THE INFLUENCE OF CERTAIN FACTORS ON THE STORAGE OF FROZEN SWEET CREAM

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Martin Van Scheid

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INTRODUCTION

The demand for dairy products, which in most cases is comparatively uniform throughout the year, does not exactly coincide with butterfat production which usually reaches a peak during the late spring and early summer months. Consequently, problems arise in times of surplus as to satisfactory storage of dairy products in such form that they may be used when a shortage occurs.

As a result of research in processing and as well as through the development of modern machinery, the quality of butter, cheese, and dry milk solids has been improved so that longer periods of storage may be used without an appreciable loss in quality.

Despite much research in ice cream, resulting in improved quality, production factors present a special problem. Not only must it be made from fresh clean-flavored milk products, but the demand for those products of manufacture is greatest at that period of the year when production of butterfat is beginning to decrease. In other words, butterfat production is usually at a peak ahead of its demand for use in the manufacture of ice cream mix. The problem, then, has been that of a satisfactory method of storage of surplus butterfat which might be utilized later when the demand for ice cream was greatest.

In storing butterfat, either as cream or a form of butter, for future use in ice cream manufacture, care should be taken that the initial flavor is excellent, that the biological and chemical properties are controlled, and, that the physical properties will not be materially altered.

Previous investigations have shown that the storage of butterfat in the form of frozen high-testing cream had possibilities as a practical

method of preserving the fat for future use in ice cream mix. This method, however, presented certain limitations. The problems of development of off-flavors in the stored frozen cream and the effect of the freezing process upon the stability of the fat emulsion indicated need of further research in this field. With these in mind, the investigation presented herein was undertaken.

REVIEW OF LITERATURE

Importance of initial quality of cream intended for frozen storage. Apparently, only cream of the highest quality having low initial acidity and free from objectionable off-flavors and odors should be preserved by freezing. Ellenberger and White (1929) indicated only high quality cream should be stored frozen. Newlander and Ellenberger (1929) noted average quality cream did not keep well. Mack (1930-b) contended the quality of the frozen cream depended largely on the quality of the cream before freezing.

Morris and Sommer (1932) and Sommer (1937) stressed the importance of using cream with low initial acidity, while Dahle and Josephson (1939) pointed out the importance of selecting a cream for freezing that had a low initial acidity and was free from copper contamination. They added that exceptional quality was desired in cream to be frozen. Dahle (1927, 1938) pointed out the advisability of using cream with a low initial acidity as did Pederson (1941-a) and Parker (1941).

Influence of pasteurization procedure on keeping properties of cream. Pasteurization has long been recognized as an essential process in assuring the keeping quality of frozen cream. Most workers advised a high-temperature pasteurization exposure.

Gould and Sommer (1939) showed that high-temperature pasteurization produced certain sulfhydryl reducing substances which were very effective in inhibiting oxidation.

Mack (1939) suggested a pasteurization temperature of 160°F. and Combs (1939) stated that most plants favored high-temperature pasteurization of cream intended for freezing and that sometimes it was deemed ad-

visable to pasteurize at 175°F. for thirty minutes. However, Dahle and Josephson (1939) considered a pasteurization procedure of 170° F. for fifteen minutes to be adequate, but Lawhorn (1939) and Dahle and associates (1940) recommended temperatures as high as 190°F. flash. They admitted cooked flavors resulted from that exposure but stated that mix made from such frozen cream did not retain the cooked flavor.

McFarland and Burgwald (1940) advocated the use of a pasteurization temperature of 172°F. for five minutes, indicating that this exposure seemed sufficient to inhibit development of the oxidized flavor. However, this exposure resulted in a cooked flavor which disappeared after one month of storage.

Pederson (1941-a) suggested 175° F. for fifteen to thirty minutes as sufficient for pasteurizating cream for frozen storage.

Lawhorn (1939) concluded, "When cream is heated to a temperature sufficiently high to produce sulfhydryl compounds, a greater degree of oxidative stability is imparted to the butterfat, as indicated by the increasing time of the induction period."

Effect of homogenization on chemical and physical properties of frozen cream. Many investigators have homogenized cream prior to cooling in attempts to improve its qualities for frozen cream. Generally, pressures of 2500 to 3000 pounds were used. However, considerable controversy exists among the workers concerning the advisability of homogenizing cream for freezing. Inasmuch as homogenization has proven effective in preventing copper-induced oxidation in milk, it seemed quite logical to assume that such treatment might be applicable to cream also.

Mack (1930-b) in a relatively early publication on the use of the

homogenizer on cream for freezing, maintained homogenization of the cream did not prevent oiling off of the frozen cream upon defrosting and indicated that he did not consider homogenization advisable.

Webb and Hall (1935) pointed out, "Homogenization of low fat cream slightly retarded fat separation of the frozen cream and that the fat clumps formed in cream by homogenization were destroyed by freezing, while the heat stability destroyed by homogenization was restored by freezing." Dahle and Josephson (1936) claimed homogenization before freezing produced a cream which oiled off to a much greater degree than did plain frozen cream and added, "Homogenizing cream before freezing was found to be more detrimental to whipping than just freezing alone."

Tracy (1936) presented data to show homogenization of milk prior to freezing materially reduced the tendency of the milk to "cream" upon defrosting. He stated that when milk was properly homogenized, most of the fat remained as a stable emulsion after the milk had been frozen and thawed. Trout,(1941) on the other hand, showed that "A marked settling of the fat and the solids-not-fat of milk was noted when homogenized milk was frozen and then thawed."

Tracy, Ramsey, and Ruehe (1933) showed that homogenization retarded copper-induced tallowiness in milk, while Thurston and associates (1936) indicated homogenization reduced or eliminated the susceptibility for the development of the oxidized flavor in frozen milk. Larsen, Gould, and Trout (1941) pointed out that homogenization of milk tended to stabilize the milk against oxidation.

Sommer (1937) suggested homogenization of the cream prior to freezing might be very beneficial in preventing tallowy flavor development. McFarland and Burgwald (1940) found homogenization to be effective in pre-

venting the development of the oxidized flavor in cream for 21 weeks even in the presence of considerable amounts of copper.

Lawhorn (1939) found homogenization caused considerable increase in the Eh of cream and claimed that homogenization improved the keeping quality. Pederson (1941-a, 1941-b) advised homogenization of the cream as did Parker (1941) also.

Influence of the use of sugar on certain properties of cream. The incorporation of sugar in the cream, either before or after pasteurization and prior to placing in the final container for freezing, has been said to improve both body and flavor of the cream. Price (1931-a) found ice cream from which all milk fat was supplied by frozen sweetened cream possessed better whipping properties than mix wherein unsweetened frozen cream was used. He concluded after extensive studies that either sucrose or invert sugar could be used in frozen cream with equal success. His data showing the effect of sweetened and non-sweetened frozen cream on the development of swell in ice cream is as follows:

Treatment of cream	Kinds of sugar	Ratio of sugar to cream	Storage period of cream	Number of trials	Time to get 90% swell	Maximum swell obtainable*
			Hours		Minutes	Per cent
Not frozen	none		48	4	8	96
Frozen	none		48	4	9	94
Frozen	sucrose	1-10	48	4	8	99
Frozen	invert	1-33:10	48	4	8	101
			Days			
Frozen	none		14	3	9	95
Frozen	sucrose	1.5:10	14	3	7	100
Frozen	invert		14	3	7	102
Frozen	sucrose	4:6	14	3	7	100

*Maximum swell obtainable with proper consistency for drawing from freezer.

Webb and Hall (1935) pointed out that increasing the solids-not-fat of the cream with additions of cane sugar, lessened the effect of the slow freezing process in the destruction of the fat emulsion. Doan and Baldwin (1936-b) agreed that the addition of sugar to the cream greatly reduced the per cent of fat de-emulsification upon defrosting.

Tracy (1937) maintained that the poor whipping quality of frozen cream mix could be overcome to a great extent by the addition of 10 to 12 per cent sugar to the cream before storage. Mack (1930-b) contended the addition of 10 per cent sugar prior to freezing was a satisfactory method of preserving surplus cream which was later used in the manufacture of ice cream mix. Lawhorn (1939) showed sugar did not improve the keeping quality of frozen cream.

Dahle, Lawhorn, and Barnhart (1940) presented data to show that the addition of 10 to 15 per cent sugar aided materially in the prevention of oiling off of frozen cream upon defrosting, but concluded that sugar did not improve the flavor of the cream after six months storage. They stated that the flavor of the unsweetened frozen cream was preferable to that to which sugar had been added.

Crowe and Winn (1941) stated, "In the case of frozen cream to which sugar has been added, the point where viscosity limits the destabilizing effect of freezing is reached early and aggregation of the colloidal particles is reduced."

Use of various types of containers for cream storage. Several different types of containers have been used for the storage of frozen cream. These include tin cans, paper cans, milk and ice cream metal cans, and even wooden barrels. Ellenberger and White (1929) after extensive study, suggested

cream containers should be free from bare or corroded spots of iron or copper, and although tinned receptacles are suitable containers, best results were obtained by employing the use of lacquer, granite, or agate coatings to the cans. Grayson (1931) suggested lacquered tin cans. Tracy (1937) was quite exacting in his recommendations, advising the use of parchment paper beneath the lid to help in the exclusion of air from the cream. He added that only new, unscratched tin cans should be used.

Combs (1939) pointed out the typical container was a straight-sided, forty-pound lard tin. Dahle and Josephson (1939) recommended the use of tin cans also. Dahle (1941) stated cream was most often stored in single service cans of five to six gallon capacity, although some used the type of paper cans commonly employed for dispensing ice cream.

Pederson (1941-a) suggested the use of well-tinned receptacles for the storage of frozen cream.

Effect of rate of freezing on stability of fat emulsion of frozen cream. The rate of freezing of a food product is important in that it controls quite largely the size of the ice crystals formed. That fast freezing is essential in securing the finest quality in the frozen food upon defrosting is no longer questioned.

Price (1931-c) advocated the use of a Miller ice cream freezer for the fast freezing of cream and suggested a method whereby the process could be made continuous.

Grayson (1935) found, "Deaerating and freezing of milk or cream under high vacuum and hardening under extremely low temperature, is a successful way to store high quality cream for consumption as the fluid product."

Webb and Hall (1935) showed a gradual precipitation of the caseinate system and an immediate destruction of the fat emulsion due to the

slow freezing of milk and cream. They also found that slow freezing caused excessive free fat separation or oiling-off during thawing. Lindquist (1938) pointed out that application of fast freezing conditions to cream partially prevented oiling off.

