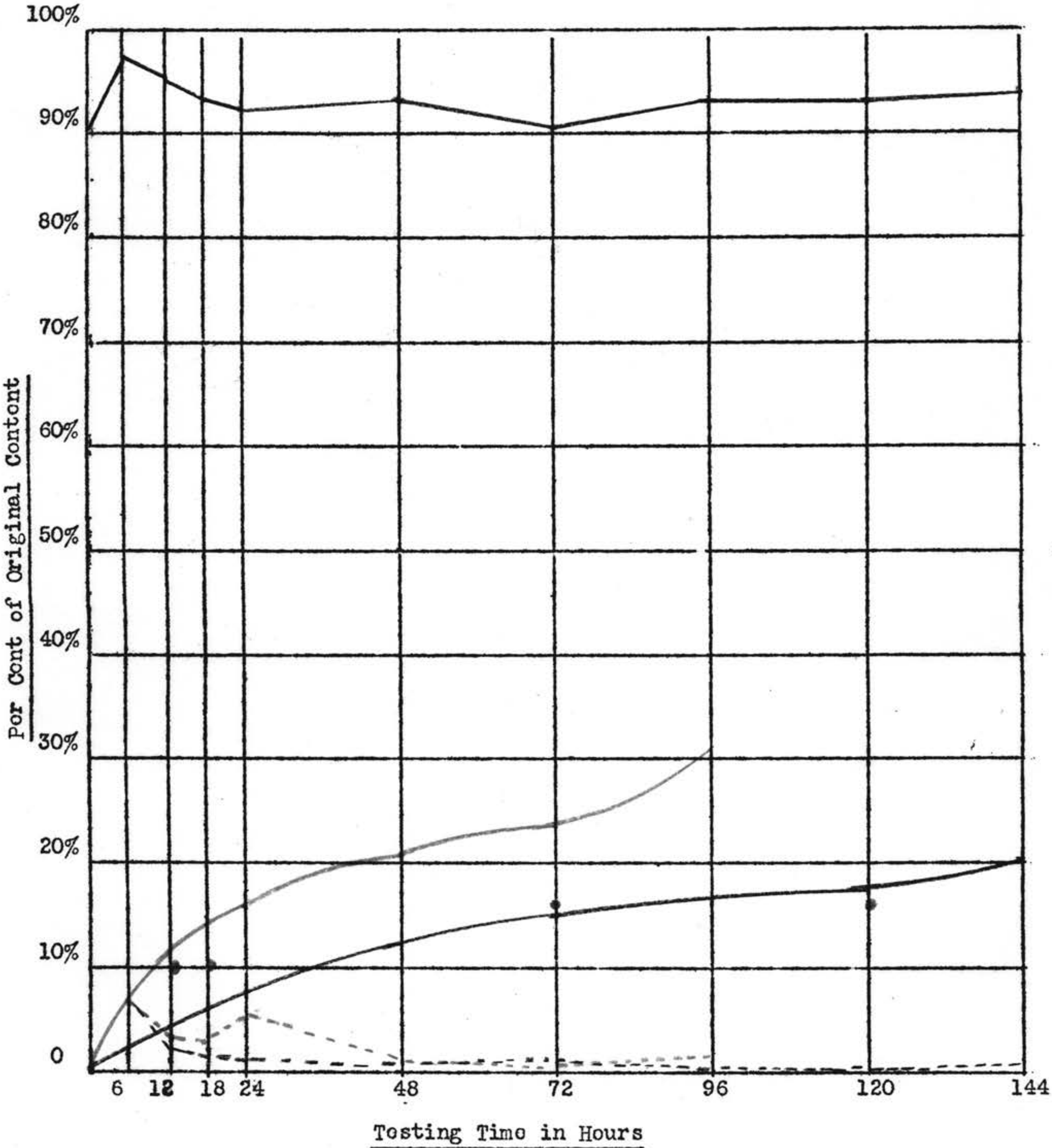
BLACK	= Ice Packed Produce
RED	= Produce at room temperature, not ice packed
BLUE	= Average room temperature °F.

