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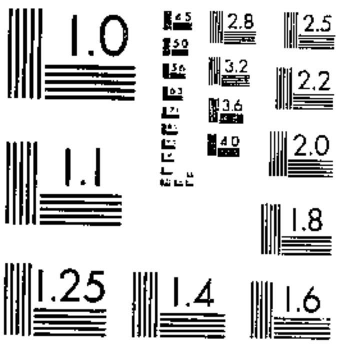

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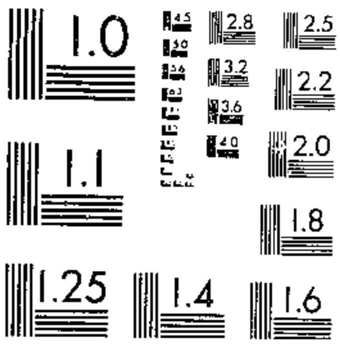

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TECHNICAL BULLETIN No. 148 JANUARY, 1930

UNITED STATES DEPARTMENT OF AGRICULTURE
WASHINGTON, D. C.

THE FROZEN-PACK METHOD OF PRESERVING BERRIES IN THE PACIFIC NORTHWEST

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INTRODUCTION

The preserving of berries in the Pacific Northwest by the frozen-pack method[3] apparently began about 20 years ago in Salem, Oreg. The industry is centralized in western Oregon and western Washington, where the climatic conditions are favorable for the production of large yields of berries of high quality.

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[2] Acknowledgment is made of the valuable assistance of the late Charles H. Stephenson, of the Food, Drug, and Insecticide Administration, and of the courteous help given by the canners and packers of berries and by cold-storage companies in the Pacific Northwest who cooperated to make these investigations possible. Of these, the Puyallup and Sumner Fruit Growers Association, of Puyallup, Wash.; the Washington Berry Growers, of Sumner, Wash.; the National Fruit Canning Co., of Seattle, Wash.; the American Packing Co., of Everett, Wash.; and the Spokane Street Terminal Cold Storage, of the port of Seattle, deserve special mention. The Western Washington Experiment Station at Puyallup assisted materially by offering its laboratory and office facilities for the work.

[3] This process is known to the trade generally as "cold pack." The term "frozen pack" is used in this bulletin as more accurately descriptive of the process and because of the use of the term "cold pack" in the canning industry, where it refers to a pack made at prevailing air temperatures.

The method used in this process consists essentially of placing the fruit in barrels or other containers, with or without sugar, and freezing and storing the pack at relatively low temperatures.

The quantity of fruit so handled has increased from a few hundred barrels at the beginning to about 100.000 barrels of 50-gallon capacity in 1928. Exact data for the earlier years are not available, but estimates of the yearly strawberry packs are given in Table 1.

TABLE 1.—*Estimated yearly frozen pack of strawberries in the Pacific Northwest, 1918–1928*

Year	50-gallon barrels	Year	50-gallon barrels	Year	50-gallon barrels
1918	3,000	1922	10,000	1926	33,000
1919	5,000	1923	15,000	1927	54,000
1920	5,000	1924	25,000	1928	70,000
1921	3,000	1925	30,000		

From the data in Table 1 it is apparent that there has been a very rapid increase in the quantity of strawberries handled by this method. To a lesser degree this has also been true of raspberries and Logan and other blackberries. The 1926 strawberry pack would have been larger if unfavorable weather conditions had not occurred, and there have been occasional fluctuations at other times in the volume of the total pack in the Pacific Northwest for the same reason.

Strawberries comprise the largest proportion of the pack and are followed closely in volume by red raspberries. The Marshall variety of strawberry is used most commonly, although other varieties grown in the Pacific Northwest are packed to some extent. The Cuthbert red raspberry is used extensively, while the Antwerp, Marlboro, and other so-called sour varieties are packed in relatively small quantities, sometimes mixed with the Cuthbert.

Logan and other blackberries are packed to some extent, and small quantities of black raspberries, currants, gooseberries, and cherries are also preserved by this method. The Evergreen and Logan varieties are used almost exclusively for the blackberry frozen pack.

Table 2 presents data showing the quantities of fruit of different kinds, type of package, and kind of pack used commercially during the seasons of 1926 and 1927.

Under the heading "Kind of pack" in Table 2, in the designations 3 plus 1 or 2 plus 1 the first figure refers to the proportion of fruit in the pack by weight and the second refers to the proportion of cane sugar used. A pack containing no sugar is generally referred to by the trade as a "straight pack."

TABLE 2.—*Type of package, kind of pack, and quantities of fruit preserved by the frozen-pack method in the Pacific Northwest in 1926 and 1927* [1]

Fruit and type of container	Kind of pack	Number of containers 1926	Number of containers 1927
Strawberries:			
50-gallon barrels	No sugar	272	870
Do	4 plus 1		1,000
Do	3 plus 1	765	1,853
Do	2 plus 1	31,295	48,963
Do	1½ plus 1		104
Do	1 plus 1		138
30-gallon barrels	3 plus 1		15
Do	2 plus 1	385	593
10-gallon kegs	do	411	372
5-gallon kegs	do	830	3,262
5-gallon cans	3 plus 1		1,374
Do	2 plus 1	4,363	3,820
Do	1 plus 1		50
30-pound tins	5 plus 1		8,400
Do	3 plus 1		17,002
Red raspberries:			
50-gallon barrels	No sugar	17,897	6,215
Do	5 plus 1		505
Do	4 plus 1		5
Do	3 plus 1	424	547
Do	2 plus 1	17,681	3,307
30-gallon barrels	No sugar		88
Do	2 plus 1	83	38
10-gallon kegs	do	100	26
5-gallon kegs	do	75	
5-gallon cans	No sugar		75
Do	4 plus 1		127
Do	3 plus 1		477
Do	2 plus 1	884	3,699
30-pound tins	5 plus 1		1,000
Do	4 plus 1		40
Do	3 plus 1		2,200
Do	2 plus 1		6,914
Logan blackberries:			
50-gallon barrels	No sugar	4,370	1,980
Do	4 plus 1		25
Do	3 plus 1		70
Do	2 plus 1	173	
Do	1 plus 1		100
30-gallon barrels	No sugar	11	78
Do	2 plus 1	50	
10-gallon kegs	No sugar	7	7
5-gallon kegs	do	176	164
Logan blackberries—Continued.			
5-gallon cans	No sugar		96
Do	4 plus 1		300
Do	3 plus 1		418
Do	2 plus 1	800	4
30-pound tins	3 plus 1		210
Other blackberries:			
50-gallon barrels	No sugar	8,167	1,543
Do	4 plus 1	10	120
Do	3 plus 1	100	75
Do	2 plus 1	31	50
30-gallon barrels	No sugar	36	
Do	2 plus 1	5	
10-gallon kegs	do	13	
5-gallon cans	No sugar	341	215
Do	4 plus 1		1,752
Do	3 plus 1	600	765
Do	2 plus 1	497	
30-pound tins	5 plus 1		600
Do	3 plus 1		2,008
Black raspberries:			
50-gallon barrels	No sugar	353	302
Do	2 plus 1	231	40
5-gallon cans	No sugar		65
Do	2 plus 1	328	131
Gooseberries:			
50-gallon barrels	No sugar	20	50
5-gallon cans	2 plus 1		320
Sour pitted red cherries:			
50-gallon barrels	3 plus 1	852	626
Do	2 plus 1	8	
5-gallon cans	3 plus 1		87
Currants:			
50-gallon barrels	No sugar	207	249
Do	2 plus 1		1
30-gallon barrels	No sugar	3	
Black pitted cherries:			
50-gallon barrels	do		8
Do	2 plus 1	10	
Prunes:			
5-gallon cans	3 plus 1		630

[1] These figures were furnished by E. M. Burns, secretary of the Northwest Fruit Barrelers Association.

The figures presented in Table 2 indicate an increase in the use of small containers for frozen-pack fruit. This phase of the industry seems to offer promise for the future, particularly if a retail market is developed and the consumer becomes acquainted with the product and its possible uses. At present, however, the main outlet for frozen-pack fruit is still through channels which prefer the larger container, such as the 50-gallon barrel.

The data also indicate that there is considerable fluctuation in the quantity of fruit packed and frozen each year in 50-gallon barrels. This is generally determined largely by crop and climatic conditions and often by the demand for berries in the fresh-fruit market or by the canneries.

Portions of the frozen product are occasionally held over for one or two seasons, pending suitable market conditions or demand; hence the pack in any one year does not necessarily constitute the entire storage stock of frozen-pack fruit for that year.

The fruit preserved by the frozen-pack method is used very largely in the commercial manufacture of preserves, jams, and jellies. Considerable quantities are employed in the preparation of crushed fruits and fruit sirup for soda-fountain use and in pie baking by large restaurants and bakers. The manufacture of ice cream with fruit flavors also utilizes an appreciable part of the total frozen pack, especially of strawberries, and a small quantity is used in the preparation of fruit extracts and flavors.

PREPARATION AND HANDLING OF FRUIT FOR FROZEN STORAGE

TYPE OF FRUIT USED FOR FROZEN PACK

Two types of fruit are used for the frozen pack—that which is grown especially for barreling purposes and that which is processed by the frozen-pack method because it is not suitable for canning or shipping or which, because of market conditions, can not be sold profitably in a fresh state.

Strawberries of the Marshall variety are used for frozen storage in the Pacific Northwest in larger quantities than any other variety, for the reason that this variety can be grown there with large yields of fruit of exceptional size and quality. The Marshall strawberries also hold up better in storage and retain their color and attractive appearance for a longer period of time. Ettersburg 121 is packed to some extent for use as candy centers.

For those berries which are also canned or shipped in the fresh state, such as raspberries and Logan and other blackberries, the frozen-pack method offers an outlet for fruit that may be somewhat overripe and soft for canning or fresh shipment but which is wholly suitable for consumption. Large quantities of berries have been frozen in barrels during the height of the harvest season when canners have been unable to handle the fruit or when the fresh market has not been a profitable one.

A considerable portion of the fruit other than strawberries ultimately used in the frozen pack is not delivered primarily for barreling but is offered by the grower for shipping or canning and is later diverted to the barreling plant if found unsuitable for these other purposes.

It is thus evident that, in the past, the frozen-pack industry has been of great value to the small-fruit industry of the Pacific Northwest in providing an orderly and economical method for marketing the surplus production.

PREPARATION OF FRUIT FOR PACKING

In the details connected with the preparation and packing of berries by the frozen-pack process there is considerable variation, depending on the packer and the locality. Only a brief discussion of the general types will be given.

Most of the fruit is hauled by the grower in wagons or trucks to the packing plants, or to assembling sheds maintained by some packers for the temporary storage of berries intended for packing in central plants located elsewhere. In the latter case, further transport by truck, by boat, or even by rail, is necessary to bring the fruit to the place where it is to be packed. Deliveries are made to such plants at rather definite hours in the morning or evening by truckmen who collect the berries from the substations.

The berries are generally brought in either early in the morning, in which case they may have been picked during the previous afternoon, or late in the afternoon and evening after the harvest of the day is finished. A few packers do the packing in sheds in the field (fig. 1), as the fruit is delivered by the pickers. In one instance the barreling crew moved about the fields to sheds located conveniently for the pickers, who brought in the berries in pails. In other cases the berries are transported in crates holding 10 to 12 pounds of fruit in 12 cups, or hallocks, which are only one layer deep in each crate, or in tin containers of about 30 pounds capacity.

FIGURE 1.—Hulling and packing strawberries in the field

Generally the berries unsuitable for shipment are handled in the shipping crates, capable of holding about 20 to 25 pounds of fruit in 24 cups. Upon arrival at the barreling or packing station, the fruit is weighed and the crates are stacked until the fruit can be packed, which is generally within 12 to 18 hours. (Fig. 2.)

Strawberries must have the hulls removed before they are ready for grading and barreling. This is done either at the packing plant, before the final inspection of the fruit, or in the field by the pickers. The latter seems to be the most common method at present, because hulling the berries in the field adds to the grower's revenue and possibly can be done a little more cheaply there. It also tends to relieve the congestion which may arise at the packing plants, if the fruit has to be hulled there before it can be put in barrels. Connected with this practice, however, there is considerable danger of greater spoilage and shrinkage in hulled berries, especially when the temperatures are high. Unless this can be overcome by prompt utilization of the fruit after picking, the hulling of the berries at the packing plant is to be preferred.

