THE INSTITUTION USE OF QUICK FROZEN FRUITS AND VEGETABLES

THESIS FOR THE DEGREE OF M. S.

Eunice C. Winans

1932

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Vegetables
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Table Frozen fruits +
vegetables

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Home economics

Hygeia
19:448
May '40

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By

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Submitted in partial fulfillment

of the requirements for the degree

of

Master of Science

Department of Institution Economics

Division of Home Economics

Michigan State College

1932

THESIS

Acknowledgements

The writer is grateful to Mrs. Mabelle Ehlers and Dr. Marie Dye for advice and suggestions given throughout this study, and for their criticisms and corrections of this manuscript.

To Dr. D. E. Devereux the writer is indebted for directing the bacteriological work and for aid in preparing the report of the experiments.

Acknowledgement is made to Mrs. Mabelle Ehlers, Miss Katherine Hart, and Miss Vera Howard for acting as judges in the palatability study.

The Institution Use of Quick-Frozen Fruits and Vegetables.

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THE INSTITUTION USE OF QUICK-FROZEN FRUITS AND VEGETABLES

I. Introduction

Considerable interest has been manifested in quick-frozen food products during the past few years. It is apparent that these foods are beginning to find their sphere of usefulness, and it is time to distinguish between the mere novelty of the new development and its practical appeal. The novelty of these frozen foods has brought about a certain amount of spectacular publicity. However, the ultimate test is always the question of how much better the new method serves our needs than those in use at the present time.

The use of quick-frozen foods in institutions is increasing, but results have not been unfailingly successful. Out of the limited selection of quick-frozen meats, fish, fruits, and vegetables offered the institution buyer by manufacturers and distributors, quick-frozen meats and fish seem to have stood the test of time with a certain degree of success. But the newer members of the quick-frozen family, fruits and vegetables, are still on probation. The lack of adequate information concerning the nature and use of these fruits and vegetables suggested the present study.

The field was too large to study in total so this investigation was confined to certain definite properties common to quick-frozen fruits and to quick-frozen vegetables. Five different aspects of the products were chosen for study:

A. The nature of the quick-frozen products per se.

B. The relative palatability of the quick-frozen products as compared with corresponding canned and fresh products.

C. The cost relationship of quick-frozen, canned, and fresh fruits and vegetables in central Michigan.

D. The extent of bacteriological growth in quick-frozen products after they have thawed.

E. The availability of quick-frozen fruits and vegetables in central Michigan.

Because of the recent advent of these quick-frozen foods on the market, it was deemed advisable to include considerable introductory material in the thesis. The definition of certain terms commonly used in the quick-frozen industry, the historical background of the industry, and the principles of freezing the fruits and vegetables are briefly treated in an effort to gain clarity.

An attempt was made to keep the conditions under which the study was carried on as nearly like those in the average institution as possible. All of the foods used were of the nature commonly encountered in such places. The quick-frozen fruits and vegetables, with one exception, were obtained from a firm in Chicago who specialize in the needs of institutions. The canned goods came from the store room of the Women's Commons on the campus of Michigan State College. In the kitchen of this institution many of the examinations were made. The canned goods were of no special brand but varied considerably in brand as is the usual situation in store rooms.

The examinations were made at a time when fresh fruits and vegetables were out of season. However, it was possible to get a few fresh products, so whenever they were available, the fresh foods were examined also.

Upon first examining the products the color, size, shape, and flavor were noted and recorded. The procedure then followed, and the information obtained is indicated by the steps below.

1. Weight E. P. (Later found not to be essential to the problem)
2. Measure E. P.
3. Time required for certain preparation processes.
4. Number of servings.
5. Samples taken for bacteriological examination (for frozen fruits only).

The foods were all prepared for table use. The same kind of food from the three classes, frozen, canned, and fresh, were prepared by the same method allowing for individual differences. A variety of methods was used in the study. Pies, sauces, shortcakes, and salads were made of the fruits. The vegetables were all cooked in water and then seasoned and buttered. The foods were then submitted to the judges to be rated according to palatability.

The cost study is based on the costs involved in the use of the experimental products. This method limits the importance of the results somewhat, but the relationship of the costs of the frozen, canned, and fresh products should be indicated. However, the prices of canned goods are known to be quite stable, and from all indications the prices of the quick-frozen foods are following suite. Consequently, the prices of the fresh products are the most unstable and probably constitute the weakest factor in this phase of the study.

For the bacteriological examinations, samples of the frozen

fruits and vegetables were taken to the laboratory of the Bacteriology Department on the campus.

The availability study embodies a survey of the distributing agencies operating in central Michigan.

B. General Aspects of the Frozen Products.

Freezing Terms.

The terms used in the frozen foods industry are still somewhat vague due to the youth of the enterprise. Cold pack, frosted, quick frozen, slow frozen, sharp frozen, frozen pack, and instant frozen are terms used in describing the foods and often lead to confusion unless they are clearly defined. Woodroof (44) gives good definitions of most of the terms now used in commercial practice.

Slow freezing is the method of freezing which makes use of a temperature ranging from the freezing point of the product to zero degrees Fahrenheit. This is the method used in all of the experimental packs of fruits until a few years ago.

Sharp freezing is the term applied to freezing at a temperature ranging from zero to -10° F. Freezing at this temperature is much more rapid and produces a better product than slow freezing.

Quick freezing refers to a temperature below -10° F. It arrests spoilage even better than sharp freezing and increases the output of a plant within a given time.

Instant freezing is a term being introduced by the Crystal Carbonic Laboratory, where a temperature ranging from -80° to -100° F. is used. Freezing at such a temperature may produce a product superior to any other system of freezing.

Cold pack refers to packing prepared foods for freezing.

Frozen pack refers to putting frozen food in containers or wrappers.

Frosted foods is a term being introduced by the General Foods Corporation for their quick frozen products.

Defrosting refers to the act of removing cold from a product. Complete defrosting is accomplished when all of the ice crystals have been removed.

Historical Background.

The effects of freezing upon plant and animal tissues were probably observed by man for centuries before the usefulness of these phenomena in his daily life came to be realized. The practical utilization of refrigeration in connection with foodstuffs began in historical times with the use of atmospheric low temperatures, ice, and snow for the cooling of foods and drinks to temperatures that make them more palatable and retard deterioration and the development of organisms causing spoilage. Not only are low temperatures and ice nature's oldest preservatives, but they have also been highly successful as shown by the finding of well preserved specimens of prehistoric animals in the northern ice by scientists after thousands of years.

Although the Chinese have for hundreds of years frozen by natural means for the purpose of transportation the very juicy and very perishable Kaki type of persimmon (38) and although the Greeks and Romans were thoroughly acquainted with the preserving action of cold (20), it is a strange fact that the commercial application of

this principle did not begin in other countries until comparatively recent times, and the freezing preservation of horticultural products is still an infant industry.

Probably the greatest early stimulus to the frozen products industry came from the handlers of fish (42). Two leaders in the frozen fish industry are Clarence Birdseye and H. F. Taylor. Birdseye became interested in quick freezing as a result of his experiences in Laborador and other northern regions where he studied the effects of extremely low temperatures on fish. He is credited with noting that under certain conditions frozen fish when thawed out resumed the life processes. Birdseye's information became the basis for developing a system for freezing fish and meats, a system that is now being experimentally used in freezing plant tissue. As long ago as 1860 in Australia Morris and Mort are seen to have been the first to freeze successfully and export beef and mutton to England. Piper in Maine was a pioneer in commercial fish freezing in 1861 (20).

H. F. Taylor (36) states that between 1861 and 1913 at least eighteen patents were granted on improvements in the art of freezing fish. During that time also in scientific journals a voluminous literature had accumulated relating to the chemistry, morphology, and microbiology of freezing foods. However, there was no evidence of a consideration of the relation of the rate of freezing and the quality of the finished product. About 1912-13, methods of freezing fish rapidly by direct immersion in cold brine were introduced on a small commercial scale in Norway and Denmark.

The period of refined applications of cold began with the end

of the Great War and was initiated by and for the fisheries industry. Rapid freezing came about in fisheries to meet an economic situation. Fish are highly irregular in production, exceedingly perishable, and the greatest demand exists during the period of lowest production.

The system of freezing saved the industry from a decline that had set in. In 1929 twenty-two million pounds of fish were frozen. The system has been taken up by the meat industry and today we have experimentation or selling going on in many firms. General Foods Company with their "Birdseye Frosted Foods" in Springfield, Mass., Swift and Company in Chicago with their identifiable cuts, the Indianapolis Abbatoir with "Sally Lee" products, and Cudahy Brothers of Wisconsin are some of the outstanding firms. With these and many such firms the industry seems to be gaining and to be on a stable basis.

Horticulturalists and plant physiologists have been observing the effects of preservation by freezing as a commercial practice on the quality of fruits and vegetables for more than thirty years, but due to the fact that freezing kills tissue, causes cell leakage, and destroys turgidity, freezing has long been considered a thing to be avoided. Thus it has been somewhat against prejudice that the project has been developed (44).

For many years the preservation of plant tissues by subjecting them to very low temperatures was regarded only with academic interest. A few scattered instances of its use are recorded. It has been reported that fruits were frozen for several years prior to 1912 in the first Statler Hotel to supply berries for the winter trade. Subsequently, berries were frozen to be served on the Northern Pacific Dining

Cars (19). Sexton and Company of Chicago report that they have used frozen fruits in their jam kitchens for years.