Kind of Produce
Hale #36
F.S. Cantaloupe

Chart No. 13

From Tests No. Average of four tests

Percentage of Ascorbic Acid Loss in Iced and Un-Iced Produce



Curves showing loss of ascorbic acid in per cent from starting content

Kind of Produce **Hale #36 S. S. Cantaloupe**

BLACK = Ice Packed Produce

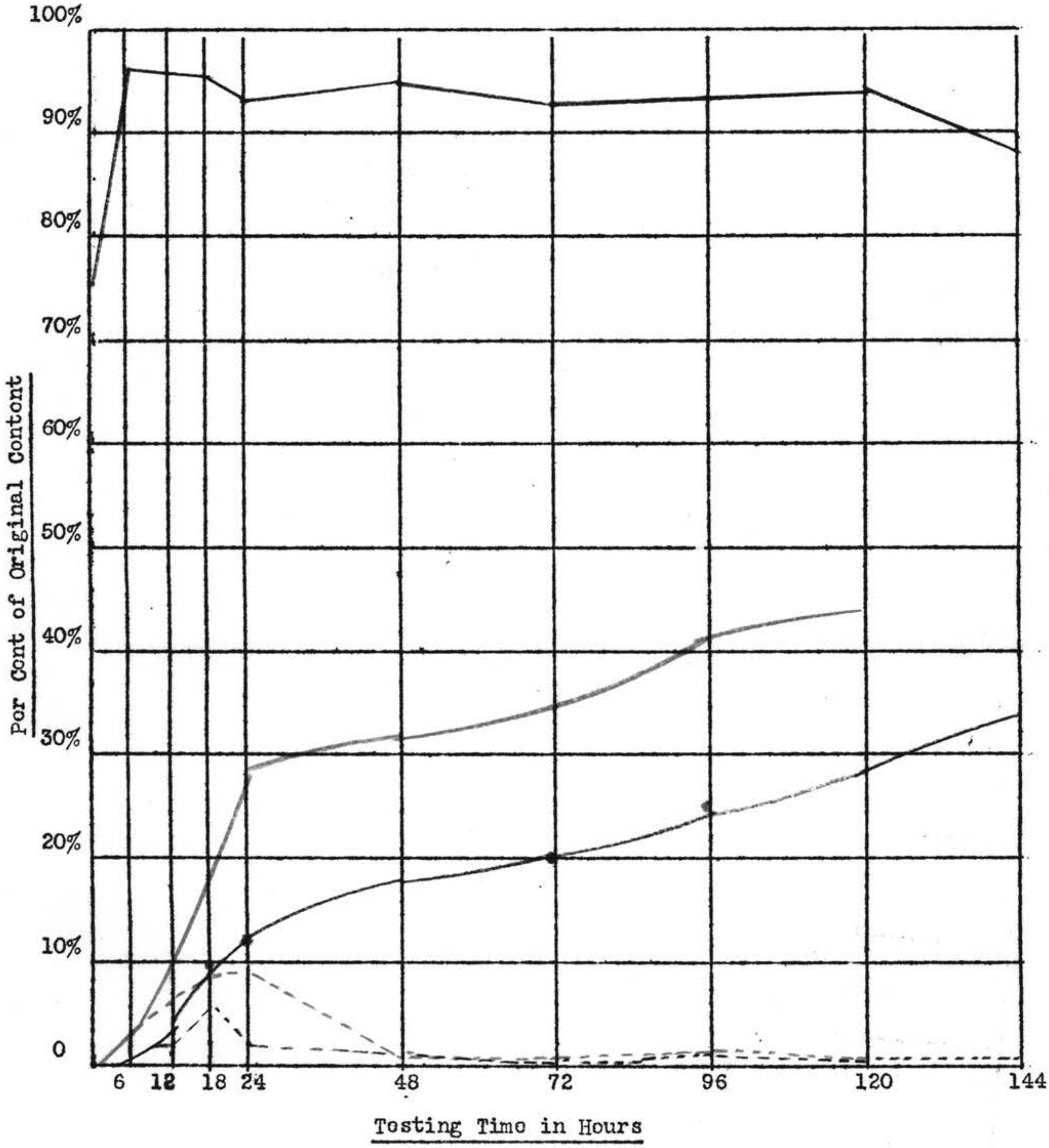
Chart No. **14**

RED = Produce at room temperature, not ice packed

From Tests No. **Average of four tests**

BLUE = **Average room temperature °F.**

Percentage of Ascorbic Acid Loss in Iced and Un-Iced Produce



Curves showing loss of ascorbic acid in per cent from starting content

BLACK = Ice Packed Produce

RED = Produce at room temperature, not ice packed

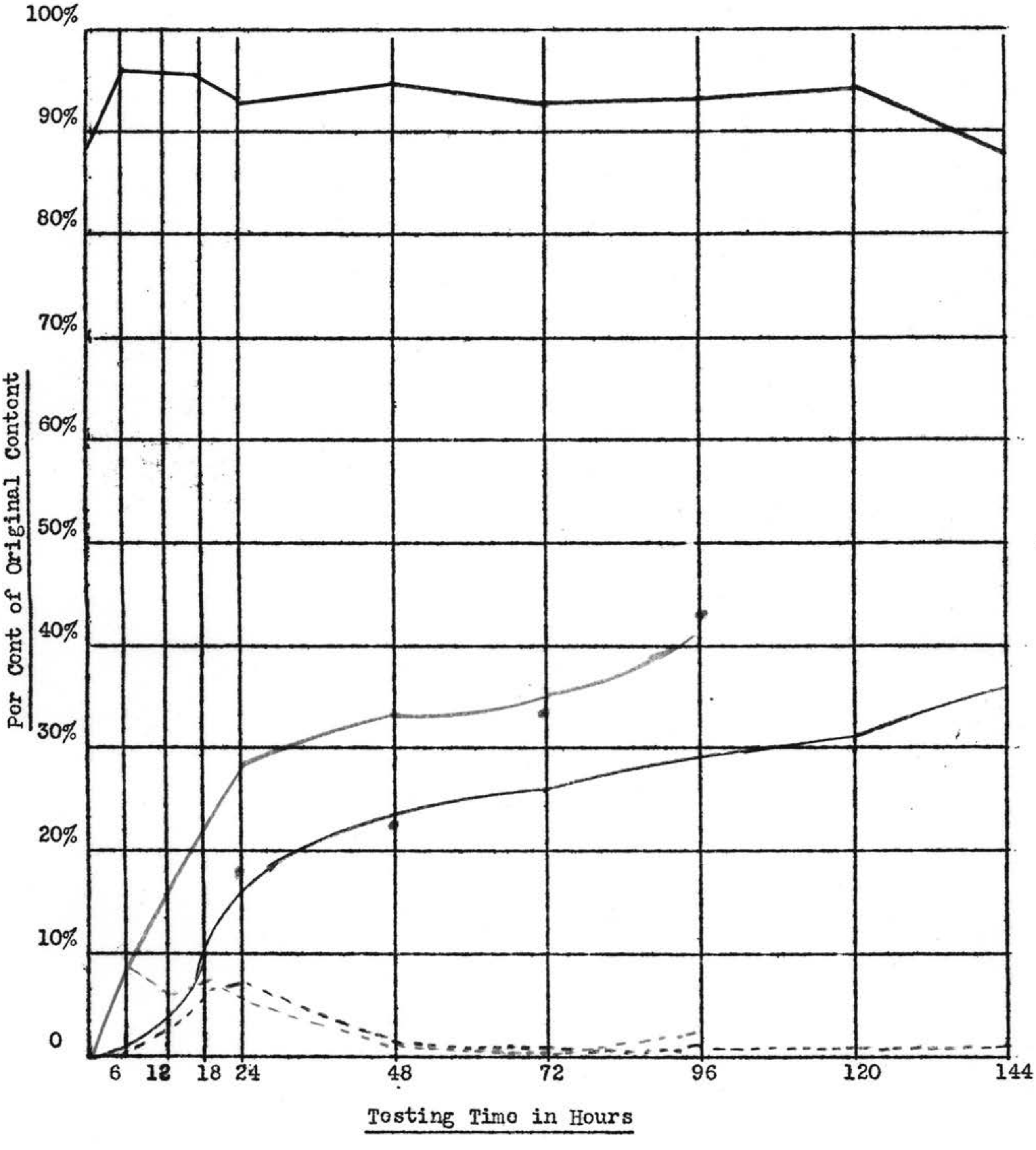
BLUE = Average room temperature °F.

