6-1-1952

Fruits and Vegetables in the Home Freezer, Factors Affecting Quality

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BULLETIN 423 JUNE 1952

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FACTORS AFFECTING QUALITY

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BROOKINGS

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Fruits and Vegetables in the Home Freezer

Factors Affecting Quality

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Freezing is one of the simplest and least time-consuming methods of preserving food, and it should yield products which have retained most of their natural color, fresh flavor and nutritive value. However, the quality of frozen food can vary a great deal if the following factors are not given careful consideration:

1. Selection of raw foods
2. Preparation of food for freezing
3. Selection of packaging materials
4. Rate of freezing
5. Temperature and length of storage
6. Preparation for table use

With the spread of rural electrification in South Dakota, home freezers are being used more and more for food preservation by rural families as well as by urban families with city power. Along with this increased use of freezers have come many questions. The studies which will be reported in this bulletin were planned to help answer some of these questions. Will food freeze as fast in one freezer as another? Does slower freezing seriously affect the palatability and nutritive value of foods? How do packaging materials influence the rate of freezing and retention of quality in frozen foods? How long may various foods be stored?

Review of Previous Work

Rate of Freezing

In the past there has been considerable controversy concerning the effect of the rate of freezing on the quality of frozen foods. Several investigators have reported that slow freezing, such as at 0° F., was satisfactory for fruits and vegetables, while others were convinced that quick freezing was essential for the production of high quality frozen vegetables. More recent studies of the effects of five widely different rates of freezing on peas and snap beans show that, although the slower rates of freezing resulted in the formation of larger ice crystals, there were no significant differences in taste, texture or vitamin content (7).[2] As a result of this and other studies, some workers in the field believe that, while very rapid freezing may be desirable for a few vegetables such as asparagus, in general, if the freezing can be completed within 24 hours, the resulting product will be satisfactory (2). They concluded, also, that too much emphasis

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[2]Figures in parentheses refer to "Literature Cited."

has been placed on the importance of freezing rate rather than on the importance of getting the food products into the freezer quickly and cooled quickly. Therefore, since very rapid freezing does not appear necessary for obtaining quality frozen fruits and vegetables, the home freezer can compete with the commercial locker in preparing quality frozen foods.

Storage Temperature

There has been some question as to the most desirable storage temperature for frozen foods. Temperatures ranging from 0° F. to –20° F. have been recommended. A few foods, namely Brussels sprouts and asparagus, apparently are benefited by even lower temperatures (5). It has been stated that for reasons of economy, frozen food should be stored at the highest temperature which will satisfactorily maintain the quality of the food (2). A survey of the literature would indicate that the majority of investigators now accept 0° F. as being a satisfactory storage temperature for most fruits and vegetables. Only with this temperature, or a lower one, can one expect the high nutritive quality of frozen vegetables to be retained from one harvest to the next. High temperatures may also cause other losses in quality, for instance, loss of color in frozen peas at temperatures above 15° F. The higher the temperature, the shorter the safe period for storing foods in the freezer. If temperatures much above 0° F. are used, storage life must be shortened.

The owner of a home freezer also faces the problem of fluctuating storage temperatures. This fluctuation may be due to many different causes—temporary breakdown in equipment, overloading of the freezer during freezing, frequent opening of the freezer (particularly of a side-opening box) or lack of a separate compartment for freezing.

Research studies indicate that day to day variations in storage temperature between 0° F. and –20° F. did not result in any impairment in food quality over a 6-month period of storage (4). On the other hand, when the storage temperature varied between 0° and 20° F. above zero, deterioration in quality was apparent (3). These high fluctuating temperatures resulted in changes in palatability, development of rancidity of the fat and loss of ascorbic acid content similar to those occurring in food stored at 10° F. In both cases the quality was definitely inferior to that of food stored at 0° F. However, fluctuating temperatures below 0° F. had little effect. All of these findings help to verify the belief that submitting products to temperatures above 0° F. causes deterioration of quality and vitamin content more than actual fluctuation in the temperature.

Ascorbic Acid (Vitamin C)

Freezing itself causes no loss of ascorbic acid if vegetables have been properly blanched (1) (10). However, frozen foods must be stored at low temperatures, 0° F. or below, or there will be slow losses during long-continued storage (6).

Equipment and Methods Employed

Freezer Units

For the main part of the study, three home freezers were used. One was a deep chest freezer with a small sharp-freeze compartment and a larger compartment for storage. A second unit was a single compartment, deep chest freezer. The third unit consisted of an upright or vertical cabinet of four compartments with drop front closures. For each of these units, the temperature control range was stated to be from 0° to −10° F.

A fourth unit, which was used for only one lot each of peas and chard, was a refrigerator with a large freezing chamber across the top and a single control switch. After 20 hours, these packages of peas and chard were transferred to a refrigerator unit with a dual control switch to complete the freezing and for storage.

Other pertinent information concerning these freezing units is given in Table 1.

Table 1. Characteristics of the Freezer Units

Style	Size (Cu. Ft.)	Type of Compressor	Size of Motor (H.P.)
Chest combination	8	Belted	⅓
Deep chest	8	Sealed	¼
Upright	7	Sealed	1/6
Refrigerator	9	Sealed	——

Temperature Measuring Equipment

For measuring the temperatures in the freezers and of the packages of food, a potentiometer calibrated for copper-constantin thermocouples was employed. The bare, twisted ends of the thermocouples were placed in the center of each package of food and against the freezing plate of each freezer. The wires were then carried past the rubber seal strip of the freezer door to the potentiometer. In order to facilitate the taking of large numbers of readings in a short span of time, 10-point rotary switches were inserted between the thermocouples and the potentiometer. Temperature readings to the nearest half-degree were made in series every 15 minutes until the temperature of the food reached 0° F.

Packaging Materials

It has been well-proven by many investigators that proper packaging can extend the storage life of frozen food. The most important requisite of frozen food packages is to be moisture vapor-proof if the highest quality of a food is to be retained. In addition, packaging materials should not permit or cause any changes in odor, flavor, or color, and be strong enough to resist breaking and tearing. Containers should be suitable in size and shape for the foods to be frozen with provisions for ease of filling and sealing.

The packaging materials used in this study were selected from among those recommended by various investigators and ones which were in general use at the time the study was made. Each year, three types of containers were compared. Those used in 1948 were: (a) a wax carton with metal closure; (b) a cellophane bag in a wax carton; and (c) a glass jar. With the appearance of new types of packaging materials, some changes were made the following year. The cellophane liner was replaced by one of polyethelene film ; and an aluminum tray was used instead of the glass jar. The plain wax carton served as a control since it was used in the same manner both years.

The particular aluminum container which was used proved much too thin and for that reason was easily bent and punctured by sharp corners of other packages of frozen food. Recently, a more durable aluminum tray container has made its appearance on the market. Another new type of container, which was temporarily unavailable at the time this study was made, is one made of a rigid plastic with a flexible cover. This container has many of the advantages of glass without its disadvantages; for example, though it will break, it will not splinter.