Roush (1939) designed a fast freezing method which was used quite successfully by Roadhouse and Henderson (1940). Carlton (1941) described several quick freezing methods used for various frozen foods. Possibly some of them might be applicable for cream although he made no statement to that effect.

Influence of fat content of the cream upon the homogeneity of freezing. There is some difference of opinion among the investigators as to whether or not cream freezes homogeneously. Most of them agreed, however, that there was little fat diffusion in cream containing forty per cent butterfat or more.

Trelogan and Combs (1936) demonstrated the relation of the per cent butterfat and the extent of fat diffusion as follows:

Type of cream	Per cent butterfat in: Side	Botton	Center	Top
Low fat	18.75	18.25	18.50	25.50
Medium fat	29.00	29.50	29.50	30.50
High fat	39.12	39.25	39.00	39.25

Baldwin and Doan (1935) summarized most of the opinions on the subject in stating, "Increasing fat concentrations of milk constituents in both milk and cream retarded the diffusion or concentration of milk constituents into the unfrozen portion of the freezing product. When the fat concentration reached 25 per cent, diffusion was practically prevented and the cream froze homogeneously, Diffusion was probably inhibted by the in-

creased viscosity of the increased fat content, and also because of the more effective sealing of the interstices between developing ice crystals by the increased fat content, and in the form of solidified globules." Doan and Baldwin (1936-a) stated that homogenization of the cream caused homogeneous freezing at a lower fat content than in nonhomogenized cream.

Apparently, fat diffusion prior to freezing is of little importance commercially because too much storage space would be required for the storing of any appreciable amount of fat if it were in the form of low fat cream.

The temperature and length of period that cream may be stored frozen. The length of time that cream may be stored at a certain temperature and yet retain its original quality is of utmost importance. Newlander and Ellenberger (1929) indicated that good quality frozen cream kept well at 0° F. for four to six months. Mack (1931) found that a room of -5° F. kept a sample of cream for six months as well as a room of 10° F. kept the same sample for four months. He recommended holding periods of less than six months at -18° F.

Lindquist (1935) used 0° to -10° F., Dahle and Josephson (1939) suggested storing cream at -10° F., while Pederson (1941) advised storing below 0° F.

Generally, the above investigators have shown that a temperature of above 0° F. is not desirable from the standpoint of frozen cream storage and the temperature of the cold-room should be 0° F. or below with the optimum temperature well below 0° F. The temperature of the ordinary ice cream hardening room, therefore, would, in most cases be applicable for cream storage. However, due to the expense involved in the building and refrigerating a hardening room, few commercial ice cream plants have sufficient space in their hardening rooms for the storage of any appreciable

amount of frozen cream. Many plants have followed the practice of freezing cream in their hardening room with the aid of blower fans and then storwith a commercial cold storage firm.

Methods used in defrosting cream. Careful defrosting of the cream is essential in prevention of excessive oiling off of the butterfat and even under the most optimum conditions, some oiling-off may still occur.

Mack (1931) stated that slow defrosting was advisable in that it resulted in better whipping qualities in the resulting ice cream mix. Lindquist (1935) found that when the cream was thawed slowly by immersion of the cans in water below 90° F., oiling-off was not prevented when the cream was later pasteurized.

Gockley (1936-a) suggested cream should be defrosted either by setting in the handling room overnight or by immersion of the cream cans in warm water, possibly in the cheese vat. The temperature could be more carefully controlled by the latter method, but the possibility of leaky cans might inhibit its use, as the freezing process often caused the expanding cream to burst the can, so the former method was probably the more practical. Pederson (1941-a, 1941-b) advised slow thawing of the cream. He suggested allowing the cream to set for two days in the handling room until all ice crystals disappeared.

Gockley (1936-b) also reported using a "Creavy ice crusher" which was an ice crusher with the teeth having been removed. This method consisted of putting the can of cream in the crusher, having the frozen cream pressed out of it and into a hopper. The frozen mass could then be added directly to the pasteurizer. The advantages claimed for this procedure were that it conserved both time and space and was equally as sanitary as other defrosting methods due to the fact that the "crusher" was easily cleaned and sanitized.

However, it destroyed the container, but on the other hand, most frozen cream containers are of the single service type, anyway.

Use of the oxidation-reduction potential in predicting keeping quality of cream. Oxidation is quite commonly referred to as the loss of electrons and reduction is known as the gain of electrons. The measurement in electric current of the proportion of oxidants to reductants in a solution is known as the oxidation-reduction potential. This is often expressed as Eh which is an intensity measure of the oxidation-reduction balance as expressed in volts of electric current.

Numerous workers have reported on the use of Eh as a means of predicting the oxidative tendencies of cream after a period of frozen storage, but they do not all agree upon the reliability of such determinations in forecasting the keeping quality of cream during a period of frozen storage.

Tracy, Ramsey and Ruehe (1933) found that copper contamination in cream has the same general effects on the oxidation-reduction measurements as it did in milk. This indicates that they found that copper caused a definite rise in the Eh of cream.

Lawhorn (1939) found considerable increase in Eh due to homogenization but concluded that homogenization tended to improve the keeping quality of the cream. However, Tracy, Ramsey, and Ruehe (1933) and later Larsen, Gould and Trout (1941) concluded that homogenization had little or no effect upon the Eh of milk and contended that while homogenization retarded development of the oxidized flavor, the explanation of that action did not appear to be associated with Eh.

Lawhorn (1939) did considerable work on the use of Eh in frozen

cream studies and concluded that the oxidation-reduction potential was not a reliable criterion of the keeping quality of cream.

Dahle, Lawhorn and Barnhart (1940) made a very extensive study of Eh and the oxidized flavor of frozen cream and cited some very interesting observations. They found that the Eh of the cream increased during the first month of frozen storage and then decreased up to the end of the eight-month period during which time the flavor might have become oxidized. They also found that high temperature pasteurization decreased and copper increased the Eh. They did conclude, however, "The initial Eh reading of the pasteurized cream before storage is a fair index of the keeping quality though not entirely reliable. It was found that cream with added copper having an initial Eh of above 0.30 volts usually developed an oxidized flavor during storage of 6 to 8 months, while those below 0.30 volts seldom did. There were a few exceptions, however."

From the above, as well as other findings, it would appear that the reliability of the use of Eh in predicting the susceptibility of cream toward oxidized flavor development is as yet questionable.

The relation of the hydrogen ion-concentration to length of storage period of cream. Although much has been done relative to the per cent titratable acidity of cream prior to freezing, little attention has been given to the hydrogen-ion concentration to that cream as measured in terms of pH.

Dahle, Lawhorn, and Barnhart (1940) found that the pH of cream decreased upon frozen storage, indicating a greater intensity of hydrogen ions. They also found that titratable acidity of heated samples decreased whereas if unheated cream were stored, the acidity increased. It is interesting to note that while in one case (unheated cream) there was a rise

in titratable acidity as compared to a lowering in the other (heated), in both instances there was an increase in the hydrogen ion concentration.

Effect of carotene on oxidized flavor development of milk and cream. Anderson (1936) cited carotene as an inhibitor of oxidized flavor development in market milk. Sommer (1938) suggested that carotene might be used as an anti-oxidant. Brown and others (1939) stated, "Carotene fed at the rate of 350 mg. per day greatly reduced the tendency for metal-induced oxidized flavor to develop and resulted in an increased amount of carotene in the milk."

However, Brown and co-workers (1940) later found a decreased carotene content of milk did not result in an increase in the intensity of oxidized flavor and concluded that the amount of carotene in the butterfat might not be the substance responsible for the reduction of milk susceptibility toward oxidized flavor development. They suggested that possibly some substance associated with the carotene rather than the carotene itself was responsible for the oxidative inhibitory action heretofore attributed to carotene.

The intensity of yellow color has been frequently used as a means of securing a comparative estimate of the carotene content of milk or cream. Sommer (1938), however, showed that assumption to be erroneous and stated that the color of milk may not be regarded as a true index of the relative carotene content due to the difference in ability of dairy breeds to assimilate carotene. He stated that feed was more important than breed as an influence on carotene content of the milk. Consequently, under normal conditions, season of year would be the predominant factor.

That carotene is quite stable in frozen milk products was demonstrated by Olson and co-workers (1939) who state, "Milk can be stored

for considerable periods without effecting the carotene or Vitamin A content."

The uses of frozen cream. The major part of frozen cream is used in the preparation of ice cream mix and it was with that in mind that the work of most investigators was undertaken. However, Roadhouse and Henderson (1940) described frozen cream which might later be used as table cream or in a reconstituted form.

Some controversy exists among the investigators relative to the proportion of the fat from frozen cream that may be used safely in ice cream mix. Mack (1930-a) contended that an ice cream of desirable flavor was made only when not more than one-third of the total fat of the mix came from frozen cream. Gockley (1936-a) used up to 60 per cent of the total fat from frozen cream; Dahle and Josephson (1939) suggested from 30 to 50 per cent of the total fat from frozen cream; but Dahle, Lawhorn and Barnhart (1940) have indicated that frozen cream may supply all of the fat of the mix.

Parker (1941), however, cautioned against using over 25 per cent of the total cream of the mix from frozen cream.

Apparently while the investigators differ considerably in opinion as to the percentage of the total fat of the mix which should come from frozen cream, they all agree that the percentage of the total fat which may be constituted by the frozen cream is directly proportional to the quality of that frozen cream. Therefore, one seems justified in assuming that when cream of such quality has been produced, the whole of the fat of the mix may be supplied by frozen cream.

Problems encountered in storing frozen cream. The difficulties encountered in the preserving of cream by freezing and low temperature storing are both chemical and physical in nature. The tendency of the cream toward development of oxidized flavor, and the occurrence of oiling-off upon defrosting and pasteurizing in the mix have resulted in considerable investigation.

1. Development of the oxidized flavor. Even under the most ideal conditions, cream often exhibits susceptibility toward the development of an oxidized flavor upon frozen storage as shown by Reid (1926). Sampey (1939) stated that when the dissolved oxygen was removed by heat and vacuum, the action of copper in accelerating the oxidation of ascorbic acid and the subsequent development of the oxidized flavor was eliminated. Cream thus treated would then have to be filled under vacuum or in the presence of an inert gas such as nitrogen before storage.

Lawhorn (1939) stated the replacement of oxygen with nitrogen in a vacuum sealed container seemed to improve the keeping quality of the cream. Roadhouse and Henderson (1940) used vacuum sealed cans and reported no oxidative changes within six weeks.

Most observers now believe that oxidized flavor is due to the oxidation of the phospholipids surrounding the fat globule rather than to the oxidation of the unsaturated fatty acids.