In most cases the berries are given some form of inspection and grading before they are placed in barrels. At that time leaves and other field débris are removed, as well as moldy berries or those otherwise unsuited for barreling. Usually berries for barreling which have previously been graded for shipping or canning purposes receive no further inspection.

The manner in which the sorting is done varies considerably. In some packing plants the berries are dumped on a moving belt which passes before sorters, who remove the undesirable fruit, the leaves, and the stems. In others the sorters pick over the fruit as it is dumped into large pans holding generally between 20 and 25 pounds of fruit, and these in turn are emptied directly into the barrels.

The washing of strawberries before packing is gradually becoming almost the universal practice in the Northwest. In some cases the

FIGURE 2.—Preparing strawberries for barreling

sorting is done first, and the fruit is then run over spray washers; in others the fruit is sorted as it is being washed. Where packing in the field is practiced the washing may be done in tubs, and the berries are sorted over at that time or as they are allowed to drain. However, this method is not so desirable as the washing done with sprays of fresh water. It is essential, of course, that as little water as possible be carried into the barrel with the fruit, because under the food and drugs act added water becomes an adulterant unless its presence is indicated on the container.

The container most commonly used for frozen-pack berries in the Pacific Northwest is a 50-gallon fir barrel, paraffin coated on the inside, the bung being in the head of the barrel. Relatively small quantities of fruit are also packed in 30-gallon barrels and in 10-gallon and 5-gallon kegs. Considerable quantities of fruit are packed in 5-gallon cans and in 30-pound tins. There is a distinct tendency toward a more extensive use of the small containers, especially as a retail market for frozen-pack fruit is developed. Five types of containers are shown in Figure 3. Cardboard containers impregnated with paraffin and friction-top cans have also been used.

Most of the strawberries are packed with cane sugar, and considerable quantities of red raspberries are so handled, although there is a tendency to pack raspberries without sugar. Logan and other blackberries are packed very largely without sugar. Most of the fruit preserved by the frozen-pack method is packed without any preservative other than cane sugar. A very small proportion, however, is prepared with benzoate of soda, and the fruit so packed is generally in small containers and is intended mainly for the soda-fountain trade. The use of the preservative is noted on the containers as required by the food and drugs act.

FIGURE 3.—Five types of containers used for frozen-pack berries

There are several methods of filling the barrels. In some cases the fruit is dumped directly into the barrels from the pans or other containers used in grading and sorting. In others the berries are allowed to drop into the barrel from the end of a moving belt, while in some packing plants both methods are used. The cane sugar is added either at short intervals or continuously from an overhead chute. In some cases the berries and sugar are actually weighed into the barrel, whereas in others they are measured from containers holding a known weight of fruit or sugar. The former method, of course, is the more accurate. Where grading belts are not used, some packers dump the berries on sloping tables or into funnellike chutes, to facilitate the examination of the fruit just before it goes into the barrels and to fill the barrels more rapidly without danger of spilling the berries.

As the barrels are being filled they are usually shaken or jolted in order to mix the sugar with the berries and to settle the fruit mass in the barrel. Some packers use large paddles to stir the fruit and sugar together, especially in the filling of the small containers. This latter method is liable to crush the berries more than the shaking or jolting method of settling the fruit. For this reason, and also because it is much more difficult to keep the packing operation on a clean sanitary basis when the paddles are used, most packers do not look with favor on the continued use of paddles.

In most packing plants shaking or rocking platforms are provided on which the barrels are placed for filling. Such contrivances may consist simply of a small platform resting on an iron pipe, (fig. 4), or on a piece of 2 by 4 inch lumber. The packer grasps the barrel at the top and rocks it back and forth with a jolting motion. Occasionally a piece of lumber nailed to the floor serves the purpose, and the barrel is rocked from side to side upon it. A few packers shake the barrel somewhat as it rests on the weighing scales while the fruit and sugar are being weighed into it.

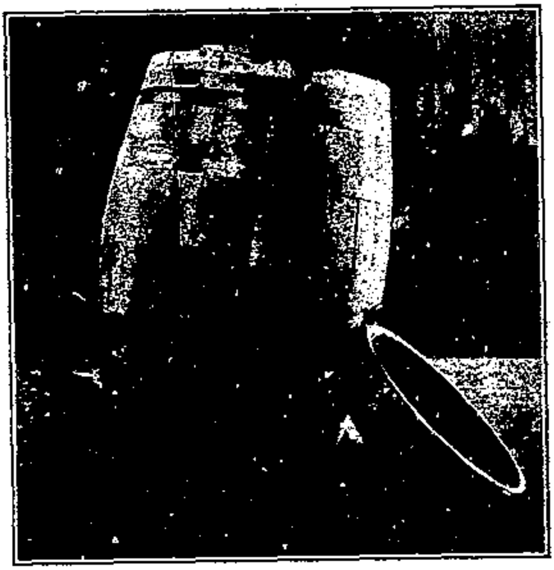
FIGURE 4.—Shaking or rocking platform

A recently developed mechanical shaker (fig. 5) gives the barrel a continuous vertical jolting throughout the filling period. Such power-driven contrivances are gradually replacing most of the hand-operated shaking platforms, especially in the larger packing plants.

When cane sugar is used with the fruit the barrels are filled almost full, the total weight of sugar and fruit generally averaging about 450 pounds. When no sugar is used, more vacant space is left in the top of the barrel, in order to provide for the expansion of the fruit mass during the freezing process, in which case about 380 pounds of fruit is usually placed in each barrel.

As soon as the barrel is filled it is headed, coopered, and the bung driven in. The barrel is then weighed and the head is usually stenciled or marked with the brand mark, the number of the barrel, the type of pack and variety of berry used, and the gross, tare, and net weights of the container.

The barrels are then ready for transport to the cold-storage rooms. The time elapsing between packing and storage will vary with the location of the packing plant in relation to the cold storage. Usually the barrels are placed in freezing storage within 6 to 8 hours after being filled. This period should be made as short as possible. The general practice is to allow a number of filled barrels to accumulate before any are sent to cold storage, the barrels being held in most cases under a roof to shelter them from the sun and to keep them as cool as possible.

Transportation of the barrels to storage is largely by autotruck, although in some cases they are carried by boat or rail. A few packing plants are located adjacent to cold-storage plants, and from them the barreled berries are stored with a minimum of delay.

After delivery to the storage plant, the barrels of fruit are generally rolled or trucked to freezing rooms, where they may be piled two or three high (fig. 6) on the chimes. In some storage plants pieces of lumber, commonly called stripping or dunnage, are placed between the tiers of barrels and between the lower tier of barrels and the floor. This hastens the cooling of the barrels and makes stacking easier.

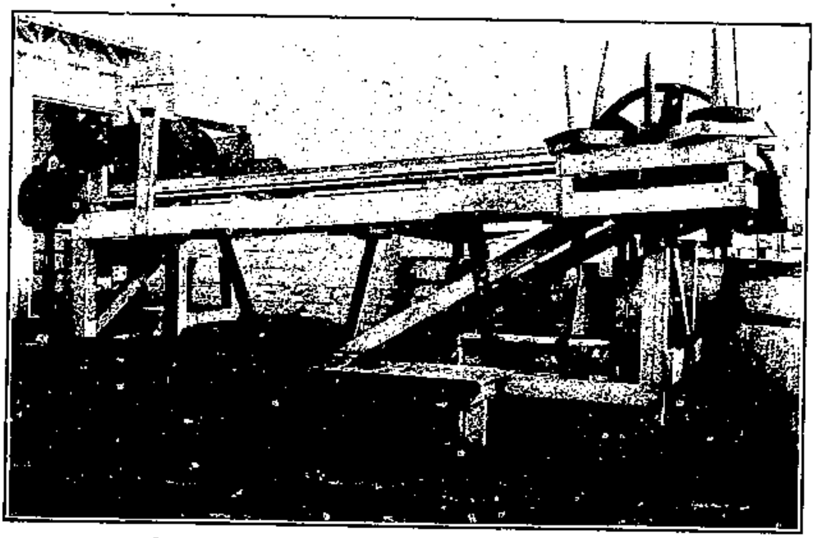

FIGURE 5.—Power grader and shaker for strawberries

In some storage plants it is the practice to freeze the fruit at a low temperature and then remove the barreled fruit to a warmer room. In such cases the barrels may be rolled into the freezer and allowed to freeze as they lie.

The temperature maintained in the average cold storage for freezing berries is generally from 10° to 15° F., but in many it is kept as low as 0°. The maintenance of the lower temperature is not difficult in seasons when a moderate volume of fruit is handled and when the barrel deliveries are evenly distributed from day to day. In some seasons, however, when large volumes of warm fruit must be handled within a relatively short time, the refrigeration capacity of the storage plants in the barreling regions is taxed to the limit. In such cases it has sometimes been impossible to maintain the desired temperatures required for quick cooling and freezing. The temperatures of rooms heavily loaded with warm fruit in the past have sometimes averaged 30° for considerable periods of time. Such a condition is very undesirable, however, and should be avoided.

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After a considerable portion of the berries have been frozen, the fruit can be shipped long distances in refrigerator cars or in the refrigerated holds of freight steamships. When shipped by rail, salt is added in the proportion of 10 to 15 per cent by weight of the ice used in the bunkers of the cars, in order to give the low temperatures necessary to keep the fruit frozen during the transit period. The customary carload consists of 120 or 160 barrels stacked in two tiers.

OUTLINE OF THE INVESTIGATIONS

The purpose of the investigational work, begun in 1924, was to examine thoroughly the different phases of the barreling and freezing of berries and to determine, if possible, the best practical procedure for handling fruit by the frozen-pack method.

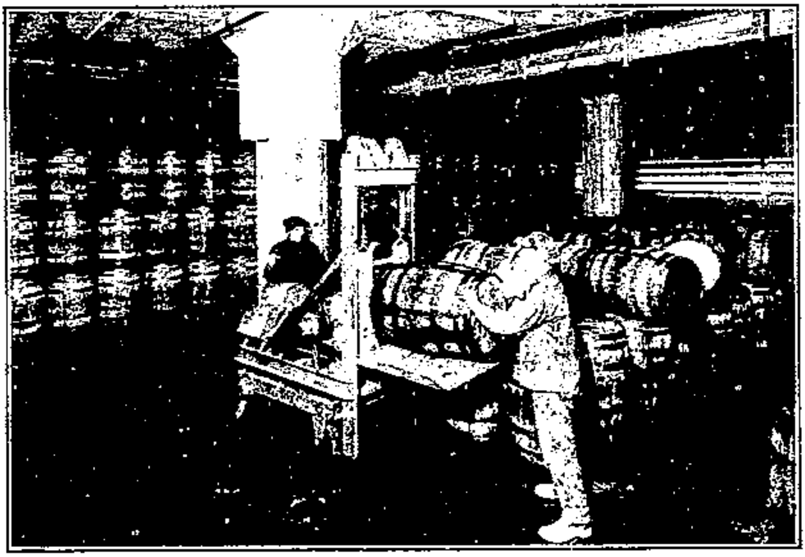

FIGURE 6.—Cold storage for barreled berries, showing method of stacking

The investigations have dealt (1) with the rates of cooling of barreled berries in different containers when packed with and without sugar and when exposed to various temperatures; (2) with the effect of different sugar concentrations upon the water content and texture of the fruit; (3) with the effects of different methods of handling the containers upon the freezing of the fruit mass and upon the sugar distribution through it; and (4) with the development of yeasts and molds and of fermentation in fruit packed with or without sugar, particularly as influenced by different temperatures.

This bulletin is a report of the investigations carried on in 1924, 1925, and 1926. Studies dealing with other phases of the frozen-pack industry, particularly problems arising from the more extensive use of the small container, now in progress, are to be reported in a later publication.

EXPERIMENTAL WORK

DETERMINATION OF RATE OF COOLING AND FREEZING OF FROZEN-PACK BERRIES

Knowledge of the rates of cooling of the fruit when packed in different containers and exposed to different temperature conditions is of prime importance. The purpose of rapidly cooling and freezing the berries is to reduce to a minimum the respiration of the fruit and the multiplication of yeast cells; it serves also to retard the growth of molds. By rapid cooling, fermentation and spoilage of the fruit can be markedly reduced or entirely prevented.

