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STORAGE OF PERISHABLE FRUITS
AT FREEZING TEMPERATURES

PRELIMINARY REPORT

BY

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INTRODUCTION

Many quickly perishable fruits such as berries, apricots, cherries and others can not be held successfully for very long periods at the usual cold storage temperatures for fruit, of 32° F. to 35° F. because of rapid softening and decay. If held without preliminary treatment at a temperature of 10° F., low enough to freeze the fruit, there is a tendency in certain fruits for the color to become brown and the flavor seriously impaired. It, therefore, seemed desirable to make a preliminary experimental study of methods of treating the above fruits before storage, at 10° F. to prevent or minimize undesirable changes in color and flavor. At these low temperatures molding or fermentation does not occur and ripening processes are effectively arrested. Therefore, if the problems of retention of color and retention of flavor could be satisfactorily solved, this method of storage should have wide application.

The investigations have included not only experiments upon the storage of various quickly perishable fruits, but also upon the utilization of such fruit in canning, preserving, confections, etc., after six to ten months storage.

The data of the first year's experiments have been so promising that it is believed the results will be of considerable immediate value to cold storage establishments, ice cream manufacturers, fruit preserving factories, and others. Former breweries are equipped with large refrigerating plants, very large glass lined or wooden tank cold storage capacity, and other facilities which could be used for the receiving, preparation and storage of the types of fruits used in the tests. It is probable that a very extensive market could be quickly developed for such fruits during the winter and early spring months and it is believed that the development of such an industry offers a very attractive field.

REVIEW OF PREVIOUS WORK

The extensive keeping of such quickly perishable fruits under refrigeration is a comparatively new undertaking. A few storage houses have adopted certain methods for particular fruits which enable them to keep the product for a considerable period of time

by employing freezing temperatures. Usually different methods are employed by the different houses. As a rule, they have simply found satisfactory methods and have not definitely determined that these are the best.

Fulton¹ in 1907 mentioned that in certain of the larger cities the practice of freezing small fruits for the purpose of holding them indefinitely in a frozen condition to be used in making ice cream and pastries had come into use to a limited extent among confectioners, bakers and restaurateurs. He pointed out that much of the fruit used for this purpose was bought when the market price was low, such as on Saturday evenings or when the market was glutted. The fruit was hurried into cold storage and frozen at a temperature ranging from about 5° F. to 12° F. Previously some restaurateurs had packed berries in dry granulated sugar and held them at a temperature of 31° F. to 32° F., but this practice has been discarded and the freezing method adopted.

Fulton gives further information based primarily upon observations, stating that frozen strawberries for ice cream have been used in a limited way by confectioners, while frozen blackberries, currants, blackcap raspberries, huckleberries, and other small fruits were being used successfully for pies and other pastries by a few restaurateurs and bakers. He cites the hearsay that when made into pies the flavor of the product was said to be practically equal to that made of fresh fruit. Considerable quantities of cherries and damson plums were also frozen by one company for use in pies. Usually these latter fruits were put into the pies whole without seeding. Sometimes, however, they were dipped into cold water to take out the frost and then pitted. The fact was noted that frozen cherries and plums shriveled somewhat in baking, and were therefore not used so successfully as some of the berries.

Fulton also mentions two tests made by the Bureau of Plant Industry. In one test Gandy strawberries were frozen and held at a temperature of 10° F. to 14° F. for ten months in tight paper wrapped cartons of paraffined cardboard, with very little change in color and practically no shrinkage. Berries frozen in open crates at the same time evaporated and shrunk away fully one-half within a few months. Fulton's advice was that if the fruit was intended for long preservation, it should be placed in loosely covered tin cans to prevent evaporation, but if it was to be kept only a short time, it could be stored in the ordinary crates in which it was conveyed to market.

¹ S. H. Fulton, The Cold Storage of Small Fruits, Bur. Plant Ind., Bull. No. 108, U. S. D. A., 1907.