Price (1932) was of the opinion that the addition of sugar to the cream before freezing protected the lecithin from oxidation. Thurston and associates (1936) indicated lecithin rather than butterfat was affected in the development of the oxidized flavor and concluded that when the absorbed lecithin was removed from the fat globule surface, there could be no oxidation taking place.

Swanson and Sommer (1940) concluded that copper-induced oxidation of milk fat was due to oxidation of the phospholipids, lecithin and cephalin. Sommer (1936) decided lecithin was probably the mother substance of the oxidized flavor and suggested that homogenization of the cream prior to freezing might be very beneficial in preventing tallowy flavor development. Barnhart (1940) concluded, "Butterfat is not the source of the oxidized flavor in frozen cream. The theory of phospholipid oxidation seems to be the more logical conclusion."

McFarland and Burgwald (1940) contended homogenization was effective in preventing the development of the oxidized flavor and also stated that pasteurization of the cream at 175° F. for five minutes seemed to prevent development of oxidation in the cream.

Copper contamination of the cream during processing is possibly the most common cause of oxidized flavor in frozen cream. With the advent of stainless steel equipment, however, and its rapidly increasing use, this source of contamination is diminishing in importance although there is yet much dairy equipment used from which metallic contamination is of vital concern.

The use of anti-oxidants has been found to be beneficial in the prevention of the development of the oxidized flavor, and of these, Avenex, an oat flour product, is the most widely used. Dahle and Josephson (1939) pointed out the addition of one to two per cent of oat flour (Avenex) to the cream before freezing, enhanced the keeping quality of the cream before freezing, and that it was especially beneficial when used in conjunction with high temperature pasteurization.

Maach and Tracy (1939) maintained oat flour was beneficial when used as an anti-oxidant in frozen cream. They suggested adding it as a gruel to

the cream. Lawhorn (1939) added oat flour at the rate of two per cent of the weight of the fat. Barnhart (1940) used effectively both oat flour and a corn flour concentrate.

Dahle and associates (1940) presented data to show the effect of oat flour on the flavor of stored frozen cream as follows:

Months in storage		0	1	3	6
Treatment of cream	Heating temperature	Flavor	Flavor	Flavor	Flavor
Control	150°F. 30	good	good	good	good
	170°F. flash	cooked	cooked	cooked	cooked
	190°F. flash*	cooked	cooked	cooked	cooked
Control + 1 p.p.m. copper	150°F. 30	good	00	0000	0000
	170°F. flash	cooked	sl.cook	sl.cook	0
	190°F. flash*	cooked	0	00	000
Control + 1 p.p.m. copper + 2% oat flour	150°F. 30	good	0	0000	0000
	170°F. flash	cooked	good	fair	good
	190°F. flash*	cooked	good	good	good

*The 190° F. flash temperatures were heated to 140° F., then to 190° F. with live steam directly injected into the cream.

2. Destabilization of the fat emulsion. Frozen cream, when defrosted and heated as in pasteurizating the mix, seems to have a general tendency toward oiling-off. Apparently the freezing process causes all cream to oil-off to some extent. However, various control measures reduce the amount of oiling-off to a minimum.

Price (1939-c) suggested fast freezing as a preventive measure against oiling-off. Lindquist (1935) upon examination of cream of four months storage, indicated that when the cream was subjected to fast freezing conditions, oiling-off was partially prevented.

Grayson (1935) and Roadhouse and Henderson (1940) have suggested methods of fast freezing cream which indicated that they were fully aware of the destabilizing effect of the freezing and thawing processes which affect both

the protein and the fat to a much greater extent in a slow than in a fast-frozen product.

Many workers have tried various ingredients added to the cream in an attempt to combat the destabilizing effect of the freezing process. Lindquist (1938) noted that the addition of sodium alginate (cocoloid) to cream reduced the tendency toward oiling-off. In another investigation, however, Lindquist (1939) indicated no beneficial results were obtained upon the addition of small amounts of sodium citrate and disodium phosphate to the cream prior to freezing.

The addition to the cream of 10 to 15 per cent sugar has been the most successful method, other than fast freezing, of increasing the stability of the fat emulsion upon thawing. Price (1931-b), Mack (1931), Webb and Hall (1935) and Dahle and Josephson (1939) all used sugar with varying degrees of success in preventing oiling-off as compared to that not containing sugar.

Dahle and associates (1940) also used sugar in an attempt to lessen the tendency toward oiling-off and reported favorable results. The following data of Dahle and associates indicate the beneficial effect of using sugar:

Trial	Treatment	Per cent "oiling off"
1	Control frozen cream	90-100
	Control + 10% sugar	40-45
	Control + 10% sugar	35-40
2	Control frozen cream	90-100
	Control + 10% sugar	45-50
	Control + 15% sugar	25-35

Use of frozen cream in ice cream mix. Little has been done on the effect of frozen cream on the flavor in finished ice cream after an appreciable

period of storage. However, it has been found that if the flavor of the frozen cream were good, that of the ice cream was equally good. In some cases, the off-flavors in the frozen cream will not be discernible in the finished ice cream, for example, a cooked flavor in the frozen cream may not appear in the final product. The flavor of the ice cream would as a rule be as good as that of the frozen cream used in its manufacture. However, the use of slightly off-flavor frozen cream in ice cream mix might be possible if only a small per cent of the total fat was furnished by frozen cream.

The chief objection, apparently to the use of frozen cream as the sole source of fat in a mix, was the poor whipping ability of the mix caused by the partial destabilization of the fat and protein of the fat and protein of the cream by the freezing process.

As previously shown, the addition of sugar to the mix was beneficial in partially restoring the whipping ability of a mix. However, its stabilizing effect was not sufficient that the mix compared favorably in whipping ability to that made of fresh cream.

In view of this condition, various attempts with reasonable success have been done to improve the whipping ability of mixes made with frozen cream. Most workers have agreed that the poor whipping ability of frozen cream mixes was due to the fact that the freezing process has removed the lecithin from the outer wall of the fat globule.

Dahle, Lawhorn and Barnhart (1940) demonstrated that the neutralization of the acidity of the mixes to or even below normal, restored the whipping ability. They advised care in the selection of a neutralizer in order not to impart an off-flavor to the cream. They found that magnesium oxide proved very satisfactory as shown by the following table:

Trial No.	Initial acidity	Final acidity	Final pH	Time to reach 90% overrun
1	0.23	0.18	6.44	9'-30"
		0.10	7.25	7'-17"
2	0.24	0.18	6.24	9'-10"
		0.10	7.23	7'-35"
3	0.22	0.18	6.42	9'-25"
		0.10	7.24	7'-10"
Control (fresh cream)	0.22	0.18	7.45	7'-30"

The addition of egg yolk, either frozen or dried, partially restored the whipping ability of frozen cream mix. Woodroof (1941) stated the whipping properties of a mix may be restored by adding 0.2 to 0.4 per cent good quality egg yolk to the mix.

PURPOSE OF EXPERIMENT

Previous investigations have shown that the freezing of cream for future use in ice cream mix seems to have very definite possibilities. Indeed, several millions of pounds of frozen fresh sweet cream are now being stored annually for future use in ice cream manufacture. The purpose of this investigation, then is:

1. To do further research on methods and processes intended to lessen the tendency toward the susceptibility of the frozen cream to the development of the oxidized flavor.
2. To add to that which already has been done toward stabilizing the fat emulsion and in turn make experimental studies toward methods which may lessen the effect of the freezing process in causing destruction of the fat emulsion.
3. To determine, according to the conditions set up in this experiment, the length of time that frozen cream may be stored without serious deterioration of body and flavor.
4. To ascertain, by use of cream preserved by frozen storage, what per cent of the total fat of the mix may be supplied by frozen cream and the relationship of the quality of the frozen cream used therein to the quality of the finished ice cream.

SCOPE OF INVESTIGATION

Although the main problems of frozen cream are largely two in number, namely, oiling-off and oxidation of the fats or fat-like substances, the factors affecting these defects are quite numerous. Consequently, a number of those factors were included in this study. Data were secured on the following phases of this investigation:

1. Influence of seasonal storage on flavor of frozen cream.
2. Effect of copper contamination on flavor.
3. Effect of sugar on the stability of fat emulsion and flavor.
4. Effect of the pasteurization exposure on the keeping quality of the cream.
5. Effect of various pressures of homogenization on stability of fat emulsion and flavor.
6. Influence of type of container used for storage upon the flavor.
7. Relation of initial titratable acidity to the keeping quality of the frozen cream.
8. Use of the Eh and pH in forecasting the keeping quality of the cream.
9. Relation of the carotene content of the cream to the keeping quality of the cream.
10. Effect of rate of freezing on the stability of the fat emulsion.
11. Relation of initial flavor of the cream to the final flavor after various periods of storage.
12. Length of time that cream may be stored, according to the conditions of this experiment, without serious deterioration of flavor.

13. The effect of the use of frozen cream as the sole source of fat on the amount and ease of obtaining overrun when the mix is frozen.
14. The effect of added egg yolk and/or sugar upon the whipping ability of frozen cream mixes.
15. The effect of storage upon the flavor of frozen cream ice cream.
16. The bacteria count of frozen cream ice cream.

EXPERIMENTAL

The cream used in this experiment, secured from the separation of fresh, raw, mixed milk either from the College Creamery or from a local dairy company, had a fat content averaging slightly above 50 per cent. The milk was separated at about 100° F. after which the cream was cooled immediately to 60° F. Pasteurization followed at once.

The cream was divided into three lots of which one was heated to 150° F. and held for thirty minutes; a second was heated to 165° F. and held for fifteen minutes; and the third was heated to 185° F. for five minutes. In handling and processing the cream, precautions were taken against copper contamination throughout, the pasteurization being accomplished in a stainless steel vat which was commonly used for the manufacture of cottage cheese.

Each lot was then subdivided into three lots which were homogenized at 0, 1500 and 3000 pounds pressure respectively, using a Union Steam Pump 200-gallon viscolizer. The cream, frequently stirred, was cooled to 50° F. in ice water.

Each lot thus pasteurized and homogenized was then subdivided into four lots, one serving as a control; a second lot having 1 part per million added copper in the form of an anhydrous copper sulfate solution; a third lot had ten or fifteen per cent sugar added; and the fourth lot contained both sugar and copper added at the rates previous mentioned.

Immediately following cooling and treatment, sufficient portions of the samples for study were put into three different types of containers, namely, glass, paper and tin. The glass container was an eight-ounce mayonnaise-type jar with a water-proof inner lining screw cover; the paper

container was a pint Sealright carton and the tin container was a number two, "C"-enamel, tin can, the lid of which was applied by an automatic, hand can sealer.