Preparation and Freezing Of Samples

The fruits and vegetables used in this study were obtained from either the horticulture department of the college or from a local truck gardener. They were prepared for freezing according to generally accepted methods the details of which are summarized in Table 2. After each lot of food had been prepared, it was thoroughly mixed in order to obtain a uniform sample. Just prior to packaging, a small quantity of the food was removed for ascorbic acid determinations and six containers of

Table 2. Preparation of Food for Freezing and Tasting

	For Freezing			For Tasting				
Food	Preparation	Scalding	Packaging* (Grams/Pkg.)	Defrosted	Water Added‡ (Grams)	Salt Added§ (Grams)	Boiling Time (Min.)	How Served
Cherries	Wash, pit	None	450†	Yes	0	0	0	Cold
Green Beans	Wash, remove ends, snap in 1″ pieces	4 min. in boiling water, chill in ice water, drain	250	No	75	1	5	Hot
Peas	Shell	2½ min. in boiling water, chill in ice water, drain	300	No	50	1	5	Hot
Chard	Wash, drain	3 min. in boiling water, chill in ice water, drain	300	No	50	1	2	Hot
Corn	Remove husk, trim silk, wash in cold water	4½ min. in boiling water, cool in running water, chill in ice water, cut off cob	350	No	75	1	2	Hot

*Regular one pint packages.
†Includes 90 grams sugar (1:4).
‡75 grams = ⅓ cup, 50 grams = ¼ cup.
§1 gram salt = ⅛ teaspoon.

Two members of the panel judging the frozen peas for appearance and palatability

each type were filled. Duplicate packages of the foods in each type of container were placed in each freezer under observation.

The cold control switches on the freezers had been turned to "freezing" position several hours previous to the placing of the food in the units. Likewise, the refrigerator control had been turned to its coldest setting. Temperature measurements were begun immediately and were made every 15 minutes therafter until the temperature at the center of the package registered 0° F. When all packages reached that temperature the cold control switch was adjusted for "storage." The following day the thermocouples were removed and the packages sealed. With the exception of the peas and chard frozen in the refrigerator unit, all packages of food were stored in the same freezer in which they were frozen. In the refrigerator, when neither the food packages nor the freezing unit had reached 0° F. after 20 hours, the packages of peas and chard were transferred to a freezer-refrigerator combination with a dual control switch where they reached 0° F. within two hours.

After storage periods of 3 to 4 months and 9 to 10 months, sample packages were removed and tested for ascorbic acid and palatability.

Ascorbic Acid Determinations

The method employed for measuring ascorbic acid content of the foods made use of the reducing action of ascorbic acid to decolorize the dye (2,6 dichlorophenolindolphenol), the amount of dye which is decolorized being proportional to the quantity of ascorbic acid present. An Evelyn photoelectric colorimeter was used to measure the color changes. A 5 percent solution of meta phosphoric acid was used to extract the ascorbic acid from the plant tissue. The frozen samples were analyzed without previous defrosting.

Palatability

Palatability was scored by a panel of experienced judges. For this, the foods were prepared as for the table. Pertinent details are given in Table 2. A 4-point rating scale with a value of 4 indicating maximum desirability was employed in judging color, texture and flavor; and in the case of peas and corn, the additional factor of sweetness.

Results

Rate of Freezing

Observed changes in the temperature of the freezers and the packages of food are shown in the appendix (Figs. 1 to 6). With a few exceptions, each curve represents the average for two packages in the same type of container being frozen simultaneously in the same freezer. These freezing curves are typical in shape showing three fairly definite stages: 1. a period of rapid cooling, 2. a period during which there is little or no change in temperature, and 3. a period of fairly rapid decrease until the temperature in the package reaches that of the freezer.

The period of rapid cooling was quite uniformly 1½ hours long for all vegetables in all freezer units except the refrigerator freezing unit in which the time required to chill the packages was two hours. The cherries took approximately two hours to reach freezing temperature which, because of the sugar concentration, was between 20° and 25° F. rather than 30° to 32° F. as observed for the vegetable products.

The period during which there is little or no change in temperature or the length of the freezing period, as measured by the length of the temperature plateau, appeared to vary from freezer to freezer and with the type of container. Moreover, it was difficult, if not impossible, to determine precisely the length of this period for many of the individual packages.

For the period during which the temperature in the package decreases until it reaches that of the freezer, the same variations and difficulties in measurement were encountered. Therefore, for the purposes of comparison, the over-all time to reach 0° was used as a meas-

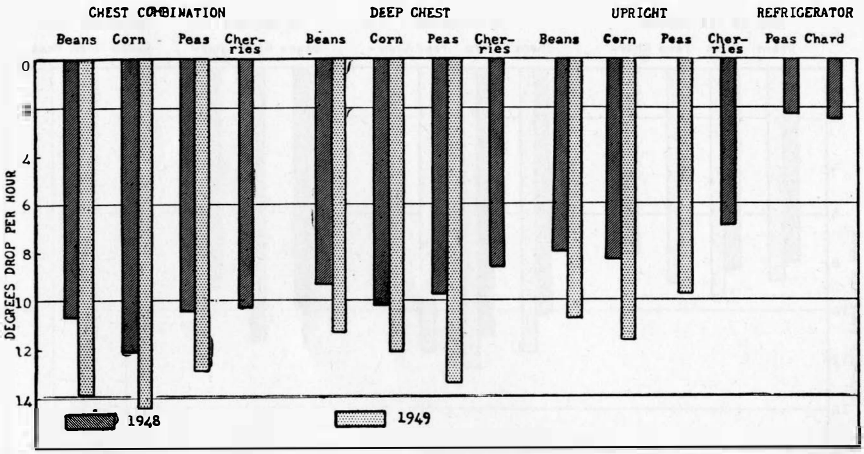


Fig. 1. Comparison of rate of freezing of fruits and vegetables in each of four home freezers showing faster rate of freezing in the chest combination and a slow rate of freezing in the refrigerator freezing unit

ure of freezing time. In addition, the rate of freezing in degree drop per hour was calculated. These data are summarized in the appendix (Tables 1 to 3) and shown in Figs. 1 and 2. Since the initial temperature of the food packages varied, a covariance analysis was used to determine the significance of the variations noted.[3]

It was found that there were statistically significant differences in freezing time between the freezer units and also between the containers studied. Comparing the three freezers for which complete data are available, it was found that for both years, food frozen in the deep chest combination with separate freezing compartment required the shortest time to reach 0° F. In 1948, food frozen in the upright freezer required a much longer time to reach 0° F. than food frozen in either of the other two units. This difference in time was highly significant. On the other hand in 1949, difference in the time required for freezing in the upright and the deep chest units was barely significant. The poor performance of the upright freezer in 1948 was possibly the result of overloading since, at that time, this freezer was very nearly filled to capacity with frozen meat. In 1949, when the upright freezer contained very little stored food, the freezing time was more nearly comparable with that of the other two freezers, and its performance was not significantly different from that of the deep chest. Freezing, however, was slower in it than in the chest with the separate freezing compartment.

It is evident that there were some characteristic differences among the containers in regard to the length of time required for food packaged in them to reach 0° F. as shown in the

[3]Analyses of variance and of covariance were applied to portions of the data to estimate the significance of the observed variations.