Kind of Produce **F.S. Elberta Peach**

Chart No. **15**

From Tests No. **Average of 6 tests**

Percentage of Ascorbic Acid Loss in Iced and Un-Iced Produce



Curves showing loss of ascorbic acid in per cent from starting content

BLACK = Ice Packed Produce

RED = Produce at room temperature, not ice packed

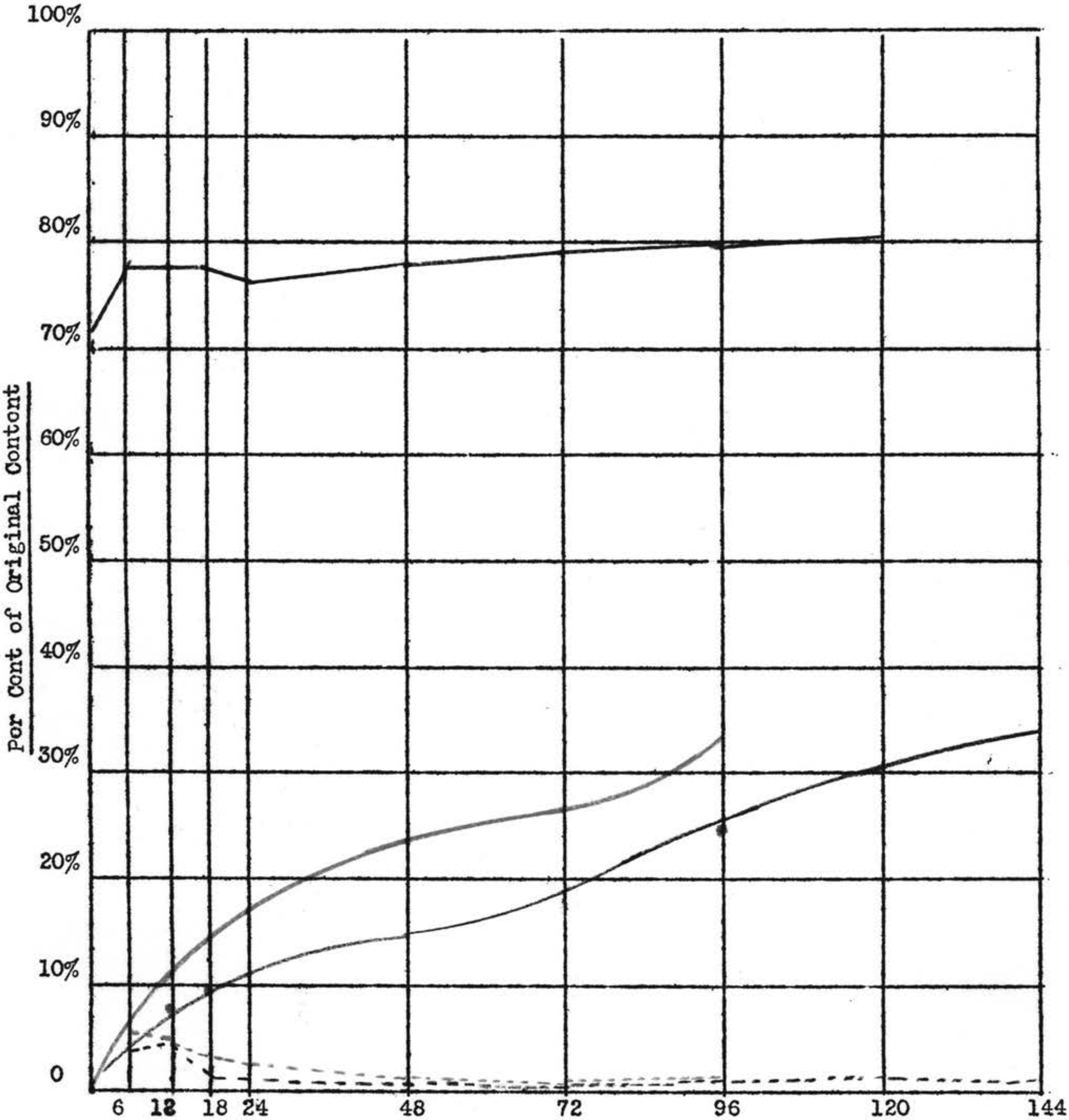
BLUE = **Average room temperature °F.**

Kind of Produce **S. S. Elberta Peach**

Chart No. **16**

From Tests No. **Average of 6 tests**

Percentage of Ascorbic Acid Loss in Iced and Un-Iced Produce



Testing Time in Hours

Curves showing loss of ascorbic acid in per cent from starting content

BLACK = Ice Packed Produce

RED = Produce at room temperature, not ice packed

BLUE = Average room temperature °F.