When a lot was packaged, the packages were taken at once to a -10° F. room for freezing. In this room the samples remained as the experiment dictated. The accompanying data sheet(page 30) furnishes an outline of the experiment insofar as preparations of the samples is concerned.

Flavor examinations were made by two experienced judges on the cream when fresh and after 3-, 6- and 12-months storage. The intensity of the oxidized flavor was designated as follows:

? = doubtful oxidized flavor

+ = slight " "

+ + = pronounced " "

+ + + = very pronounced " "

For practical purposes in making tables and graphs these designations were given a numerical rating of 1, 2, 3 and 4, respectively.

The off-flavor recorded in the frozen cream samples was in every case the oxidized flavor. In the case of the presence of the cooked flavor which often occurred when pasteurization exposure exceeded 160° F., it was not considered to be an off-flavor, inasmuch as the cooked flavor in the frozen cream did not re-appear in the ice cream mix or in the frozen ice cream.

Fat content of the cream not containing sugar was determined by the Babcock method, whereas, that containing sugar was tested for fat according to the Minnesota method.

The oxidation-reduction potential was determined on the nonhomogenized samples at 0, 180 and 360 days according to the Leeds and Northrup

potentiometer employing the use of the calomel half-cell and platinum electrodes. The quinhydrone electrode was used for the pH determination.

Titratable acidity was determined by the use of N/10 sodium hydroxide using phenolthalein as the indicator. The initial acidity of the controls and of the nonhomogenized samples was taken immediately after cooling the cream.

Fat emulsion stability was measured according to a method which was quite similar to that used by Webb and Hall (1935). It consisted of weighing nine grams of fresh unfrozen cream into regulation 9-gram 50-per cent cream test bottles, freezing by different methods and holding for various periods of time. The bottles were then filled to the 50 per cent mark with 100° F. water. The samples were then centrifuged at 800 r.p.m. in an ordinary centrifuge commonly used for making the Babcock test of milk and cream. The centrifuge was warmed by the heat coil for fifteen minutes prior to and during the centrifuging period. The samples were then held 24 hours at 40° F. after which they were warmed for fifteen minutes in 100° F. water, prior to re-centrifuging for thirty minutes as before. After tempering the fat columns for three minutes in a 135° F. water bath, glymol was added to the top of the fat after which the fat columns were read immediately. Tests were made of the unfrozen cream and that stored frozen for 1, 90, 180 and 360 days.

The carotene content of the cream in this experiment was determined under the direction of Dr. L. A. Moore, formerly of Michigan State College, according to the method devised by him. The procedure followed in making the carotene analysis of cream was as follows: A ten-gram sample of cream was weighed into a test tube and warmed to about 70° to 80° F. and to this,

ten ml. of ethyl alcohol was added and the sample well shaken. Ten ml. of benzin which was distilled over at 68° to 70° C. was added and again the sample was well shaken. After shaking, the sample was set into cool water, care being taken to avoid cooling sufficiently to cause fat solidification. During a setting period of ten minutes that followed, the samples were shaken three times for one minute each. After centrifuging at 1900 r.p.m. in a high speed centrifuge for four minutes, 1 ml. of the top (fat) portion was pipetted into a cell of a photo-electric colorimeter and read through a number 440 filter. The carotene content, derived by calculation, was expressed as gammas or micrograms per gram of fat in the cream.

As a second part of the experiment, five-gallon lots of cream were frozen and stored for future use in ice cream manufacture. This cream was secured as before from the College Creamery and was pasteurized at 165° F. for 15 minutes, after which it was cooled to 55° F. To one lot of cream, 10 per cent sugar was added, while a second lot was stored without sugar. The cream, in lard-type tin containers, was placed in a cold room and frozen in still air at -10° F. Laboratory analysis of these samples included fat, flavor and titratable acidity.

Mixes containing 12 per cent fat, 10 per cent serum solids, 15 per cent sugar, and 0.35 per cent gelatin of 275 Bloom were made from fresh control cream and from cream which had been stored frozen for 6, 3 and 1 month. Defrosting was brought about in the heating of the mix. Pasteurization of the mix at 150° F. for thirty minutes was followed by homogenization at 3000 pounds pressure in a single-stage, 200-gallon viscolizer.

The mixes were cooled to 50° F. and aged for 18 hours before freezing. Freezing was done in a 50-quart, direct-expansion, batch freezer equipped with a Drawrite indicator. A batch of regular mix was frozen and the freezer rinsed with one gallon of regular mix before freezing the mixes of the experiment. The rinsing procedure between batches was followed throughout the freezing trials.

The time required to secure 90 per cent overrun was indicated by a stop watch. Samples of the ice cream were taken at 90 per cent overrun for future scoring. The maximum overrun obtainable was also recorded.

There was no regular sequence of freezing the mixes. In fact, they were chosen at random, inasmuch as rinsing of the freezer between batches would make similar freezing conditions for each of the batches of mix.

Scoring of the finished ice cream was done each week for the first two months, separate samples having been secured for each scoring, and thereafter at three and six months by two experienced judges. Examinations for flavor, body and melting quality were done "blind". In addition, the mixes were tested for flavor, acidity and oiling-off as previously indicated.

Another group of mixes similar to the first was made, frozen and judged as before, excepting that 0.35 per cent dried egg yolk was added to the mix.

EXPERIMENTAL DATA

Freezing and Storage of Sweet Cream

Sample _____ Factor studied _____ Date examined _____

Treatment

Original Cream	Heat Treatment	Storage in	0# Control	0# 1 ppm Cu	0# 15% Sucrose	0# Cu + Sucrose	1500# Control	1500# 1 ppm Cu	1500# 15% Sucrose	1500# Cu + Sucrose	3000# Control	3000# 1 ppm Cu	3000# 15% Sucrose	3000# Cu + Sucrose
RAW (Separated at 100-110°F.)			After 6 months at 0°F.											
		Glass												
		Paper												
	150°F.- 30 min.	Tin												
Tests:			After 12 months at 0°F.											
Fat _____		Glass												
Acid. _____		Paper												
Flav. _____		Tin												
Caro-tene _____			After 6 months at 0°F.											
Bact. _____		Glass												
Misc. _____		Paper												
	165°F.- 15 min.	Tin												
			After 12 months at 0°F.											
		Glass												
		Paper												
		Tin												
			After 6 months at 0°F.											
		Glass												
		Paper												
	185°F.- 5 min.	Tin												
			After 12 months at 0°F.											
		Glass												
		Paper												
		Tin												

RESULTS

PART I

FACTORS AFFECTING FLAVOR AND FAT EMULSION STABILITY OF FROZEN CREAM

A. The Influence of Several Factors on the Keeping Quality of Frozen Cream. Cream secured each month throughout the year was treated by various methods as outlined in the procedure and stored frozen at 0° to -10° F. for 12 months during which time the samples were examined at 3, 6 and 12 month intervals for flavor.

1. The effect of copper contamination on oxidized flavor development of frozen cream. As copper contamination is a very common cause of the development of oxidized flavor in dairy products, it was considered advisable to ascertain just what effect the addition of copper to the cream after pasteurization and prior to freezing might have on the flavor of the resulting frozen cream.

Consequently, 1 part per million copper was added to the cream which was then well mixed and put immediately into containers for freezing.

The data in tables 1 to 4, inclusive, show the effect of the added copper on the flavor of the frozen cream after the various periods of storage. An analysis of the data reveals that when copper was present in the strength of 1 part per million, none of the conditions used in this experiment would render the cream entirely free from the development of the oxidized flavor.

When similar samples were processed with no added copper and with very little copper, if any, due to contamination, the development of old, stale, oxidized flavors depended upon other factors, such as the pasteurization exposure.

Data in tables 1 to 4 indicate the flavor of all glass samples throughout the twelve-month period. Tables 5 to 16, inclusive, give the flavor data of the entire group of samples after 6 and 12 months storage. Figure 1 shows the comparison of the various treatments on the flavor of the cream.

Data in tables 1 and 3 show quite clearly that cream may be preserved frozen for at least one year with no detrimental effect on flavor if the proper pasteurization exposure is followed and the cream is kept free of copper. When the cream was held for 12 months, in no case was there any indication of the presence of the oxidized flavor in the samples pasteurized at 185° F. for 5 minutes, and that of 324 examinations made, only 4 were oxidized when the pasteurization exposure was 165° F. for 15 minutes. However, samples were frequently oxidized when pasteurized at 150° F. for 30 minutes.

When 10 per cent sugar and 1 part per million copper were added to the samples, a slight advantage in flavor for the samples containing sugar was noted. However, sugar did not improve the flavor sufficiently to be of commercial significance when 1 part per million copper was present, as shown in table 4.

The data in table 3 show little improvement in flavor as a result of additions of sugar without copper contamination. However, as both series of samples examined were largely without flavor criticism, it would be natural to assume that flavor improvement, if any, could only be very slight. While in this series of samples, there was no significant difference in the number of samples having off-flavors, it also appeared that the flavor of the sugared samples was equally as clean and fresh as those of the control lot.

The chief advantages of sugar additions, therefore, seem to be associated with its effect on the body of the cream. This will be discussed later in greater detail.

2. The influence of homogenization on flavor of frozen cream. To ascertain the influence of homogenization upon inhibition of development of the oxidized flavor in normal and copper contaminated cream, batches of cream were passed through the viscolizer at 0, 1500 and 3000 pounds pressure, respectively. The data on the effect of homogenization upon flavor development are in tables 1 to 16, inclusive.

An analysis of these data reveals that there was very slight inhibitory effect on oxidation due to homogenization. However, it should be emphasized that inasmuch as the oxidative inhibitory action is so very slight even in the samples containing 1 part per million copper (Figure 2), and due to the fact that if the cream had been properly processed it would likely have been excellent quality anyway (Figure 3), it is very doubtful whether homogenization of the cream prior to freezing would be of commercial significance.

On the other hand, it must be borne in mind that homogenization was slightly beneficial. In plants wherein the quality of the cream was such that oxidized flavors were prone to develop very slightly upon prolonged storage, homogenization might prove of slight value.

3. Type of container used for cream storage. All the cream samples in these studies were stored in glass, paper and tin to ascertain the effect upon flavor. Data secured are presented in tables 17 to 24, inclusive.

A study of these data shows no material difference in flavor characteristics of any specific type of container. However, the paper as a group appeared to be the least desirable, from the flavor standpoint, as

old, stale, flavors were sometimes noted in the cream which were not noticed when the other two types of container were used.

4. Influence of pasteurization exposure on development of the oxidized flavor in frozen cream. The pasteurization exposures used in this experiment are outlined on the date sheet and were 150° F. for 30 minutes, 165° F. for 15 minutes and 185° F. for 5 minutes. Data in tables 1 to 4 show the effect of these exposures upon the flavor of the cream after various storage periods.