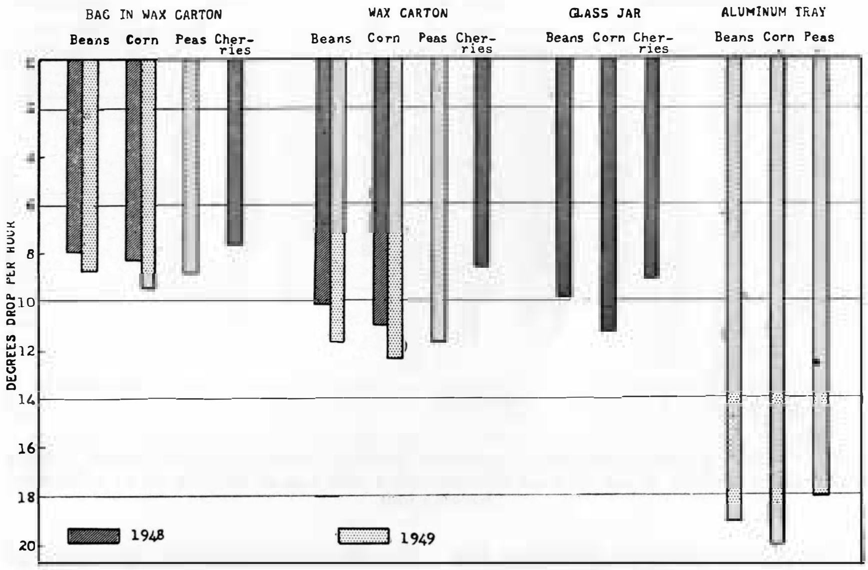


Fig. 2. Comparison of rate of freezing of fruits and vegetables packaged in four types of containers showing a very fast rate of freezing of food in an aluminum tray and a slower rate of freezing in the bag in wax carton

appendix (Figs. 1 to 6 and Tables 1 to 3). Almost without exception, food in the cellophane or polyethelene bag in wax carton required the longest time and that in the aluminum tray by far the shortest time, with the wax carton and glass jar showing intermediate values. Analyses indicate that the differences between the glass jar and the wax carton are not significant, whereas the differences between the values for the other containers are highly signficant.

The slower rate of freezing in the cellophane or polyethelene bag in a wax carton is, no doubt, the result of the insulating action of the air layer between the bag and the carton. That this slowing effect can be avoided by freezing food in the bag alone and then placing it in the wax carton is indicated by work done at Michigan State College (8) where a slightly faster rate of freezing food in the bag alone was observed. The very fast rate of freezing food in the aluminum tray results from the rapid conduction of heat by the aluminum.

The very slow rate of freezing in the refrigerator unit as compared to any of the freezers and the very rapid rate of freezing of food in the foil containers is shown clearly in Figs. 1 and 2, and in the appendix (Tables 1 to 3). Likewise, the rate of freezing during the second year was consistently higher for all freezers and all containers than for the first year. This difference would appear to be related to the amount of food stored in the freezers when the tests were made. In 1948 all freezers contained appreciable quantities of frozen meat, whereas in 1949 all of them were relatively empty.

Separation of the food being frozen from that already in storage is at least one possible factor in the superior performance of the unit with small separate freezing compartment. Another possible factor contributing to the observed variations in rate of freezing is the size of the motor which is important in determining the temperature of the freezer. The unit showing the fastest rate of freezing was the chest combination which had a 1/3 H.P. motor, whereas the upright freezer had the least powerful motor (1/6 H.P.) and the slowest rate of freezing. The single compartment chest freezer had a 1/4 H.P. motor and an in-between freezing rate.

Quality of the Foods After Storage

Thus it has been shown that there were statistically significant differences in the rates of freezing among the four freezing units studied. The next question to be answered was whether the quality of the frozen products was seriously affected by the slower rates observed for the upright freezer and for the refrigerator unit. Two measures of quality were employed in this evaluation: 1. scoring of color, texture, flavor and sweetness by a panel of tasters, and 2. changes in ascorbic acid content. These tests were made on the frozen foods after storage periods of 4 and 10 months.

Scoring of color, texture, flavor and sweetness. There were no significant differences in the palatability scores given any of the foods which could be traced to either the freezer or the type of container used, with the exception of the flavor of the 1948 samples of corn frozen and stored in the upright freezer. These corn samples were poorer in flavor than those frozen and stored in either of the other freezers.

In a comparison of the scores for foods stored for the two different periods of time, it was found that the scores for color and texture showed few differences, and, in only one instance, was the observed difference significant. The texture scores for the 1949 samples of corn stored 10 months were lower than those for the samples stored 4 months.

Flavor and sweetness, on the other hand, showed a greater tendency toward deterioration, significant losses of flavor occurring in the corn stored 10 months in 1948. However, the average scores for green beans in 1948 and for the chard, which had been frozen in the refrigerator unit, indicated some improvement in the flavor of the product at 10 months over that at 4 months. Other workers have reported similar results for peas and wax beans (8). Highly significant losses of sweetness were observed for corn in 1949 as well as in 1948. With peas, the loss of sweetness was less evident.

These results would lend support to the view that, with few exceptions, the rate of freezing is of much less importance in the production of high quality frozen fruits and vegetables than is the length of time between harvesting and the placing of the food in the freezer and the time required to chill the product to freezing temperature (2).

Changes in abscorbic acid content. The mean ascorbic acid content of the green beans, cherries, peas and corn grouped by freezers and containers and by length of time in frozen storage is summarized in Figs. 3 to 5 and in the appendix (Tables 4 to 7). Also shown in these tables is the percent loss of ascorbic acid. It is evident that there were appreciable losses of this nutritional essential after 4 months' storage and still greater loss, in some cases as much as 40 percent, after 10 months' storage for all foods studied. An analysis of variance indicated that these differences due to length of storage were highly significant. On the other hand, the relatively small differences observed between the four types of containers were not significant for any of the foods under investigation.

The results for the freezers were much less consistent than those for either storage periods or containers. In 1948 the ascorbic acid losses for green beans in the two chest-type freezers were relatively small and quite similar; whereas green beans frozen and stored in the upright freezer showed losses of 22.8 and 47.2 percent, respectively, at 4 and 10 months storage. Although it was not practicable to obtain continuous records of the freezer temperature during the storage period, frequent checks were made. Twice in the course of the 1948-49 experimental period, mechanical failure caused interruption in operation of the upright freezer which permitted the temperature to rise above 0° F. Hence it is not surprising to find extensive losses of ascorbic acid in food stored in this freezer. The ascorbic acid in the cherries was apparently better able to withstand the effects of above-zero temperatures, at least for the shorter of the two test periods. Unfortunately, no data are available for this freezer in 1949, since all samples were lost prior to the four months' test period as a result of the freezer being inadvertantly disconnected.