Information obtained by investigators concerning the growth rates of such plant organisms as are commonly found in frozen-pack fruit indicates that their development is markedly reduced at temperatures below 40° F., although it does not cease entirely until freezing actually occurs. Hence under commercial conditions it is desirable that the fruit temperatures be reduced below 40° as soon as possible, in order to check fermentative activity.

In the experimental work the determination of the rates of cooling and freezing of packed berries was made by inserting waterproofed resistance thermometers into the fruit mass in the containers. This was done after the containers were filled, headed, and placed in cold-storage rooms, the leads to the resistance thermometers passing out of the containers either through the bung in the barrels or through other openings. The temperatures in different positions in the containers could thus be read at any time without disturbing the contents.

When barrels were used, the resistance thermometers were usually placed in three positions: (1) 4 to 6 inches from the bottom of the barrel, (2) 4 to 6 inches from the side of the barrel, midway between the top and the bottom, and (3) at the center of the barrel. In some instances temperature readings were also taken 4 to 6 inches below the top of the fruit mass. All readings were made while the barrels were standing on end. With smaller containers the temperatures were determined only at the center of the fruit mass.

Figure 7 shows graphically the rates of cooling in four different positions in a 50-gallon barrel of Marshall strawberries packed with cane sugar (2 plus 1 pack) and held at an average temperature of approximately 14° F. It is apparent that the cooling was most rapid at the top and sides of the barrel, and slowest, as might be expected, at the center. At that location about 9 hours elapsed before there was any appreciable cooling. After the cooling began it progressed at a fairly steady rate until a temperature near 30° was reached. The fruit was relatively cool when packed, the temperature being about 60°. At the end of 24 hours the temperature at the center in this barrel was about 53°, and after 48 hours, 42°. At the end of three days it had reached 34°. It is apparent, therefore, that even under very favorable cooling conditions a period of two or three days will elapse before the fruit in the center of the barrel is sufficiently cooled to stop the fermentation process.

During the first two or three days the fruit at the sides and top of the barrel cooled much faster than did that at the center, the temperatures in the latter position averaging approximately 10° higher than those at the top and sides of the barrel. A period of approximately

24 hours longer was required to cool the center of the barrel to 40° F. than to cool the sides to this temperature. After the fruit had cooled to the point where freezing began, however, there was no marked difference in temperature in different positions in the barrel, the center being at this time about as cold as the top and sides. At the end of this test, after six and one-half days, the fruit in the bottom of the barrel had the lowest temperature, while that at the top had the highest, about 27°. The reason for this difference is probably that the freezing process increases the concentration of the sirup in the barrel, the increase not being the same in all parts of the barrel. The fruit mass in the bottom of the barrel had the lowest freezing point, owing to an accumulation there of the heavy sugar solution. The fruit sirup on the top of the barrel, being the least concentrated, had the highest freezing point. Intermediate readings were obtained for the center and side positions.

Figures 8 and 9 show the rates of cooling of the fruit at the centers of barrels of Marshall strawberries and Cuthbert raspberries, re-

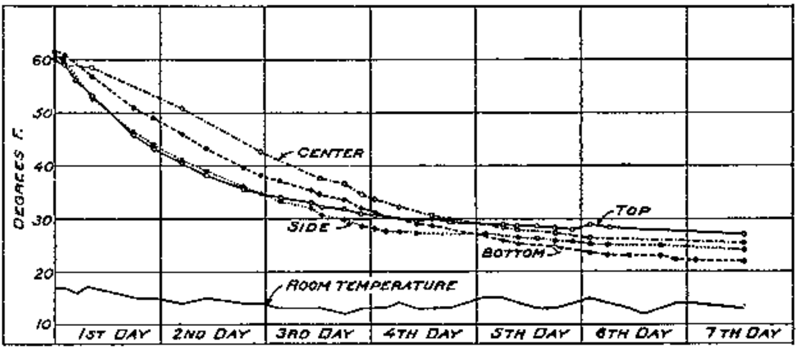

FIGURE 7.—Rate of cooling at the center, side, bottom, and top of a 50-gallon barrel of 2 plus 1 pack Marshall strawberries held at about 14° F.

spectively, packed with cane sugar (2 plus 1 pack) when held in storage at 30°, 15°, and 0° F. The data indicate that a period approximately twice as long is required to cool the center of a barrel in storage at 30° as is required at 0°. The rate of cooling at 15° is intermediate. At 30°, 3½ days were required to reduce the temperature at the center of the barrel to 40° and about 5½ days to bring it to 32°. Even at 40° fermentation and respiration are not entirely stopped, so it is apparent that if the fruit is held at 30° a period of several days will elapse during which fermentation may occur. At 0° F. a temperature of 40° at the center of the barrel was reached after 1½ days; at 15° this temperature was reached in about 2 days, while 32° was obtained in a little more than 3 days.

The temperature curves in Figure 9 are similar to those shown in Figure 8. The fruit, particularly in the barrel stored at 30° F., was somewhat cooler when packed than that used in the tests shown in Figure 8. The center of the barrel held at 0° reached this temperature after 2 days.

Figure 10 shows graphically the rate of cooling of Logan blackberries packed without sugar when held at 0° and at 15° F. Under the conditions of this test the cooling at 0° was only slightly faster than that at 15°. The temperature of the fruit was about 70° when packed and was reduced to 40° at the center of the barrel in less than two days when placed in storage at 0°, and in slightly more than two days in storage at 15°.

There was no marked difference in the rates of cooling obtained for strawberries, raspberries, and Logan blackberries packed in barrels when held under similar conditions.

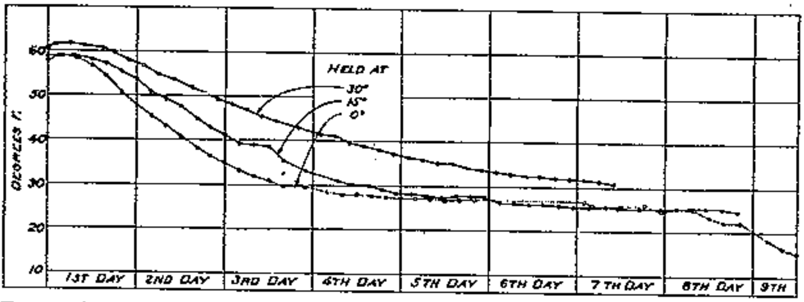

FIGURE 8.—Rate of cooling at the centers of 50-gallon barrels of 2 plus 1 pack Marshall strawberries held at about 0°, 15°, and 30° F.

The temperature curves in Figures 8, 9, and 10 emphasize again the fact that after placing the barrels in cold storage considerable time elapses before there is appreciable cooling in the fruit mass at the center. Usually there is practically no cooling during the first 12 hours, and often there is a slight rise in temperature for a few hours, probably due to the heat produced by the respiration of the fruit.

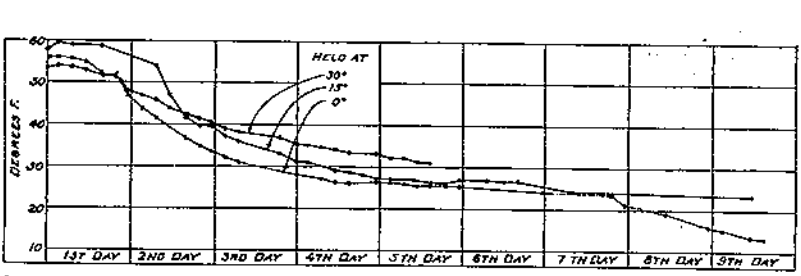

FIGURE 9.—Rate of cooling at the centers of 50-gallon barrels of 2 plus 1 pack Cuthbert raspberries held at about 0°, 15°, and 30° F.

EFFECT OF ICE ON RATE OF COOLING BARRELED FRUIT

As shown in Figure 7, the center of the barrel cools considerably more slowly than the sides, bottom, and top. Consequently, when there is fermentation and spoilage it is most likely to be found at the center. It would seem that a method of cooling the fruit at the center of the barrel more quickly would do much to minimize the hazard of fermentation and spoilage. This is particularly important in the case of berries packed without sugar and which lack the preservative action of sugar while the fruit is above 40° F. It was therefore planned to determine what effect a small quantity of ice placed in the center of the barrel would have on the temperatures prevailing in different portions of the berry mass. Temperatures obtained in two barrels of Cuthbert raspberries, one packed with 5 pounds of ice in the center of the barrel and the other without ice, are shown in Figure 11. Comparison of the temperatures prevailing at the centers of the two barrels shows that the ice reduced the temperature at the

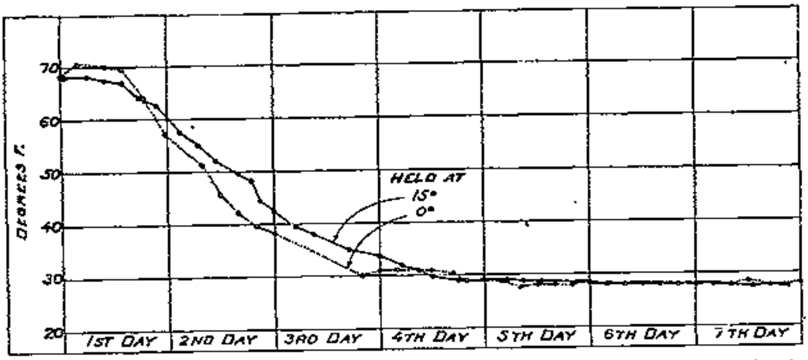

FIGURE 10.—Rate of cooling at the centers of 50-gallon barrels of Logan blackberries, packed without sugar and held at about 0° and 15° F.

center from 65° to about 47° by the time the first readings were taken. The fruit at the center of the barrel packed with ice reached a temperature of 40° in one and one-half days, while that at the center of the barrel packed without ice required more than two and one-half days to reach the same temperature. Thus it is apparent

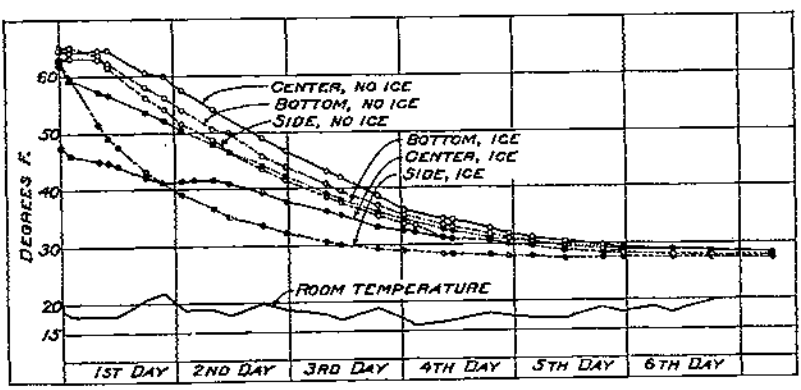

FIGURE 11.—Rate of cooling at the centers, bottoms, and sides of 50-gallon barrels of Cuthbert raspberries, packed without sugar and with or without a 5-pound piece of ice at the center of the barrel, held at about 19° F.

that the ice had a marked effect on the rate of cooling of the fruit at the center of the barrel.

Along the sides of the barrel there was also a noticeable influence of the ice on the rate of cooling. The temperature at this location in the barrel which was packed with ice reached 40° within 24 hours, whereas more than two days were required in the same location in the barrel packed without ice. There was not so much difference in the rate of cooling the bottoms of the barrels, although the one packed with ice had a slightly lower temperature there.

From the foregoing it is apparent that ice at the center of the fruit mass will accelerate the rate of cooling of the berries in that portion of the barrel. The use of ice, however, means that storage and transportation charges must be paid on water, and the presence of ice must be marked on the head of the barrel to conform to the requirements of the food and drugs act. With sound fruit and with satisfactory storage conditions the use of ice is not necessary. Under conditions where there is probability of spoilage, however, the use of ice in the container may prove of value in rapidly lowering the temperature at the center of the barrel. Precooling the berries before packing will, of course, materially improve temperature conditions in the container before freezing storage begins.