That pasteurization is absolutely essential in any type of cream designated for frozen storage was well illustrated by the examination of the raw control samples which were stored each month in a glass container. The common defects of these samples were: very strong rancid, putrid, cheesy and bitter. In view of the condition of these samples even on the short three-month storage period, it was not considered necessary to include tables and graphs in this discussion. In no case was the raw sample in such condition that it might have any value as a human food product.

Pasteurization at 150° F. for 30 minutes was easily the poorest of the lot so far as stabilizing the flavor was concerned. Even so, under certain conditions the cream treated in this manner was of good quality as shown by figure 4.

Between the processes of 165° F. for 15 minutes and 185° F. for 5 minutes, there was little to choose. Both were very effective in preventing the appearance of the oxidized flavor. Of the two, the process of 185° F. for 5 minutes was the most effective in preventing oxidation, but imparted a slightly more cooked flavor to the cream which did not disappear even in one year of frozen storage.

Figure 5 graphically points out the inability of any pasteurization

procedure to render a desirable flavored cream in the presence of 1 part per million copper.

5. Effect of season of the year on keeping quality of frozen cream. Inasmuch as fats and carotenoids of cream vary seasonally due to change in feeds, samples of cream were processed and stored each month throughout the year to determine what effect, if any, normal seasonal changes would have upon the stability of flavor.

The data included in tables 1 to 4 show that seasonal variation had very little effect on the flavor of the frozen cream. As seasonal variation also included such variations as feed and stage of lactation, this finding was especially interesting. Apparently one can store cream at any season of the year under identical conditions that might be used at any other period with equal success. The existence of this condition greatly facilitates matters in that it makes much simpler the recommended procedure of treatment of the cream inasmuch as it can be handled alike at any time of year.

6. The influence of storage period on flavor of frozen cream. In an effort to determine the length of time that cream can be held by frozen storage, this portion of the experiment was set up for a long-time holding period, with regular intervals for flavor examination.

Data in tables 1 to 4 show the effect of the storage periods of 3, 6 and 12 months on the resulting flavor of the frozen cream. Obviously, the flavor of the cream, regardless of treatment, is inversely proportional to the length of the storage period. Under any condition, one should use the frozen cream as soon as possible. However, these data show that cream can be kept in excellent condition for a period of one year if properly processed, and other trials are now in progress in which samples will be removed and examined at two years.

7. Effect of carotene content of cream on oxidized flavor development. Carotene analysis were made on the nonhomogenized samples when fresh and after 6 and 12 months storage according to the method outlined under "Experimental". Table 25 and figure 6 show the relationship between the amount of carotene in the cream and the presence of the oxidized flavor.

Analysis of these data shows no correlation existing between intensity of oxidized flavor and content of carotene in the sample.

Indeed, even in samples containing copper, there was no significant difference between its carotene content and that of the control sample although there was a marked difference in the flavor of the two.

8. Influence of initial titratable acidity on oxidized flavor development in frozen cream. Titratable acidity determinations were made on the fresh nonhomogenized samples. The titratable acidity of all groups of samples stored is presented in table 26.

As titratable acidity determinations were not made on any of the samples after a period of storage, no comparison can be made between it and the flavor after storage. Since the initial acidity of cream intended for storage is always of great importance, such determinations were made only on the fresh unfrozen cream. There did not appear to be any significant difference between the titratable acidity of the fresh samples due to the additions of copper, sugar or to the type of processing.

There appeared to be a correlation between the titratable acidity and intensity of off flavors, especially in those samples pasteurized at 150° F. for 30 minutes, upon storage (Table 26 and Figure 7). Apparently, this pasteurization exposure was not as effective as the other methods in preserving the cream when the initial acidity was unusually high.

Undoubtedly, sweet cream of quite high initial acidity may be stored

frozen if the proper processing methods are used (Table 26 and Figure 8). However, for best results, a cream having a low initial acidity is highly recommended.

9. The use of hydrogen-ion concentration determinations in fresh and frozen cream. Hydrogen-ion concentration determinations were made on the non-homogenized glass samples when fresh, and at 6 and 12 months according to the method outlined under "Experimental".

The pH of the samples pasteurized at 165° F. for 15 minutes and the influence of time of storage upon the hydrogen-ion concentration of a frozen, high testing cream are shown in table 27. The pH did not appear to be materially altered by the addition of either copper, sugar, or copper and sugar, either when the cream was fresh or after a period of storage.

Several discrepancies in pH were noted as shown in table 28. These are largely unaccounted for and possibly may be due to some extent to experimental error. However, it should be borne in mind that the average fat test of the cream used was slightly over 50 per cent and even went as high as 60 per cent in one case, so it is considered that the presence of free fat in the defrosted cream due to the destabilized fat emulsion together with the low percentage of the serum may have been responsible for some of these inconsistencies.

As a rule, there was a slight lowering of the pH, or a gradual increase in the hydrogen-ion concentration, as the period of storage increased (Figure 9).

10. The oxidation-reduction potential of fresh and stored cream. The oxidation-reduction potential was determined on the nonhomogenized glass samples at 0, 6. and 12 months. The Eh of all samples examined taken when fresh are shown in table 29; the arithmetic mean of all samples over the 12 month period being shown in table 30.

Data in these tables show that the Eh of fresh cream is affected by a number of factors, mainly, copper, and pasteurization exposure. A comparison of the effect of copper to the control sample at each of the pasteurization exposures used is shown in figure 10.

The addition of 1 part per million copper to the cream quite materially increased the Eh of the sample. This shows quite clearly that the presence of a strong oxidant will noticeably affect the Eh of a high fat cream.

Conversely, the high temperature pasteurization exposure (Figure 10) materially lowered the Eh due probably to the liberation of the sulfhydryls, glutathione and cysteine. Of especial interest, however,was the observation that under the conditions of the experiment, the pasteurization exposure had no effect upon the Eh of the cream when the cream was contaminated with 1 part per million copper.

The seasons appeared to have an effect upon the Eh of the fresh cream. As this experiment included cream of each of the 12 months, it is interesting to note that the Eh was higher in the late fall and winter months and lower in the middle summer months. Indeed, the Eh appears to coincide quite closely with the temperature of the season. However, it must be borne in mind that only one 30-gallon lot of cream was processed and stored each month and this condition could have very easily been due, at least in part, to individual variations of the various lots of cream and might not be considered as conclusive evidence of the Eh of cream for that season. Also as seasons vary with geographical location, conditions found in this experiment might differ with the findings for the same month of another location.

Table 1. The flavor of control samples of cream in glass containers at various periods of storage.

Month	Homogenization pressure (lbs.)	Oxidized flavor of cream stored: 3 months when pasteurized at 150°F. 30"	3 months when pasteurized at 165°F. 15"	3 months when pasteurized at 185°F. 5"	6 months when pasteurized at 150°F. 30"	6 months when pasteurized at 165°F. 15"	6 months when pasteurized at 185°F. 5"	12 months when pasteurized at 150°F. 30"	12 months when pasteurized at 165°F. 15"	12 months when pasteurized at 185°F. 5"
March	0	♦	-	-	♦	-	-	?	-	-
	1500	♦♦	-	-	-	-	-	-	-	-
	3000	-	-	-	-	-	-	-	-	-
April	0	♦	-	-	♦	-	-	♦	-	-
	1500	-	-	-	♦	-	-	-	-	-
	3000	-	-	-	-	-	-	-	-	-
May	0	-	-	-	-	?	-	?	-	-
	1500	-	-	-	-	♦	-	-	-	-
	3000	-	-	-	?	?	-	-	-	-
June	0	-	-	-	-	-	-	♦♦	?	-
	1500	-	-	-	-	-	-	♦	-	-
	3000	-	-	-	-	-	-	♦	-	-
July	0	-	-	-	♦♦	-	-	♦♦♦	-	-
	1500	-	-	-	-	-	-	♦	-	-
	3000	-	-	-	-	-	-	♦	-	-
August	0	-	-	-	-	-	-	?	-	-
	1500	-	-	-	-	-	-	?	-	-
	3000	-	-	-	-	-	-	♦	-	-
Sept.	0	?	-	-	-	-	-	-	-	-
	1500	?	-	-	♦♦	-	-	-	-	-
	3000	-	-	-	-	-	-	-	-	-
Oct.	0	-	-	-	♦	-	-	♦♦	-	-
	1500	-	-	-	♦	-	-	-	-	-
	3000	-	-	-	-	-	-	-	-	-
Nov.	0	-	-	-	?	-	-	?	-	-
	1500	-	-	-	-	-	-	-	-	-
	3000	-	-	-	-	-	-	-	-	-
Dec.	0	-	-	-	-	-	-	♦	-	-
	1500	-	-	-	-	-	-		-	-
	3000	-	-	-	-	-	-	-	-	-
Jan.	0	-	-	-	?	-	-	♦	-	-
	1500	-	-	-	-	-	-	♦	-	-
	3000	-	-	-	-	-	-	-	-	-
Feb.	0	-	-	-	?	-	-	♦	-	-
	1500	-	-	-	-	-	-	-	-	-
	3000	-	-	-	-	-	-	-	-	-

Table 2. The flavor of copper treated cream samples in glass containers at various periods of storage.

Month	Homogenization pressure (lbs.)	Oxidized flavor of cream stored: 3 months when pasteurized at 150°F.	165°F.	185°F.	6 months when pasteurized at 150°F.	165°F.	185°F.	12 months when pasteurized at 150°F.	165°F.	185°F.
		30"	15"	5"	30"	15"	5"	30"	15"	5"
March	0	++	+	-	+++	+++	++	+++	++	++
	1500	++	+	?	++	++	++	++	lost	+
	3000	+	++	+	+++	++	+	++	+	+
April	0	+++	+++	++	++	++	++	+++	+++	+++
	1500	+++	++	++	++	++	++	+++	++	++
	3000	+++	++	++	++	++	++	+++	+++	++
May	0	+++	+	+	+	++	++	+++	+++	++
	1500	++	+++	+++	+	++	++	+++	+++	+
	3000	+++	++	++	++	++	++	+++	++	+
June	0	++	++	++	+++	++	++	+++	++	++
	1500	++	++	++	++	++	++	+++	+	+
	3000	++	++	++	++	++	++	+++	+	+
July	0	++	++	++	+++	++	++	+++	+++	+++
	1500	++	++	++	++	++	++	+++	+++	+++
	3000	++	++	++	++	++	++	+++	+++	+++
August	0	+++	+++	++	+++	+++	++	+++	+++	+++
	1500	+++	+++	+++	+++	+++	+	+++	+++	+++
	3000	+++	++	++	+++	+++	+	+++	+++	+++
Sept.	0	+++	++	++	+++	++	+	+++	++	++
	1500	+++	++	++	+++	++	++	+++	++	++
	3000	++	++	++	+++	++	++	+++	++	++
October	0	+++	++	+	+++	++	++	+++	+++	++
	1500	++	++	?	+++	++	++	+++	+++	++
	3000	++	+++	+	+++	++	++	+++	+++	++
Nov.	0	?	-	-	++	++	++	+++	++	+
	1500	?	-	-	++	++	++	++	+	+
	3000	?	-	-	+++	++	+	++	++	+
Dec.	0	++	?	?	++	++	+	+++	++	++
	1500	+	?	?	++	++	+	+++	++	++
	3000	+	?	?	++	++	+	+++	+	++
Jan.	0	+++	++	+	+++	+++	++	+++	+++	+
	1500	+++	+++	+	+++	++	++	+++	++	+
	3000	++	++	+	+++	+	+	+++	++	+
Feb.	0	+++	+++	+	+++	++	++	+++	+++	+++
	1500	+++	++	+	+++	++	++	+++	++	++
	3000	++	++	+	+++	++	++	+++	+++	++

Table 3. The flavor of sugared cream samples in glass containers at various periods of storage.