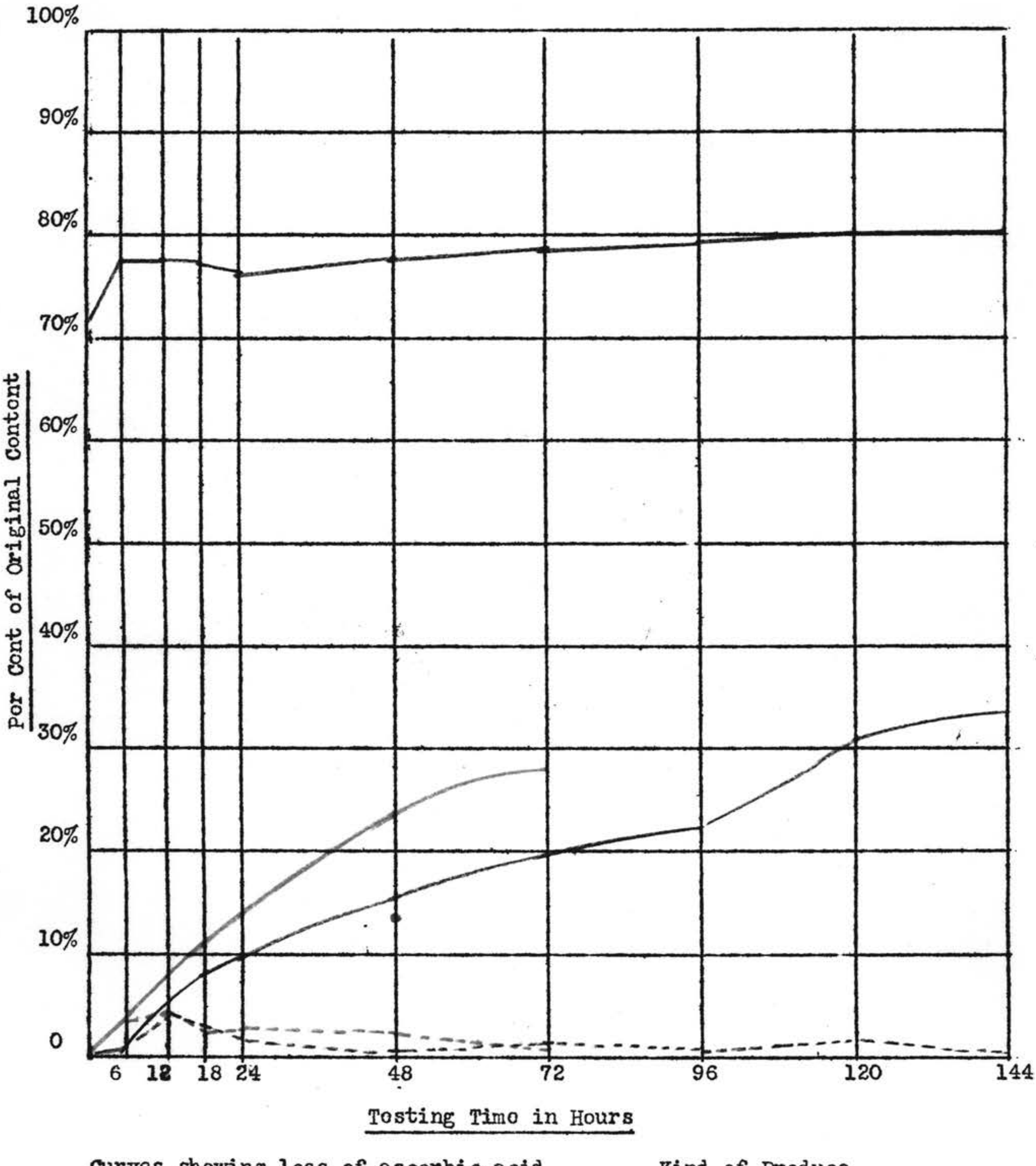
Kind of Produce

F. S. Blakemore Strawberry

Chart No. 17

From Tests No. Average of 4 tests

Percentage of Ascorbic Acid Loss in Iced and Un-Iced Produce



Curves showing loss of ascorbic acid in per cent from starting content

BLACK	=	Ice Packed Produce
RED	=	Produce at room temperature, not ice packed
BLUE	=	Average room temperature °F.

Kind of Produce

S. S. Blakemore Strawberry

Chart No. 18

From Tests No. Average of 4 tests

Plate 1 Green Snap Bean on Cracked Ice
Store Sample Field Sample

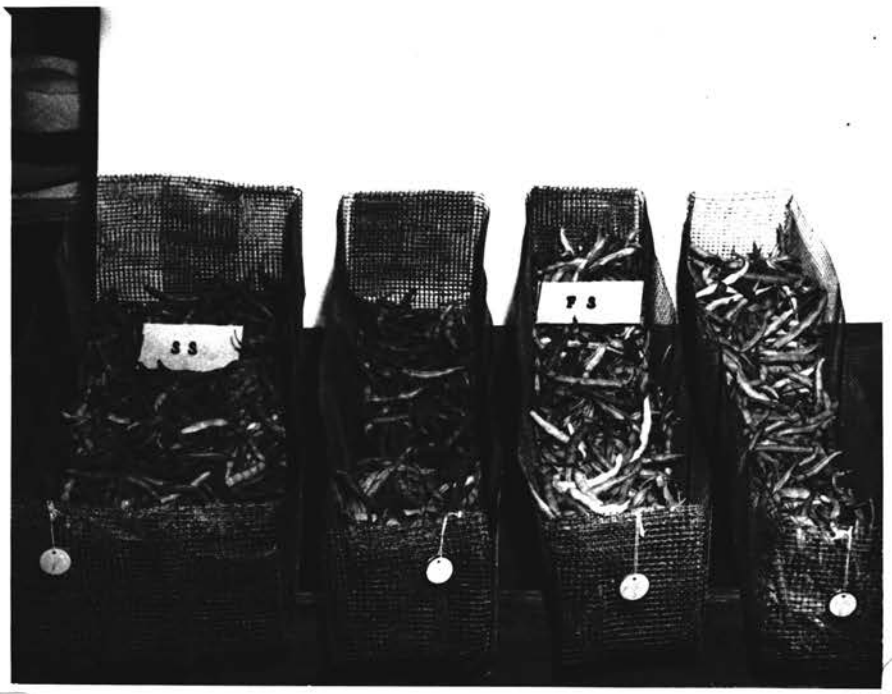


Plate 2 Green Snap Bean at Room Temperature

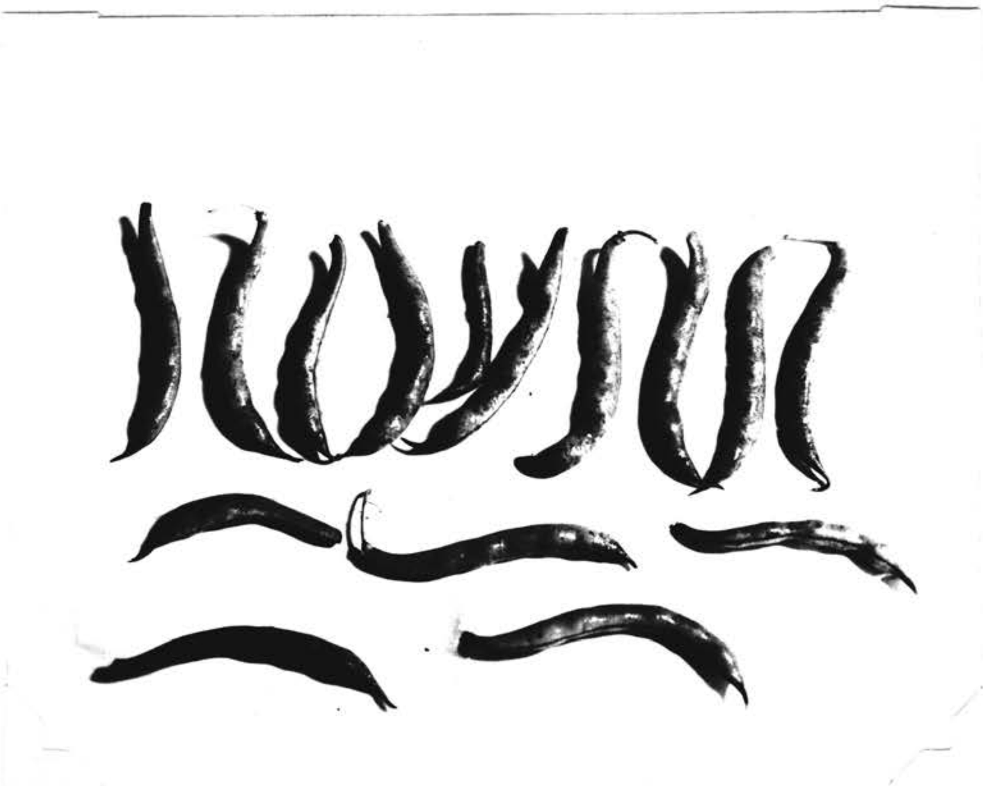


Plate 3 Portrays "Weathering" Effect on Green Snap Beans that appeared in Twenty-Four Hours at Room Temperature After Six Days on Cracked Ice Display.