In the other test Gandy and Tennessee varieties of strawberries and Miller and Kansas raspberries were frozen and stored in different styles of packages at a temperature of 12° F. in a general freezing room containing meats, poultry, and game. The packages used were (1) paper-wrapped paraffined cardboard carton; (2) the same carton with an additional heavy paraffined paper wrap over the cardboard, which with the outside paper jacket constituted a triple thick carton; and (3) the common open slat crate generally used. After approximately seven months, the fruit was still normal in appearance except for a slight fading in the color of the strawberries and a slight shrinkage of both strawberries and raspberries in the open crates. The fruit in the closed packages was plump and attractive in appearance. The flavor of the fruit of both strawberries and raspberries in the open crates was objectionable since apparently the fruit had absorbed odors from other commodities in the storage room. The flavor of the fruit in the triple box was a little better, but Fulton believed it had been "tainted" through the effect of the carbon-dioxide gas exhaled by the fruit before it was solidified in freezing. The flavor of the fruit in the double carton which was not so impervious to the air, was not contaminated, and it retained much of the sprightliness and flavor of the fresh fruit. In Fulton's judgment this test seemed to indicate that for frozen fruit, the best results can be obtained by the use of a closed package provided the package is not so tight as to prevent the escape of the gases given off by the fruit after it is packed and before it is frozen.

Darrow² writes of two methods of preserving strawberries in cold storage which seem to be practices followed by a few cold storage houses. The first method is suggested as being adapted for packing small quantities of strawberries for use when not in season, with the preservation of the fresh-fruit flavor. Sound, ripe berries are selected, washed and hulled. A tin of convenient size to which a tight cover can be fitted is used. To each ten pounds of fruit one cup of sugar is added. The cans are filled with sugar and berries, the tops are fitted on and their edges covered with the adhesive tape used in sealing packages. The containers of fruit are then put in freezing cold storage and kept frozen until wanted. Darrow describes this product as being satisfactory when used for short-cakes, by restaurants and hotels, and as crushed fruit at soda fountains, and by ice cream manufacturers.

The second method outlined is referred to as being the one employed by the large manufacturers of the crushed fruits and syrups

² George W. Darrow, Strawberry Culture, Western United States Farmers' Bulletin 1027, U. S. D. A., 1919.

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used by the soda fountain and ice cream trade in the preparation of their product. The uncooked berries are kept in barrels in cold storage, preserved in the following manner: the strawberries are hulled, sorted and then washed. The washing is done by running the berries on a belt through a tank of water. They are then conveyed over another belt, where they are slowly turned and sprayed with water. After the washing, the berries drop into pans and are weighed. From one-half to one pound of sugar is added to each pound of berries, proportions used depending upon the variety, the ripeness of the fruit, the moisture conditions, and the way in which the product is to be used. The proportions most commonly used are one-half pound of sugar to one pound of fruit.

Heavy water-tight barrels holding about 375 pounds of the mixture of berries and sugar are used. Before use they are carefully cleaned and coated on the inside with parafine, which is applied hot with a paint-brush. The sugar and berries are put in alternate layers and mixed by a machine or by hand. As soon as the barrels are headed they are shipped in a refrigerator car to a cold storage warehouse, where they are held at a temperature of 30° F. or lower. Several thousand barrels of strawberries are put up in this manner each year.

Darrow writes that if equal weights of sugar and berries are used, the barrels of fruit may be stored at a temperature of 34° F. to 36° F., but if the fruit is to be held for long periods the flavor is best preserved at a lower temperature.

EFFECT OF PRELIMINARY TREATMENT³

The experiments reported in this publication have been divided into two groups, namely "Effect of Preliminary Treatment" and "Utilization of Fruits from Freezing Storage."

During the summer of 1919, strawberries, loganberries and red raspberries, currants, Royal Anne cherries and Royal Apricots were received at the University. With the exception of the apricots, which came from the University Farm at Davis, the fruits were purchased from local commission houses. The cherries were grown in Oregon; the other fruits were California-grown products. The fruits were prepared in the Fruit Products Laboratory for storage. In most cases stoneware crocks were used as containers. The fruit was then placed in rooms of the cold storage plant of the Division of Pomology. Temperatures of 32° F. and 10° F. were compared and small lots of the fresh fruits were made into preserves and stored in glass jars

³ The authors wish to thank Mr. A. W. Christie, Instructor in Fruit Products, for suggestions and assistance given during preparation of the fruit for storage.

at room temperature to serve as checks for the various lots held in cold storage.

The following tables and observations summarize the results obtained.

TABLE 1.—CHERRIES

Stored at 8° F. to 12° F.

Date stored, June 23, 1919.