Month	Homogenization pressure (lbs.)	Oxidized flavor of cream stored: 3 months when pasteurized at 150°F. 30"	3 months when pasteurized at 165°F. 15"	3 months when pasteurized at 185°F. 5"	6 months when pasteurized at 150°F. 30"	6 months when pasteurized at 165°F. 15"	6 months when pasteurized at 185°F. 5"	12 months when pasteurized at 150°F. 30"	12 months when pasteurized at 165°F. 15"	12 months when pasteurized at 185°F. 5"
March	0	?	-	-	-	-	-	-	-	-
	1500	+	-	-	-	-	-	-	-	-
	3000	-	-	-	-	-	-	-	-	-
April	0	+	-	-	?	-	-	-	-	-
	1500	-	-	-	+	-	-	-	-	-
	3000	-	-	-	-	-	-	-	-	-
May	0	-	-	-	-	-	?	?	-	-
	1500	-	-	-	-	?	?	-	-	-
	3000	-	-	-	-	+	?	-	-	-
June	0	-	-	-	-	-	-	+	-	-
	1500	-	-	-	-	-	-	+	-	-
	3000	-	-	-	-	-	-	+	-	-
July	0	-	-	-	-	-	-	+	-	-
	1500	-	-	-	-	-	-	?	-	-
	3000	-	-	-	-	-	-	?	-	-
August	0	-	-	-	-	-	-	-	-	-
	1500	-	-	-	-	-	-	-	-	-
	3000	-	-	-	-	-	-	-	-	-
Sept.	0	-	-	-	-	-	-	-	-	-
	1500	-	-	-	-	-	-	-	-	-
	3000	-	-	-	-	-	-	-	-	-
Oct.	0	-	-	-	?	-	-	+	-	-
	1500	-	-	-	-	-	-	-	-	-
	3000	-	-	-	-	-	-	-	-	-
Nov.	0	-	-	-	-	-	-	?	-	-
	1500	-	-	-	-	-	-	-	-	-
	3000	-	-	-	-	-	-	-	-	-
Dec.	0	-	-	-	-	-	-	+	-	-
	1500	-	-	-	-	-	-	?	-	-
	3000	-	-	-	-	-	-	?	-	-
Jan.	0	-	-	-	-	-	-	?	-	-
	1500	-	-	-	-	-	-	-	-	-
	3000	-	-	-	-	-	-	-	-	-
Feb.	0	-	-	-	-	-	-	?	-	-
	1500	-	-	-	-	-	-	-	-	-
	3000	-	-	-	-	-	-	-	-	-

Table 4. The flavor of sugared and copper treated cream samples in glass containers at various periods of storage.

Month	Homogenization pressure (lbs.)	Oxidized flavor of cream stored: 3 months when pasteurized at 150°F. 30"	3 months when pasteurized at 150°F. 15"	3 months when pasteurized at 150°F. 5"	3 months when pasteurized at 165°F. 30"	3 months when pasteurized at 165°F. 15"	3 months when pasteurized at 165°F. 5"	3 months when pasteurized at 185°F. 30"	3 months when pasteurized at 185°F. 15"	3 months when pasteurized at 185°F. 5"
	0	++	++	-	++	++	++	++	+	++
	1500	+	+	?	+++	+	?	++	+	+
March	3000	+	+	+	++	++	++	+	?	?
	0	+++	++	+	+++	+	++	+++	++	++
	1500	+++	++	++	++	+	+	++	+	+
April	3000	++	+	-	++	+	+	++	++	+
	0	++	?	-	+	++	+	++	++	++
	1500	++	++	++	+	+	++	++	+	+
May	3000	+	++	?	+	++	+	+++	+	-
	0	+++	++	++	+++	+	++	+++	++	+
	1500	++	+	++	++	+	+	+	+	+
June	3000	+	++	++	++	+	+	+	+	+
	0	++	++	++	+++	+	+	+++	+++	++
	1500	++	++	++	++	+	+	+++	+++	++
July	3000	++	++	++	++	+	+	+++	+++	++
	0	+	++	++	+++	++	+	+++	+++	++
	1500	++	+++	++	+++	++	+	+++	++	++
August	3000	++	++	++	+++	++	+	+++	lost	++
	0	++	+	+	+++	++	+	+++	+	+
	1500	++	++	+	++	++	+	++	+	+
Sept.	3000	++	++	+	++	++	+	++	+	+
	0	++	++	+	+++	++	+	+++	++	+
	1500	++	++	+	+++	++	++	+	++	++
October	3000	+	+	+	+++	++	+	+	++	+
	0	?	-	-	++	++	+	++	+	+
	1500	-	-	-	++	++	+	+	+	+
Nov.	3000	-	-	-	++	++	+	++	++	+
	0	?	?	-	++	++	+	+++	++	++
	1500	?	?	?	+	+	+	+++	++	++
Dec.	3000	?	?	?	-	+	+	+++	++	++
	0	++	++	+	++	++	+	+++	++	-
	1500	+	+	+	++	+	+	++	++	+
Jan.	3000	+	+	+	++	+	+	+++	++	+
	0	++	+	?	++	+	+	+++	++	++
	1500	+	+	?	++	+	+	++	+	+
Feb.	3000	+	+	?	++	+	+	++	++	+

EXPERIMENTAL DATA

Table 5. Freezing and Storage of Sweet Cream

Sample March 18, 1940 Factor studied Intensity of oxidized flavor Date examined 9-20-40 3-24-41

Treatment

Original Cream	Heat Treatment	Storage In	0# Control	0# 1 ppm Cu	0# 15% Sucrose	0# Cu + Sucrose	1500# Control	1500# 1 ppm Cu	1500# 15% Sucrose	1500# Cu + Sucrose	3000# Control	3000# 1 ppm Cu	3000# 15% Sucrose	3000# Cu + Sucrose
			After 6 months at 0°F.											
RAW (Separated at 100-110°F.)		Glass	+	+++	-	++	-	++	-	+++	-	+++	-	++
		Paper	++	+++	++	++	-	++	-	++	-	++	+	+
	150°F.- 30 min.	Tin	+	+++	+	+++	-	++	?	++	-	+++	-	++
Tests:			After 12 months at 0°F.											
Fat 48.0%		Glass	?	+++	-	++	-	++	-	++	-	++	-	+
Acid.		Paper	?	++	-	++	-	++	-	+	-	++	-	?
Flav.		Tin	?	+++	-	++	-	++	-	+	-	++	-	+
Caro-tene			After 6 months at 0°F.											
Bact.		Glass	-	+++	-	++	-	++	-	+	-	++	-	++
Misc.		Paper	?	++	-	+	?	+	-	++	-	++	-	++
	165°F.- 15 min.	Tin	-	++	-	++	-	++	-	+++	-	++	-	++
			After 12 months at 0°F.											
		Glass	-	++	-	+	-	lost	-	+	-	+	-	?
		Paper	-	++	-	+	-	+	-	+	-	+	-	?
		Tin	-	++	-	+	-	+	-	+	-	+	-	?
			After 6 months at 0°F.											
		Glass	-	++	-	++	-	++	-	?	-	+	-	++
		Paper	?	++	-	++	-	++	-	++	-	++	-	++
	185°F.- 5 min.	Tin	-	++	-	+	-	++	-	++	-	+	-	++
			After 12 months at 0°F.											
		Glass	-	++	-	++	-	+	-	+	-	+	-	?
		Paper	-	++	lost	+	-	+	-	+	-	+	-	?
		Tin	-	++	-	+	-	+	-	+	-	+	-	?

EXPERIMENTAL DATA

Table 6. Freezing and Storage of Sweet Cream

Sample April 12, 1940 Factor studied Intensity of oxidized flavor Date examined 10-11-40, 4-12-41

Original Cream	Heat Treatment	Storage in	Treatment: 0# Control	0# 1 ppm Cu	0# 15% Sucrose	0# Cu + Sucrose	1500# Control	1500# 1 ppm Cu	1500# 15% Sucrose	1500# Cu + Sucrose	3000# Control	3000# 1 ppm Cu	3000# 15% Sucrose	3000# Cu + Sucrose
RAW (Separated at 100-110°F.)			After 6 months at 0°F.											
		Glass	+	++	?	++	+	++	+	++	-	++	-	+
		Paper	++	+++	+	++	+	+++	+	++	+	++	-	++
	150°F.- 30 min.	Tin	+	++	-	++	+	++	-	++	-	++	+	++
Tests:			After 12 months at 0°F.											
Fat 52.0		Glass	+	+++	-	+++	-	+++	-	++	-	+++	-	++
Acid.		Paper	++	+++	-	++	++	+++	-	++	+	+++	+	++
Flav.		Tin	+	+++	-	+++	-	+++	-	++	-	+++	-	++
Caro-tene			After 6 months at 0°F.											
		Glass	-	++	-	+	-	++	-	+	-	++	-	+
Bact.		Paper	+	++	+	+	+	++	+	+	+	++	+	++
Misc.	165°F.- 15 min.	Tin	-	++	-	++	-	++	-	+	-	+	-	+
			After 12 months at 0°F.											
		Glass	-	+++	-	++	-	++	-	+	-	+++	-	++
		Paper	-	+++	-	++	?	++	-	+	-	++	-	+
		Tin	-	+++	-	++	-	+++	-	+	-	++	-	+
			After 6 months at 0°F.											
		Glass	-	+	-	++	-	++	-	+	-	++	-	+
		Paper	-	+	-	+	-	++	-	+	-	++	-	+
	185°F.- 5 min.	Tin	-	+	-	+	-	++	-	++	-	++	-	+
			After 12 months at 0°F.											
		Glass	-	+++	-	++	-	++	-	+	-	++	-	+
		Paper	-	++	-	+	-	++	-	+	-	++	-	+
		Tin	-	++	-	+	-	++	-	-	-	++	-	+