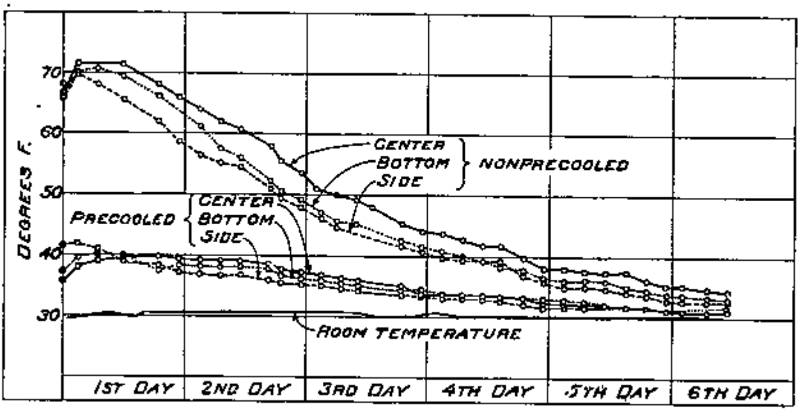

FIGURE 12.—Rate of cooling at the centers, bottoms, and sides of 50-gallon barrels of precooled and nonprecooled Cuthbert raspberries, packed without sugar and held at about 30° F.

EFFECT OF PRECOOLING BERRIES ON TEMPERATURES PREVAILING IN THE BARRELS

In order to determine the value of cooling the fruit before placing it in the barrel, a test was conducted in which berries were used that were thoroughly cooled before being barreled. The field crates containing the fruit (Cuthbert raspberries) were placed in a cold-storage room held at from 32° to 34° F. for about 18 hours. The berries were then hauled to the packing plant, placed in the barrels, and returned to the storage plant, about two hours being required for the whole operation. A comparable lot of fruit was held at the packing plant and was placed in the barrel without being cooled.

The temperature prevailing in the fruit in different parts of these barrels are shown graphically in Figure 12. The temperatures in the barrel filled with precooled berries were from 36° to 42° F. at the time the barrel was returned to the cold-storage plant. Both barrels were held at 30°, a relatively high temperature. Within 10 hours the temperature in all parts of the barrel of precooled berries was below 40°. There were only slight differences in temperature in the different portions of the barrel, although the fruit near the side of the barrel cooled slightly faster than that at the center. In the barrel filled with nonprecooled berries the temperature of the fruit was between 65° and 70° when the barrel was filled, and it averaged above 60° at the end of 24 hours. Almost four days were required for the temperature at the center of this barrel to reach 40°.

This test demonstrated that cooled fruit can be removed from storage, placed in the barrels, and returned to storage without a marked rise in the temperature of the fruit. Such a method is ideal from the standpoint of handling, in preserving high quality in the fruit, and in reducing fermentation and spoilage to a minimum. At present, facilities for cooling the fruit prior to barreling are, in most cases, not available. When the fruit is sound and suitable storage conditions are available, very satisfactory results can be obtained by packing the fruit without precooling and then placing it in freezing storage, though precooling where feasible is more satisfactory.

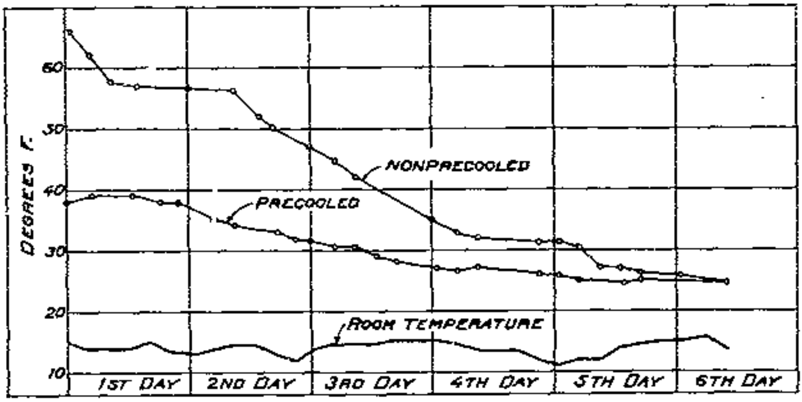

FIGURE 13.—Rate of cooling at the centers of 50-gallon barrels of precooled and nonprecooled 2 plus 1 pack Marshall strawberries held at about 15° F.

Figure 13 shows graphically the temperatures prevailing at the centers of barrels of precooled and nonprecooled Marshall strawberries packed with cane sugar (2 plus 1 pack) and held at 15° F. The temperature curves shown in Figure 13 again indicate that with the precooled fruit the temperature did not rise above 40°. About two and one-half days were required to cool the center of the barrel of nonprecooled fruit to the temperature prevailing in the barrel of precooled fruit when the latter was placed in storage.

RATE OF COOLING OF FROZEN-PACK BERRIES IN DIFFERENT CONTAINERS

In order to determine the relative rates of cooling in the various commercial containers used for packing and freezing berries a series of tests was made, using 30-gallon barrels, 10-gallon or 90-pound kegs, 5-gallon or 45-pound kegs, and 5-gallon or 45-pound rectangular cans. These containers were filled with Cuthbert raspberries packed with sugar (2 plus 1 pack in all cases) and were held in storage at 0°, 15°, and 30° F. The temperatures obtained at the centers of these containers, as well as the prevailing room temperatures, are shown graphically in Figure 14.

From a study of the temperature curves shown in Figure 14 it is apparent that fruit packed in small containers cools more rapidly than that packed in barrels. For example, in the 15° F. storage room the temperature in the center of a 30-gallon barrel was reduced below 40° in slightly less than 1½ days. A similar temperature was reached in about 20 hours in the 90-pound keg, in about 12 hours in the 45-pound keg, and in about 10 hours in the 45-pound can.

Although the rates of cooling were slower in the 30° F. room, the relation of the temperature curves for different containers is the same. Similar results were also obtained at 0°. In all cases the fruit packed in the 45-pound or 5-gallon can cooled most rapidly. The more rapid cooling of the berries in the rectangular can than in the wooden keg holding a similar quantity of fruit was due apparently to the more rapid heat transfer through the metal walls of the can.

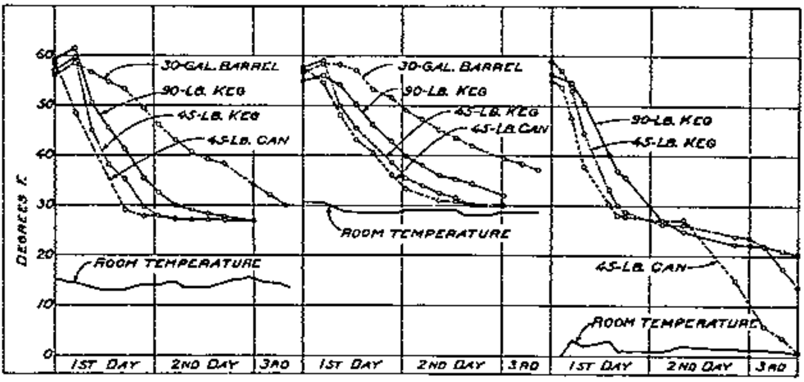

FIGURE 14.—Rate of cooling at the centers of different containers of 2 plus 1 pack Cuthbert raspberries held at about 0°, 15°, and 30° F.

There is no question that the use of smaller containers results in more rapid cooling and freezing of the frozen-pack fruit. Obviously this is very desirable and results in minimum danger of fermentation and spoilage and in higher quality in the packed fruit.

INFLUENCE OF SUGAR CONCENTRATION IN FROZEN-PACK FRUIT ON RATE OF COOLING

The opinion has been prevalent in the trade that berries packed without sugar cool more rapidly and freeze more readily than those packed with cane sugar. It has also been claimed that berries packed with equal parts of cane sugar and fruit cool more slowly than those packed with 2 or 3 parts of fruit to 1 part of sugar. To determine the influence of the proportion of sugar on the rate of cooling, barrels of Marshall strawberries packed 1 plus 1, 2 plus 1, and 3 plus 1 were stored at 0° and 30° F., and the rates of cooling at the centers of the different barrels were determined. The results of this test are shown graphically in Figure 15. It is apparent that at both temperatures the 1 plus 1 pack cooled most rapidly, whereas on the average the 2 plus 1 pack cooled slightly faster than the 3 plus 1 pack. A study of the rates of cooling in other tests indicates that fruit packed with cane sugar cools somewhat faster than that packed without sugar.

The higher the proportion of sugar used, the less the weight of berries in the barrel. The berry tissue consists largely of water, which cools much more slowly than an equal weight of sugar; consequently, both from a theoretical standpoint and in actual tests, the packs containing the most sugar cool the most rapidly. Fruit packed with cane sugar freezes at considerably lower temperatures than fruit packed without sugar, however, and this probably accounts for the opinion that the latter cools and freezes more easily.

DISTRIBUTION OF SUGAR IN FROZEN-PACK BERRIES

At the present time practically all of the strawberries and about half of the raspberries packed in the Pacific Northwest for freezing storage are put up with cane sugar, mainly in the proportion of 2 parts of fruit to 1 part of sugar by weight. The use of cane sugar in sufficient quantities retards the development of yeasts and molds, even at relatively high temperatures, and reduces the danger of fermentation. It also preserves the color of strawberries and to some extent preserves the flavor and the aroma of the berries. The texture of strawberries, at least for preserving purposes, may be considerably improved by frozen storage. The use of sugar increases the cost of handling, however, since a smaller quantity of berries can be packed per barrel, and freight and storage charges must be paid on sugar as well as on fruit. For some purposes it would be more desirable for the preserver or other manufacturer to add sugar as he uses the fruit. As the market for frozen-pack fruit in small containers is developed it is possible that the housewife or the restaurant operator would prefer to add all, or at least a major portion, of the sugar as the fruit is used; consequently, it is desirable to use the minimum quantity that will satisfactorily preserve the color, flavor, and quality. Cane sugar is not extensively used for Logan and other blackberries. Their color holds satisfactorily without it, although the flavor is improved if sugar is added.

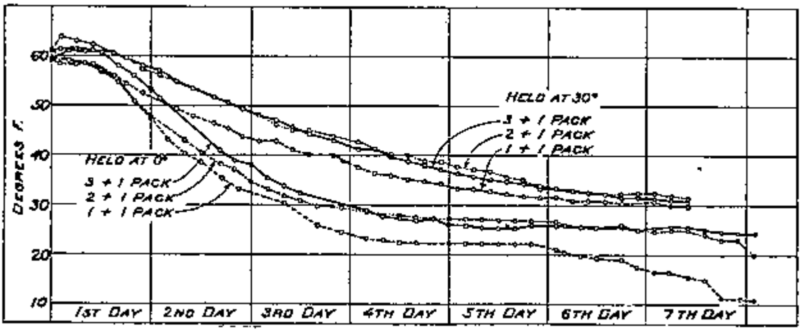

FIGURE 15.—Rate of cooling at the centers of 50-gallon barrels of Marshall strawberries, packed in 1 plus 1, 2 plus 1, and 3 plus 1 packs and held at about 0° and 30° F.

When the cane sugar is added to the berries, water is drawn from the fruit tissue by osmosis, the water passing out through the skin of the fruit. The sugar dissolves in this water, forming a concentrated sirup which gradually settles by gravity to the bottom of the container, the rate of movement being slower the lower the temperature at which the packed fruit is held.

The berries shrink considerably, the degree of shrinkage depending on the sugar concentration in the sirup, on the variety, and to some extent on the length of the storage period. After several days a mass of somewhat shrunken partly frozen berries will usually be floating in the sirup. At the bottom of the barrel there will be a concentrated sirup practically free from berries.

Samples of the sirup or juice present at the tops and bottoms of the barrels were taken in order to obtain information on the distribution of the sugar in barreled fruit. A screened tube was inserted into the barrels, either at the top of the fruit mass or toward the bottom of the barrel, and a sample of the sirup was drawn up by suction. The temperature of the sirup was allowed to come to approximately 60° F., and the concentration was determined by a Balling saccharometer.