Expt. No.	Treatment before storing	Notes on August 2, 1919	Samples taken out and thawed on January 23, 1920			Date spoiled at room temperature
			Color	Flavor	Texture	
15	Whole cherries, no treatment	Brown color	Dark brown	Good to fair	Medium	January 27th.
5	Pitted cherries	Brown color	Dark brown	Good to fair	Medium	January 27th.
1	Pitted, frozen in water	Color not changed	Very good, natural	Excellent	Good	January 29th.
2	Pitted, frozen in 10% sugar solution	Color not changed	Very good, natural	Excellent	Good	January 29th.
3	Pitted, frozen in 20% sugar solution	Color not changed	Very good, natural	Excellent	Good	January 29th.
4	Pitted, frozen in 40% sugar solution	Color not changed	Very good, natural	Excellent	Good	January 29th.
7	Same as No. 1 but heated to 175° F. before storage	Color pinkish	Bleached to greyish pink	Very good	Medium to poor	January 27th.
8	Same as No. 2, but heated to 175° F. before storage	Color pinkish, color and flavor gone into juice to some extent	Bleached to greyish pink	Very good	Medium to poor	January 27th.
9	Same as No. 3, but heated to 175° F. before storage	Color pinkish, color and flavor gone into juice to some extent	Bleached to greyish pink	Very good	Medium to poor	January 27th.
10	Same as No. 4, but heated to 175° F. before storage	Color pinkish, color and flavor gone into juice to some extent	Bleached to greyish pink	Very good	Medium to poor	January 28th.
11	Same as No. 1, but heated to 212° F. before storage	Color bleached	Bleached to greyish pink or light gray	Good	Poor	January 27th.
12	Same as No. 2, but heated to 212° F. before storage	Color bleached	Bleached to greyish pink or light gray	Good	Poor	January 27th.

TABLE 1 —CHERRIES—(Continued)

Expt. No.	Treatment before storing	Notes on August 2, 1919	Samples taken out and thawed on January 23, 1920			Date spoiled at room temperature
			Color	Flavor	Texture	
13	Same as No. 3, but heated to 212° F. before storage	Color bleached	Bleached to greyish pink or light gray	Good	Poor	January 27th.
14	Same as No. 4, but heated to 212° F. before storage	Color bleached		Good	Poor	January 29th.
18	Same as No. 11, but heated to 212° F. 20 min. before storage	Color bleached	Bleached	Good	Flavor of cherry in juice	
	At Room Temperature:					
6	Cherries in water with sulfurous acid		Bleached white	Flavorless	Tough	
	At 32 F.:					
16	Whole cherries	Spoiled before August 2d.				

TABLE 2.—APRICOTS

Stored at 8° F. to 12° F.

Date stored, July 31, 1919

Expt. No.	Treatment before storage	Observations, December 5, 1919	Observations, February–March, 1920			After 15 days at room temperature
			Color	Flavor	Texture	
1	Whole fruit	Color of skin dark, flavor good	Flesh light, skin dark	Disagreeable cold storage flavor	Very soft	Spoiled
2	Halved and pitted	Browned badly, flavor good	Browned	Disagreeable flavor	Very soft	Spoiled
2a	Halved and pitted in water	Very bright color, flavor good	Bright	Good, fresh	Rather soggy	
3	Halved and pitted in 30% sugar syrup	Color good; taste somewhat too sweet	Good	Excellent	Better than in water	Sour
4	Same as No. 3, but 50% syrup used	Color good, sweet, not frozen	Good	Very good	Better than in water	Poor flavor
5	Crushed	Frozen solid, flavor good, brown only on top	Good	Good, fresh		Spoiled
6	Crushed+equal sugar	Not frozen, good flavor and color	Good	Very good		No change
7	Halved, 50% sugar syrup, heated to 165° F.	Good color, tastes sweeter than No. 4	Good	Preserve-like flavor but good	Very soft	Fermented
8	Same as No. 7, but heated to 212° F.	Good color, tastes sweeter than No. 4	Good	Not so good as No. 7, more preserved flavor	Very soft	Sour, moldy
13	Crushed+ $\frac{1}{2}$ sugar and boiled	Good color and flavor	Good	Not so good as No. 7, more preserved flavor		No change
9	Stored at 32 F.: Same as No. 5	Moldy by Aug. 15, 1919				
10	Same as No. 6	As good as No. 6	Good	Good		No change
11	Whole fruit (as No. 1)	Moldy by Aug. 20, 1919				
12	Crushed+equal sugar, heated to 212° F.	Coating of sugar on top, good color and flavor	As on Dec. 5	As on Dec. 5, preserve-like flavor		

TABLE 3.—LOGANBERRIES

Stored at 8° F. to 12° F.

Date stored, July 3, 1919.