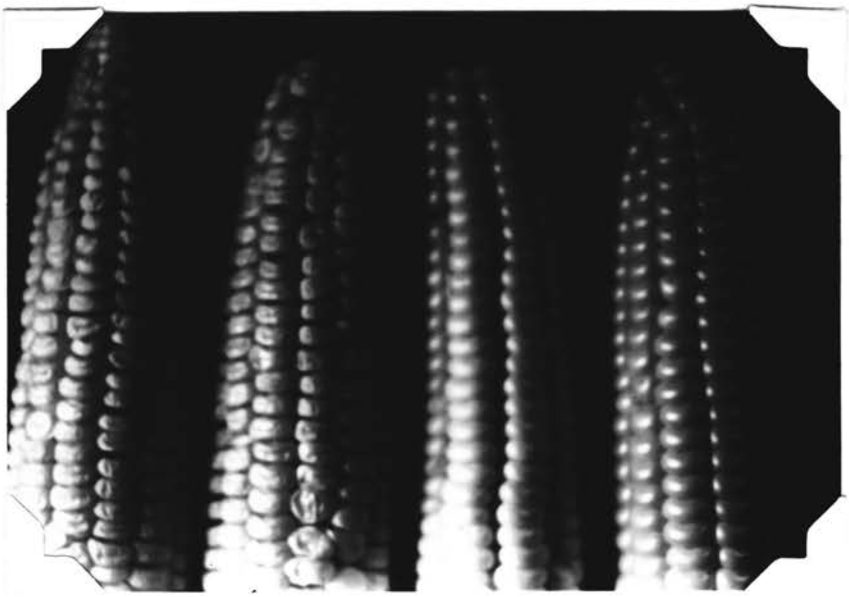


Plate 4
Green Sweet Corn
Left: 6 Days at Room Temperature
Right: 6 Days on Cracked Ice

Plate 5
Green Sweet Corn
Left: 6 Days at Room Temperature
Right: 6 Days on Cracked Ice

Plate 6
Tomato
Left: Store Sample 6 Days on Cracked Ice
Right: Field Sample 6 Days on Cracked Ice

Plate 7
Tomato
Left: Store Sample 6 Days at Room Temperature
Right: Field Sample 6 Days at Room Temperature

Plate 8
Peach
Field Sample
6 Days on Cracked Ice

Plate 9
Peach
Field Sample
6 Days at Room Temperature

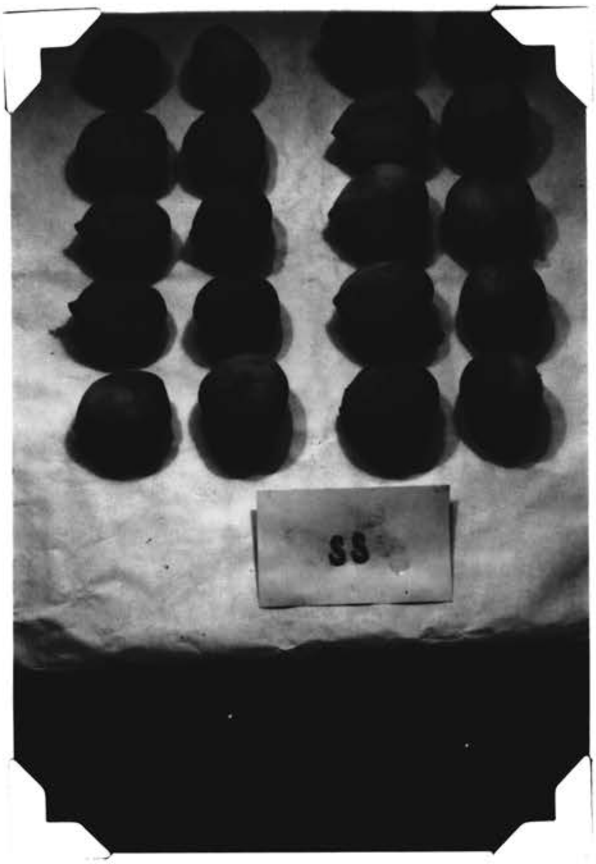


Plate 10
Peach
Store Sample 2 Days at Room Temperature

Moisture Changes

Average changes in moisture content of fruits and vegetables occurring in six days unless otherwise indicated: *

Product	Field Sample		Store Sample	
	Iced	Uniced	Iced	Uniced
Asparagus	0.5% +	2.2% -	0.9% + 18 Hrs. 0.2% +	2.7% -
Green Snap Bean	0.5% -	1.5% -	0.3% -	5.3% -
Green Sweet Corn	2.4% -	12.9% -	1.0% -	16.1% -
Mustard	0.3% -	9.6% -	0.1% +	4 Days 3.4% -
Spinach	0.4% -	5 Days 7.6% -	1.6% -	3 Days 4.0% -
Tomato	0.6% -	0.7% -	0.3% -	0.3% -
Cantaloupe	0.1% -	4 Days 0.5% +	0.1% +	4 Days 0.0% -
Peach	1.4% -	2.1% -	1.9% -	3.5% -
Strawberry	0.4% -	1 Day 0.6% - 3 Days 0.1% +	1.1% - 3 Days 0.3% -	3 Days 0.7% -

* + = Increase in per cent moisture.

\- = Decrease in per cent moisture.

As indicated in above table, the moisture loss was greater in produce held at room temperature. There was very little difference between icing and room temperature with respect to the tomato, cantaloupe, and strawberry. The greatest loss of moisture occurred with leafy vegetables and green sweet corn at room temperature.

Color Changes

Changes in color of the fresh fruits and vegetables were determined by matching with the color plates of the Dictionary of Color (24).

Results:

Asparagus: Mary Washington

Iced: Little or no change in color. (Plate 20, K-4 to K-5)

Uniced: The color became lighter and in some stalks changed to a near white. (Plate 20, J-1 to K-7).

Green Snap Bean: Burpee's Stringless Greenpod

Iced: No appreciable change in color. (Plate 18, I-6 to I-7). When the samples were removed from ice at end of six days and left at room temperature for one day, brown spots appeared on the pods. This condition was due to a physiological breakdown which has been called "weathering" (31). This often appears on green beans that have been held for some time in cold storage (31). Tests with similar green beans stored in a refrigerator for one day did not show this condition.

Uniced: Developed a lighter color. (Plate 18, E-6 to B-3).

Green Sweet Corn: Tendermost

Iced: Very little change in the kernel (Plate 10, I-3 to I-4) or husk color.

Uniced: Slight change in kernel color. (Plate 10, I-3 to J-3). The husk faded from green to white and to dryness of the husk of mature corn.