EXPERIMENTAL DATA

Table 7. Freezing and Storage of Sweet Cream

Sample May 13, 1940 Factor studied Intensity of oxidized flavor Date examined 11-16-40, 5-17-41

Original Cream	Heat Treatment	Storage in	Treatment: 0# Control	0# 1 ppm Cu	0# 15% Sucrose	0# Cu + Sucrose	1500# Control	1500# 1 ppm Cu	1500# 15% Sucrose	1500# Cu + Sucrose	3000# Control	3000# 1 ppm Cu	3000# 15% Sucrose	3000# Cu + Sucrose
RAW (Separated at 100-110°F.)			After 6 months at 0°F.											
	150°F.- 30 min.	Glass	-	+	-	+	-	+	-	+	?	++	-	+
		Paper	?	+	-	+	?	+	-	+	?	+	-	+
		Tin	?	+	-	+	?	+	-	+	?	++	-	+
			After 12 months at 0°F.											
		Glass	?	+++	?	++	-	+++	-	++	-	+++	-	+++
		Paper	?	+++	-	+++	-	+++	-	++	-	+++	-	++
		Tin	-	+++	-	+++	-	+++	-	++	-	++	-	++
			After 6 months at 0°F.											
	165°F.- 15 min.	Glass	?	++	-	++	+	++	?	+	?	++	+	++
		Paper	-	++	-	+	?	++	?	+	-	++	?	++
		Tin	-	++	-	+	?	++	?	++	?	++	?	++
			After 12 months at 0°F.											
		Glass	-	+++	-	++	-	+++	-	+	-	++	-	+
		Paper	-	+++	-	+	-	++	-	+	-	++	-	+
		Tin	-	+++	-	++	-	++	-	+	-	++	-	+
			After 6 months at 0°F.											
	185°F.- 5 min.	Glass	-	++	?	+	-	++	?	++	-	++	?	+
		Paper	-	+	?	+	-	++	?	++	-	+	?	+
		Tin	-	++	?	++	-	+	?	+	-	+	?	+
			After 12 months at 0°F.											
		Glass	-	++	-	++	-	+	-	+	-	+	-	-
		Paper	-	++	-	?	-	+	-	-	-	+	-	-
		Tin	-	++	-	+	-	++	-	-	-	++	-	-

Tests:
Fat 50.0%
Acid.
Flav.
Caro-tene
Bact.
Misc.

EXPERIMENTAL DATA

Table 8. Freezing and Storage of Sweet Cream

Sample June 7, 1940 Factor studied Intensity of oxidized flavor Date examined 12-5-40, 6-7-41

Treatment

Original Cream	Heat Treatment	Storage in	0# Control	0# 1 ppm Cu	0# 15% Sucrose	0# Cu + Sucrose	1500# Control	1500# 1 ppm Cu	1500# 15% Sucrose	1500# Cu + Sucrose	3000# Control	3000# 1 ppm Cu	3000# 15% Sucrose	3000# Cu + Sucrose
RAW (Separated at 100-110°F.)	150°F.- 30 min.		After 6 months at 0°F.											
		Glass	-	+++	-	+++	-	++	-	++	-	++	-	++
		Paper	+	++	-	+++	-	+++	-	++	-	+++	-	+
		Tin	+	+++	-	+++	+	+++	-	++	-	++	-	++
			After 12 months at 0°F.											
		Glass	++	+++	+	+++	+	+++	+	++	+	+++	+	+
		Paper	++	+++	+	+++	++	+++	+	++	++	+++	+	+
		Tin	+++	+++	+	++	++	+++	+	++	++	+++	+	+
	165°F.- 15 min.		After 6 months at 0°F.											
		Glass	-	++	-	+	-	++	-	+	-	++	-	+
		Paper	-	++	-	+	-	++	-	+	-	++	-	+
		Tin	-	++	-	+	-	++	-	+	-	++	-	++
			After 12 months at 0°F.											
		Glass	?	++	-	++	-	+	-	+	-	+	-	+
		Paper	+	+++	-	++	+	+++	-	+	?	+	-	+
		Tin	+	+++	-	++	+	+++	-	+	-	+	-	+
	185°F.- 5 min.		After 6 months at 0°F.											
		Glass	-	++	-	++	-	++	-	+	-	++	-	+
		Paper	-	++	-	+	-	++	-	+	-	+	-	+
		Tin	-	++	-	++	-	++	-	+	-	++	-	+
			After 12 months at 0°F.											
		Glass	-	++	-	+	-	+	-	+	-	+	-	+
		Paper	-	++	-	+	-	++	-	+	?	+	-	+
		Tin	-	++	-	+	-	++	-	+	-	+	-	+

Tests:
Fat 52.0
Acid.
Flav.
Caro-tene
Bact.
Misc.

EXPERIMENTAL DATA

Table 9. Freezing and Storage of Sweet Cream

Sample July 12, 1940 Factor studied **Intensity of oxidized flavor** Date examined 1-13-41, 7-10-41

Original Cream	Heat Treatment	Storage in	Treatment: 0# Control	0# 1 ppm Cu	0# 15% Sucrose	0# Cu + Sucrose	1500# Control	1500# 1 ppm Cu	1500# 15% Sucrose	1500# Cu + Sucrose	3000# Control	3000# 1 ppm Cu	3000# 15% Sucrose	3000# Cu + Sucrose
RAW (Separated at 100-110°F.)			After 6 months at 0°F.											
		Glass	++	+++	-	+++	-	++	-	++	-	++	-	++
		Paper	++	+++	-	+++	+	++	-	++	-	++	-	++
	150°F.- 30 min.	Tin	++	+++	-	+++	+	+++	-	+++	-	+++	-	+++
Tests:			After 12 months at 0°F.											
Fat 48.0%		Glass	+++	+++	+	+++	+	+++	?	+++	+	+++	?	+++
Acid.		Paper	++	+++	?	+++	++	+++	-	+++	+	+++	?	++
Flav.		Tin	++	+++	+	+++	++	+++	+	+++	++	+++	+	+++
Caro-tene			After 6 months at 0°F.											
		Glass	-	++	-	+	-	++	-	+	-	++	-	+
Bact.		Paper	?	++	-	++	-	++	-	++	-	++	-	++
Misc.	165°F.- 15 min.	Tin	-	++	-	++	-	++	-	++	-	++	-	++
			After 12 months at 0°F.											
		Glass	-	+++	-	+++	-	+++	-	+++	-	+++	-	+++
		Paper	-	+++	-	+	-	+++	-	++	-	+++	-	++
		Tin	-	+++	-	+++	-	+++	-	++	-	+++	-	+++
			After 6 months at 0°F.											
		Glass	-	++	-	+	-	++	-	+	-	++	-	+
		Paper	-	++	-	+	-	++	-	+	-	++	-	++
	185°F.- 5 min.	Tin	-	++	-	+	-	+	-	+	-	++	-	+
			After 12 months at 0°F.											
		Glass	-	+++	-	++	-	+++	-	++	-	+++	-	++
		Paper	-	+++	-	++	-	+++	-	++	-	+++	-	++
		Tin	-	+++	-	++	-	++	-	+	-	++	-	+

EXPERIMENTAL DATA

Table 10. Freezing and Storage of Sweet Cream

Sample August 16, 1940 (glass only) Factor studied Intensity of oxidized flavor Date examined 2-12-41 8-8-41

Original Cream	Heat Treatment	Storage in	Treatment: 0# Control	0# 1 ppm Cu	0# 15% Sucrose	0# Cu + Sucrose	1500# Control	1500# 1 ppm Cu	1500# 15% Sucrose	1500# Cu + Sucrose	3000# Control	3000# 1 ppm Cu	3000# 15% Sucrose	3000# Cu + Sucrose
RAW (Separated at 100-110°F.)	150°F.- 30 min.		After 6 months at 0°F.											
		Glass	-	lost	-	+++	-	+++	-	+++	-	+++	-	+++
		Paper												
		Tin												
			After 12 months at 0°F.											
		Glass	?	+++	-	+++	?	+++	-	+++	+	+++	-	+++
		Paper												
		Tin												
	165°F.- 15 min.		After 6 months at 0°F.											
		Glass	-	+++	-	++	-	+++	-	++	-	+++	-	++
		Paper												
		Tin												
			After 12 months at 0°F.											
		Glass	-	+++	-	+++	-	+++	-	++	-	+++	-	lost
		Paper												
		Tin												
	185°F.- 5 min.		After 6 months at 0°F.											
		Glass	-	++	-	+	-	+	-	+	-	+	-	+
		Paper												
		Tin												
			After 12 months at 0°F.											
		Glass	-	+++	-	++	-	+++	-	++	-	+++	-	++
		Paper												
		Tin												

Tests:
Fat 51.0%
Acid.
Flav.
Caro-tene
Exct.
Misc.

EXPERIMENTAL DATA

Table 11. Freezing and Storage of Sweet Cream

Sample September 17, 1940 Factor studied Intensity of oxidized flavor Date examined 3-20-41, 9-4-41

Original Cream	Heat Treatment	Storage in	Treatment: 0# Control	0# 1 ppm Cu	0# 15% Sucrose	0# Cu + Sucrose	1500# Control	1500# 1 ppm Cu	1500# 15% Sucrose	1500# Cu + Sucrose	3000# Control	3000# 1 ppm Cu	3000# 15% Sucrose	3000# Cu + Sucrose
			After 6 months at 0°F.											
RAW (Separated at 100-110°F.)	150°F.- 30 min.	Glass	-	+++	-	+++	++	+++	-	++	-	+++	-	++
		Paper	-	+++	-	+++	-	+++	-	+++	-	+++	-	++
		Tin	-	+++	-	+++	-	+++	-	+++	-	+++	-	++
			After 12 months at 0°F.											
		Glass	-	+++	-	+++	-	+++	-	++	-	+++	-	++
		Paper	-	+++	-	++	-	++	-	++	-	++	-	+
		Tin	-	+++	-	++	-	++	-	++	-	++	-	+
	165°F.- 15 min.		After 6 months at 0°F.											
		Glass	-	++	-	++	-	++	-	++	-	++	-	++
		Paper	-	++	-	++	-	++	-	++	-	++	-	++
		Tin	-	++	-	+	-	++	-	+	-	++	-	+
			After 12 months at 0°F.											
		Glass	-	++	-	+	-	++	-	+	-	++	-	+
		Paper	-	++	-	+	-	++	-	+	-	++	-	+
		Tin	-	++	-	+	-	++	-	+	-	++	-	+
	185°F.- 5 min.		After 6 months at 0°F.											
		Glass	-	+	-	+	-	++	-	+	-	++	-	+
		Paper	-	++	-	+	-	++	-	+	-	++	-	+
		Tin	-	++	-	+	-	++	-	+	-	++	-	+
			After 12 months at 0°F.											
		Glass	-	++	-	++	-	++	-	+	-	++	-	+
		Paper	-	+	-	+	-	+	-	+	-	+	-	+
		Tin	-	++	-	+	-	+	-	+	-	+	-	+

Tests: Fat 55.0% Acid. Flav. Caro-tene Bact. Misc.