Ascorbic acid losses for green beans stored in the chest combination in 1949 (appendix, Table 6) were very much greater than for the same vegetable in 1948, but were similar to the losses in the upright freezer the preceding year. Here again there were known interruptions in the operation due to mechanical breakdown. Previous work has shown that temperatures above 0° F. may lead to much loss of ascorbic acid when food is stored for more than a short period of time (6). Thus it may be presumed that above-zero temperatures occurring in the chest combination during the 1949 storage period, were at least partially responsible for the high losses observed. For foods in the single compartment chest freezer, losses of ascorbic acid were similar for both years, with only a few exceeding 15 percent at 4 months or 20 percent at 10 months. Likewise, they were quite comparable with values secured for green beans, corn and peas in a commercial locker.

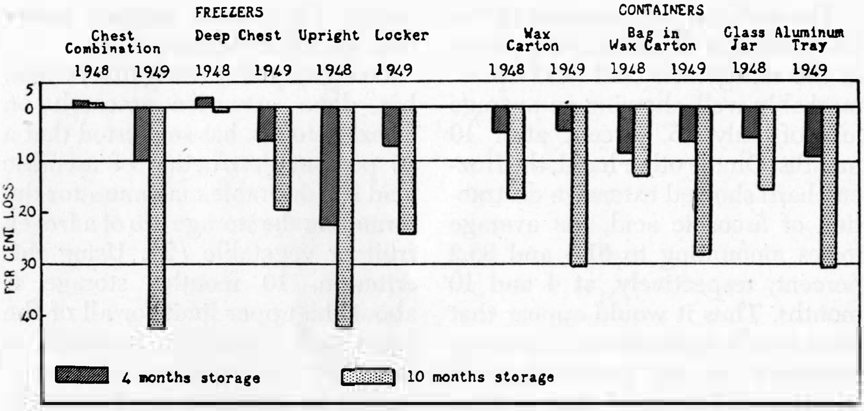


Fig. 3. Average percent loss of ascorbic acid in green beans grouped by freezers and containers showing large losses in the upright freezer in 1948 and the chest combination in 1949 after storage for 10 months

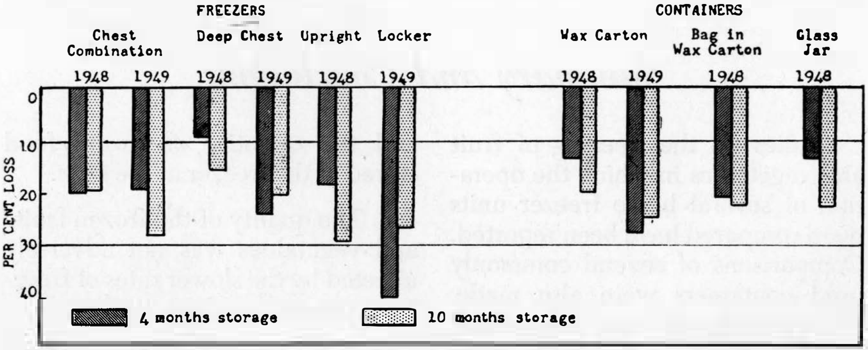


Fig. 4. Average percent loss of ascorbic acid in cherries grouped by freezers and containers showing relatively uniform losses

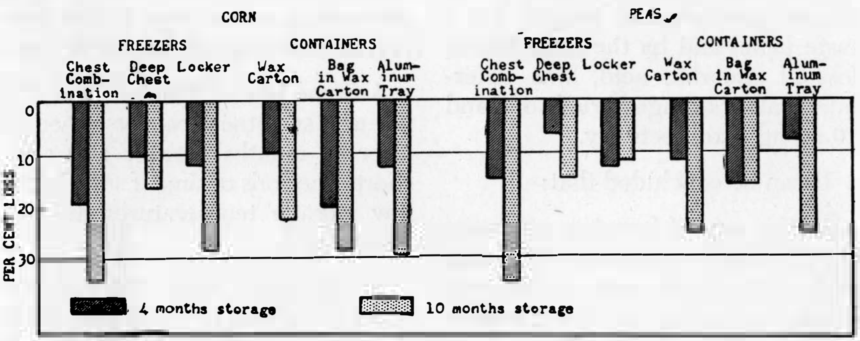


Fig. 5. Average percent loss of ascorbic acid in corn and peas grouped by freezers and containers showing greater losses after 10 months' storage

The ascorbic acid content of the two packages of frozen peas stored in the refrigerator unit held up remarkably well, showing an average loss of only 15 percent after 10 months. On the other hand, the frozen chard showed extensive destruction of ascorbic acid, the average losses amounting to 61.8 and 88.2 percent, respectively, at 4 and 10 months. Thus it would appear that more nearly optimum conditions are necessary for the preservation of ascorbic acid in chard than in peas. Furthermore, the conditions of storage in this refrigerator unit are apparently not adequate for all foods except for storage periods under four months in length.

One group of investigators, which has done extensive research on freezing foods, has suggested that a 25 percent destruction of ascorbic acid is a desirable maximum for determining the storage life of a frozen fruit or vegetable (2). Using this criterion, 10 months' storage is about the upper limit for all of the fruits and vegetables included in this study. On this basis, the storage conditions provided by the upright freezer in 1948 and the chest combination in 1949 were not satisfactory for the longer period of storage.

Summary and Conclusions

Studies on the freezing of fruit and vegetables in which the operation of several home freezer units were compared have been reported. Comparisons of several commonly used containers were also made. The freezing rate was determined by measuring the temperature of the food packages until a temperature of 0° F. was reached. Quality of the frozen products, as judged by a taste panel and by the retention or loss of ascorbic acid, was determined after storage periods of 4 and 10 months, respectively.

It can be concluded that:

1. The rate of freezing may vary significantly from freezer to freezer; and in the same unit at different times depending on a number of factors such as power of the motor, amount of primary freezing surface, and the quantity of frozen food stored in the freezer at the time.

2. The quality of the frozen fruits and vegetables was not adversely affected by the slower rates of freezing occurring in these studies.

3. A separate freezing compartment may be effective in shortening actual freezing time as well as in preventing undue rises in the temperature of food already in storage.

4. Some loss of ascorbic acid, flavor and sweetness can be expected after 10 months' storage and after shorter periods of time if sufficiently low storage temperatures are not maintained.

5. Although there were differences in the rate of freezing foods in the four types of containers, it would appear that these containers

were all quite satisfactory for preserving palatability and nutritive value.

6. Use of aluminum containers can markedly shorten the time required for foods to freeze and thus result in a saving of electricity.

7. In the light of these studies, some points to consider in selecting a home freezer are:

a. Is the unit dependable and not subject to mechanical difficulty?
b. Does the motor have enough power to maintain adequate freezing and storage temperatures when the freezer is completely filled?
c. Would a separate freezing compartment be desirable for your particular needs; that is, do you freeze in quantities and often enough to warrant this separate compartment?