However, the industry really had its inception about twenty-four years ago in the Pacific Northwest. Fulton (21), Baker (1), and Culpepper (10) describe some of the conditions and results of early experiments in freezing berries and peaches. State experiment stations in at least two widely different growing regions early approved freezing as a method of preserving fruits. These stations were Michigan in 1917 (32) and California in 1919 (8) and 1920 (9). Berry fruits were packed experimentally in the Pacific Northwest as early as 1912, but no commercial packs were made until 1918 (20). Success in these fruits led to investigations in other fruits and also in vegetables. Georgia entered the frozen fruit field experimentally in 1925 and commercially in 1930 (42). Kidd and West (28) in Great Britain (1925-26) satisfactorily preserved peas, asparagus, and cauliflower.

Originally freezing was a means of disposing the surplus fruit. As the industry grew, produce was grown especially for freezing and only the choicest fruit was used. The very juicy and very perishable Georgia peach was found in 1929 to withstand freezing successfully (38). The preservation of cherries by quick freezing in Wisconsin, begun in 1925, found its value in providing an orderly and economical method of marketing the surplus product. Incidently, no other method of preservation produces cherries so like the fresh ones as the quick-freezing method (39).

It can still be said that the bulk of quick-frozen fruits is packed for the wholesale or remanufacturing trade, confectioners,

preservers, pie bakers, syrup manufacturers, and ice cream makers, but in the past three or four years production and marketing in the retail container has been developed considerably (37).

The field for the quick-freezing of vegetables is much more limited than that of fruits. The institution trade consisting of restaurants, hotels, caterers, and other institutions, and the retail trade comprise its sphere. The development of this class of frozen foods has been within the last four years and is carried on in a much smaller scale than for fruits. At present the industry is in a stage of flux and experimentation.

The magnitude of the frozen fruit and vegetable industry can be shown somewhat by estimates of the packs of some of the most important products during recent years. Ullsperger (39) stated that approximately one hundred million pounds of fruit are packed annually. D. Taylor (37) made the statement that in the past decade and a half cold packing of fruits in the Pacific Northwest has grown from almost nothing to an industry with an annual output valued at wholesale at $5,000,000 or more. One plant alone in Georgia packed seven hundred thousand pounds of peaches in 1930 (38). In the same year the frozen pack of cherries by one organization in Wisconsin was eight million pounds (39). Figures on the frozen vegetable pack were not available, but the trend is the same as for fruits only on a much smaller scale.

Distributors report increasing activity in the frozen fruit and vegetable line. John Sexton and Company, Chicago, wholesale distributors, assert that their sales per year have reached thirty car loads. In the retail distributing field the General Foods Corporation

has taken the lead. One hundred different types of meats, fish, vegetables, and berries are packed and put on the market under the name of "Birdseye Frosted Foods" (17). They further claim that two hundred retail stores are selling these products and are located in the eastern states, chiefly in New England.

The question of the present status of the industry would not be completely considered without some estimate of the demand factor. Birdseye (3), Ullsperger (39), Tucker (38), and H. Taylor (35) show that the demand is unquestionably increasing. Ullsperger (39) asserts that all the large markets in the United States are using large quantities of Wisconsin cherries each year--Chicago ten to fifteen thousand barrels, Philadelphia twenty-five thousand barrels, New York fifteen to twenty thousand, with smaller cities such as Indianapolis, St. Louis, Columbus, and Cincinnati using from five to ten thousand barrels.

The Hotel Monthly Magazine (18) reports that frozen fruits find favor in hotels and restaurants. Food experts (15) (6) in popular women's magazines point out the interest and acclaimation of the public.

The very fact that state experiment stations are spending time and effort in the study of quality factors involved in freezing fruits and vegetables points to the importance to the public. At the Frozen Pack Laboratory (14) of the Bureau of Plant Industry, United States Department of Agriculture, at Seattle, Washington, a wide range of horticultural products totaling nearly thirty thousand small containers have been prepared and examined. At the Georgia Experiment Station (43) twenty-five kinds and seventy-one varieties of fruits and vegetables

have been studied. Several manufacturing concerns maintain research laboratories also. More of such work seems particularly essential at present when many technical problems are yet imperfectly understood.

Principles of Freezing Plant Foods.

At present there is some difficulty explaining how freezing is so destructive under some conditions and has such marked preservative properties under others. Authorities are not entirely agreed upon the factors essential to the satisfactory development of quick-frozen fruits and vegetables. However, they do admit that there is a much different problem with frozen plant tissue than with animal tissue.

Three leaders in the experimental field, Diehl (12), (13), (14), Birdseye (3) (4), and Woodroof (42) (44), emphasize the close relationship between the horticultural character, varietal peculiarity, maturity of the raw materials, and the quality of the finished product. Not all varieties of the same fruit or vegetable are equally good for quick freezing, nor are the same varieties grown in different parts of the country of like value. It seems that truck garden varieties usually are more desirable than those found suitable for the canning industry. The maturity of raw material is also a matter of primary importance. Experimentation on each class and variety of fruit and vegetable is required to determine the specific degree of maturity which produces the most successful product. As a rule their maturity should be comparable to that required if they were to be eaten fresh from the garden. The ultimate choice of raw material should be based upon a composite of several factors of production, adaptability, quality, and cost.

The preparation of the products for freezing requires much care. All of the products are cleaned and graded, and much care is exercised in handling them. Special treatment is given many products as well. It has been found that blanching is desirable for almost all vegetables although some of them apparently do not require it for the preservation of color and flavor. Other advantages of blanching are that it tends markedly to reduce the population of microorganisms which are naturally present on all vegetables, and that with leafy vegetables the wilting produced aids in packing since it reduces the volume.

The addition of extraneous materials has been found to lessen the damage of quick freezing for many fruits. Diehl reports that almost all the fruits that he has tested give the best results when they are prepared with sirup of a concentration depending upon the nature of the fruit, particularly as to acidity. Joslyn and Cruess (27), Joslyn (25) (26), Diehl (14), and Woodroof (42) (44) have found that a more satisfactory product is obtained when syrup rather than dry sugar is used. Birdseye has obtained successful results without the addition of sugar through his freezing method which requires a very low temperature. The addition of citric acid to a few of the fruits such as peaches and white cherries helps to solve the problem of oxidation. Diehl is in favor of adding brine to many vegetables prior to packing since it helps protect the product from direct exposure to the atmosphere.

Many factors affect the choice of container. The two most popular types are the paper board box and the tin can. Each one has

its particular advantages and disadvantages.

Obviously, the freezing plant should be located at or very near the production point if the processing is to be done when conditions are most advantageous. Portable quick-freezing units are now being transported from one point of production to another to accomplish this objective.

There are four general classes of machines and devices for doing the quick-freezing operation. These general types of refrigerants are as follows:

1. Direct contact or emersion in a brine, usually calcium chloride.
2. Indirect contact with a brine.
3. Cold air blast.
4. Direct or indirect contact with solid carbon dioxide.

It is too early in the life of the process to say much about the relative value of these refrigerants.

As general commercial practice for fruits and vegetables at the present time, cooling and freezing at a temperature centering about zero degrees Fahrenheit seem to be commonly accepted and based on the best information available. However, the range may go down as far as fifty degrees below zero Fahrenheit. Low temperatures are more successful as a preservative than any other single agent tried. Birdseye (4), Woodroof (43), and Diehl (12) all adhere to that theory, and there is a growing tendency to freeze at a lower temperature than formerly. Woodroof believes that a drop of ten degrees in the temperature in a range of moderate temperatures above zero degrees F. is more effective than

is a similar drop in a range of very low temperatures or below -50° F.

The fact that living tissue frozen at a temperature just below the freezing point is more broken down after defrosting than a similar tissue frozen at -50° F. is known to scientists. Just how this destruction is produced is not agreed upon. Birdseye (3) (4) claims that it is the relative size of crystals that produces different effects upon the tissue--the slower the freezing the larger the crystals and consequently the more the destruction on thawing. On the other hand, the cell walls of vegetable matter are composed of inelastic cellulose and are therefore sure to be broken by the mere expansion of moisture whether the freezing is slow or fast.

Taylor (34) (35), Fellers (20), Diehl (12), (13), (14), Joslyn (25) (26), and Woodroof (42) (44) adhere to the following theory. Ice crystallization in plant tissues ordinarily begins not within the cells themselves but in the intercellular spaces, where the ice crystals may grow further in size through crystallization of water without drawing from the living protoplasm of the cells. This process may continue until cell shapes are pressed and distorted by ice masses, and in rapid freezing at very low temperatures there may eventually occur a rupturing of the cell walls. Inherently, however, the freezing of plant tissues is really a drying phenomenon, due to the more or less rapid withdrawal of water from the cell contents to the crystallization foci in the intercellular spaces.

The physiological character of these cell contents may be irretrievably altered so that the living material of which they are composed takes on a changed permeability to tissue juices, and leaking

of the latter occurs. The cell contents consist of a colloidal gel containing proteins, salts, and water. When the bound water of the colloidal complex is withdrawn on freezing, the gel structure is broken down. This reaction in plants is irreversable, so that after thawing the water is not reabsorbed and the fruits and vegetables lose their turgidity and original firm structure. Some of the tissues or portions of them may eventually die as a result of the changes brought about by freezing and undergo chemical decomposition. In all this the piercing of cell walls and mass crushing of protoplasmic materials by growing ice crystals probably plays a less important role than is popularly supposed.

There are varying degrees of injury caused by freezing based upon the capacity of the material to be restored after thawing. In most cases death to the cells is produced. Freezing to death may be defined as injury by freezing, involving the disorganization of the substances essential for carrying on the life processes in the organism.