The results of some preliminary tests on the distribution of sugar in frozen-pack berries are shown in Table 3. Barrels numbered 1 to 10 were prepared by adding berries and sugar alternately in quantities of approximately 20 pounds of berries and 10 pounds of sugar. The barrels were shaken by hand on a simple shaking platform and were rolled to the storage plant, this practice involving some further mixing of the sugar and berries. Several days elapsed before the sugar determinations were made. Barrels marked 11 to 14, inclusive, were from a commercially packed lot of fruit. The packer used the paddle method of mixing the sugar and fruit, which were added to the barrel in accurately weighed quantities. The barrels marked 15 to 18 were filled by a second commercial packer who measured portions of fruit and sugar and used the shaking method of mixing and settling the contents. The sugar analyses for the fruit in barrels marked 11 to 14 were taken one week after the containers had been placed in storage; those for the fruit in barrels marked 15 to 18 were taken after 11 days in storage.

TABLE 3.—*Concentration of sirup in barrels of Marshall strawberries*

[Miscellaneous commercial packs sampled in storage at 15° F.]

Barrel No.	Kind of pack	Saccharometer readings at 60° F. of sirup from—		Barrel No.	Kind of pack	Saccharometer readings at 60° F. of sirup from—	
		Top of barrel	Bottom of barrel			Top of barrel	Bottom of barrel
1	2 plus 1	30	56.5	10	1 plus 1	34	58.5
2	do	30	48	11	2 plus 1	32.5	49.0
3	do	31.5	48.5	12	do	32	52.0
4	do	26	44.5	13	do	33.5	52.5
5	do	28.5	44.0	14	do	39.0	49.0
6	do	34.5	49.0	15	do	33.5	58
7	do	30.5	47.5	16	do	36.0	56
8	do	31	50	17	do	28.5	58
9	3 plus 1	29.5	38	18	do	44.0	55

It is apparent from the results reported in Table 3 that the sirup concentration at the bottom of the barrels is considerably higher than at the top. This is particularly true with the commercially packed fruit which had stood for some time before the samples were taken.

Another series of tests was made with sirup from the bottom of barrels of 3 plus 1 pack Cuthbert raspberries, all packed at one barreling plant. Samples of the sirup were taken after the fruit had been in storage at 15° F. from 1 to 22 days. The sirup concentration at the end of 9 days was 46° to 47° Balling; at the end of 14 days, 47° to 48° Balling; and after 22 days, 51° to 55° Balling. After 1 day the concentration was practically the same as after 9 days. This fact indicates that a relatively high cane-sugar concentration in the bottom of the container exists soon after packing—as soon as the sugar and water from the fruit mix. There is, however, a slight increase in concentration as increasing quantities of water are changed to ice.

In order to determine the effect of different proportions of cane sugar and different storage temperatures on the concentration of sirup found in the tops and bottoms of the barrels, Marshall strawberries and Cuthbert raspberries packed in the proportions of 1 plus 1, 2 plus 1, and 3 plus 1 were held in storage at temperatures of 0°, 15°, and 30° F. Table 4 presents readings of the sirup concentration of samples taken from the top and bottom portions of the barrels after they had been held in storage for one week.

TABLE 4.—*Effect of storage temperatures and quantity of cane sugar on sirup concentration in frozen-pack berries*

Kind of pack	Storage temperature	Saccharometer readings at 60° F. from—	
		Top of barrel	Bottom of barrel
	° F.		
1 plus 1	0	----	61
	15	41	57
	30	35	57
2 plus 1	0	----	59
	15	27	55
	30	23	59
	30	20	57
3 plus 1	0	----	54
	15	20	55
	30	17	55

There was relatively only a slight variation in the concentration of the sirup at the bottoms of the barrels, depending upon whether 1 plus 1, 2 plus 1, or 3 plus 1 sugar packs had been used. There was somewhat more variation in the cane-sugar concentration in the top of the barrel, this being approximately twice as high in the 1 plus 1 pack as in the 3 plus 1 pack. The sirup in the bottoms of the barrels in all cases was apparently very nearly a saturated solution at the prevailing temperatures.

The foregoing tests demonstrated that there is considerable fluctuation in the concentration of sirup in different portions of the barrels under commercial handling conditions. Tests were made to determine the possibility of obtaining a more uniform mixture of sirup through the fruit by reversing the position of the barrels during storage or by altering the methods of filling the containers.

A number of barrels of Marshall strawberries packed in a 2 plus 1 mixture were placed in storage at from 15° to 20° F. Two barrels were stored with the bung end up and two others with the bung end down for 60 hours and then reversed. There was no significant difference in sirup concentration in the fruit mass in the tops and bottoms of these barrels. From a fifth barrel the contents were removed and packed into another barrel after a short period in storage. When tested about two days later the sirup concentration in this barrel was very uniform, the reading at the top being 40 per cent and at the bottom 40.5 per cent.

Another experiment with barrels of 3 plus 1 pack Marshall strawberries was conducted in which the filling of the containers was done with and without shaking. The filled containers were stored both with bung end up and bung end down. After two weeks in storage these barrels showed a sugar concentration of 50 to 58 per cent at the bottom, the fruit mass at the top being at that time hard frozen. There was no apparent correlation between the method of handling the barrels and the sirup concentration in the fruit mass in the top and bottom of the container.

While it apparently was not possible to obtain a uniform distribution of sirup in the barrel, either by varying the methods of adding the cane sugar to the fruit or by changing the position of the barrels in storage, such treatments had some effect on the appearance and character of freezing of the berries. It has been observed also that the mechanical jolting method of settling the fruit is preferable to the hand-shaking method because it does not shake so much undissolved sugar to the bottom of the barrel, where it is of little value in preserving the fruit.

DISTRIBUTION OF FREEZING IN FROZEN-PACK BERRIES

Freezing in the barrels of berries and sirup invariably begins in the fruit mass at the top of the barrel. A layer of ice and frozen berries gradually forms across the top of the barrel, followed by freezing down the sides of the container. This apparently is due to the lower sirup concentration at the top of the barrel and consequently to the higher freezing point of the fruit mass in that location. In frozen-pack fruit practically no ice formation occurs in the bottoms of the barrels except after long storage at low temperatures. Even then, with the relatively high sirup concentrations existing, the frozen mass has a slushy consistency. When the sirup is more dilute the fruit mass after freezing becomes hard and crystalline.

Table 5 shows the data for both sirup distribution and for the character of freezing in barrels of Cuthbert raspberries, packed with sugar and held in storage at 15° and 18° F. Some of these barrels were filled by adding sugar and berries and shaking the mixture, and others were filled without shaking. In some, all of the sugar was scattered through the fruit in the upper halves of the barrels, these being shaken during the filling process.

TABLE 5.—*Sirup concentration and character of freezing in 2 plus 1 pack Cuthbert raspberries handled in various ways and stored at 18° or 15° F.*

Storage temperature, barrel No., and filling treatment	Position in storage	Saccharometer readings of 60° F. of sirup from—		Condition of top of fruit mass			Ice in bottom	Undissolved sugar
		Top of barrel	Bottom of barrel	Appearance	Flavor	Character of freezing		
Stored at 18° F.:								
1, shaken by hand	Bung end up	39.0	53.0	Rough, lumpy	Rather sweet	Slushy	None	None.
2, shaken by hand	Bung end down	36.5	52.0	Rather smooth	Sweet; pleasant	do	do	On barrel head.
3, not shaken	Bung end up	37.5	52.5	Smooth	do	do	do	None.
4, not shaken	Bung end down	38.0	49.5	do	Very sweet and pleasant.	do	do	Do.
5, shaken; sugar all in upper half	Bung end up	35.0	55.5	Rough, lumpy	Not sweet or pleasant.	Rather hard	Slushy	Do.
6, shaken; sugar all in upper half	Bung end down	37.0	57.0	do	do	do	do	Do.
7, not shaken; sugar all in upper half.	Bung end up	35.5	56.5	Rather smooth	Rather sweet	Slushy	None	On barrel head.
8, not shaken; sugar all in upper half.	Bung end down	45.0	47.0	Rough, lumpy	Not sweet	Rather hard	Slushy	None.
Stored at 15° F.:								
1, shaken by hand	Bung end up		54.5	Rather rough	Slightly sweet	do	do	Slight quantity on top.
2, shaken by hand	do		55.0	do	do	do	do	Do.
3, shaken by hand	Bung end down		54.0	Smooth; attractive	Sweet	Slushy	None	On barrel head and top of fruit.
4, shaken by hand	do		55.5	do	do	do	do	Do.
5, not shaken	Bung end up		54.0	Smooth	do	do	Slushy	None.
6, not shaken	Bung end down		50.0	Rough, lumpy	Not sweet	Hard	None	In top of fruit mass.
7, shaken; sugar in upper half only.	Bung end up		51.0	Smooth	Sweet	Slushy	do	Do.
8, shaken; sugar in upper half only.	do		52.0	do	do	do	do	Do.
9, shaken; sugar in upper half only.	do		51.5	do	do	do	do	Do.
10, shaken; sugar in upper half only.	do		52.5	Rather rough	do	Fairly hard	Slushy	None.

While the results of these treatments are not clear cut, it is evident that the barrels which are shaken by hand as the cane sugar is mixed throughout the fruit mass and which are stored upright as they are packed usually exhibit a rather rough, lumpy, and hard-frozen condition in the top of the fruit mass. The character of this hard freezing will of course be determined largely by the freezing temperatures and their duration, together with the sugar concentration in the top of the fruit mass. Cane sugar often sifts down through the fruit in an undissolved condition when the barrel is shaken and may be found at the bottom of the barrel, especially in the 1 plus 1 packs. From the standpoint of obtaining the maximum preservative action of the sugar in the top of the fruit mass and of improving the appearance of the frozen product and its flavor and color, the proper mixing of sugar throughout the fruit mass is of importance. The experiments indicated that the extent and degree of hard freezing could be reduced somewhat by placing the barrels in freezing storage in a position the reverse of that in which they were packed.

The filling of the barrels without shaking also tended to give a somewhat smoother and more desirable appearance in the fruit mass when the barrel was opened, as well as a more pleasantly flavored product when it thawed. Shaking or jolting of the barrels is, however, almost indispensable, since it is often not possible to place the proper quantity of fruit in the barrels unless there is some way of settling the berries.

Scattering all of the cane sugar through the fruit in the top half of the barrels before much shaking was done resulted, in some cases, in a more attractive appearance at the top as well as an improved flavor when the barrels were opened. The sirup concentrations at the bottom of the barrels under such conditions of packing were somewhat less than in most of the barrels packed in other ways.

The best means of distributing the cane sugar throughout the fruit mass was not definitely established by these tests. As a practical measure the frequent addition of sugar in small quantities as packing goes on and the storing of the barrels in a position the reverse of that in which they are packed involves no additional expense and seems to be about the best method. Observations were also made on the character of the freezing that occurs in the fruit mass in barrels packed with different sugar concentrations and placed in storage at different temperatures. Barrels of Marshall strawberries packed 3 plus 1, 2 plus 1, and 1 plus 1 were held in storage at temperatures of 0°, 15°, and 30° F. The fruit mass in the barrels held at 30° showed no freezing, but gradually settled toward the bottom; that in the barrel held at 15° showed freezing, the degree and character of which varied with the quantity of sugar. At this temperature the 3-plus-1 pack fruit showed the greatest extent of freezing, being frozen deeply over the top and around the sides, with the sirup confined entirely to the center and bottom of the barrel. The 1-plus-1 pack was frozen solidly over the top to a depth of about 8 inches, with some slushy ice at the sides and a concentrated sirup at the bottom. The 2-plus-1 pack showed freezing of an intermediate degree and character.

In the 0° F. storage room, the 3-plus-1 and the 2-plus-1 packs had a bulging, hard-frozen dome at the top center of the fruit mass. The top of this dome was raised at least 8 inches above the former level of the fruit and was pressed tightly against the head of the barrel.

The berry mass in these two barrels was frozen solidly at least halfway down the barrel. The ice crust could be broken only with difficulty, especially in the 3-plus-1 pack, and in each case the upper portion seemed to be quite free from sugar or sirup. The 1-plus-1 pack showed no bulging dome in the center but was also hard frozen at the top, and unfrozen sirup was present only in the lower half of the fruit mass.