Appendix

Appendix Table 1. Summary of Freezing Data for Green Beans Grouped by Freezers and Containers

	Av. Starting Temperature (Degrees F.)		Av. Time to Reach 0° F. (Hours)		Av. Rate (Degree Drop per Hour)	
	1948	1949	1948	1949	1948	1949
Freezers*						
Chest Combination	61.75	60.46	5.75	4.36	10.74	13.87
Deep Chest	60.21	58.79	6.49	5.20	9.28	11.30
Upright	59.79	61.17	7.51	5.73	7.96	10.68
Containers†						
Bag in Wax Carton	61.42	62.38	7.68	7.09	8.00	8.80
Wax Carton	59.12	61.71	5.82	5.25	10.16	11.66
Glass Jar	61.21	—	6.24	—	9.81	—
Aluminum Tray	—	56.33	—	2.97	—	18.97
L.S.D.‡—5% level			0.5	0.3		
L.S.D.—1% level			0.8	0.5		

Appendix Table 2. Summary of Freezing Data for Corn Grouped by Freezers and Containers

	Av. Starting Temperature (Degrees F.)		Av. Time to Reach 0° F. (Hours)		Av. Rate (Degree Drop per Hour)	
	1948	1949	1948	1949	1948	1949
Freezers*						
Chest Combination	67.25	70.54	5.55	4.91	12.12	14.37
Deep Chest	67.17	68.83	6.60	5.67	10.18	12.14
Upright	64.75	72.00	7.80	6.13	8.30	11.74
Containers†						
Bag in Wax Carton	65.75	71.96	7.92	7.56	8.30	9.52
Wax Carton	66.83	71.83	6.08	5.78	10.99	12.43
Glass Jar	66.58	—	5.94	—	11.21	—
Aluminum Tray	—	67.58	—	3.37	—	20.05
L.S.D.‡—5% level			0.4	0.6		
L.S.D.—1% level			0.8	0.8		

*Average for freezer regardless of type of container.
†Average for container regardless of freezer.
‡Least significant difference.

Appendix Table 3. Summary of Freezing Data for Cherries and Peas Grouped by Freezers and Containers

	Av. Starting Temperature (Degrees F.)		Av. Time to Reach 0° F. (Hours)		Av. Rate (Degree Drop per Hour)	
	Cherries 1948	Peas 1949	Cherries 1948	Peas 1949	Cherries 1948	Peas 1949
Freezers*						
Chest Combination	71.50	62.08	6.95	4.82	10.29	12.88
Deep Chest	70.33	62.58	8.13	5.60	8.65	13.41
Upright	69.38	62.62	10.07	6.52	6.89	9.60
Refrigerator Unit	......	52.33	—	22.90	—	2.28
Containers†						
Bag in Wax Carton	70.88	64.81	9.17	7.27	7.73	8.91
Wax Carton	68.75	62.56	8.02	5.35	8.57	11.69
Glass Jar	71.58	—	7.96	—	8.99	—
Aluminum Tray	—	56.92	—	3.16	—	18.01
L.S.D.‡—5% level			0.4			
L.S.D.—1% level			0.6			

Appendix Table 4. Summary of Average Ascorbic Acid Content of Green Beans after 4 and 10 Months' Frozen Storage Grouped by Freezers and Containers

	Months in Storage						
	0	4			10		
	Amount (Mg./100G.)	Amount (Mg./100G.)	Loss (Mg./100G.)	Loss (%)	Amount (Mg./100G.)	Loss (Mg./100G).	Loss (%)
			1948				
Freezers*							
Chest Combination	13.40	13.54	0.14	1.0	13.53	0.13	1.0
Deep Chest	13.40	13.64	0.24	1.8	13.23	–0.17	–1.3
Upright	13.40	10.35	–3.05	–22.8	7.08	–6.32	–47.2
Containers†							
Wax Carton	13.40	12.72	–0.68	–5.1	11.07	–2.33	–17.4
Bag in Wax Carton	13.40	12.18	–1.22	–9.1	11.62	–1.78	–13.3
Glass Jar	13.40	12.62	–0.78	–5.8	11.15	–2.25	–16.8
L.S.D.—5% level			0.92				
L.S.D.—1% level			1.25				
			1949				
Freezers							
Chest Combination	16.74	14.87	–1.87	–11.2	9.05	–7.69	–45.9
Deep Chest	16.74	15.44	–1.30	–7.8	13.28	–3.46	–20.7
Upright	16.74	—	—	—	—	—	—
Commercial Locker	16.74	14.41	–1.33	–7.9	12.57	–4.17	–24.9
Containers							
Wax Carton	16.74	15.87	–0.87	–5.2	11.48	–5.26	–31.4
Bag in Wax Carton	16.74	14.78	–1.96	–11.7	11.94	–4.80	–28.7
Aluminum Tray	16.74	15.07	–1.67	–10.0	11.46	–5.28	–31.5
L.S.D.‡—5% level			0.75				
L.S.D.—1% level			1.02				

*Average for freezer regardless of type of container.
†Average for container regardless of freezer.
‡Least significant difference.

Appendix Table 5. Summary of Average Ascorbic Acid Content of Cherries After 4 and 10 Months' Frozen Storage Grouped by Freezers and Containers

	Months in Storage						
	0	4			10		
	Amount (Mg./100G.)	Amount (Mg./100G.)	Loss (Mg./100G.)	Loss (%)	Amount (Mg./100G.)	Loss (Mg./100G).	Loss (%)
			1948				
Freezers*							
Chest Combination	15.36	12.28	-3.08	-20.0	12.32	-3.04	-19.8
Deep Chest	15.36	13.94	-1.42	-9.2	12.95	-2.41	-15.7
Upright	15.36	12.52	-2.84	-18.5	10.88	-4.48	-29.2
Containers†							
Wax Carton	15.36	13.30	-2.06	-13.4	12.33	-3.03	-19.7
Bag in Wax Carton	15.36	12.18	-3.18	-20.7	11.95	-3.41	-22.2
Glass Jar	15.36	13.27	-2.09	-13.6	11.87	-3.49	-22.7
L.S.D.‡—5% level			2.13				
L.S.D.—1% level			2.88				