Chemical activities brought about through the influence of enzymes is inhibited by freezing but not destroyed. On the thawing of the foods the deterioration proceeds rapidly, in some cases much more rapidly than before freezing, and manifests itself both in the color and flavor of the product. Oxidation of the products, due to the activity of the enzyme oxidase, is one of the most difficult problems of the industry. The use of very low temperatures, sirups, brines, blanching, etc. seem to offer some hope of meeting this problem successfully. In addition, respiration processes that result

in the loss of fresh flavor, aroma, and color may not be prevented by freezing. For a full discussion of the effect of freezing plant tissue, see Taylor (34), Birdseye (3), Woodroof (42), (43), (44), Magoon (30), Joslyn (26), and Diehl (12).

At no time during the whole process of freezing, storing, or transporting is one out of the danger of damage resulting from the temperatures going up. A failure to keep the proper temperature renders useless all of the operations that have gone before; and no amount of subsequent care will counteract the damage done. It has not yet been determined definitely at just what temperature or under what conditions fruit is rendered worthless by accidental or temporary defrosting. The following temperatures are recommended for the storage of fruits and vegetables:

Woodroof (42) recommends		8° to 14° F.
Theiss* (John Sexton & Co.) recommends		0° to 10° F.
Ullsperger (39) (for cherries)	"	5° to 10° F.
Birdseye (3) (4)	"	-20° to 5° F.

At any rate it is agreed that a fluctuation of storage temperatures seriously affects the quality of the foods.

As for the nutritive value of frozen fruits and vegetables, there seems to be little definite data. Fellers (20) believes that freezing per se has very little effect on the nutritive properties. Collateral facts and studies lead strongly to this conclusion. Woodroof (44), Taylor (34), and Diehl (12) report no significant changes in chemical constituents. As for the vitamin content, the freezing

*Interview with Mr. M. H. Theiss of John Sexton Co., Chicago.

process does not seem to harm it, but the effect of long storage is somewhat questioned (11), (40), (15), (5), (23).

Practically no studies of the care of the frozen products by the consumer have been made. However, the effect of handling the products have been observed and the following advice is given. Ireland (22) believes that the best results with bulk fruits were obtained when they were defrosted in the original containers without exposing to the air; Eddy (15) recommends thawing the foods in the refrigerator; Woodroof (43) found that defrosting at room temperature an hour or so left the products in an excellent condition. Diehl (14) said that for vegetables which have to be cooked, rapid thawing with the container immersed in water about room temperature involved no significant deterioration of the product. Emphasis was made that the frozen food be treated like perishables and used promptly upon thawing, since any slightest thawing or even approach to it is fatal to the quality of the food.

The extent of the adaptability of fruit and vegetable products to the freezing method of preservation indicates the future possibilities of the industry. Tables I and II list the fruits and vegetables that are said to be adapted to the process and indicate the authority.

Table I.

Fruits Adaptable to Freezing.

No.	Fruit	Diehl (12) U.S.D.A.	Woodroof (44) Ga.	Joslyn (26) Cal.	Birdseye (3)
1	apples	+	+	+	
2	apricots	+		+	
3	avocados		+	+	
4	bananas		+		
5	blackberries	+	+	+	+
6	blueberries	+		+	
7	cantaloupe		+	+	
8	cherries	+		+	+
9	cranberries	+			
10	currants				
11	dewberries		+		
12	figs		+	+	
13	grapes		+	+	
14	grapefruit				
15	gooseberries	+		+	
16	huckleberries	+		+	
17	loganberries	+		+	+
18	peaches	+	+	+	
19	pears		+	+	
20	persimmons	+		+	
21	pineapple	+		+	
22	plums (It. Prune)	+	+	+	+
23	raspberries	+	+	+	+
24	rhubarb		+		+
25	strawberries	+	+	+	+
26	watermelon		+	+	

Table II.

Vegetables Adaptable to Freezing.

No.	Vegetables	Diehl (12) U.S.D.A.	Woodroof (44) Ga.	Joslyn (26) Cal.	Birdseye (4)
1	artichokes	+		+	
2	asparagus		+	+	+
3	brussel sprouts	+			
4	carrots	+			
5	cauliflower	+			
6	corn	+		+	+
7	Italian Broccoli	+			
8	kale	+			
9	lima beans	+			+
10	parsnips	+			
11	peas	+		+	+
12	spinach	+		+	+
13	string beans			+	+
14	wax beans				+

Vegetables that are said not to be well adapted to preservation by freezing are tomatoes, celery, lettuce, cucumbers, radishes, and egg plant.

C. Review of Literature.

There is very little information available on the use of quick frozen fruits and vegetables by the consumer. Woodroof (42) and Diehl (14) recommend using them as the corresponding fresh ones are used. Collateral material concerning factors which influence the use of the products has been found reported in scientific, trade, and business journals, as well as official publications.

In the first place, the feasibility of freezing a wide range of fruits and vegetables has been proved by the investigations of Diehl (12) (14); H. F. Taylor (35) (36); Woodroof (42), (43), (44); Joslyn (26); Joslyn and Cruess (27); Birdseye (3) (4); The British Food Industrial Board (7); the Council of Scientific and Industrial Research in Australia (31); The Low Temperature Experiment Station (29), Cambridge, England; Magoon (30); Fellers (20); and Wiegand (41).

Diehl (13) (14), Joslyn and Cruess (27), Birdseye (3) (4), Woodroof (42), H. F. Taylor (36), Tucker (38), and Rhodes* claimed that certain frozen products are successfully preserved both in color and flavor.

Magoon (30) considered that with a few exceptions the flavor and aroma was unnatural in the products. Woodroof (43) reported only slight traces of this condition.

Eddy (15), Diehl (14), and Birdseye (4) claimed that, due to the fact that most of the products are frozen at the point of production within a few hours of harvest, the frozen horticultural products reach the consumer considerably fresher than much of the fruits

*In a recent communication from T. Cecil Rhodes, director of Medical Arts Laboratory, Jenkintown, Pa., he states that frozen peaches were found to have all the original properties of the fresh fruit.

and vegetables offered on city markets.

Leaders in the commercial field give us some indication of the net cost of the frozen plant foods. Birdseye (3) claimed that the cost of the frozen products is lower than that of the corresponding fresh food, particularly if out-of-season demands are to be met. He further stated that, due to added convenience in the cleanliness and completely edible form of the products, prices above those of the fresh products have been proved economically justifiable. Tucker (38) reported that the price of frozen Georgia peaches was the same as the fresh peaches on the New York market. Ullsperger (39) said that the cost of frozen cherries is greater than canned but less than fresh cherries in crates.

Birdseye (4) and Woodroof (44) believed that the actual cost of the frozen products was reduced by the fact that freezing had the same effect on the tissues as far as tenderness is concerned, and therefore the cooking time required is reduced. Also the elimination of practically all waste from the frozen foods at the point of production lowered the actual cost.

What work has been done on the microbial growth in frozen foods has been done very recently. Fellers (20) gave the best review of the subject. Birdseye (3), Diehl (14), and Magoon (30) believed that the original bacteria content of fresh foods is reduced by freezing. Prescott et al (33) and Diehl (14) found that the reduction of bacteria content increases with the length of the storage time. The work of James (25) indicated that the spores of clostridium botulinum (type B) are inactivated by freezing but not killed. Berry claimed

that he has never with certainty recovered clostridium botulinum from frozen vegetables upon long storage after thawing or even when the vegetables have been previously inoculated with the spores.

Fellers (20) reported that the examination of seventeen samples of frozen fruits and vegetables reveal that the microbial growth is slower in fruits than in vegetables and that the varieties of bacteria are relatively few, and that vegetables, particularly, are made less resistant to bacteria by freezing.

Publications from the Frozen Pack Laboratory of the United States Department of Agriculture (12) and from the State Experiment Stations of California (26) and Georgia (44) list the fruits and vegetables which are adapted to the freezing process of preservation.

A. The Nature of the Foods Studied.

Altogether, twenty-four different quick-frozen plant foods were examined; fourteen kinds of fruits and five kinds of vegetables. Two of the vegetables, asparagus and spinach, were not reported since they are not on the market due to imperfect quality and the danger of the development of the poisonous botulinus toxin. The regular institution packs of eight and one half, ten, and sixteen pounds, expressed from Chicago, arrived in good condition, being solidly frozen even after approximately twenty-four hours out of refrigerated storage. They were packed in corrugated fiber-board shipping cases supplied with additional insulation by pads or liners.

Upon delivery the cases were placed in refrigerated rooms. The temperature of the particular room in which they were placed depended upon whether the use was to be immediate or delayed. Immediate use meant within twenty-four to thirty-six hours, and delayed use meant at a time more than thirty-six hours after delivery. For immediate use the products were placed in a room in which a temperature between forty to fifty degrees F. was maintained. This temperature allowed the products to thaw gradually. At the end of thirty-six hours few ice crystals remained in the foods. The refrigerator in which the foods for delayed consumption were placed maintained a temperature of approximately -10° Fahrenheit and did not permit the products to thaw. These products, due to the low storage temperature, required a longer time for thawing.

The fancy grade of canned fruits and vegetables were selected as being the ones which would most nearly approximate the grade of the

quick-frozen products. A corresponding canned sample was tested for each quick-frozen food except for blackberries and red currants, which were not on hand. The brands of the canned food varied, as they do in the average institution store room. The size of the can was number ten, except for the grape fruit which was number five.

In every case when the fresh products were available, they were purchased from wholesale distributors and examined also. Green peas, strawberries, rhubarb, grape fruit, and apples were so used.