Observations were also made on barrels of fruit packed without sugar and held in temperatures similar to those prevailing in the experiments just mentioned. Fruit packed without sugar expands to a considerable extent during freezing and difficulty has been experienced under commercial conditions, from the bursting of the barrel heads from the pressure of the expanded frozen-berry mass. This is especially true for temperatures around 0° F., and has led to the almost universal use of about 380 pounds of fruit per 50-gallon barrel in which the berries are packed without sugar. Hard freezing, such as is generally obtained at 0°, especially if small containers are used, is not always necessary for the proper preservation of frozen-pack fruit. There is some question whether rapid freezing does not extract water from the fruit tissues in such a way as to result in a product more disintegrated when thawed than when somewhat higher temperatures of 10° to 15° are used.

The rapid cooling and freezing which occur in barrels of frozen-pack berries when they are exposed to air temperatures around 0° F. are often desirable for the quick retardation or inhibition of fermentative processes and the development of organisms. But the prolonged holding of such fruit at these temperatures is often uneconomical and generally unnecessary and may result in very hard freezing, with the danger of bursting the containers if they are too nearly full.

In the tests conducted at air temperatures of 10° to 15° F. very hard freezing did not occur, and there was no appreciable bulging of the fruit mass in fruit packed with sugar. Occasionally there was some bulging in barrels of fruit packed without sugar, especially after prolonged storage, but this was not commercially significant. For long storage a temperature of 15° to 20° has been found satisfactory after the fruit mass in the containers is thoroughly frozen.

EXTRACTION OF WATER FROM FROZEN-PACK BERRIES AS INFLUENCED BY SUGAR CONCENTRATION IN THE SIRUP

One of the results of mixing cane sugar with berries is the withdrawal of water from the fruit by osmotic action through the higher concentration of the solution around the berries. This process begins before freezing and continues at a constantly decreasing rate until the mass is frozen.

When freezing begins, the sirup concentration around the fruit is increased, and this results in a more rapid withdrawal of water from the berries. Apparently, however, a considerable part of the water extraction from the fruit occurs before ice formation has taken place, although if freezing is prolonged until the fruit mass is hard frozen large quantities of water are removed from the tissues. A certain reabsorption of extracted water by the tissues undoubtedly takes place during thawing, but the quantity is determined largely by the degree of freezing that has occurred and by the conditions existing during the thawing process. In any event, very considerable quantities of water remain unabsorbed by the tissues, and the concentration of soluble solids in the tissue juice is increased thereby.

One of the important results of this withdrawal of water is a shrinkage in the volume of the fruit tissue to a degree more or less proportional to the sugar concentration. The preserve manufacturer particularly is interested in the proportions of fruit tissue and sirup present in frozen-pack fruit. The quantity of fruit per barrel and its texture and appearance are of real importance to the preserving trade.

As a preliminary experiment, determinations of the concentration of soluble solids in Marshall and Ettersburg 121 strawberries in different stages of maturity were made soon after the berries were harvested. The results of these tests indicated that there was considerable variation in the concentration of soluble solids in the juice expressed from berries which, to the eye, appeared to be at about the same stage of maturity and also that varieties of strawberries might differ in this respect.

As the berries matured there was generally an increase in soluble solids in the juice, but in the same berry there was comparatively little difference between the soluble solids in the juice from the firm or from the soft side or between the red-colored and the greenish white portion of unripe berries.

With the object of determining the effect of different cane-sugar concentrations upon the texture and loss in volume of Marshall strawberries, a series of experiments was conducted with single berries packed in sirups of various concentrations. All precautions were taken to obtain proper samples of sirup and juice from the berries. The concentrations were determined in these as well as in the preliminary tests with an Abbe refractometer, the use of which made it possible to work with very small quantities of liquid.

The berries were packed in cans after the fruit had been thoroughly mixed with cane sugar, and the mixing was continued as the filling was going on in order to insure as thorough a distribution of the sugar as possible. The berries were put up without sugar and with sugar in the proportions 4 plus 1, 2 plus 1, and 1 plus 1.

The environmental conditions chosen for this experiment involved a gradual lowering of the temperature similar to that which takes place in the fruit in the center of a barrel. Hence the cans were left at 70° F. for 24 hours, after which some were withdrawn for examination, while the rest were removed to 45°, where they were left for 48 hours. Another lot was then withdrawn; the rest of the cans were placed in 30° and held for 72 hours. Some cans were examined at the end of this time, while the remainder were removed to 15° for periods of 48 hours, after which they also were examined. Where the fruit was frozen it had first to be thawed, of course, before readings on the soluble solids could be made.

A composite picture of the results obtained from many tests is given in Table 6.

TABLE 6.—*Influence of proportion of cane sugar in pack on concentration of soluble solids in the pulp of Marshall strawberries held at various temperatures and finally frozen*

Treatment of pulp	Soluble solids in different packs (per cent)			
	No sugar	4 plus 1	2 plus 1	1 plus 1
Held 24 hours at 70° F.	8.08	17.99	20.74	21.25
Held 24 hours at 70° and 48 hours at 45° F.	8.16	17.59	19.77	25.21
Held 24 hours at 70°, 48 hours at 45°, and 72 hours at 30° F.	8.36	19.86	22.61	26.80
Held 24 hours at 70°, 48 hours at 45°, 72 hours at 30°, and 48 hours at 15° F.	9.21	21.33	23.91	30.44

Table 6 indicates that with an increase in the cane-sugar concentration in the pack there is also more water extracted from the fruit, as shown by the increased percentages of soluble solids in the fruit itself. Most of the extraction occurs before freezing and takes place in the first 24 hours, although there is generally a slight increase at the different temperatures and for the duration of these experiments.

The berries packed without sugar show very little change in soluble solids until freezing has taken place, and even then the change is not marked. The degree to which the further sirup concentration resulting from freezing will extract additional water from the tissues after they have been stored in sirup for some time before freezing is shown by the table to be relatively small, except at the highest cane-sugar concentration used. It may be that this concentration completely plasmolyzes the cells of the berries and thereby renders the protoplasts more permeable, so that the quantity of water extracted is somewhat greater than when lower sugar concentrations are used.

Determinations of soluble solids were made on the sirup obtained from cans of fruit that had been treated in the same manner as those in the experiment just described, but which had been frozen for 48 and 168 hours. There was no consistent change in the sirup concentration in any of the packs after the longer period of freezing, which would indicate that the greater part of the water extraction due to sirup concentration following freezing occurs relatively soon after freezing begins.

There is a noticeable decrease in the size of the berries under conditions that bring about water extraction. Measurements of many berries held in sirups of different concentrations show that the decrease in size occurs relatively soon after immersion and that the rate of decrease in size is much slower after the first 24 hours. The decrease in size for any time period is proportional to the cane-sugar concentration in the sirup.

As the berries decrease in size it becomes increasingly difficult to squeeze juice from them, and they become tough and leathery, especially in the high cane-sugar concentrations.

Determinations of soluble solids made on the juice taken from the center portions of berries packed in different cane-sugar concentrations, as well as that pressed from the outer portion of the fruit, do not show consistent differences such as would occur if there were an actual penetration of sugar into the fruit tissue.

Tests were made in which measured berries were immersed in sirups of different concentrations. Measurements were made to determine the decrease in size of the fruit, and determinations of soluble solids were made at intervals, both of the sirup surrounding the berries and of the juice extracted from them. There was a rather consistent increase in soluble solids in the berries, roughly proportional to the quantity of cane sugar in the sirup, and this was paralleled by a decrease in soluble solids in the sirup, which would indicate a dilution of the sirup by water extracted from the fruit.

EFFECT OF FREEZING ON CHEMICAL COMPOSITION OF BERRIES

Certain experiments were conducted with samples of ripe strawberries, raspberries, and Logan and other blackberries to determine the effect of freezing upon the chemical composition of the fruit.

Each sample of berries was carefully mixed and divided into four portions. One of these was analyzed immediately; one was mixed with distilled water, sealed in No. 10 cans, and processed; another was mixed with one-half its weight of cane sugar, sealed in No. 10 cans, and frozen; and the fourth portion was sealed in No. 10 cans without the addition of sugar and frozen. The two frozen portions were stored at about 25° F. The canned and frozen berries were held for a period of from six to eight months before being analyzed.

The results of these analyses are given in Table 7.[4] The percentages are calculated on the basis of the fresh-fruit weight, correction having been made for the water or sugar added in each case.

TABLE 7.—*Chemical composition of frozen-pack berries, as compared with the chemical composition of untreated and canned berries*

Variety of fruit	Where grown	Method of preservation	Water-insoluble solids	Alcohol-insoluble solids	Pectic acid	Ash
			Per cent	*Per cent*	*Per cent*	*Per cent*
Marshall strawberry.	Longley, Wash	None	2.56	0.597	0.429	0.427
Do	do	Canned, 2 parts fruit to 1 part distilled water.	3.06	.617	.402	.420
Do	do	Frozen, 2 parts fruit to 1 part sugar.	2.67	.562	.307	.448
Do	do	Frozen	2.79	.585	.346	.421
Cuthbert raspberry	Puyallup, Wash	None	6.18	.629	.303	.399
Do	do	Canned, 2 parts fruit to 1 part distilled water.	6.00	.613	.293	.351
Do	do	Frozen, 2 parts fruit to 1 part sugar.	6.46	.618	.259	.366
Do	do	Frozen	6.33	.617	.261	.345
Logan blackberry	Auburn, Wash	None	5.27	.456	.201	.360
Do	do	Canned, 2 parts fruit to 1 part distilled water.	5.20	.485	.188	.398
Do	do	Frozen, 2 parts fruit to 1 part sugar.	5.28	.484	.188	.405
Do	do	Frozen	5.18	.489	.187	.398
Evergreen blackberry.	Puyallup, Wash	None	5.79	.486	.283	.460
Do	do	Canned, 2 parts fruit to 1 part distilled water.	5.87	.526	.278	.409
Do	do	Frozen, 2 parts fruit to 1 part sugar.	5.80	.531	.287	.421
Do	do	Frozen	5.38	.526	.267	.452

[4] The chemical analyses reported in these tables were made according to methods described in the following publication: ASSOCIATION OF OFFICIAL AGRICULTURAL CHEMISTS. OFFICIAL AND TENTATIVE METHODS OF ANALYSIS. COMPILED BY THE COMMITTEE ON EDITING METHODS OF ANALYSIS. Revised to July 1, 1924. Ed. 2, 535 p., illus. Washington, D. C. 1925.

These analyses show that the chemical characteristics of berries which are important in the manufacture of jams and jellies are not significantly affected by the storage of the fruit in the frozen state. It was noted, however, that strawberries frozen without sugar showed a decided loss in flavor and color as compared with the fresh fruit as originally packed. This was not true of the berries frozen with sugar, in which case the fruit was much like fresh berries mixed with the same proportion of sugar.

In later experiments mixtures of about 300 pounds of strawberries or raspberries with 150 pounds of cane sugar were frozen in 50-gallon barrels commonly used for this purpose. Storage of these containers was generally at about 25° F. for periods of one to nine months. In preparation for analysis the pulp was separated from the juice by draining for a few minutes on an 8-inch screen, the pulp and the sirup being analyzed separately. The results of these analyses are given in Table 8. Corrections were not made for added sugar, and due allowance must be made for this fact in comparing the analyses.