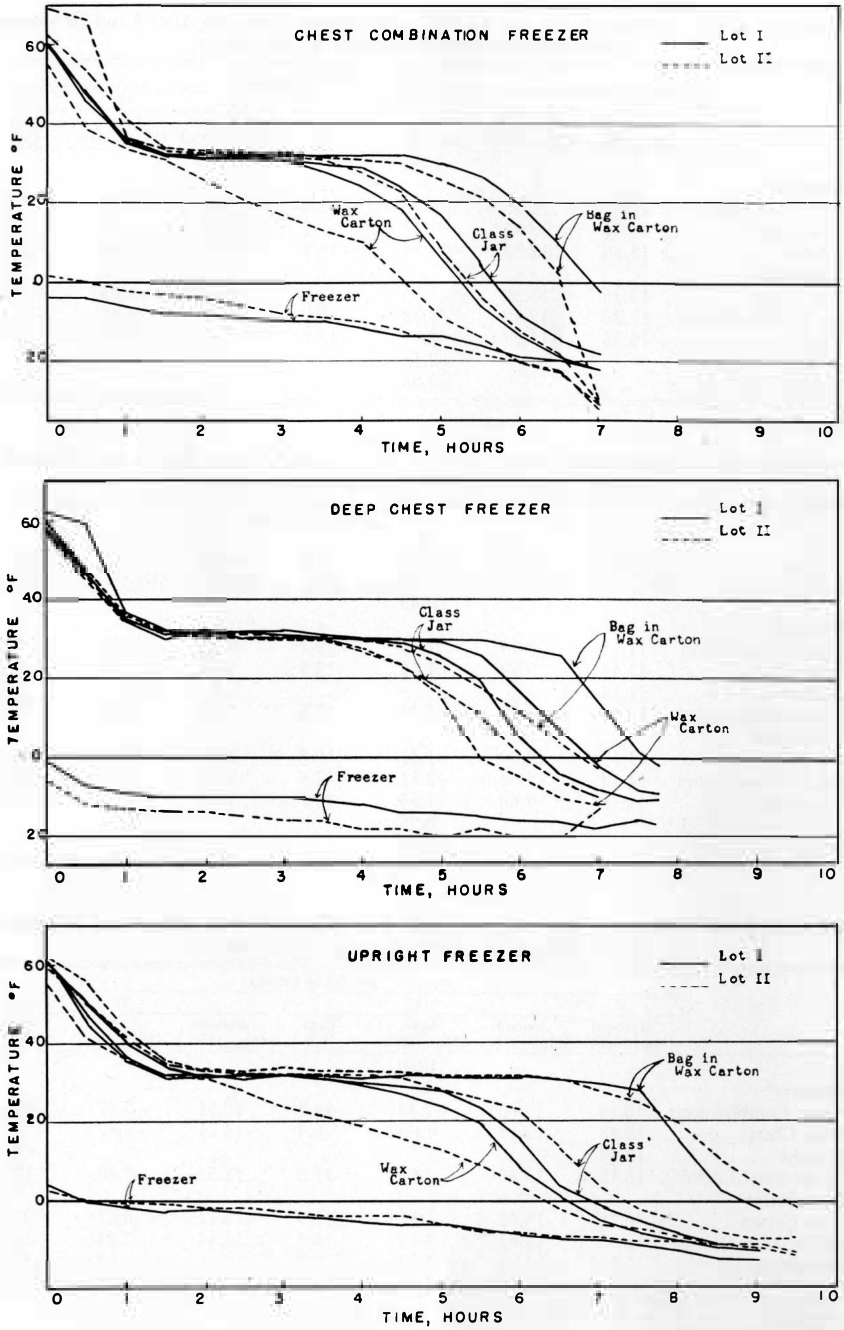
Appendix Table 6. Summary of Average Ascorbic Acid Content of Corn After 4 and 10 Months' Frozen Storage Grouped by Freezers and Containers

	Months in Storage						
	0	4			10		
	Amount (Mg./100G.)	Amount (Mg./100G.)	Loss (Mg./100G.)	Loss (%)	Amount (Mg./100G.)	Loss (Mg./100G).	Loss (%)
			1949				
Freezers*							
Chest Combination	11.13	8.94	-2.19	-19.7	7.18	-3.95	-35.5
Deep Chest	11.13	9.59	-1.54	-13.8	9.30	-1.83	-16.4
Upright	11.14	—	—	—	—	—	—
Commercial Locker	11.13	9.69	-1.44	-12.9	7.80	-3.33	-29.9
Containers†							
Wax Carton	11.13	10.00	-1.13	-10.2	8.47	-2.66	-23.9
Bag in Wax Carton	11.13	8.62	-2.51	-22.6	7.95	-3.18	-28.6
Aluminum Tray	11.13	9.60	-1.53	-13.7	7.76	-3.37	-30.3
L.S.D.‡—5% level			0.58				
L.S.D.—1% level			0.78				

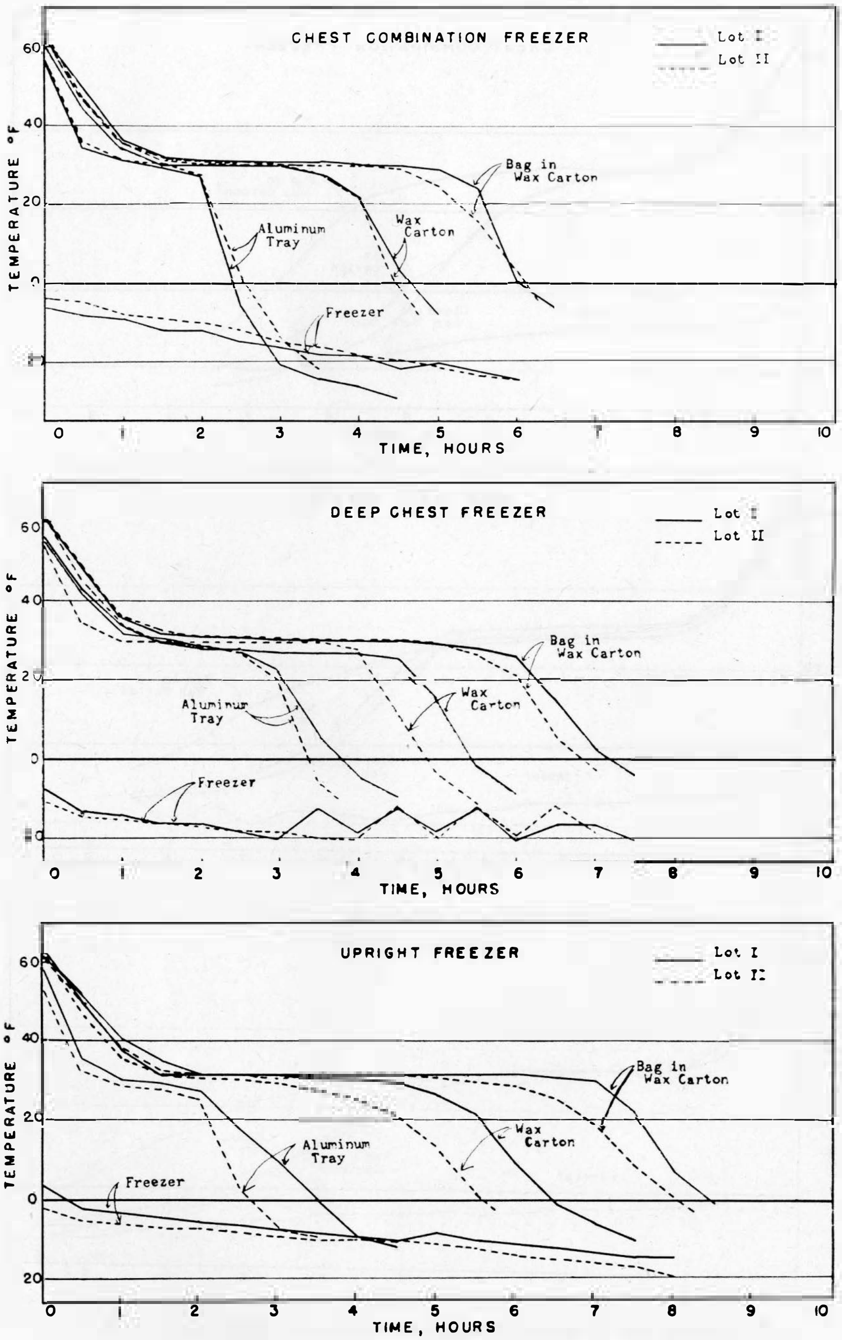
Appendix Table 7. Summary of Average Ascorbic Acid Content of Peas After 4 and 10 Months' Frozen Storage Grouped by Freezers and Containers