Much information concerning the foods used is shown in Table III. The information concerning the variety of the product and the region in which it was produced was obtained from the distributors of the foods. In some instances such information was not available. The style and grade of the products are also indicated for the commodities which exhibit those factors.

Table III.

Variety, Source, Style, and Grade of the Experimental Products.

	Name		Variety	Region of Production	Style s--with sugar	Grade
1	Apples	frozen	Winesap	Wash.	s, sliced solid pack	Fancy
		canned	Baldwin	New York	sliced solid pack	Fancy
		fresh	Wagner	Mich.		Orchard Run
2	Apricots	frozen	Moorpark	Calif.	halves with skins on	Fancy
		canned	Moorpark	Calif.	halves with skins off	Fancy
3	Blackberries	frozen	Evergreen or Lawton	Wash.	s	Fancy
		canned	Evergreen	Wash.		Fancy
4	Blueberries	frozen	Wild	Newfound-land		Fancy
		canned	Wild	Maine		Fancy
5	Red Cherries (sour)	frozen	Montmor-ency	Mich.	pitted	Fancy
		canned	Montmor-ency	Mich.	pitted	Fancy
6	Red Currants	frozen	Red Cherry	New York	Stemmed	Fancy
7	Grapefruit	frozen	Seedless	Florida	Sections	Fancy
		canned	Various	Florida	Sections	Fancy
		fresh	Various	Florida	Sections	
8	Gooseberries	frozen	Downing	Wash.		Fancy
		canned	Downing	Mich.		Fancy
9	Loganberries	frozen	Wild	Oregon	s	Fancy
		canned	Wild	Oregon		Fancy

Table III Continued

	Name		Variety	Region of Production	Style s--with sugar	Grade
10	Peaches	frozen	South Haven	Mich.	sliced	Fancy
		canned	Mid-Summer	Calif.	sliced	Fancy
		frozen	Elbertas	New York	halves	Fancy
		canned	Midsummer	Calif.	halves	Fancy
11	Plums	frozen	Italian	Calif.	pitted, s, halves	Fancy
		canned	Italian	Calif.	whole	Fancy
12	Raspberries (red)					
		frozen	Cuthbert	Wash.	s	Fancy
		canned	Cuthbert	Wash.		Fancy
13	Rhubarb	frozen	Strawberry Red	Ore.		Fancy
		frozen	Common	New York	s	Fancy
		canned				Fancy
		fresh		Mich.		
14	Strawberries					
		frozen	Marshall	Wash.	s	Fancy
		canned	Etterbury	Oregon		Fancy
		fresh	Aroma	Tenn.		
15	Corn	frozen	Golden Bantam	Minne.	on cob	Fancy
		canned	Golden Bantam	Minne.	on cob	Fancy
16	Peas (a)	frozen	Gem Sweet	Minne.		Fancy
	(b)	frozen	Green Grant	Minne.		Fancy
		canned				
		fresh	Telephone	Calif.		
17	Green Lima Beans					
		frozen	Henderson's Bush	Minne.		Fancy
		canned	" "	Mich.		Choice

Although the information in Table III is useful in evaluating the foods, it is far from adequate if a discriminatory analysis is to be made. Such physical characteristics as size, shape, and condition must be considered as well as color and flavor. Such is the material that appears below, or the outstanding characteristics of each product as they were observed individually. No attempt was made to evaluate the elements in this stage. The evaluation will be shown later in the palatability study of the foods.

Apples
Frozen -- practically colorless, coarse grained, plump slices, flat in flavor. Variety probably mediocre.
Canned -- pale yellow color, juicy, mediocre flavor.

Fresh -- medium size, greenish color, crisp, sub-acid flavor.

Apricots
Frozen -- small size, ripened orange color with orange red cheek, skins on and somewhat wrinkled.
Canned -- medium size, uniform, pale orange color, skins removed.

Blackberries
Frozen -- turgid condition, ripe color and flavor.

Blueberries
Frozen -- plump berries, redish blue color, sweet ripe flavor.

Canned -- flabby condition, gray-blue color, sirup cloudy.

Red Cherries
Frozen -- flesh firm, skins tough, color bright red, flavor sour.

Canned -- flabby condition, skins soft, dull faded color, mediocre flavor; age of pack probably responsible for much of deterioration.

Red Currants
Frozen -- stemmed, turgid condition, many unripe berries throughout pack, flavor very sour. Appearance and color judged to be better than the canned currants but second to the fresh currants.

Grapefruit
Frozen -- sections firm and plump, sweet flavor.

Grapefruit (continued)
Canned -- sections soft and somewhat broken, ragged in appearance, sweet flavor.
Fresh -- coarse texture, very sour, bitter flavor.

Gooseberries
Frozen -- pale green color, tough skins, turgid, flavor fresh.

Canned -- rather large though not uniform in size, skins somewhat tough, dull dark color, ripe flavor.

Loganberries
Frozen -- plump berries, bright color, ripe flavor.

Canned -- mushy berries, bright color, sweet flavor.

Peaches
Frozen -- sliced, yellow flesh, oxidized at top of can, slices very thin, soft condition, sweet flavor.

Canned -- sliced, yellow flesh, plump, slices thicker than in frozen peaches, flavor good.
Frozen -- halves, yellow flesh, red color in pit cavity, flavor mediocre.
Canned -- halves, uniform pale yellow color, firm, mild flavor.

Plums (Prune)
Frozen -- halves firm, skins blue color and tough, flavor ripe and fresh.
Canned -- whole soft, skins somewhat broken and red-blue color, ragged in appearance, flavor sweet. Not exceptionally good for canned plums.

Raspberries
Frozen -- soft, color bright, flavor fresh and like ripe berries. Quality probably injured by accidental thawing and refreezing.
Canned -- mushy berries, dull purple color, disintegrated and unattractive, much juice.

Rhubarb
Frozen -- Western -- not uniform in size of stalk or cut. Uncooked color green with red streaks; cooked color pale pink, flavor fresh. Some storage damage.
Frozen -- Crimson -- uniform in size and cut, red color before and after cooking, flavor mild.
Canned -- uniform in size and cut, gray green color, sirup clear, flavor mediocre, quality not exceptional for canned rhubarb.
Fresh -- red and green color before cooking, red predominated after cooking. Flavor excellent.

Strawberries

Frozen -- turgid, field-ripened color, flavor fresh. Suffered from improper care.

Canned -- soft, compact berries, dull brown color, flavor unnatural. Good example of canned strawberries.

Corn on Cob

Frozen -- firm condition, bright yellow color, odor, flavor starchy and "cob" like.

Canned -- deep color, flavor fresh.

Gr. Peas

(a) Frozen -- condition firm, medium in size, skin tough, color green, flavor sweet and pronounced.

(b) Frozen -- condition firm, medium size, pale green color, skins more tender than in (a), mild flavor.

Canned -- soft, somewhat broken skins, dull green color, sweet flavor.

Fresh -- out-of-season dark brilliant color, marked natural flavor. Showed a high percentage of waste (68.7%) since the pods were poorly filled.

Gr. Lima Beans

Frozen -- firm, skins tough, green in color, flavor good.

Canned -- soft texture, skins tender, dull pale color, flavor mediocre.

B. Palatability.

Palatability in a food is a difficult quality to define. Sweetman (34) in discussing the scientific study of the palatability of food said that palatability is a subjective quality; the term refers in a broad sense to the property of being agreeable to the taste, even agreeable in all sensory appeals. She states, further, that the element of individual preference is the biggest limit to any ambition for a science of palatability, and that recent studies of the origins of food preferences demonstrate that the connection between them and the sensation-producing qualities of foods is one of association rather than of inherent relationship.

Because the human equation in the study of palatability is large, the methods used in this study were chosen in an effort to minimize that element. The method consisted of measuring the intensity of the sensation-producing qualities of foods and of rating their qualities according to the preferences. The score sheet used as the standard is an adaptation of one suggested by Sweetman, and it appears on the next page as Table IV.

Since each quality factor is continuous and only one figure was given each gradation, the judges resorted to decimals to express variations. Some products did not seem to show distinctly certain qualities, such as texture, so that quality was not scored in such cases. When texture was omitted the highest possible score was twenty-eight, otherwise, it was thirty-five. Four different ratings were obtained for each of the thirty-one foods examined. The judges were two members of the Institution Economics staff and one graduate student from the Home Economics Division of Michigan State College.

The average scores for palatability appear in Table V. The score for each of the five palatability qualities are shown separately and are totaled and averaged. In addition the average total score for each food is given. Since the highest possible score was either twenty-eight or thirty-five, these two groups of scores were kept separate as is indicated by group A and group B. It will be noticed that the relationship of the scores of the three classes of foods, frozen, canned, and fresh, in the average scores of group A and group B is the same.

Table IV.

Palatability Score Sheet

Product _____ Date _____ Judge _____

Quality	7	6	5	4	3	2	1
Appearance	Very Attractive	Attractive	Good	Mediocre	Poor	Very Poor	Extremely Poor
Texture	Extremely Fine	Very Fine	Fine	Slightly Coarse	Moderately Coarse	Coarse	Very Coarse
Tenderness	Very Tender	Tender	Moderately Tender	Slightly Tough	Tough	Very Tough	Extremely Tough
Color	Excellent	Very Good	Good	Mediocre	Poor	Very Poor	Extremely Poor
Flavor	Excellent	Very Good	Good	Flavorless	Poor	Very Poor	Extremely Poor

FOOD SCORED

SCORE FOR APPEARANCE					
" " TEXTURE					
" " TENDERNESS					
" " COLOR					
" " FLAVOR					
TOTAL SCORE					

The highest possible score is 35.