Expt. No.	Treatment before storing	Notes on August 14, 1919	Samples taken from storage on January 20, 1920			Date spoiled at room temperature
			Color	Flavor	Texture	
1	None	Color and flavor good, probably not quite so good as No. 2	Natural, a trifle bleached	Aroma not so good as No. 3, fresh good flavor	Fair	January 23d.
2	Crushed	Frozen, solid mass, color and flavor good	Natural or a trifle lighter	Aroma not so good as No. 3, fresh good flavor		January 24th.
3	Crushed + equal sugar	Not frozen, flavor excellent	Natural	Rich aroma, flavor very sweet, excellent	Some berries hard; in general good	February 28th discontinued, very slight deterioration
4	Crushed + equal sugar, heated to 165° F.	Not quite so good as No. 2, slight preserved flavor	Natural	Same as No. 3, but slight preserved flavor	Soft	February 28th discontinued, very slight deterioration
5	Crushed + equal sugar, heated to 212° F.	Not quite so good as No. 2, slight preserve flavor	Natural	Same as No. 3, but preserved flavor somewhat more pronounced	Soft	February 28th discontinued, very slight deterioration
6	Crushed, heated to 212° F.	Color and flavor good, but slight preserve flavor	Natural	Similar to No. 2 but not so fresh in flavor	Soft	January 25th.
7	Stored at 32° F. Drawer of fruit	Molded by July 27th.				

TABLE 4.—STRAWBERRIES

Stored at 32° F.

Date stored, July 3, 1919.

Expt. No.	Treatment before storing	Observations on August 14, 1919	Samples removed from storage January 28, 1920			Date of spoiling at room temperature
			Color	Flavor	Texture	
1	No treatment (2 baskets)	Spoiled				
2	Stemmed (2 baskets)	Spoiled				
16	Crushed + equal sugar	Flavor and color good	Very good	Good (very sweet)		Color faded but flavor fair on March 6, 1920 when discarded
21	Crushed + equal sugar and heated to 212° F.	Slight preserve flavor, color good	Good, very slightly faded and somewhat brownish	Slight preserve flavor; too sweet		Color faded but flavor fair on March 6, 1920 when discarded
22	Crushed + 1½ wt. sugar, heated to 212° F.	Slight preserve flavor, color good	Good, but very slightly faded	Preserve flavor		Color faded but flavor fair on March 6, 1920 when discarded
	Stored at 8° F. to 12° F.:					
8	Stemmed (4 baskets)	Frozen solid, color and flavor good	Good, slightly bleached	Fresh	Soft	
3	Stemmed, stored in water	Flavor very good, some color in the water	Natural, good	Fresh, very good	Soft	January 31st.
4	Stemmed, stored in 10% sugar syrup	Better than No. 3 for flavor, some color in syrup	Natural, good	Fresh, excellent	Soft	February 2d. (sour)
5	Stemmed, stored in 20% sugar syrup	Better than No. 3 for flavor, some color in syrup	Natural, good	Good excellent	Soft	February 2d. (sour)
6	Stemmed, stored in 40% sugar syrup	Better than No. 3 for flavor	Natural, good	Good (sweet)	Soft	February 4th.

TABLE 4.—STRAWBERRIES—(Continued)

Stored at 8° F. to 12° F.:

Date stored, July 3, 1919.

Expt. No.	Treatment before storing	Observations on August 14, 1919	Samples removed from storage January 28, 1920			Date of spoiling at room temperature
			Color	Flavor	Texture	
7	Stemmed, stored in 60% sugar syrup	Better than No. 3 for flavor, some color in syrup	Natural, good	Good, but some what too sweet	Soft	February 6th.
9	Crushed berries, no sugar	Flavor and color good	Natural, good	Good, fresh		February 2d. (sour)
10	Crushed berries + $\frac{1}{4}$ wt. of sugar	Flavor and color better than No. 9	Natural, good	Very good (sweet taste)		February 6th.
11	Crushed berries + $\frac{1}{2}$ wt. of sugar	Flavor and color better than No. 9, plastic	Natural, good	Very good (sweet taste)		February 16th.
12	Crushed berries + $\frac{3}{4}$ wt. of sugar	Nearly unfrozen, color good	Natural, good	Very good (quite sweet)		Color impaired but flavor fair; discontinued on March 6th
13	Crushed berries +equal wt. of sugar	Unfrozen, color good	Natural, good	Very good (very sweet)		Color impaired but flavor fair; discontinued on March 6th
14	Crushed berries + $1\frac{1}{4}$ wt. of sugar	Unfrozen, too syrupy, color good, berries tend to float	Natural, good	Very good (too sweet)		Color impaired but flavor fair; discontinued on March 6th
15	Crushed berries + $1\frac{1}{2}$ wt. of sugar	Unfrozen, too syrupy, color good, berries tend to float	Natural, good	Very good (too sweet)		Color impaired but flavor fair; discontinued on March 6th
17	Same as No. 11, but heated to 165° F.	Flavor scarcely as fresh as No. 11, some preserve flavor	Slight darkening	Sweet, slight preserve flavor		February 20th.
18	Same as No. 13, but heated to 165° F.	Syrupy, color good	Good, but slight darkening	Very sweet, some preserve flavor		March 6th color impaired, flavor fair; discontinued