	Months in Storage						
	0	4			10		
	Amount (Mg./100G.)	Amount (Mg./100G.)	Loss (Mg./100G.)	Loss (%)	Amount (Mg./100G.)	Loss (Mg./100G).	Loss (%)
			1949				
Freezers*							
Chest Combination	16.18	13.80	-2.38	-14.7	10.51	-5.67	-35.0
Deep Chest	16.18	15.14	-1.04	-6.4	13.71	-2.47	-15.3
Upright	16.18	—	—	—	—	—	—
Commercial Locker	16.18	13.30	-2.88	-17.8	13.53	-2.65	-16.4
Containers†							
Wax Carton	16.18	14.32	-1.86	-11.5	12.11	-4.07	-25.2
Bag in Wax Carton	16.18	13.53	-2.65	-16.4	13.54	-2.64	-16.3
Aluminum Tray	16.18	14.94	-1.24	-7.7	12.10	-4.08	-25.2

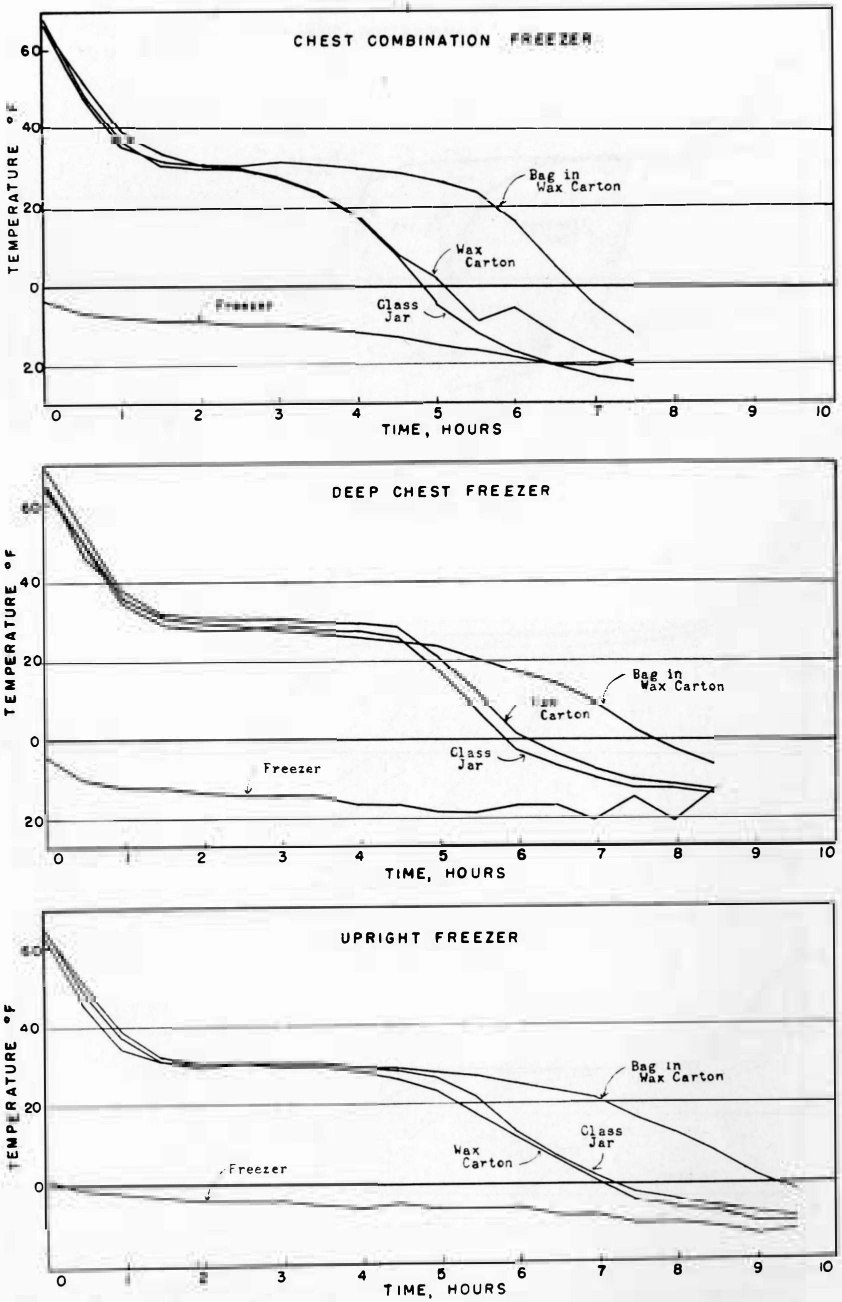
*Average for freezer regardless of type of container.
†Average for container regardless of freezer.
‡Least significant difference.



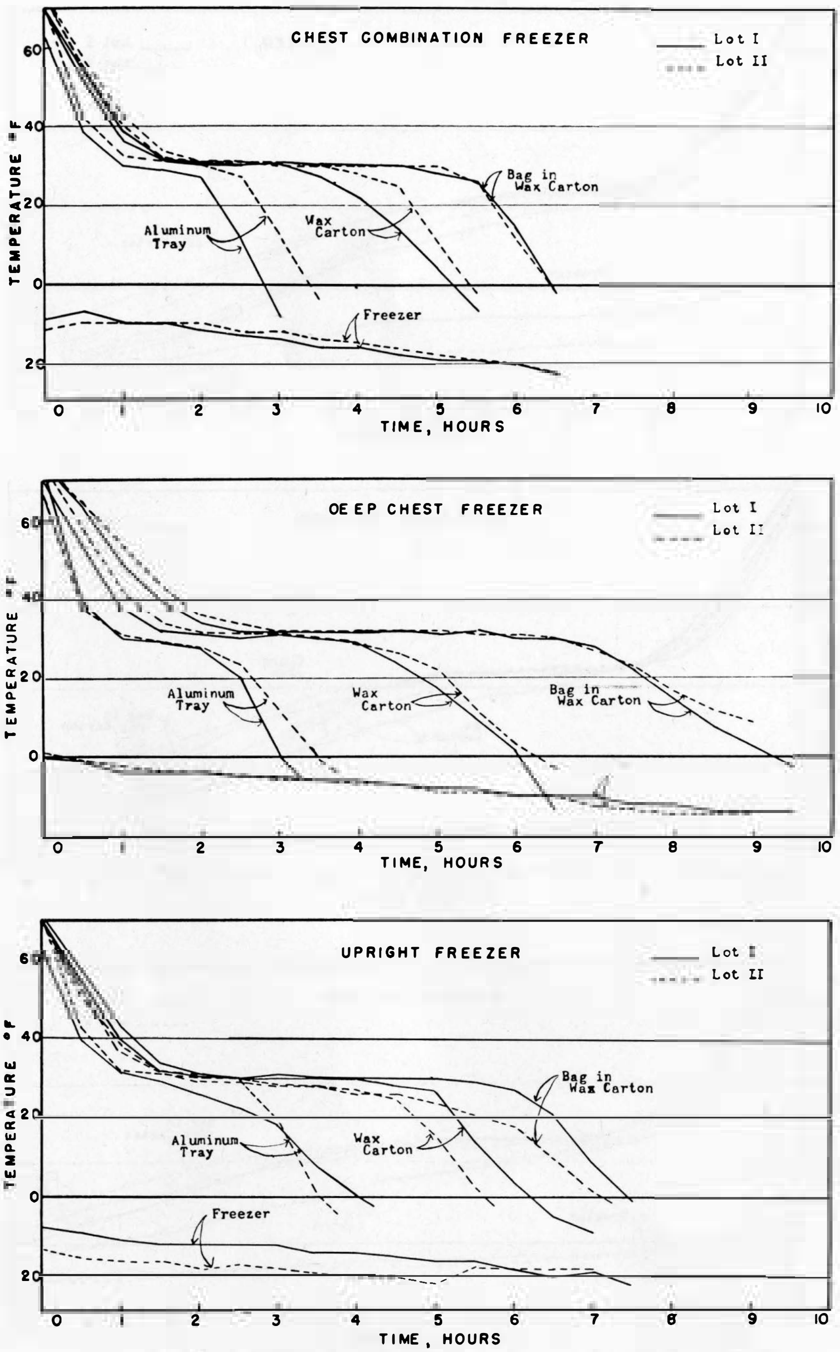
Appendix Fig. 1. Changes in temperature during freezing of green beans in 1948