Table V.

Average Scores for Palata bility

a - High Score - 35
b - High Score - 28

	Product	Frozen					Canned					Fresh					Totals					
																	Frozen		Canned		Fresh	
		App.	Tex.	Ten.	C.	F.	App.	Tex.	Ten.	C.	F.	App.	Tex.	Ten.	C.	F.	a.	b.	a.	b.	a.	b.
1	Apples	5.5	5.75	5.62	5.62	4.75	5.75	5.75	5.12	6.	5.5	6.75	6.75	6.75	6.75	7.	27.31		28.1		34.	
2	Apricots	6.2	6.	6.75	7.	6.5	6.75	6.5	6.62	6.5	6.38	not available					32.5		32.7			
3	Blackberries	6.85	6.5	6.85	7.	6.75	not available					" "					34.					
4	Blueberries	7.	6.2	6.5	7.	6.75	5.	5.	6.	5.5	5.25	" "					33.		27.			
5	Red Cherries	7.	6.75	6.12	7.	7.	5.	5.75	6.5	5.	4.87	" "					33.9		27.1			
6	Red Currants	6.12	5.87	6.5	6.25	6.38	not available					" "					31.1					
7	Grapefruit	7.	7.	6.62	7.	6.5	5.87	5.75	6.3	6.6	6.12	6.75	6.2	6.3	6.95	6.5	34.1		30.7		32.5	
8	Gooseberries	6.85	6.75	6.5	6.62	6.9	6.62	5.87	6.5	6.2	5.2	not available					33.7		30.4			
9	Loganberries	6.5	6.	5.75	6.75	5.75	5.25	4.75	5.75	4.75	5.62	" "					30.7		26.1			
10	Peaches (sliced)	6.5	5.75	6.5	6.0	6.25	6.25	5.5	6.25	6.75	5.	" "					31.		30.			
11	Peaches (halves)	6.38	6.12	6.12	7.	5.12	7.	6.75	6.75	6.75	5.62	" "					30.7		32.2			
12	Prune Plums	7.	6.75	5.75	7.	7.	4.75	5.87	7.	5.12	5.8	" "					33.5		28.7			
13	Raspberries	6.2	6.6		6.85	6.95	5.25	5.7		5.75	6.02	" "						26.6		22.7		
14	Rhubarb (a)	6.	6.38	6.12	6.62	6.	6.57	5.82	5.62	5.87	5.12	6.38	6.85	7.	7.	7.	31.1		27.3		34.2	
15	Rhubarb (b)	6.5	6.5	7.	7.	6.57											33.57					
16	Strawberries	6.38	6.45		6.38	6.7	4.62	5.62		3.75	5.5	6.5	6.7		7.	7.		25.9		19.4		27.2
17	Corn on Cob	7.		5.75	7.	4.85	5.75		6.5	5.75	6.3	not available						24.6		24.4		
18	Peas (a)	5.87		5.75	6.5	6.5	4.62		6.75	4.25	5.75	6.62		5.	6.62	6.12		25.1		21.4		24.3
19	Peas (b)	6.62		6.38	6.5	5.5						not available						25.				
20	Green Lima Beans	6.85		6.38	6.62	6.5	5.6		6.	4.37	4.8	" "						23.5		20.8		
	Total	130.32	101.37	112.96	139.94	125.22	91.65	74.63	87.66	88.91	88.95	33.	26.5	25.05	34.32	33.62	450.18	150.7	320.3	108.7	100.7	51.5
	Average	6.516	6.33	6.27	6.54	6.26	5.72	5.74	6.26	5.55	5.56	6.6	6.62	6.26	6.86	6.72	32.15	25.1	29.1	21.74	33.63	25.75

Tables VI, VII, VIII, and IX present the information in Table V in a somewhat different manner. Table VI shows the average scores given each of the five palatability qualities for each class of food. The maximum and minimum scores of each quality show the range covered.

Table VI.

Average, Minimum, and Maximum Palatability Scores

Product	Frozen			Canned			Fresh		
Scores Used	Average	Extremes		Average	Extremes		Average	Extremes	
		Min.	Max.		Min.	Max.		Min.	Max.
Appearance	6.51	5.5	6.85	5.72	4.62	7.	6.6	6.38	6.75
Texture	6.33	5.75	6.75	5.74	4.75	6.75	6.62	6.2	6.85
Tenderness	6.27	5.62	6.85	6.26	5.12	7.	6.26	5.	7.
Color	6.54	5.62	7.	5.55	3.75	6.75	6.86	6.62	7.
Flavor	6.26	4.75	7.	5.56	4.8	6.38	6.72	6.12	7.
Totals*(a)	32.15	27.31	34.1	29.11	26.1	32.7	33.63	32.7	34.2
Totals (b)	25.1	23.5	26.6	21.74	19.4	24.4	25.75	24.3	27.2

*Due to the fact that the highest possible score with some products was 35 and with others 28, all the scores could not be averaged together. Totals (a) include those with the highest possible score of 35, and totals (b) include those with the highest possible score of 28. It will be noticed that the trend is the same.

Table VII shows the rating of the three classes of foods by each quality. The class of food receiving the highest score, the second high score, and the low score is indicated. The actual scores are also shown for comparative purposes. The relationship of the total scores are shown in the same manner.

Table VII

Rating of the Foods by Qualities and Total Scores

No.	Quality	Highest Score		Second High		Low Score	
1	Appearance	Fresh	6.6	Frozen	6.51	Canned	5.72
2	Texture	Fresh	6.62	Frozen	6.33	Canned	5.75
3	Tenderness	Frozen	6.27	Fresh	6.262	Canned	6.261
4	Color	Fresh	6.86	Frozen	6.54	Canned	5.55
5	Flavor	Fresh	6.72	Frozen	6.26	Canned	5.56
6	Total Scores (Group a)	Fresh	33.63	Frozen	32.15	Canned	29.11

Tables VIII and IX show the relationship of the three classes of foods, frozen, canned, and fresh, according to the scores they received. The class that was given the highest score, the second high score, and the low score is shown respectively. Two tables were necessary to distinguish between the foods that were available in the frozen, canned, and fresh state and were therefore compared in groups of three (Group A), and those that were available in the frozen and canned state only and were therefore compared in groups of two (Group B).

Table VIII.

Rating of Foods in Group A for Palatability.

No.	Kind of Food	Highest Score	Second High Score	Low Score
1	Apples	Fresh	Canned	Frozen*
2	Grapefruit	Frozen	Fresh	Canned
3	Peas	Frozen	Fresh	Canned
4	Rhubarb	Fresh	Frozen	Canned
5	Strawberries	Fresh	Frozen	Canned

*The low score for apples can probably be explained largely by the fact that a variety was used which does not freeze well.

Table IX.

Rating of Foods in Group B

No.	Kind of Food	High Score	Low Score
1	Apricots	Canned	Frozen
2	Blueberries	Frozen	Canned
3	Red Cherries	Frozen	Canned
4	Gooseberries	Frozen	Canned
5	Logan berries	Frozen	Canned
6	Peaches (sliced)	Canned	Frozen
7	Peaches (halves)	Frozen	Canned
8	Prune Plums	Frozen	Canned
9	Raspberries	Frozen	Canned
10	Corn on the Cob	Frozen	Canned
11	Lima Beans	Frozen	Canned

In general, there seems sufficient indication from our examinations to conclude that quick-frozen fruits and vegetables rank high in palatability. As compared with the fresh products, the quick-frozen products stand out very favorably in appearance and color. For tenderness the frozen foods are preferred to the fresh, since the effect of freezing foods in respect to tenderness is similar to that of cooking them. In flavor and texture the frozen products are rated second to the fresh products but decidedly superior to the canned products. There can be little doubt that, as far as palatability is concerned, the frozen products are preferable to the canned.

Since the production of quick-frozen plant foods is still in the experimental stage, it is fair to expect much variation in the products. Diehl (13), Woodroof (44), and Joslyn, who are doing extensive scientific work in the field at present, are of the opinion that as the technique of freezing improves more of the natural attributes of

quality will be retained in the products. It is possible that in cases where frozen foods compete with out-of-season fresh products they will even be preferred to the fresh products.

C. The Cost in Central Michigan.

In computing the actual cost of food in an institution it is necessary to include the cost of several different factors. But since the object of this price study is to find only the relative level of the cost of the quick-frozen fruits and vegetables as compared with the level of the prices of the corresponding fresh and canned products, only the major factors contributing to the cost were considered. The principal factor is, of course, the market price of the foods. In addition, the utilization of the food, or the relation between the edible portion and the waste, and the relative cost of preparation are included. Other cost factors such as the efficiency of the workers or of the equipment, are ignored in this study.

The basis for the cost comparison is the cost of the individual portions of the foods. By using this basis, which includes of course only the net available yield, the question of waste is automatically taken care of because the market price is allocated to the edible portions only. The cost of preparation involves two elements, which are: first, the labor cost, and second, the fuel cost if the food is cooked. Since only the relative aspect of the question is desired, such costs were determined only if the cost was not a common one to all the foods being compared.

In the matter of waste or inedible material, the problem is handled in the frozen food field in much the same manner as it is in

the canning industry. Practically all waste material is eliminated. Fruit stones, inedible fruit and vegetable skins, and tough membranes are all removed from the product before they are quick frozen. Therefore, in the case of the fresh products alone do we have any appreciable amount of waste.