TABLE 4.—STRAWBERRIES—(Continued)

Stored at 8° F. to 12° F.

Date stored, July 3, 1919.

Expt. No.	Treatment before storing	Observations on August 14, 1919	Samples removed from storage January 28, 1920			Date spoiling at room temperature
			Color	Flavor	Texture	
19	Same as No. 15, but heated to 165° F.	Syrupy, color good	Good, but slight darkening	Too sweet, some preserve flavor		March 6th color impaired, flavor fair; discontinued
20	Same as No. 13, but heated to 212° F.	Preserve flavor, color deeper red than No. 13	Darkening of natural color	Very sweet, more preserve flavor than No. 18		
23	Whole berries, stemmed + equal sugar and heat to 212° F. for 4 minutes	Preserve flavor marked, color decidedly darker	Dark red not natural red	Very sweet, more preserve flavor than No. 18	Fair, as in preserves	Color nearly unchanged, flavor same
24	Same as No. 23, but 1½ sugar by weight added at room temperature	Preserve flavor marked, color decidedly darker	Dark red not natural red	Too sweet	Fair, as in preserves	Color nearly unchanged, flavor same
25	Strawberries + equal weight of sugar heated to boiling and sealed hot in jars, stored at room temperature	Quality and color fair	Bleached to light brown	Poor	Soft	

TABLE 5.—RED RASPBERRIES AND CURRANTS

Stored July 3, 1919

Expt. No.	Treatment before storing	Observations, August 14, 1919	Observations, January 20, 1920, on thawed samples from storage			Date of spoiling at room temperature
			Color	Flavor	Texture	
1	RASPBERRY* No treatment	Solid, color good flavor good	Very good	Very good	Fair to soft	January 23d.
2	RASPBERRY* Crushed + $\frac{2}{3}$ wt. of sugar	Plastic, color and flavor good	Very good	Very sweet, excellent	Seeds con- spicuous	February 12th.
3	RASPBERRY* Same as No. 2 but heated to 165° F.	Plastic, color good, flavor not quite as good as No. 2	Good	Very sweet, excellent	Seeds con- spicuous	February 16th.
4	RASPBERRY* Same as No. 2 but heated to 212° F.	Plastic, color good, flavor not quite as good as No. 2	Good	Very sweet, excellent	Seeds con- spicuous	February 16th.
5	RASPBERRY* Crushed, heated to 112° F.	Solid, color and flavor good	Good	Very sweet, excellent	Seeds con- spicuous	January 23d.
6	RASPBERRY† Untreated	Date of mould- ing earlier than August 14th.				
7	RASPBERRY† Made into jam and stored at room temper- ature	Color and flavor good	Brown	Poor	Poor	
1	CURRANTS (red)* No treatment	Solid, color and flavor good	Good	Good	Soft	January 23d.
2	CURRANTS (red)* Crushed + equal sugar	Unfrozen, fresh color and taste	Good	Excellent very sweet		Test dis- continued on Feb- ruary 28th flavor slightly stale
3	CURRANTS (red)* Crush + equal sugar, heat to 212° F.	Darker than No. 2, unfrozen	Good	Not as fresh as No. 2, more preserved taste		Test dis- continued on Feb- ruary 28th flavor slightly stale

*Stored at 8° F.—12° F. †Stored at 32° F.

TABLE 6.—GRAPE JUICE AT 8° F. TO 12° F.