Mustard: Southern Giant Curled

Iced: No appreciable change in color (Plate 21, K-7 to K-8).

Uniced: Changed to a lighter green color and in limited instances a few of the leaves became completely yellow at the end of six days. (Plate 21, K-7 to L-3).

Spinach: Bloomsdale Longstanding

Iced: Developed a slightly darker green color. (Plate 22, K-7 to K-8).

Uniced: Developed a slightly lighter green color. (Plate 22, K-7 to K-1).

Tomato: Stokesdale

Iced: A deeper red color developed but at a slower rate than in those at room temperature. (Plate 3, C-12 to H-12).

Uniced: A deeper red color developed at a more rapid rate than in those on cracked ice. (Plate 3, C-12 to K-12).

Cantaloupe: Hale No. 36

Iced: No appreciable change in internal flesh color. (Plate 11, B-8 to B-9).

Uniced: Slight change to a lighter internal flesh color. (Plate 11, B-8 to E-9).

Peach: Elberta

The light colored side of the peach was used for the color determination as the changes were more noticeable on that portion of the fruit.

Iced: No appreciable color change. (Plate 10, E-10 to E-11).

Uniced: Color developed slightly deeper. (Plate 10, E-10 to G-10).

Strawberry: Blakemore

Iced: The color faded and in a few berries changed to a near white. (Plate 2, L-9 to J-3).

Uniced: The color changed to a slightly darker red. (Plate 2, L-9 to L-12).

Flavor Changes

In general, the flavor of the fresh fruits or vegetables in the cracked ice display case changed very little from the start of the test until the end of the six day period with the exception of the following: strawberry, in which the flavor was good until mold developed by the third to fourth day; peach, in which slight deterioration of flavor was noticeable by the end of five days. Green sweet corn lost its fresh flavor within four or five days as the starch content increased. Generally, the flavor of the store samples changed one day earlier than that of the field samples.

The flavor of the fruits and vegetables at room temperature changed noticeably within two to three days with the exception of the tomato which held for five days. Frequently, spoilage acted as the principal factor affecting the flavor changes. Other factors may have been chemical changes occurring within the plant tissues and loss of moisture.

Texture Changes

Scale of Evaluation of Texture

1. Firm, crisp, tender, milky.
2. Slightly firm, slightly crisp, slightly tough, slightly starchy.
3. Slightly soft, wilted, medium tough, medium starchy.
4. Soft, flabby, tough, starchy.
5. Very soft, shriveled, very tough, very starchy.

-- Produce Spoiled (test terminated).

Effect of Time and Treatment on Texture of Fresh Fruits and Vegetables

Test		ICED						ROOM TEMPERATURE					
Material	Days	1	2	3	4	5	6	1	2	3	4	5	6
	F.S.*	1	1	1	1	1	1	1	2	3	4	-	
Asparagus	S.S.*	2	2	2	2	2	2	2	2	3	5	-	
Green Snap	F.S.	1	1	1	1	1	1	1	3	4	4	4	4
Bean	S.S.	2	2	2	2	2	2	2	4	4	4	4	5
Green Sweet	F.S.	1	1	1	1	1	2	1	2	3	4	5	5
Corn	S.S.	2	2	2	2	2	3	2	3	4	5	5	5
	F.S.	1	1	1	1	1	1	1-3	4	4	5	-	
Mustard	S.S.	1	1	1	1	1	1	1-3	5	5	-		
	F.S.	1	1	1	1	1	1	1-3	2	3	4	5	-
Spinach	S.S.	2	1	1	1	1	1	2	3	4	-		
	F.S.	1	1	1	1	1	1	1	1	1	2	3	4
Tomato	S.S.	1	1	1	1	1	1	1	1	2	3	4	5
	F.S.	1	1	1	1	1	1	1	1	3	4	5	-
Cantaloupe	S.S.	1	1	1	1	1	1	1	2	4	5	-	
	F.S.	1	1	1	1	1	1	1	1	3	4	5	-
Peach	S.S.	1	1	1	1	1	1	1	3	4	5	-	
	F.S.	1	1	2	3	5	-	2	3	5	-		
Strawberry	S.S.	1	1	2	3	5	-	3	5	-			

*F.S. Field Sample

*S.S. Store Sample

The terms firm, slightly soft, soft, and very soft apply to the fleshy fruits and vegetables, while flabby and shriveled refer specifically to green snap beans.

The terms crisp or wilted apply to the leafy vegetables and to asparagus.

The terms tender, milky or tough refer to green sweet corn.

Effect of Time and Treatment on Retention of

Market Quality of Fruits and Vegetables

Test Material	ICED		UNICED	
	F.S.	S.S.	F.S.	S.S.
Asparagus	-	-	2 Days	2 Days
Green Snap Bean	-	-	3 Days	2 Days
Green Sweet Corn	-	-	2 Days	2 Days
Mustard	-	-	2 Days	2 Days
Spinach	-	-	2 Days	2 Days
Tomato	-	-	5 Days	4 Days
Cantaloupe	-	-	3-4 Days	3 Days
Peach	-	-	3-4 Days	2-3 Days
Strawberry	4-5 Days	3-4 Days	1-2 Days	18 hrs.-1Day

F.S. Field Sample

S.S. Store Sample

\- Did not become unmarketable within the 6-day period.

Spoilage

None of the iced produce, except strawberry, spoiled within the six days of the test. The produce displayed at room temperature spoiled within the period indicated:

Asparagus:	Field Sample	3-6 Days
	Store Sample	3-4 Days
Mustard:	Field Sample	4-6 Days
	Store Sample	3-4 Days
Spinach:	Field Sample	3-5 Days
	Store Sample	3 Days
Cantaloupe:	Field Sample	4-5 Days
	Store Sample	3-4 Days

Peach:	Field Sample	5 Days	Brown rot
	Store Sample	4 Days	Brown rot
Strawberry:	Field Sample	3 Days	
	Store Sample	2-3 Days	

Green snap bean and green sweet corn apparently were not affected by decay organisms during the test period. Tests indicated that freshly harvested produce remained in good condition from one to two days longer than samples purchased locally from stores. This result is, in part, due to the difference in time of harvest as well as to previous handling and storage conditions. Where spoilage (produce became unsuitable for food) occurred due to decay organisms, the display case was cleaned with formalin solution following the test.

DISCUSSION

The effect of cracked ice on both freshly harvested and store purchased produce was beneficial from the standpoint of retention of Vitamin C, color, flavor, and texture, which remained excellent for six days of the test period except for strawberries and peaches. The strawberry on cracked ice changed to a lighter color and a few berries changed to a near white. This change in color reduces the market value of the strawberry. In the peach there was a slight deterioration of flavor noticeable at the end of five days which did not make the peach unmarketable.