The quick-frozen products are also prepared for cooking or table use. Cleaning processes, peeling, cutting, pitting, sorting, and such operations are all carefully done prior to freezing. In this respect the quick-frozen products are similar to the canned. With the fresh products there is a different problem. All the labor cost necessary in preparing the products for use must be added to the market price to obtain the actual price.

Although the amount of fuel required to cook a food is a factor in the actual cost of the food, this factor was not computed in this study. Not all of the fruits were cooked since they were suitable for table use as purchased. The time required to cook the foods that were so treated is somewhat indicative of what the relative fuel cost would be. All of the fruits, except rhubarb, which were cooked were made into pies, and did not show any noticeable variation in the baking time. The three vegetables and the rhubarb were stewed and showed the variations in the time required as indicated in Table X.

Table X.

Cooking Time Required

No.	Name	Frozen	Canned*	Fresh
1	Green Peas	20 min.	10 min.	25 min.
2	Green Lima Beans	26 min.	10 min.	
3	Corn on the Cob	15 min.	10 min.	
4	Rhubarb	8 min.		10 min.

*This was merely heated through.

As would be expected, the fresh products require the longest cooking time. Since freezing tends to have the same effect on some products as cooking does, some of the frozen foods require less cooking time than the fresh. Canned foods, of course, have been subjected to cooking in the preservation process. This material is by no means conclusive. It merely indicates the possibility that the fuel cost may be less for frozen foods than for fresh.

The data in Table XI show the factors used in computing the cost of the products, and the final cost per individual portion.

Table XI.

Essential Factors Used in Computing the Cost of the Products and the Final Cost.

	Name		Market Unit	Weight per Unit lbs.	Weight per Unit oz.	Measure per Unit	How Used	Size of Unit or Portion	No. of Portions	Local Market Price per Unit	Labor Cost Rate per hr. $.35	Total Cost per Unit	Cost of Individual Portion
1	Apples	frozen		13		7 qts.	4 pies	12" tins	40	.65		$.65	$ .016
		canned	No. 10 can	6	4	3 qts.	3 pies	12" tins	30	.47		.47	.016
		fresh	1 peck			4 qts.	4 pies	12" tins	40	.25	.35	.60	.015
2	Apricots	frozen		16		190 halves	sauce	3 halves	63	2.72		2.72	.043
		canned	No. 10 can	6	4	67 halves	sauce	2 halves	33	.83		.83	.025
3	Blackberries	frozen		16		7½ qts.	sauce	No. 12 scoop	75	2.32		2.32	.031
		canned	No. 10 can	6	6	3 qts.	sauce	No. 12 scoop	30	1.00		1.00	.033
4	Blueberries	frozen		8		4 qts.	3 pies	12" tins	30	1.56		1.56	.052
		canned	No. 10 can	6	6	3 qts.	3 pies	12" tins	30	.90		.90	.03
5	Red Cherries	frozen		8		4½ qts.	3 pies	12" tins	30	1.25		1.25	.041
		canned	No. 10 can	6	8	3½ qts.	3 pies		30	.92		.92	.03
6	Red Currants	frozen		16		8 qts.			80	3.52		3.52	.044
7	Grapefruit	frozen		8½		4 qts.	salads		40	1.52		1.52	.038
		canned	No. 5 can	3	8	1¾ qts.	salads		15	.58		.58	.039
		fresh	96's (50 per bu.)			12 sections	salads	4 sections	3	.03	.042	.072	.024
8	Gooseberries	frozen		10		9½ qts.	9 pies	12" tins	90	1.75		1.75	.019
		canned	No. 10 can	6	6	3½ qts.	3 pies	12" tins	30	.67		.67	.022
9	Loganberries	frozen		8		3½ qts.	sauce	No. 12 scoop	35	1.52		1.52	..043
		canned	No. 10 can	8		3 qts.	sauce	No. 12 scoop	30	.95		.95	.032

	Name	Packet Unit	Material	Essential Factors Used in Computing Std Cost			
			Material	per Unit	per Unit	Std. Cost	
1	Abbjee	Loose	Lt		7 dzs.	4 bies	
		Canned	No. 10 can	6	4	5 dzs.	5 bies
		Fresh	1 Peck			4 dzs.	4 bies
2	Abricote	Loose	Lt		15	pasture	ounce
		Canned	No. 10 can	6	4	75	ounce
						pasture	
3	Blackpetties	Loose	Lt			$\frac{1}{2}$ dzs.	ounce
		Canned	No. 10 can	6	6	3 dzs.	ounce
4	Blueberries	Loose	Lt			4 dzs.	5 bies
		Canned	No. 10 can	6	6	3 dzs.	3 bies
5	Cranberries	Loose	Lt			4 dzs.	4 bies
		Canned	No. 5 can	3	3	1 dzs.	celery
		Fresh	50 #			1	stalks
			(20 per bu)			sections	
6	Gooseberries	Loose	Lt			2 dzs.	2 bies
		Canned	No. 10 can	6	6	3 dzs.	sauce
7	Loganberries	Loose	Lt			3 dzs.	sauce
		Canned	No. 10 can	6		3 dzs.	sauce
8	Red Currants	Loose		Lt		8 dzs.	
9	Strawberries	Loose		Lt		4 dzs.	
		Canned	No. 5 can	3	3	1 dzs.	celery
		Fresh	24 #				stalks
			(20 per bu)			sections	
10	Red Cherries	Loose		Lt		8 dzs.	2 bies
		Canned	No. 10 can	6	6	3 dzs.	3 bies
11	Blueberries	Loose		Lt		4 dzs.	3 bies
		Canned	No. 10 can	6	6	3 dzs.	3 bies
12	Blackberries	Loose		Lt		4 dzs.	3 bies
		Canned	No. 10 can	6	6	3 dzs.	3 bies

Table XI.

Essential Factors Used in Computing Std Cost

Table XI (Con tinued)

Essential Factors Used in Computing the Cost of the Products and the Final Cost.

	Name	Market Unit	Weight per Unit lbs.	oz.	Measure per Unit	How Used	Size of Unit or Portion	No. of Portions	Local Market Price per Unit	Labor Cost Rate per hr. $.35	Total Cost per Unit	Cost of Individual Portion
10	Peaches frozen sliced		8½		3½ qts.	3 pies	12" tins	30	$ 1.35		$ 1.35	$ .045
	canned sliced	No. 10 can	6	11	3 qts.	3 pies	12" tins	30	.64		.64	.021
	frozen halves		8½		56 halves	sauce	1 half	56	1.40		1.40	.025
	canned halves	No. 10 can	6	11	35 halves	Sauce	1 half	35	.64		.64	.018
11	Prune Plums frozen		8		220 halves	sauce	4 halves	55	1.12		1.12	.02
	canned	No. 10 can	6	10	52 wholes	sauce	2 wholes	26	.64		.64	.024
12	Raspberries frozen		16		7 qts.	sauce	No. 12 scoop	70	3.04		3.04	.043
	canned	No. 10 can	6	10	3 qts.	sauce	No. 12 scoop	30	1.40		1.40	.046
13	Rhubarb frozen (W)		16		8 qts.	sauce	No. 12 scoop	100	2.16		2.16	.022
	frozen (c)		16		9½ qts.	sauce	No. 12 scoop	120	2.16		2.16	.018
	canned	No. 10 can			3 qts.	sauce	No. 12 scoop	30	.44		.44	.015
	fresh		4		2 qts.	sauce	No. 12 scoop	16	.10	.12	.22	.014
14	Strawberries frozen		8		4 qts.	sauce	No. 12 scoop	40	1.64		1.64	.041
	canned	No. 10 can	6	14	3 qts.	sauce	No. 12 scoop	30	1.46		1.46	.048
	fresh		2		3 cups	sauce	No. 12 scoop	4	.16	.06	.22	.055
15	Corn on the Cob frozen	carton			8 doz.	buttered	one 6" ear	96	4.80		4.80	.05
	canned	No. 10 can	6		15 ears	buttered	one 6" ear	15	.82		.82	.055
16	Peas frozen (a)		10		6½ qts.	buttered	No. 12 scoop	65	2.80		2.80	.043
	frozen (b)		6			buttered	No. 12 scoop	36				
	canned	No. 10 can	6	10	3 qts.	buttered	No. 12 scoop	32	.90		.90	.028
	fresh		10		1 qt.	buttered	No. 12 scoop	22	1.80	.318	2.118	.096
17	Lima Beans Frozen		10		7 qts.	buttered	No. 12 scoop	72	3.40		3.40	.047
	Canned	No. 10 can	6	10	3 qts.	buttered	No. 12 scoop	33	.86		.86	.026

In Tables XII, XIII, XIV, XV, and XVI are shown the price relationships on different bases. The data in Table XII show the average costs of the three classes of foods for both fruits and vegetables. The minimum and maximum cost figures are given to show the range in the prices of the different classes of foods.

Table XII.

Average Cost of Each Class of Product.

	Fruits			Vegetables			
Class	Average	Extremes		Class	Average	Extremes	
		Minimum	Maximum			Minimum	Maximum
Frozen	.033	.016	.052	Frozen	.047	.043	.05
Canned	.028	.015	.055	Canned	.036	.026	.055
Fresh	.027	.014	.024	Fresh	.096*		

*The only fresh vegetable available was green peas.

The data in Tables XIII and XIV show by columnar graphs the average price levels of the foods. The products are divided into two groups depending upon the number of classes of each food that was compared. The proportion of the total cost that was due to labor is shown in the case of the fresh products but not in the others because of the relative unimportance of labor in the cost of the canned and the frozen foods.