On September 20th, 1919, several lots of ripe grapes of the varieties indicated in the following table were received from the University Farm. The red varieties were crushed; heated to 150° F., and pressed to extract the color. White varieties were crushed and pressed only. The juices were strained and placed in cold storage at 8° F. to 12° F. in open stoneware crocks. Check lots of the same juice were pasteurized at 165° F. in glass bottles and stored at room temperature for future comparison with the lots from cold storage.

Lot	Variety	Treatment	Observations, May 11, 1920
1	Alicante Bouschet	Stored at 8° F. to 12° F.	Color deep purplish red, flavor good, rich and fresh. No cooked taste. Superior to No. 2
2	Alicante Bouschet	Pasteurized at 165° F., stored at room temperature	Inferior to No. 1 in color, flavor, and aroma; noticeable cooked taste; color brownish red
3	Muscat	Stored at 8° F. to 12° F.	Flavor and aroma equal to those of fresh grapes although not so intense. Probably some flavor and aroma have evaporated. Much superior to No. 4
4	Muscat	Pasteurized at 165° F., stored at room temperature	Inferior to No. 3; "raisin pie" flavor
5	Muscat + Alicante Bouschet	Stored at 8° F. to 12° F.	Rich Muscat flavor; color purplish red; much superior to No. 6
6	Muscat + Alicante Bouschet	Pasteurized. Stored at room temperature	Inferior to No. 5. Color brownish red. Flavor cooked. Aroma poor. Juice is better than average commercial juice
7	Isabella	Stored at 8° F. to 12° F.	Very rich Isabella flavor and aroma. Color deep purplish red
8	Isabella	Pasteurized, stored at room temperature	Inferior to No. 7. Color brownish red. Flavor noticeably cooked
9	Petite Sirah	Stored at 8° F. to 12° F.	Flavor about same as fresh juice. Color deep purplish red. No noticeable cooked taste
10	Petite Sirah	Pasteurized, stored at room temperature	Inferior to juice No. 9. Color brownish red. Flavor cooked

DISCUSSION OF TABLES

From the results given in the foregoing tables certain conclusions may be drawn. The discussion of the results of the various tables will be taken up according to the individual fruits.

Cherries.—Untreated cherries in open containers stored at 8°–12° F. soon became brown in color throughout by oxidation. This held true for both the pitted and unpitted fruit.

Freezing the untreated cherries in water prevented darkening of the color during storage probably as a result of the exclusion of air.

The natural light pink color of the Royal Anne was well preserved by this method. The substitution of syrups varying from 10–40% cane sugar content seemed to be no improvement over water as a storage medium, in so far as retention of color, quality and texture of the fresh fruit was concerned, although these syrups added something to the flavor.

Heating the fruit to 175° F. in water or dilute syrups before storage resulted in bleaching of the color of the cherries and in the imparting of a noticeable cooked taste. Heating to 212° F. intensified these defects giving a product very similar to ordinary canned cherries. Therefore, heating the fruit before storage seems inadvisable and an unnecessary expense.

Untreated cherries stored at 32° F. soon became moldy. No storage tests of this fruit in syrups at 32° F. were made.

Cherries stored in sulfurous acid by the usual commercial methods were inferior in flavor to those stored by the various freezing methods noted above.

Apricots.—This fruit gave excellent results in several methods of storage at 8°–12° F. because of its stable color and rich flavor.

The skin of whole untreated fruit stored at 8°–12° F. became brown; both the skin and flesh of the halved untreated fruit became brown at 8°–12° F. The fruit in both cases after several months' storage developed a very disagreeable "cold storage" flavor rendering the products made from them almost inedible.

The halved fruit stored at 8°–12° F. in water or in syrups of 30% and 50% cane sugar, retained a remarkably fresh flavor and color, although the fruit softened noticeably on thawing. It appeared equal in all other respects to the fresh fruit.

The crushed fruit with an equal weight of sugar added and stored at 8°–12° F. retained its fresh flavor and color in an excellent manner. It was found very suitable for ice cream, short cake, etc. Very ripe fruit required only about one-half its weight of sugar to give good

results. Fruit crushed and with no sugar added, became brown at the surface, but the remainder of the lot to which air had no access was of excellent fresh color and flavor, indicating that sugar is not necessary for the retention of flavor and color of the crushed fruit.

Crushed fruit at 32° F. spoiled in about two weeks. Crushed fruit plus an equal weight of sugar stored at 32° kept perfectly. This same mixture heated to 212° F. and stored at 32° F. kept well, but possessed an "apricot preserve" flavor. The unheated fruit was preferable to the cooked article and much superior in flavor to the ordinary canned apricot of commerce.