At room temperature all fruits and vegetables deteriorated rapidly with considerable loss of Vitamin C and moisture. The color, flavor, and texture changes were noticeable within one to three days. Store purchased produce usually deteriorated one day earlier than freshly harvested material.

The produce on cracked ice display, except for strawberry, remained marketable for the six day test period. On room temperature display the produce became unmarketable within one to three days. The losses from spoilage in room temperature display of fruits and vegetables was serious.

Cracked ice was effective in maintaining a higher Vitamin C content, moisture content, and in preserving the freshly harvested appearance of the fruits and vegetables studied (except for strawberries).

As shown in charts one to eighteen (pages 18 to 35) the peak rate of loss occurs within the first twenty-four hours of storage. After this peak is reached the rate declines and remains nearly constant. In freshly harvested produce on room temperature display the peak rate of loss is reached at the first six hour period. On cracked ice the peak was reached at the first twelve hours. In store purchased produce the time at which the peak rate of loss occurred was six to twelve hours later than in freshly harvested produce. In nearly all instances, the rate of loss was higher in produce on room temperature display than on cracked ice display throughout the test period. Perhaps the lower temperature decreased the chemical activity or enzymatic action which increased the amount of time required for the peak rate of loss to occur.

The moisture content of freshly harvested asparagus on cracked ice increased 0.5% in six days. All other produce lost from 0.4% to 2.4% moisture. Produce obtained from a local grocery and placed on cracked ice increased in moisture content; asparagus 0.2% to 0.9%, mustard 0.1%, and cantaloupe 0.1%. Tests of freshly harvested produce at room temperature indicated an increase in moisture content; cantaloupe 0.5% in four days and strawberry 0.1% in three days. These increases may be due to sampling error as both were in poor condition after three to four days at room temperature. Freshly harvested produce in room temperature display showed moisture losses of 0.6% to 12.9% in five to six days. Store purchased produce lost 0.3% to 16.1%. This shows a greater loss in moisture content in room temperature display as compared to cracked ice display.

The fresh color was retained in all produce on cracked ice display, except strawberries. In this instance the color faded and a few berries changed to a near white. Produce at room temperature lost fresh color rapidly in comparison with that on cracked ice.

Flavor, texture and market quality are apparently somewhat interrelated as indicated by tabulated results which show fairly close agreement. On ice, the produce retained flavor, texture and market quality, with the exception of strawberries. Produce at room temperature deteriorated in flavor, texture, and market quality within one to four days.

Of the iced produce none, except strawberry spoiled within the test period. Strawberry spoiled within two to four days, depending on time of harvest and treatment. The produce at room temperature spoiled within two to five days, except snap bean and sweet corn which were not affected by decay organisms within the test period.

CONCLUSION

These data indicate the beneficial effect of cracked ice that may be expected on fresh fruits and vegetables at harvest, during transportation, and while displayed in the retail markets. This effect is due to greater retention of Vitamin C, improved appearance, and keeping quality. Thus it is shown that freshly harvested spinach (for example) on cracked ice display lost 14% of the original Vitamin C content in three days. Similar spinach at room temperature lost 42%. Iced spinach retained the freshly harvested appearance and was in good condition at the end of six days. At room temperature storage the freshly harvested appearance was lost in one day and was unfit for food in three to five days.

Cracked ice combines the factors of low temperature and high humidity which aid in retaining the nutritional value and appearance of the produce. The result is more apparent in leafy vegetables. The loss of moisture was less and the amount of waste due to trimming and spoilage was reduced when the vegetable was stored on ice.

The grocer will benefit by use of cracked ice on fresh produce which reduces shrinkage (moisture loss) and waste due to trimming and spoilage. Freshly harvested sweet corn when iced lost 2.4% moisture and retained the fresh appearance and was salable at the end of six days. Similar sweet corn at room temperature lost 12.9% moisture and was unsalable at the end of two days; at the end of six, the kernels were dented and very tough.

A higher rate of loss of Vitamin C occurred with room temperature display as compared to cracked ice display. As soon as harvested, produce should be placed in cracked ice and the protection thus afforded maintained throughout the transportation and marketing period.

SUMMARY

1. Cracked ice preserves the freshness and food value (ascorbic acid) of fruits and vegetables at harvest, during transportation, and on sales display.

2. Moisture loss from fruits and vegetables was less in cracked ice storage than in room temperature storage.

3. The losses of Vitamin C and color, flavor, and texture changes were greater in produce at room temperature than when produce was displayed on cracked ice.

4. The rate of loss of Vitamin C from the produce was higher at room temperature than at the temperature of cracked ice.

5. Cracked ice storage was more beneficial with mustard, spinach, asparagus, and peach than with tomato, snap bean, sweet corn, cantaloupe, and strawberry.

6. The strawberry lost its fresh color and remained in good condition only one day longer on cracked ice than at room temperature.

7. The data indicate losses from spoilage are negligible where cracked ice is used, with the exception of strawberries. The loss from spoilage at room temperature was serious.

8. The expense of icing may be offset by higher retail prices due to better appearance and reduction in losses due to spoilage. The possibility of greater sales volume should not be overlooked.

LITERATURE CITED

1. Anonymous. Food and Nutrition Investigations of the Agri. Exp. Stations 1945. U.S.D.A. Agri. Res. Administration Reprint from Report on the Agri. Exp. Stations; p. 14. 1945.

2. Bessey, O. A. A Method for the Determination of Small Quantities of Ascorbic Acid and Dehydroascorbic Acid in Turbid and Colored Solutions in the Presence of Other Reducing Substances. J. Biol. Chem. 126; 771-84. 1938.

3. Bessey, O. A. and C. G. King. The Distribution of Vitamin C in Plant and Animal Tissues and its Determination. J. Biol. Chem. 103; 687-98. 1933.

4. Brasher, E. P. et. al. The Preservation of Freshness in Vegetables and Fruits from Harvest to Consumption. Fruit Products J. and Amer. Food Manufacturer, 25 No. 6; 168-170. February, 1946.

5. Brown, A. P. and F. Morse. Vitamin C Content of Tomatoes. Food Research 6; 45-55. January, 1941.

6. Burkhart L. and R. A. Lineberry. Determination of Vitamin C and Its Sampling Variation in Strawberries. Food Research 7; 332-7. July, 1942.