TABLE 8.—*Comparison of the chemical composition of the berries and the sirup in frozen-pack mixtures and of berries not frozen*

Variety of fruit and place grown	Storage conditions		Weight (pounds) of drained—		Solids		Total sugar as invert	Other carbohydrates	Alcohol insoluble solids	Pectic acid	Acidity as cubic centimeters N/10 HCl	Ash
	Length of storage period	Temperature (°F.)	Pulp	Sirup	Total	Water insoluble						
					P. ct.	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*		*P. ct.*
Cuthbert raspberry:												
Bellingham, Wash	None				17.84	6.27	8.92	8.92	0.07	0.24	181.5	0.37
Do	1 month	25	242		45.33	7.18	36.80		.50	.19	134.8	.40
Do	do	25		201	49.57		47.66		.22	.08	101.2	.38
Do	None				18.27	6.45	9.27	9.00	.63	.28	183.8	.39
Do	1 month	25	238		43.23	7.55	34.13		.49	.20	141.5	.37
Do	do	25		210	50.55		49.28		.22	.08	105.6	.30
Do	None				18.47	6.53	9.51	8.96	.65	.26	184.1	.37
Do	1 month	25	297		41.60	6.30	33.44		.40	.19	136.4	.35
Do	do	25		155	56.42		55.30		.21	.05	92.4	.27
Do	None				14.88	4.88	7.53	7.35	.58	.29	158.4	.40
Do	9 months	25	323.5		49.20	7.13	40.80				126.1	.30
Do	do	25		125.5	45.00		42.98				124.6	.30
Marshall strawberry:												
Everett, Wash	None				11.70	2.80	7.15	4.55	.60	.37	161.1	.39
Do	3 months	15	192		33.10	5.34	25.80		.62	.36	138.4	.32
Do	do	15		258	49.01		48.32		.19	.09	85.1	.23
Puyallup, Wash	None				11.32	2.52	6.68	4.64	.63	.31	195.8	.41
Do	3 months	25	164.5		37.63	6.97	27.36		.91	.52	148.1	.37
Do	do	25		282.5	45.30		43.73		.13	.05	111.6	.24
Wilson strawberry:												
Portland, Oreg	None				10.87	2.95	5.95	4.92	.50	.35	182.1	.49
Do	5 months	25	157		43.72	5.57	35.76		.80	.44	151.3	.34
Do	do	25		293	48.45		45.07		.11	.05	132.0	.25

The data indicate that the pectic-acid content of the drained juice is very much lower than that of the drained pulp. This is due to the fact that pectin is insoluble in water until the fruit mass has been heated in the presence of water and acid.

It will also be noted that there was some loss of pectin in the berries in some cases, due perhaps to the longer period of time required to freeze the fruit mass in such instances, which might result in a further ripening of the fruit and a possible breaking down of pectic materials.

The analyses show no significant changes in the chemical constituents of the berries other than these few cases of loss in pectic materials.

The analyses also show that a period of several months is required for the sugar concentration in the fruit to come into equilibrium with that in the sirup. Even after storage for nine months at about 25° F. the proportion of sugar in the juice is somewhat higher than that in the drained fruit.

YEAST DEVELOPMENT, MOLD GROWTH, FERMENTATION, AND SPOILAGE IN FROZEN-PACK BERRIES

Temperature is one of the most important factors in the preservation of fruit by the frozen-pack method. It is known that high temperatures may cause a marked acceleration in the respiration as well as in other vital processes of the fruit and may bring about the rapid development of fungous and bacterial organisms. The primary purpose of the handling and freezing practices employed in the frozen-pack method of preserving fruit is the reduction of yeast and mold development to a minimum and the prevention of fermentation and spoilage.

Fermentation may be influenced by other factors which arise more or less directly from the vital processes heretofore mentioned, such as the accumulation of carbon dioxide in the containers of fruit, the depletion of free oxygen in the air which is present in the fruit tissue as it is packed in the container, and the presence of alcohol resulting from fermentation.

Some of these factors have a depressing effect on fermentative activity. The presence of carbon dioxide in frozen-pack fruit does not ordinarily retard fermentation.

The absence of oxygen possibly prevents the multiplication of yeast cells, but it does not destroy their fermentative powers. Hence it will be noted in a subsequent table that considerable fermentation can occur even when the number of yeast cells is relatively small and shows no indication of increasing.

Aside from fermentation, with its consequent deterioration in the value of the frozen-pack fruit, there may also be a loss in dessert quality in the fruit where conditions exist in which the oxygen is depleted, even though actual spoilage has not occurred. Such deterioration has been observed in the taste and appearance of the fruit, but its demonstration chemically generally is not possible.

The concentration of cane sugar in the sirup may, of course, markedly influence fermentative activity. The extraction of water, both from the berry cells and from the cells of the organisms involved in fermentation and spoilage, materially influences the rates of their activity. Sugar concentrations may be prepared of such strength that they practically inhibit fermentative activity, even though temperatures remain relatively high. Such concentrations are obtained regularly in the bottoms of barrels of frozen-pack berries packed with sugar, but they occur less frequently in the tops of the barrels. Hence it has been emphasized that the fruit mass in the top and at the center of the barrel is the most liable to fermentation and spoilage because of the difficulty of retaining sufficient sugar at these points during the packing and because of difficulties in cooling the fruit.

The percentages of alcohol which have an inhibiting effect on the fermentative activity of yeast cells are such that they are not significant in the prevention of loss because of spoiled berries. The fermenting enzyme is active only within the cells of the yeast, but the alcohol readily diffuses from these into the sirup. It is obvious that only when alcohol is present in high concentration does it materially affect the vital processes of the yeast. Commercially, the fruit is spoiled long before this point is reached.

In the determination of the yeast, spore population, and molds present in frozen-pack berries, the method for microanalysis described by Howard and Stephenson[6] was followed. Determinations by this method are made with a compound microscope, special counting cells being used on which drops of the sample, diluted to a known standard strength, are spread out under a thin cover glass for examination. For yeasts and spores the "count" means the number found per one-sixtieth of a cubic millimeter of the sample; for molds it means the percentage of ruled squares, microscopic fields by number, which show molds present, such fields having been viewed under definitely prescribed conditions. Both of these are arbitrary criteria, but when obtained under carefully standardized conditions they furnish a reliable measure of the yeast, spore, and mold content of different packs or lots of the same or different commodities. And this content is, of course, some indication of the quality of the various packs or lots under examination. For example, in an analysis by Howard and Stephenson of nine samples of tomato sauces made from acceptable or fairly acceptable stock, the yeast and spore count averaged 40 per one-sixtieth of a cubic millimeter and the mold count 14 per cent; that is, 14 per cent of the microscopic fields examined showed molds. The averages for 24 samples of sauces made from bad or questionable stock were 475 for yeast and spores and 53 per cent for molds. These authors make the statement that "a low mold, yeast and spore, or bacterial count does not necessarily indicate sound stock, but a high count in any of these organisms always indicates bad stock or improper handling."

In using the Howard and Stephenson method on frozen-pack fruit all necessary precautions in sampling and in preparing the samples for examination were employed, in order to insure accurate and representative results. In some cases, samples were taken directly from barrels of fruit prepared for the experiments; in others, the berry and sugar mixtures were prepared and held in storage at different temperatures in cans, sealed after packing. The fruit in these cans was held under temperature conditions similar to those that would prevail in barrels of frozen-pack fruit as they were being cooled at freezing temperatures.

A preliminary count for yeast, spore population, and molds made on Marshall strawberries, as they were delivered for packing, indicated that a considerable variation could be expected, even in berries that appear to be in an entirely satisfactory condition. The

[6] HOWARD, B. J., and STEPHENSON, C. H. MICROSCOPICAL STUDIES ON TOMATO PRODUCTS. U. S. Dept. Agr. Bul. 581, 24 p., illus. 1917.

magnitude of these counts depends on various cultural and climatic factors. In general, however, the counts were quite low, ranging from 4 to 24 for the yeasts and spores, and 4 to 20 per cent for the molds. Raspberries have generally shown higher values than strawberries in this respect for fruit that appeared to be in comparable condition. The reason for this lies perhaps in the structure of the berry.

The first experiments with frozen-pack berries were conducted with barrels of Marshall strawberries and Cuthbert raspberries, packed without sugar and with cane sugar in the proportions 3 plus 1, 2 plus 1, and 1 plus 1. These barrels were divided into three groups and held at 0°, 15°, and 30° F. for periods of 6 to 10 days.

Yeast and spore counts made before and after the period of storage showed no consistent or appreciable increase. There was no alcohol present in the fruit mass in any of the barrels, and the berries had an entirely satisfactory flavor and appearance. It was evident that with berries having a low yeast and spore count at packing time there was no considerable increase in numbers under the conditions of this experiment and no fermentation or spoilage. The experiment emphasizes the fact, also, that it is practicable to preserve good berries in a fresh, dry condition by means of low temperatures.

The relatively satisfactory results obtained even when the barrels were held for 6 to 10 days at 30° F., a temperature which is not recommended and at which no freezing occurs, indicate that spoilage in storage may be due in a large part to the condition of the fruit at packing time or to failure to maintain proper storage temperatures.

The condition of the fruit at packing time has a very important bearing on its behavior in storage even when rapidly cooled. Obviously, where decayed, soft, overripe berries are used for the frozen pack, the quality of the fruit after freezing and thawing can not be better than it was at the beginning. Rapid cooling and freezing merely help to retain the fruit in the condition that existed at the time of packing.

Some experiments made with precooled berries packed in 50-gallon barrels indicated that such a practice helped materially in keeping down the development of organisms and stopping fermentation. Small containers, in which the fruit can be cooled rapidly, are especially advantageous. Under the conditions of these experiments, it was found that the fruit packed in 50-gallon barrels in a 3 plus 1 mixture was as satisfactory as that in the 1 plus 1 packs. This indicates that the cane-sugar concentration found in the fruit mass at the top of the barrel is sufficient to preserve the mass if the fruit is in good condition when packed and is cooled fairly rapidly.

In order to test further the effect of different temperatures on the development of organisms in frozen-pack berries and on fermentation, various mixtures of berries and cane sugar were prepared accurately by weight and held at different temperatures in sealed cans. The results obtained from these tests are given in Table 9. The alcohol determinations were made by actual analysis.

TABLE 9.—*Yeast and spore counts and alcohol determinations made on Cuthbert raspberries and Marshall strawberries packed with and without cane sugar and held at 45° and 75° F.*

Fruit variety and character of pack	Storage temperature (°F.)	Yeast and spore count		Percentage of alcohol
		At beginning	After two days	
Cuthbert raspberries:				
No sugar	45	4	18	None.
3 plus 1	45	4	9	Do.
2 plus 1	45	4	7	Do.
No sugar	75	4	72	0.1.
3 plus 1	75	4	16	None.
2 plus 1	75	4	12	Do.
Marshall strawberries:				
No sugar	45	6	80	Do.
3 plus 1	45	5	8	Do.
2 plus 1	45	4	5	Do.
No sugar	75	5	640	0.55.
3 plus 1	75	6	80	None.
2 plus 1	75	10	8	Do.

The influence of temperature as well as that of cane-sugar concentration upon the yeast and spore population is evident from these results. Longer periods of exposure up to three days at these temperatures have given even higher yeast and spore counts and larger amounts of alcohol even in the 45° F. storage. After a period of only 24 hours no alcohol was observed in any of these experimental lots, and the counts were generally lower than those found for berries held for two days.

An extensive series of experiments was conducted with Marshall strawberries, Cuthbert raspberries, and Evergreen blackberries, packed with and without cane sugar and held in small containers at temperatures of 75°, 45°, and 30° F.

The results obtained from the microanalytical studies, together with notes on the presence or absence of fermentation, are given in Table 10. Actual analyses for alcohol could not be made in these experiments.

TABLE 10.—*The development of yeast spores and molds and the presence or absence of fermentation in sealed cans of Marshall strawberries, packed and stored under various conditions*

Time held and type of pack	Storage temperature (°F.)	Time examined	Yeast count	Mold (per cent)	Fermentation
Fruit held 15 hours after being harvested before being packed:					
No sugar	75	When packed	12	12	None.
		After 18 hours	45	8	Moderate.
		After 30 hours	66	8	Bad.
		After 42 hours	102	4	Do.
		After 54 hours	180	4	Do.
4 plus 1	75	When packed	12	12	None.
		After 18 hours	30	12	Moderate.
		After 30 hours	18	4	Do.
		After 42 hours	39	8	Do.
		After 54 hours	84	8	Bad.
2 plus 1	75	When packed	24	16	None.
		After 12 hours	21	16	Do.
		After 24 hours	24	8	Do.
		After 26 hours	18	8	Do.
No sugar	45	When packed	24	16	Do.
		After 48 hours	12	12	Do.
		After 72 hours	15	8	Do.