Table XIII

AVERAGE PRICES FOR FRUITS

Per Individual Portion

Prices of Group A	
Frozen	.037
Canned	.028

Prices of Group B	
Frozen	.027
Canned	.03
Fresh	.027

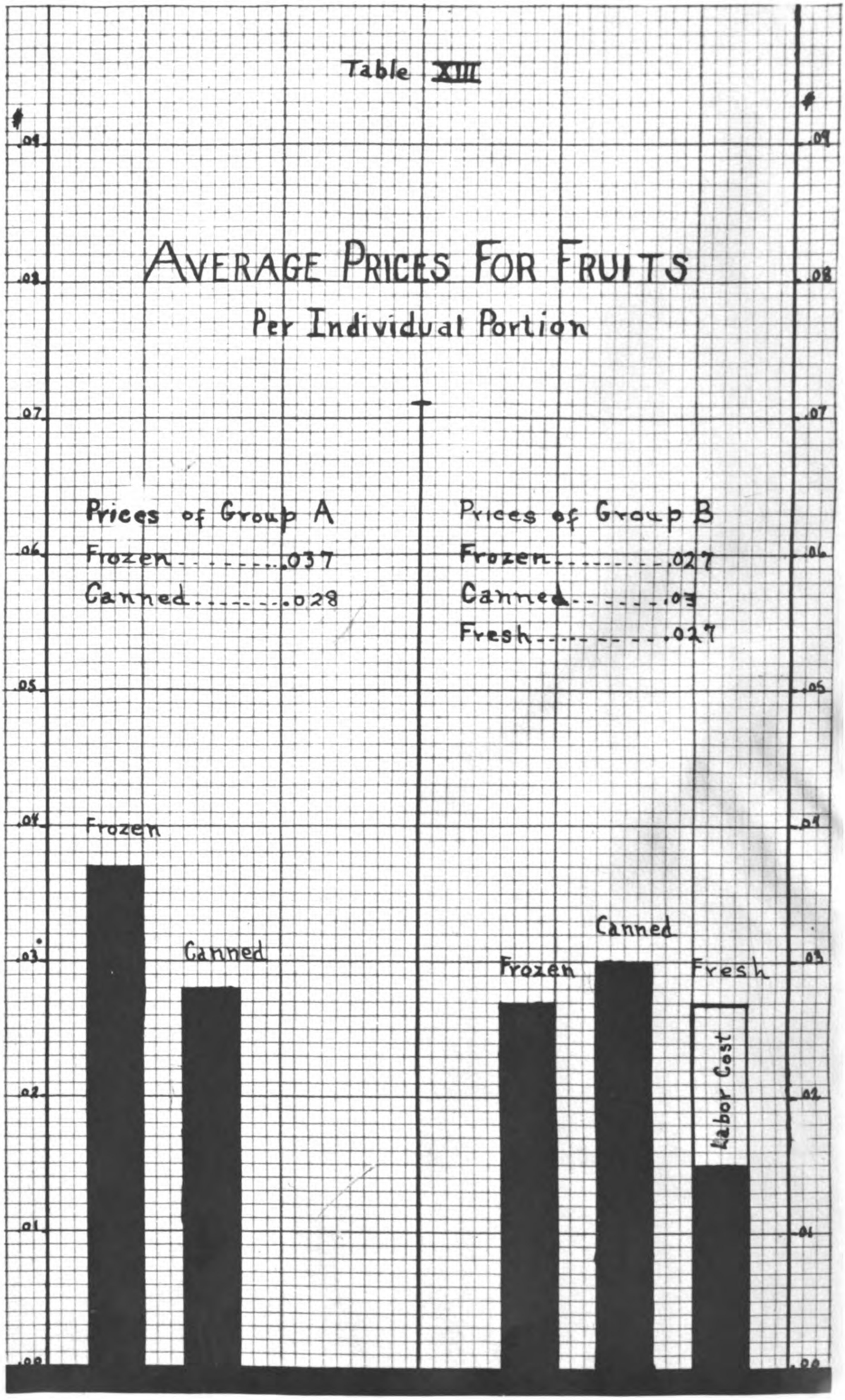
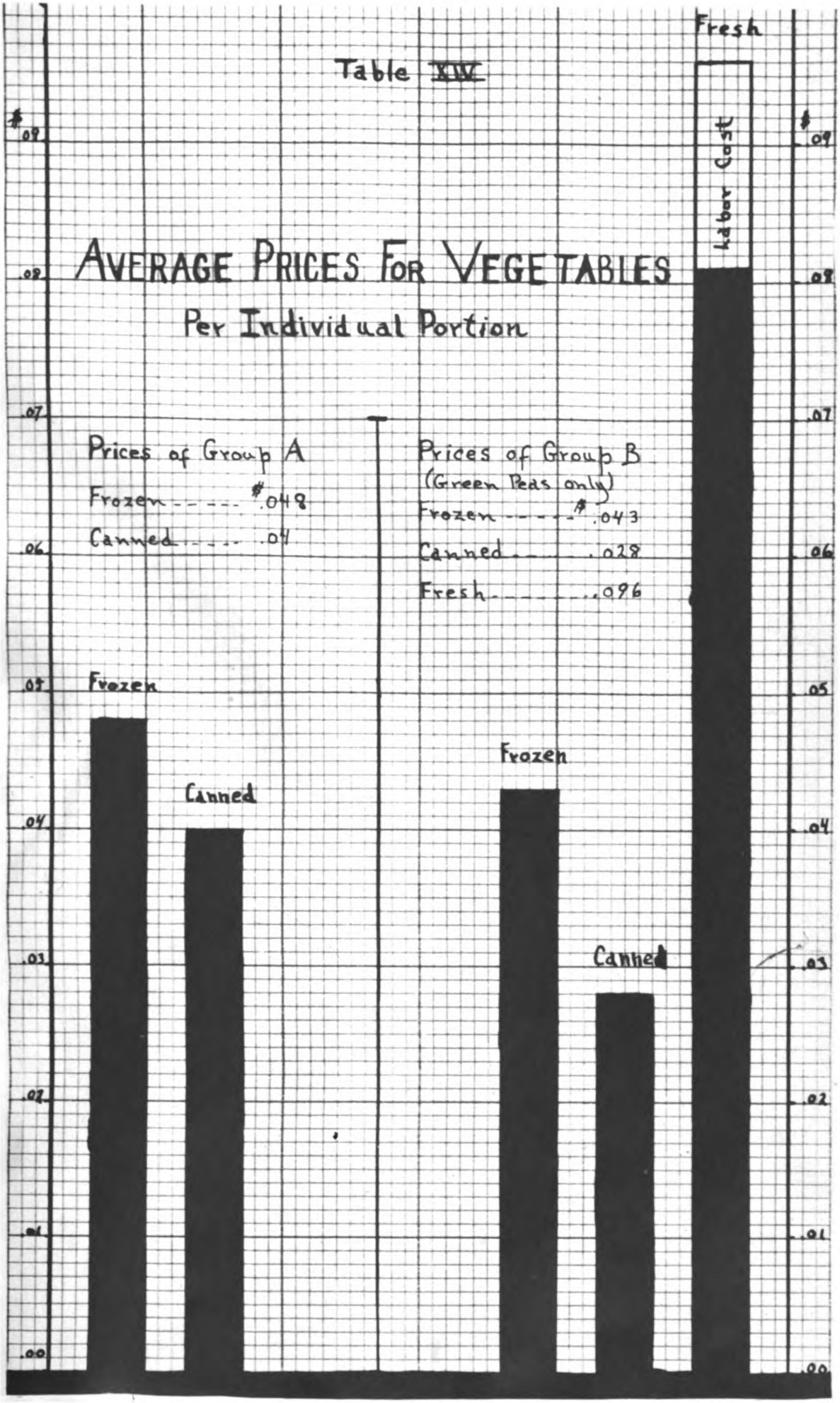


Table XIV

Average Prices For Vegetables

Per Individual Portion



The data in Tables XV and XVI show the cost levels of the different classes of foods rated with each other. The class which had the highest cost, the second high cost, and the low cost for each fruit and vegetable which were available in the three forms is shown in Table XV. This group of products is called Group A.

Table XV.

Cost Levels of the Products in Group A By Classes

No.	Kind of Food	Highest Cost	Second High Cost	Low Cost
1	Apples	frozen	canned	fresh
2	Grapefruit	canned	frozen	fresh
3	Peas	fresh	frozen	canned
4	Rhubarb	frozen	canned	fresh
5	Strawberries	fresh	canned	frozen

The data in Table XVI is similar to that in Table XV except that only two classes of foods are compared instead of three since the fresh product was not available. This group of foods is called Group B.

Table XVI.

Cost Levels of the Products in Group B

No.	Kind of Food	Higher Cost	Lower Cost
1	Apricots	frozen	canned
2	Blackberries	canned	frozen
3	Blueberries	frozen	canned
4	Red Cherries	frozen	canned
5	Gooseberries	canned	frozen
6	Loganberries	frozen	canned
7	Peaches	frozen	canned
8	Prune Plums	canned	frozen
9	Raspberries	canned	frozen
10	Corn on the Cob	Canned	frozen
11	Green Lima Beans	frozen	canned

In general the correlation between the price levels seems to be closer between the frozen products and the fresh products than between the frozen and the canned ones. In the absence of a fresh product on the market, the price level of the frozen product is higher than that of the canned. However, the average difference in cost under such conditions is only $.008 per individual portion.