7. Burrell, R. C. and V. R. Elbright. Vitamin C Content of Fruits and Vegetables. J. Chem. Educ. 17; 180-2. 1940.

8. Clow, B. and A. L. Marlatt. Study of Vitamin C in Fresh and Canned Tomatoes. J. Agri. Research 40; 767-75. 1930.

9. Crocker, E. C. Flavor. New York; McGraw Hill Book Co. Inc., p. 172. 1945.

10. Currence, T. M. Vitamin C in Tomato. Market Growers J. 64; 103. February, 1939.

11. Davis, W. B. Extraction of Ascorbic Acid from Plant Tissue. Ind. and Engr. Chem. (News Ed.) 17; 752. 1939.

12. Dunker, C. F. et. al. Stability of Vitamin C in Sweet Corn to Shipping, Freezing and Canning. Proc. Amer. Soc. Hort. Sci. 34; 553. 1937.

13. ______________ and C. R. Fellers. Vitamin C Content of Spinach. Proc. Amer. Soc. Hort. Sci. 36; 500-4. 1938.

14. Elvehjem, C. A. Newer Findings in Vitamin Research. J. Amer. Dietetic Assoc. 19; 743-5. 1943.

15. Feener, S. L. et. al. Seasonal Variation in Vitamin C Content of Fresh Market Vegetables. Refrig. Engr. 34; 101-5. 1937.

16. Fenton, F. Vitamin Retention as a Criteria of Quality and Nutritive Value in Vegetables. J. Amer. Dietetic Assoc. 16: 524-35. 1940.

17. Fincke, M. L. and E. Hansen. The Effect of Storage on the Ascorbic Acid Content of Berries. Nat'l Coop. Project (Conservation of Nutritive Values of Food) Progress Notes (Oregon State College, Corvallis, Oregon) Leaflet: p. 2. 1946.

18. Fitzgerald, G. A. and C. R. Fellers. Carotene and Ascorbic Acid Content of Fresh Market and Commercially Frozen Fruits and Vegetables. Food Research 3: 109-20. 1938.

19. Gilligan, G. M. and C. W. Woodmansee. Effect of Storage Conditions on Ascorbic Acid Content of Kale and Cantaloupe. Delaware Agri. Exp. Sta. Pamphlet 23. January, 1946.

20. Gordon, L. et. al. Effect of Snow Ice on the Retention of Vitamin C in Green Vegetables Displayed in a Retail Market. Mich. Agri. Quart. Bul. 27 No. 3: 322-7. 1945.

21. Hauck, C. A. Marketing in Consumer Units. Market Growers. LXXV Number 5: 38. May, 1946.

22. Kifer, H. B. and H. E. Munsell. Vitamin Content of Three Varieties of Spinach. J. Agri. Research 44: 767-71. 1932.

23. Lineberry, R. A. and L. Burkhart. The Vitamin C Content of Small Fruits. Proc. Amer. Soc. Hort. Sci. 41: 198-200. 1942.

24. Maerz, A. J. and M. R. Paul. A Dictionary of Color. New York: McGraw Hill Book Co. Inc., p. 207. 1930.

25. Mayfield, H. L. and J. E. Richardson. Ascorbic Acid Content of Strawberries and Their Products. Montana Agri. Exp. Sta. Bul. 412. 1943.

26. McCollum, J. P. Some Factors Affecting the Ascorbic Acid Content of Tomatoes. Proc. Amer. Soc. Hort. Sci. 45: 382-6. 1944.

27. Maclinn, W. A. et. al. Tomato Variety and Strain Differences in Ascorbic Acid (Vitamin C) Content. Proc. Amer. Soc. Hort. Sci. 34: 543-552. 1936.

28. Mosely, M. A. and G. H. Satterfield. Ascorbic Acid (Vitamin C) Content of Six Varieties of Cantaloupe. J. Home Ec. 32: 104-7. February, 1940.

29. Olliver, Mamie. The Ascorbic Acid Content of Fruits and Vegetables with Special Reference to the Effect of Cooking and Canning. Soc. Chem. Ind. Journal (Trans. and Commun.) 55: 153T-163T. 1936.

30. Platenius, H. Effect of Temperature on the Rate of Deterioration of Fresh Vegetables. J. Agri. Research 59: 41-58. 1939.

31. ______________ et. al. Studies in Cold Storage of Vegetables. Cornell (New York) Agri. Exp. Sta. Bul. 602.

32. Proctor, B. E. and D. C. Greenlie. Determination of Optimum Conditions for Domestic Refrigeration of Foods. Market Growers J., Number 21, p. 55.

33. Satterfield, G. H. and M. Yarbrough. Varietal Differences in Ascorbic Acid Content (Vitamin C) of Strawberries. Food Research 5: 241-5. 1939.

34. Schrader, G. M. et. al. The Influence of Variety, Size and Degree of Ripeness upon the Ascorbic Acid Content of Peaches. J. Nutrition 25: 503. 1943.

35. ______________ et. al. Cantaloupe -- Factors Affecting Their Vitamin C Content. Arizona Agri. Exp. Sta. Mimeo. Report 53: 1-8.

36. Spiers, M. et. al. The Effect of Icing on Retention of Quality and Ascorbic Acid in Vegetables. Ice and Refrigeration. Volume 3 Number 1: p. 19-22. July, 1946.

37. Tressler, D. K. Importance of Refrigeration in Conserving the Vitamin C Content of Fresh Vegetables. Food Proc. Packing and Marketing 7: 432. 1938.

38. ______________. Bacteria, Enzymes, and Vitamins Indices of Quality in Frozen Vegetables. Refrig. Engr. 36: 319-21. 1938.

39. ______________ et. al. Factors Influencing the Vitamin C content of Vegetables. Amer. Jour. Public Health 26: 905-9. September, 1936.

40. Tripp, F. et. al. Varietal Differences in the Vitamin C (Ascorbic Acid) Content of Tomatoes. J. Home Ec. 29: 258-62. 1937.

41. Wade, B. L. and M. S. Kanapaux. Ascorbic Acid Content of Strains of Snap Beans. J. Agri. Research 66: 313-24. 1943.

42. Wheeler, E. et. al. Vitamin C Content of Vegetables: Broccoli, Cauliflower, Endive, Cantaloupe, Parsnip, New Zealand Spinach, Lettuce, and Kale. Food Research 4: 593-603. 1939.

43. Whittwer, S. H. et. al. Vegetable Crops in Relation to Soil Fertility: Vitamin C and Nitrogen Fertilizers. Soil Science 59: 329-36. April, 1945.

44. Yaroshenko, V. N. Change in the Vitamin C Content of Fresh Vegetables Within a Short Time. Chem. Abstract 34: 6378. 1940.

45. Zepplin, M. et. al. Effect of Refrigeration on Retention of Ascorbic Acid in Vegetables. J. Food Research 9: 100-11. 1944.

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