TABLE 10.—*The development of yeast spores and molds and the presence or absence of fermentation in sealed cans of Marshall strawberries, packed and stored under various conditions*—Continued

Time held and type of pack	Storage temperature (°F.)	Time examined	Yeast count	Mold (per cent)	Fermentation
Fruit held 15 hours after being harvested before being packed—Continued.					
4 plus 1	45	When packed	24	16	None.
		After 48 hours	9	8	Do.
		After 72 hours	24	8	Do.
		After 120 hours	36	12	Do.
2 plus 1	45	When packed	24	16	Do.
		After 48 hours	12	8	Do.
		After 72 hours	27	4	Do.
		After 120 hours	21	12	Do.
No sugar	30	When packed	24	16	Do.
		After 48 hours	9	8	Do.
		After 120 hours	12	8	Do.
		After 240 hours	9	10	Do.
		After 480 hours	57	12	Do.
4 plus 1	30	When packed	24	18	Do.
		After 48 hours	6	6	Do.
		After 120 hours	15	12	Do.
		After 240 hours	21	24	Do.
		After 480 hours	18	4	Do.
2 plus 1	30	When packed	24	16	Do.
		After 48 hours	15	8	Do.
		After 120 hours	24	8	Do.
		After 240 hours	21	4	Do.
		After 480 hours	30	4	Do.
Fruit held 40 hours after being harvested before being packed:					
No sugar	75	When packed	18	28	Do.
		After 12 hours	30	24	Slight.
		After 24 hours	36	36	Moderate.
4 plus 1	75	When packed	18	28	None.
		After 12 hours	15	32	Do.
		After 24 hours	21	20	Do.
2 plus 1	75	When packed	18	28	Do.
		After 12 hours	24	36	Do.
		After 24 hours	24	24	Do.
No sugar	45	When packed	18	28	Do.
		After 48 hours	18	36	Do.
		After 96 hours	36	24	Moderate.
4 plus 1	45	When packed	18	28	None.
		After 48 hours	15	24	Do.
		After 96 hours	33	12	Moderate.
2 plus 1	45	When packed	18	28	None.
		After 48 hours	21	48	Do.
		After 96 hours	12	28	Do.
No sugar	30	When packed	18	28	Do.
		After 48 hours	9	40	Do.
		After 96 hours	27	48	Do.
		After 216 hours	18	40	Do.
4 plus 1	30	When packed	18	28	Do.
		After 48 hours	18	20	Do.
		After 96 hours	24	16	Do.
		After 216 hours	15	52	Do.
2 plus 1	30	When packed	18	28	Do.
		After 48 hours	12	40	Do.
		After 96 hours	15	28	Do.
		After 216 hours	18	40	Do.

The data presented in Table 10 and the results of other experiments not here reported indicate that under the conditions of the experiments there was a marked increase in the yeast count in fruit packed without sugar and held at high temperatures. The presence of cane sugar was a decided deterrent to the multiplication of the yeast cells, no significant increase being found in the 2 plus 1 pack. Keeping the fruit in the open air prior to packing only slightly increased these counts.

The mold counts did not show an increase under the anaerobic conditions present deep in the fruit mass in barrels of berries even with high temperatures and when the berries had been packed without sugar. The mold count increased rapidly, however, while the fruit was standing in contact with the air, prior to packing. Fermentation in the fruit packed without sugar and in that packed 4 plus 1 and held at 75° F. was noted within 18 hours. This is very important when it is considered that from 10 to 12 hours elapse after barrels are placed in storage before any appreciable cooling occurs in the center of the barrel. These data indicate that fruit packed without sugar or with sugar in low concentration must be moved to storage promptly and cooled as quickly as possible if fermentation is to be avoided.

A temperature of 45° F. preserved the fruit without fermentation during the time covered by these tests. No measurable fermentation had occurred at the end of 72 hours in the fruit packed without sugar or at the end of 120 hours in the fruit packed 4 plus 1. Fruit packed 4 plus 1 and 2 plus 1 and stored at 30° showed no fermentation in 20 days. There was no consistent increase in yeast or mold count in any of the lots held at 45° or lower while the experiments were in progress.

It will be noticed that fermentation was present in samples having a yeast and spore count as low as 18, although the average spore count for raspberries in which fermentation occurred was somewhat higher. Since many samples can be found which have counts of the same or even of greater magnitude but in which no measurable fermentation occurred, it is evident that while the magnitude of the yeast and spore population is in many cases an indication that fermentation is taking place or has occurred previous to the sampling, it is not necessarily so in all cases. Large yeast and spore counts suggest that the fruit may have been improperly handled after packing, or if accompanied by mold counts of considerable magnitude may indicate that such fruit was of inferior quality at packing time. The physiological reasons for the possibility of fermentation occurring with relatively low yeast and spore counts have already been mentioned. The finding of alcohol in the fruit mass is positive evidence, of course, that fermentation has occurred.

Prompt packing of the fruit will improve its quality, especially since mold development is thereby reduced. Prompt cooling to a temperature of at least 40° F. is, however, the best insurance against fermentation and spoilage. In the fruit held at 30° there was no fermentation in any of the samples, even after a delay of 40 hours before the fruit was placed in storage. Freezing of the organisms of course entirely stops their development and prevents fermentation.

As the data obtained for Cuthbert raspberries and Evergreen blackberries were similar to those obtained for strawberries, they are not presented in detail.

It seemed, however, that, all other conditions being the same, the original yeast and spore counts on raspberries were generally higher than those on strawberries. Fermentation seemed to begin more readily in raspberries and spoilage occurred more quickly when the fruit was held at relatively high temperatures for some little time before being packed. A lowering of the temperature from 75° to 60° F. slightly reduced fermentative activity and probably the development of organisms, but temperatures around 40° were required to retard these processes materially.

SUMMARY

The rates of cooling and freezing of frozen-pack berries packed in different types of containers and exposed to freezing temperatures are given.

The rate of cooling of such fruit is slowest in the center of the container, and it is at this point that there is the greatest danger of fermentation and spoilage. The lower the holding temperature, the sooner the fruit will be cooled below the temperature at which fermentation can take place.

It requires approximately twice as long to cool fruit packed in the center of a barrel to a temperature of reasonable safety from fermentation with air temperature at 30° F. as is required if the temperature is 0°; at 15° it requires about half a day longer than at 0°.

There appears to be little significant difference in the rate of cooling of strawberries, raspberries, or Logan or other blackberries.

The use of ice in the centers of the barrels markedly increases the rate of cooling in that portion of the fruit mass, although there are some trade objections to the practice. Precooling the fruit prior to filling the barrels results in the maintenance of very satisfactory temperatures in the berries from the time they are packed.

The smaller the container, the more rapid will be the cooling. Fruit packed in cans cools faster than that packed in wooden containers of similar capacity.

Fruit packed with cane sugar cools slightly faster than fruit packed without sugar. The more sugar in the pack the more rapid the rate of cooling.

The use of considerable quantities of cane sugar in packing frozen-pack fruit retards the development of yeasts and molds (even at relatively high temperatures), reduces the danger of fermentation, preserves the color of the fruit, and to some extent preserves the flavor and the aroma of the berries. Its use, however, has some disadvantages, and only the necessary quantity should be used. Raspberries can be packed quite satisfactorily without sugar. Strawberries, however, are preserved in much more satisfactory condition if packed with sugar.

The addition of cane sugar to the berries causes a withdrawal of water from the fruit. The sugar dissolves in this juice and forms a concentrated sirup, which gradually drains to the bottom of the container. Hence after a few days in storage the sirup concentration in the fruit mass in the lower portion of the barrel is considerably higher than that in the upper portion. For any of the commercial packs, it seems to be very nearly a saturated solution of cane sugar at the prevailing temperatures. The concentration in the top of the barrel varies more widely, depending on the proportions of cane sugar and berries used.

One of the results of this withdrawal of water from the berries is a shrinkage in tissue volume more or less proportional to the sugar concentration. This decrease in size seems to occur relatively soon after the fruit is packed, occurring mostly in the first 24 hours. In high sirup concentrations the fruit tissues may eventually become tough and leathery.

The best means of mixing sugar throughout the fruit mass was not definitely established by these tests. As a practical measure, the frequent addition of sugar in small quantities as packing goes on and the storing of the barrels in a position the reverse from that in which they were packed appears to be most satisfactory. This procedure has generally resulted in the berries being more attractive in appearance and having a more pleasing flavor. The mechanical jolting method of settling the fruit mass in the container is preferable to shaking it by hand, because the undissolved sugar does not so readily sift through to the bottom.

Ice formation in barrels of berries exposed to freezing temperatures invariably begins in the fruit mass at the top and extends down the sides of the container. This is probably because of the lower sirup concentration in the top of the barrel, and the consequent higher freezing point of the fruit mass in that part of the container.

Practically no ice formation occurs in the bottoms of barrels, except after long storage at low temperatures. Even then, with the relatively high sirup concentrations, the frozen mass is slushy rather than hard and crystalline.

Fruit tissues expand in volume to a considerable degree during freezing. Whether the fruit is packed either with or without sugar, if freezing is prolonged or very rapid, precautions should be taken to prevent the bursting of the containers, especially when these have been filled to capacity.

Hard freezing, such as is generally obtained at 0° F., especially if small containers are used, is not always necessary for the proper preservation of frozen-pack fruit. There is some question as to whether very rapid freezing of this kind does not extract water from the fruit in such a way as to result in a more disintegrated product when thawed than does the employment of temperatures of 10° to 15°. The rapid cooling that takes place in barrels of frozen-pack berries when exposed to temperatures around 0° is often desirable for the quick retardation of fermentative processes and the development of organisms, but to hold the fruit at such temperatures is unnecessary.

There was considerable variation in the concentration of soluble solids in the juice of berries that appeared to be at about the same stage of maturity. As the berries matured there was generally an increase in soluble solids in the juice, but in the same berry there was comparatively little difference between the concentrations in the juice from the firm and that from the soft side or between that from red-colored and that from greenish white portions of unripe berries.

Determinations of soluble solids made on the juice taken from the central portions of berries packed in different sugar concentrations, as well as that pressed from the outer portions of the fruit, did not show any consistent or significant differences such as would occur if there were an actual penetration of sugar into the fruit tissue.

The chemical characteristics of berries which are important in the manufacture of jams and jellies are not significantly affected by storage of the fruit in the frozen state. The texture of strawberries, for preserving purposes at least, may be considerably improved by frozen storage, but strawberries frozen without sugar showed a decided loss in flavor and color as compared with the fresh fruit at the time of packing.

The studies on yeast and spore population and mold development in frozen-pack berries emphasize the importance of packing only clean, fresh fruit and the need for prompt cooling to at least 40° F. in the center of the fruit mass.

Although it requires freezing temperatures to actually stop the development of organisms in frozen-pack berries, reduction to a temperature of 40° F. as quickly as possible will very markedly retard the growth and multiplication of organisms and reduce the danger of fermentation and spoilage.

After the fruit mass in the containers is frozen, a temperature of 15° to 20° F. has been found satisfactory for long storage.

Studies on the yeast-spore population and mold growth in strawberries as they are delivered for packing indicate that a considerable variation can be expected even in berries that are apparently in an entirely satisfactory condition. In general, the counts are low, ranging in these tests from 4 to 24 for the yeasts and spores, and from 4 to 20 per cent for the molds, according to the Howard and Stephenson method of microanalysis. The magnitude of these numbers depends on various cultural and climatic conditions.

In raspberries apparently in a satisfactory condition the yeast and spore counts have generally been higher than in any of the other berries seemingly in the same condition that were used for the frozen pack.

Under the conditions existing in barrels of berries there is a marked increase in the yeast count in fruit packed without sugar and held at high temperatures. The presence of sugar greatly reduces the rate of multiplication of the yeast cells, no significant increase having been found in the 2 plus 1 pack. The mold counts do not show an increase under the partially anaerobic conditions present deep in the fruit mass in barrels of berries, even with high temperatures and in packs containing no sugar. The mold count increases rapidly, however, while the fruit is in contact with the air, prior to packing.

Fruit packed without sugar or with low cane-sugar concentrations must be moved to storage promptly and cooled as quickly as possible if fermentation is to be avoided.

The magnitude of the yeast and spore population is in many cases an indication that fermentation is taking place or has occurred previous to sampling, but it is not necessarily so in all cases. Large yeast and spore counts suggest that the fruit may have been improperly handled after it was packed, or if accompanied by mold counts of considerable magnitude it may indicate that such fruit was inferior in quality at packing time. The presence of alcohol in the fruit mass is positive evidence that fermentation has occurred.

Harvesting the fruit at the proper stage of maturity, careful handling, prompt packing, quick cooling to freezing temperature, and freezing are the essential factors in the satisfactory preservation of frozen-pack fruit.

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