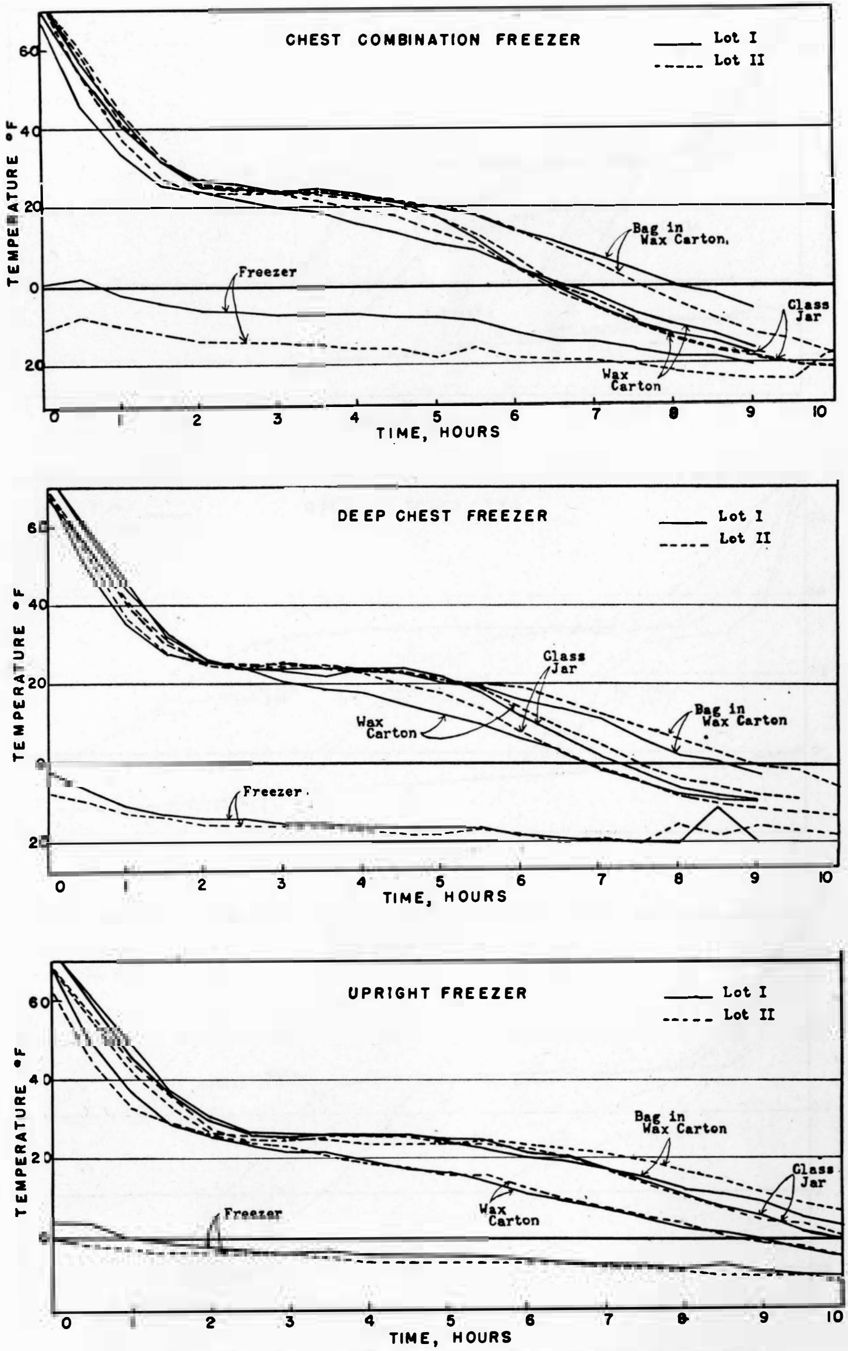
Appendix Fig. 2. Changes in temperature during freezing of green beans in 1949



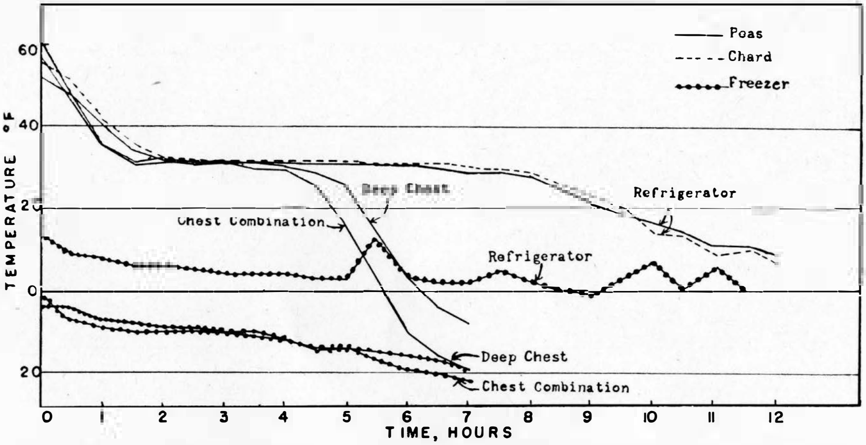
Appendix Fig. 3. Changes in temperature during freezing of corn in 1948



Appendix Fig. 4. Changes in temperature during freezing of corn in 1949



Appendix Fig. 5. Changes in temperature during freezing of cherries in 1948



Appendix Fig. 6. Changes in temperature during freezing of peas and chard in 1948 and 1949

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