Loganberries.—Fewer tests were made upon this fruit than upon strawberries. Because of its extremely rich and permanent flavor as well as its deep color, the loganberry is a very satisfactory fruit for freezing storage.

The fruit kept fairly well without treatment at 8°–12° F. There was, however, considerable shriveling and some loss of color and flavor.

Untreated crushed fruit kept perfectly and seemed equal to the fresh fruit in every way. Sugar added to the crushed fruit reduced its tart flavor and made the fruit richer than the unsweetened article.

Heating the crushed and sweetened fruit to 165° F. and 212° F. imparted a noticeable "jam"-like flavor. Heating is not recommended although it does deepen the color of the juice and softens the fruit. Unheated sweetened fruit if not thoroughly crushed tended to become hard through the effect of the sugar's removing moisture from the berries.

Untreated fruit at 32° F. became moldy in less than three weeks time. No tests of sweetened fruit were made at this temperature.

Red Raspberries.—This fruit required less sugar than loganberries for the imparting of a rich flavor.

The untreated fruit at 8° F. to 12° F. shriveled slightly but retained its color and flavor well.

The crushed fruit plus two-thirds its weight of sugar retained more of the fresh fruit aroma and flavor than did the unsweetened fruit. This amount of sugar rendered the fruit very sweet in flavor; a slightly smaller proportion would have been sufficient. The seeds of the crushed berries were quite conspicuous.

Heating the fruit to 212° F. before storage imparted a cooked flavor. The unheated fruit was preferable to the heated product.

Currants.—Untreated currants at 8°–12° F. retained their color and flavor remarkably well and were as suitable for jelly and jam as the fresh fruit. The crushed fruit to which was added an equal weight of sugar retained its fresh flavor to a greater degree than did

the untreated fruit. Heating the crushed fruit to boiling before storage injured the quality slightly and is not recommended.

Strawberries.—Strawberries held untreated at 32° F. spoiled in less than six weeks. The same fruit after crushing and mixing with an equal weight of sugar retained very well its flavor, color and aroma without molding or fermenting at 32° F. Heating the crushed fruit and sugar before storage injured the color and flavor. The use of one and one-half times as much sugar as fruit was tested, but this amount of sugar is not necessary and rendered the fruit too sweet.

Berries frozen in water or dilute syrups and stored at 8°–12° F. were superior to the same fruits stored untreated at this same temperature. The berries tended to float in very heavy syrups. The flavor and color of the fruit stored in water was as good as those of the lots stored in syrups. Untreated berries in open containers shriveled slightly and lost some of their color.

Crushed unsweetened berries retained their flavor and color very well at 8°–12° F. The addition of sugar to the crushed berries before storage made the flavor richer but this addition is not necessary. With more than an equal weight of sugar the crushed fruit tended to float.

Heating the crushed fruit impaired the color and quality.

Strawberries preserved by the usual household method by cooking with an equal weight of sugar and storing in sealed containers were much inferior to fruit preserved at 8°–12° F. after similar preliminary treatment; and very much inferior to the sweetened unheated fruit stored at 8°–12° F.

Grape Juice.—All grape juices stored 8°–12° F. were very much superior in every respect to the same juices preserved by pasteurizing at 165° F. The bright fresh color of the juices from cold storage was in great contrast to the brownish red color of the pasteurized juices.

Pasteurized Muscat juice possesses a strong characteristic “raisin” flavor; the juice held at 8°–12° F. resembles the fresh juice in flavor and aroma.

The juices in cold storage were held in open containers, a condition which resulted in considerable volatilization of flavor and aroma. Doubtless sealed containers would greatly reduce this loss. In general, the quality of the cold stored juices was so much superior to that of the pasteurized juices that freezing as a means of preserving fruit juices should in time compete with pasteurization.

Preliminary tests with apple juice indicate that it also retains its flavor and aroma very well at 8°–12° F.

UTILIZATION OF FRUITS FROM FREEZING STORAGE

The fruit from the more important experiments described elsewhere in this report were made into various products such as jellies, jams, canned fruits, preserves, candied fruits and ice cream.

Cherries held in freezing storage in water or syrup gave excellent results for candying, for preserves, for cooking purposes and for canning. Those stored untreated in open containers were brown in color and inferior in flavor for the above purposes, to fruit stored in water or syrup. The texture of the products was in all cases good. Storage of pitted cherries in water at 8°-12° F. should prove a satisfactory method of storing the fruit for use in the preparation of Maraschino and candied cherries. This product is certainly more wholesome and more attractive in flavor than is the same fruit held in sulfurous acid solution. Cherries stored without treatment were not so satisfactory for pies as were those stored under water.