The presence of fresh products on the market changes the relative price levels of the classes of foods somewhat. In addition the effect differs for fruits and for vegetables. For fruits the price levels for the frozen and the fresh products are the same, and they hold a position below the price of the canned fruits. Green peas were the only fresh vegetable on the market during the course of our study, but the price levels of peas probably indicate the relative positions of the three classes of vegetables. The canned vegetables undoubtedly have the lowest level; the fresh vegetables reach the highest level; and the frozen vegetables find a plane somewhere between the levels of the canned and the fresh but show a notable correlation with the fresh products.

D. The Growth of Bacteria in Frozen Fruits and Vegetables After They Have Thawed*

The object in this part of the study was to secure general information on the growth of bacteria in frozen fruits and vegetables after they had thawed. Samples of the foods used in the other experiments were taken immediately after the containers were opened and were exposed to conditions which would be similar to the expected institution-kitchen conditions. By observation over a period of time it was believed that the changes would be measurable, and by the correlation of these some conclusions could be drawn.

This report includes data on nine different items: six fruits—blackberries, currants, peaches, gooseberries, strawberries, and raspberries, and three vegetables--peas, corn, and rhubarb. All the foods were selected as representing types of foods often treated by the quick-freezing process. The indirect-brine method of freezing was used for preserving all the experimental products except the green peas, which were frozen by the cold-air-blast method. The frozen foods had been in storage a considerable time when the tests were made. Although it was necessary to allow the foods to thaw to some extent before taking the samples, when the samples were taken each food showed the presence of ice crystalls. The samples were stored in a Frigidaire cabinet set at a temperature of approximately 49° F., which temperature allowed complete thawing. Examinations were made in general at intervals of two days in the beginning, but these intervals were lengthened to a week as the test progressed.

*The writer gives with sincere gratitude full credit for the work in this part of the study to Dr. E. D. Devereux of the Bacteriology Department.

The bacteriological examinations were made on successive tests of the same sample. Dilutions and platings were carried out in the usual manner. Bacto nutrient agar was used as the medium. The plates were incubated at 37° C. for 48 hours. Platings were made of each sample until the sample showed that the development of molds, yeasts, fermentation, or products of oxidation had progressed well past the stage which would be acceptable in a food used in an institution-kitchen. Since the products were all commercial it would be expected that they might vary in the number of bacteria and that the numbers might be expected to fluctuate. The order of magnitude is therefore of more significance than the actual counts. Table XVII presents the results of the examinations. A brief statement of the trend of bacterial numbers for each food is also given.

Table XVII

Growth of Bacteria in Quick-Frozen Fruits and Vegetables After Thawing
Number Bacteria per Gram

Storage Time	Blackberries	Currants	Peaches	Gooseberries	Strawberries	Raspberries	Corn	Peas	Rhubarb
0 days	250	140	80	20	110	40	8,000	200,000	250
2 "	2,000	1,700	60	30			Covered with growth	Covered with growth	
4 "	2,300	2,200							10
6 "	25,000	60							
7 "					24,000	100			70
8 "	55,000	10							mold
9 "			10	20					
12 "					24,000	2,500			
14 "									
15 "	fermented mold	120							
16 "		mold	3,000	30					
19 "			oxidized	fermented yeast	fermented	54,000			
						mold			

1. Blackberries

The bacteria count was fairly low at the beginning of the examinations but showed a marked increase throughout the experiment.

2. Currants

The currants showed an increase up through the fourth day, then a decrease occurred. A fluctuation also was noted.

3. Peaches

The growth of the bacteria population in the peaches showed much fluctuation. First a decrease then a decided increase is indicated. Evidence of oxidation appeared early in the experiment.

4. Gooseberries

The bacteria count in the gooseberries was low throughout, and a slight fluctuation is indicated. Probably gooseberries do not furnish a satisfactory medium for bacterial growth.

5. Strawberries

The numbers of bacteria in strawberries were quite low in the beginning. However, the count jumped considerably in a week and stayed quite constant.

6. Raspberries

The number of bacteria in the raspberries was very low, and it took a longer time to increase than in the strawberries. This indicates resistance to bacteria growth.

7. Corn

The corn showed a high count from the start which increased very rapidly. A mold growth caused the sample to be discarded early.

8. Green Peas

The bacteria count in peas was very high in the beginning. The sample had to be discarded on the fourth day.

9. Rhubarb

The count on the rhubarb was low in the beginning and decreased with age. A fluctuation in the count was noticed. Probably rhubarb is another poor medium for bacteria development.

In general, the results show that the bacteria population develops slowly in fruits after they are thawed. In the vegetables the opposite seems to be true. The bacterial growth, as well as other causes of spoilage, develop very rapidly in vegetables. In the fruits other causes of spoilage seem to be more important in the deterioration process than do the bacteria. Fluctuations in counts were common to both classes of foods.

From the limited number of experiments it is impossible to draw conclusions. These results, however, indicate that the foods can be used for a limited time after thawing with an adequately low microorganism content.

Furthermore, the chemical and physical changes in the foods, such as limited changes in color, flavor, or drip*, probably can not be explained except to a small extent by the growth of bacteria.

*Drip is a term used to indicate the tissue juices which leak from the plant cells after the products have been frozen and thawed.

E. Availability in Central Michigan.

The question of the availability of the quick-frozen fruits and vegetables in central Michigan was studied by making a survey of the agencies distributing the products. There were no published data on the subject so the information had to be obtained directly from the distributing agencies. No doubt the major organizations supplying frozen fruits and vegetables to institutions in central Michigan are included.

The distribution of the frozen fruits and vegetables to the institution consumers is done either by the producers of the frozen products themselves or by wholesale jobbers. Since Michigan is far from the two leading centers of production, consisting of the Pacific Northwest (26) and the tri-state district of Delaware, Maryland, and Virginia, there are relatively few producers in the state. However, in the production of frozen red sour cherries, Michigan, Wisconsin, and New York lead the other states by a considerable margin. The Fruit Growers Union of Traverse City are responsible for part of the frozen cherry pack in Michigan. There is a tendency for large users of fruits and vegetables to freeze the fresh products for future use. For instance, the Home Dairy Company, which has establishments in several of the larger Michigan cities, is now freezing rhubarb for its own use and is planning to freeze berries during the next season.

Most important in the distributing field for the institution trade are the nationally known wholesale grocers. The names of important distributors who sell in this locality and the items they carry are listed below.

John Sexton and Company, Chicago, Illinois, distribute frozen apples, apricots, blackberries, blueberries, red sour cherries, red currants, grapefruit, gooseberries, loganberries, peaches both sliced and halves, Italian prune plums, raspberries, rhubarb, strawberries, corn on and off the cob, peas, and green lima beans.

Durand-McNeil-Horner Company, Chicago, Illinois, distribute frozen apples, blueberries, blackberries, cherries, grapefruit, sliced peaches, pitted Oregon prunes, red raspberries, strawberries, peas, and spinach.

Libby, McNeill and Libby, Chicago, Illinois, distribute red cherries, loganberries, peaches, plums, raspberries, and strawberries.

There are a few distributors of frozen fruits who furnish them primarily to ice-cream manufacturers. Among these are the Stirling-Wilson-Hamblin Company, Detroit, Michigan, who distribute frozen strawberries and frozen raspberries, and the H. C. Shrank Company, Milwaukee, Wisconsin, who distribute frozen strawberries.

In general, it is evident that a substantial number of quick-frozen fruits are available in central Michigan at present. As for the vegetables, quick-frozen peas, green lima beans, spinach, and corn are easily obtained. It is reasonable to expect a longer list of frozen fruits and vegetables on the market in the future since the advent of new items is largely a matter of improving the freezing technique. The small number of vegetables on the market at present points to the caution being exercised by the industry in not distributing vegetables until all doubt is removed as to the danger of the poisonous clostridium botulinus toxin developing during storage.

III. Conclusion and Summary.

The novelty of quick-frozen fruits and vegetables may serve to introduce them into an institution, but much more is required of any food before it can become eligible for frequent use. Good quality and reasonable cost are features which the consumer has a right to demand. These criteria have been kept in the foreground during this study. The conclusions resulting from the study are as follows:

1. Quick-frozen fruits and vegetables can be used successfully in an institution food department.

2. The frozen foods showed much variation individually as to quality, cost, and resistance to bacterial growth.

3. As a whole, the frozen fruits and vegetables compared favorably with the fresh products in quality and excelled the canned products.

4. The frozen products showed a striking resemblance to the fresh in color and general appearance.

5. The frozen products had flavors somewhat different from the natural flavors of the foods, but this change was for the most part slight.

6. The flavor of the frozen fruits was best when the product was in the frozen state.

7. When the fresh products were available, the average cost of the frozen commodities was either the same or below the average cost of the fresh. It was the same as the average cost of the fresh for fruits and below the average cost of the fresh for vegetables. With corresponding products the average cost of the canned fruits was

above the cost of the frozen, while the average cost of the canned vegetables was below the average cost of the frozen.

8. In the event that there was no fresh product on the market, the average cost of the frozen food was higher than the average cost of the canned food.

9. The multiplication of bacteria in the frozen fruits after they were thawed was slow, even when stored a comparatively long time. The development of mold, oxidation, and other indications of deterioration was more rapid and caused the food to be discarded before the bacterial growth was large enough to be dangerous. In the case of vegetables the growth of bacteria after the products were thawed was rapid as well as the development of other spoilage factors. However, the evidence shows that frozen fruits and vegetables can be used safely if they are utilized promptly upon thawing.

10. A good variety of quick-frozen fruits is available in central Michigan. The number of frozen vegetables available is small but since packers are improving their technique, it may be expected that more of these products will be found on the market in the future.

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