Apricots stored untreated in open containers became brown in color and developed a very disagreeable flavor which precluded their satisfactory use in preserves, etc. The fruit held at 8°-12° F. under water or syrup was excellent for jams and marmalades, although somewhat soft for canning. The flavor of jams made from this fruit was equal to that of the same products made from the fresh fruit.

Crushed apricots preserved at 8°-12° F. with an equal weight of sugar produced an ice cream of very rich fresh fruit flavor and of excellent color. No additional sugar was necessary in preparing the ice cream. The crushed unsweetened apricots made an excellent ice cream after sweetening with sufficient sugar. The heated fruit produced an ice cream of very pleasing flavor, but slightly darker in color with more of a cooked flavor than did the other two lots. As a check ice cream was made from home preserved apricots. Although of good quality, this ice cream was not equal in flavor to that prepared from the unheated crushed fruit.

The tests clearly demonstrated the superiority of the crushed unheated fruit from cold storage for use in ice cream and other frozen dishes where the fresh rather than the "preserved" flavor of the fruit is desired.

Strawberries yielded results in the preparation of various products similar to those obtained with apricots. The unsweetened crushed fruit, the crushed unheated sweetened fruit and the crushed sweetened fruit heated to 165° F. before storage were used in ice cream making. Of these the unheated, unsweetened crushed fruit gave the best flavor. The fruit heated to 165° F. gave a slightly darker ice cream of less

fresh fruit flavor than did the other two lots, but was still of very pleasing quality.

The crushed sweetened berries were used successfully without further sweetening in short cakes. The flavor and color of this fruit for this purpose were equal to those of the fresh fruit.

Using the fruit from cold storage, a comparison was made of the quality of strawberry jams and preserves made by the usual open kettle process and by cooking under a vacuum. The latter process gave products of remarkably fresh fruit flavor and color; superior in every way to the usual kettle-cooked article. The same results were obtained with loganberries, red raspberries and apricots. This method deserves attention from preserve manufacturers.

Loganberries from the cold storage tests previously described were tested for ice cream and for pies. The results were similar to those obtained with strawberries. The crushed fruit was very satisfactory when used on ice cream "sundaes" and should be excellent for ice cream sodas and similar fountain specials.

The unsweetened fruit was satisfactory for jelly making, giving a jelly of good color, flavor and texture, but for some reason not yet clearly understood, the sweetened fruit failed to give a firm jelly. This same trouble was also encountered with sweetened currants from freezing storage.

Raspberries crushed, sweetened with two-thirds of their weight of sugar and held at 8°-12° F. gave excellent ice cream. This crushed fruit was also very satisfactory for use as a jam or spread for bread or as a dressing for ice cream sundaes, etc. The heated fruit was satisfactory, but not of quite such fresh flavor as the unheated.

Currants stored without sugar gave good results in jelly making. The product was equal in every way to that made from the fresh fruit.

In general, fruits of the varieties used in the tests were after six to ten months at 8°-12° F. equal to the fresh fruits for most purposes.

SUMMARY

1. Soft fruits such as apricots, cherries and berries can be preserved at cold storage temperatures of 32° F. for not more than a week to three weeks. Present commercial methods of storing these fruits at temperatures lower than 32° F. are not standardized and are in many cases unsatisfactory.

2. These fruits if held in water or syrup at 8°-12° F. retain their flavor and color very well for at least a year. Lots of certain of these

same fruits held at 8°-12° F. in open containers without liquid, in time lose color and flavor. This is especially true of cherries, which become brown, and of apricots which in time develop a disagreeable "cold storage" flavor and a brown color. Berries in open baskets retain their color and flavor very well.

3. The crushed fruits with or without sugar retained their color and flavor almost perfectly at 8°-12° F. for almost a year; the duration of these tests. This fruit was excellent for ice cream, for pies, for use as a jam on bread, for shortcakes and general soda fountain use.

4. Grape juice stored at 8°-12° F. was very much superior to the juice preserved by pasteurization.

5. Former brewing plants are well equipped for undertaking the storage of soft fruits and fruit juices by the methods discussed and recommended in this report. The storage of these fruits should form a profitable method of utilizing such otherwise idle equipment.

6. The storage of these fruits will be studied further during the present fruit season.

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