EXPERIMENTAL DATA

Table 12. Freezing and Storage of Sweet Cream

Sample October 9, 1941 Factor studied Intensity of Oxidized Flavor Date examined 9-9-41 4-14-41

Original Cream	Heat Treatment	Storage in	Treatment: 0# Control	0# 1 ppm Cu	0# 15% Sucrose	0# Cu + Sucrose	1500# Control	1500# 1 ppm Cu	1500# 15% Sucrose	1500# Cu + Sucrose	3000# Control	3000# 1 ppm Cu	3000# 15% Sucrose	3000# Cu + Sucrose
RAW (Separated at 100-110°F.)			After 6 months at 0°F.											
		Glass	+	+++	?	+++	?	++	-	+++	-	+++	-	+++
		Paper	+	+++	?	++	+	++	-	++	-	+++	-	++
	150°F.- 30 min.	Tin	+	+++	?	+++	+	+++	?	+++	-	+++	-	++
ests:			After 12 months at 0°F.											
Fat 60.0%		Glass	++	+++	*	+++	-	+++	-	+	-	+++	-	+
Acid.		Paper	++	+++	+	+++	-	+++	-	+	-	+++	-	+
Flav.		Tin	++	+++	+	+++	-	+++	-	+	-	+++	-	++
Caro- tene			After 6 months at 0°F.											
		Glass	-	++	-	++	-	++	-	++	-	++	-	++
Bact.		Paper	-	++	-	+	-	++	-	+	-	++	-	+
Misc.	165°F.- 15 min.	Tin	-	++	-	++	-	++	-	++	-	++	-	++
			After 12 months at 0°F.											
		Glass	-	+++	-	++	-	+++	-	++	-	+++	-	++
		Paper	-	+++	-	++	-	+++	-	+	-	+++	-	++
		Tin	-	+++	-	++	-	+++	-	++	-	+++	-	++
			After 6 months at 0°F.											
		Glass	-	++	-	+	-	++	-	++	-	++	-	+
		Paper	-	++	-	+	-	++	-	+	-	++	-	+
	185°F.- 5 min.	Tin	-	++	-	+	-	++	-	++	-	++	-	++
			After 12 months at 0°F.											
		Glass	-	++	-	+	-	++	-	++	-	++	-	+
		Paper	-	++	-	+	-	++	-	+	-	++	-	+
		Tin	-	++	-	+	-	++	-	++	-	++	-	+

EXPERIMENTAL DATA

Table 13. Freezing and Storage of Sweet Cream

Sample November 20, 1940 Factor studied Intensity of Oxidized Flavor Date examined 5-25-41 11-14-41

Original Cream	Heat Treatment	Storage in	Treatment: 0# Control	0# 1 ppm Cu	0# 15% Sucrose	0# Cu + Sucrose	1500# Control	1500# 1 ppm Cu	1500# 15% Sucrose	1500# Cu + Sucrose	3000# Control	3000# 1 ppm Cu	3000# 15% Sucrose	3000# Cu + Sucrose
			After 6 months at 0°F.											
RAW (Separated at 100-110°F.)		Glass	?	++	-	++	-	++	-	++	-	+++	-	++
		Paper	-	++	-	++	-	++	-	++	-	++	-	++
	150°F.- 30 min.	Tin	-	++	-	++	-	++	-	++	-	++	-	++
ests:			After 12 months at 0°F.											
Fat 56.0%		Glass	?	+++	?	++	-	++	-	+	-	++	-	++
Acid.		Paper	++	+++	?	++	-	++	-	+	?	++	-	++
Flav.		Tin	++	+++	+	++	-	++	-	+	-	++	-	++
Caro-tene			After 6 months at 0°F.											
Bact.		Glass	-	++	-	+	-	+	-	+	-	++	-	++
Misc.		Paper	-	+	-	+	-	+	-	+	-	++	-	+
	165°F.- 15 min.	Tin	-	++	-	+	-	++	-	+	-	++	-	++
			After 12 months at 0°F.											
		Glass	-	++	-	+	-	+	-	+	-	++	-	++
		Paper	-	+	-	+	-	+	-	+	-	+	-	+
		Tin	-	+	-	+	-	+	-	+	-	+	-	+
			After 6 months at 0°F.											
		Glass	-	++	-	+	-	+	-	+	-	+	-	+
		Paper	-	++	-	+	-	+	-	+	-	+	-	+
	185°F.- 5 min.	Tin	-	++	-	+	-	+	-	+	-	+	-	+
			After 12 months at 0°F.											
		Glass	-	+	-	+	-	+	-	+	-	+	-	+
		Paper	-	+	-	+	-	+	-	+	-	+	-	+
		Tin	-	+	-	+	-	+	-	+	-	+	-	+

EXPERIMENTAL DATA

Table 14. Freezing and Storage of Sweet Cream

Sample December 18, 1941 Factor studied Intensity of oxidized flavor Date examined 6-17-41 2-16-41

Treatment

Original Cream	Heat Treatment	Storage in	0# Control	0# 1 ppm Cu	0# 15% Sucrose	0# Cu + Sucrose	1500# Control	1500# 1 ppm Cu	1500# 15% Sucrose	1500# Cu + Sucrose	3000# Control	3000# 1 ppm Cu	3000# 15% Sucrose	3000# Cu + Sucrose
			After 6 months at 0°F.											
RAW (Separated at 100-110°F.)	150°F.-30 min.	Glass	-	++	-	++	-	++	-	+	-	++	-	-
		Paper	?	+++	-	++	-	++	-	+	-	++	-	++
		Tin	-	+++	-	++	-	++	-	++	-	++	-	+
			After 12 months at 0°F.											
Tests:		Glass	+	+++	+	+++	?	+++	?	+++	-	+++	?	+++
Fat 54.0		Paper	+	+++	+	+++	+	+++	?	+++	-	+++	-	+++
Acid.		Tin	+	+++	+	+++	-	+++	-	++	-	+++	-	++
Flav.			After 6 months at 0°F.											
Caro-tene	165°F.-15 min.	Glass	-	++	-	++	-	++	-	+	-	++	-	+
Bact.		Paper	-	++	-	++	-	++	-	+	-	++	-	+
Misc.		Tin	-	++	-	++	-	++	-	+	-	++	-	?
			After 12 months at 0°F.											
		Glass	-	++	-	++	-	++	-	++	-	+	-	++
		Paper	-	++	-	++	-	++	-	++	-	++	-	++
		Tin	-	++	-	++	-	++	-	+	-	++	-	++
			After 6 months at 0°F.											
	185°F.-5 min.	Glass	-	+	-	+	-	+	-	+	-	+	-	+
		Paper	-	+	-	+	-	+	-	?	-	+	-	+
		Tin	-	+	-	+	-	+	-	?	-	+	-	+
			After 12 months at 0°F.											
		Glass	-	++	-	++	-	++	-	++	-	++	-	++
		Paper	-	++	-	++	-	++	-	++	-	++	-	++
		Tin	-	++	-	++	-	++	-	++	-	++	-	++

EXPERIMENTAL DATA

Table 15. Freezing and Storage of Sweet Cream

Sample January 18, 1941 Factor studied Intensity of oxidized flavor Date examined 7-10-41 / 1-8-42

Treatment

Original Cream	Heat Treatment	Storage in	0# Control	0# 1 ppm Cu	0# 15% Sucrose	0# Cu + Sucrose	1500# Control	1500# 1 ppm Cu	1500# 15% Sucrose	1500# Cu + Sucrose	3000# Control	3000# 1 ppm Cu	3000# 15% Sucrose	3000# Cu + Sucrose
RAW (Separated at 100-110°F.)			After 6 months at 0°F.											
		Glass	?	+++	-	++	-	+++	-	++	-	+++	-	++
		Paper	++	+++	-	++	?	+++	-	++	-	+++	-	++
	150°F.- 30 min.	Tin	?	+++	?	++	-	+++	-	++	-	+++	-	++
ests:			After 12 months at 0°F.											
Fat		Glass	+	+++	?	+++	+	+++	-	++	-	+++	++	+++
Acid.		Paper	++	+++	+	+++	+	+++	-	++	?	+++	-	++
Flav.		Tin	+	+++	+	+++	+	+++	?	++	+	+++	-	+++
Caro-tene			After 6 months at 0°F.											
Bact.		Glass	-	+++	-	++	-	++	-	+	-	+	-	+
Misc.		Paper	-	+++	-	++	-	++	-	lost	-	++	-	+
	165°F.- 15 min.	Tin	-	+++	-	++	-	++	-	lost	-	++	-	+
			After 12 months at 0°F.											
		Glass	-	+++	-	++	-	++	-	++	-	++	-	++
		Paper	?	+++	-	++	-	+++	-	++	-	+++	-	++
		Tin	-	+++	-	++	-	++	-	++	-	++	-	++
			After 6 months at 0°F.											
		Glass	-	++	-	+	-	++	-	+	-	+	-	+
		Paper	-	++	-	+	-	++	-	+	-	+	-	+
	185°F.- 5 min.	Tin	-	++	-	+	-	++	-	+	-	+	-	+
			After 12 months at 0°F.											
		Glass	-	+	-	-	-	+	-	+	-	+	-	+
		Paper	-	++	-	++	-	+	-	+	-	+	-	+
		Tin	-	++	-	++	-	+	-	+	-	+	-	+

EXPERIMENTAL DATA

Table 16. Freezing and Storage of Sweet Cream

Sample February 15, 1941 Factor studied Intensity of oxidized flavor Date examined 8-11-41 2-5-42

Treatment

Original Cream	Heat Treatment	Storage in	0# Control	0# 1 ppm Cu	0# 15% Sucrose	0# Cu + Sucrose	1500# Control	1500# 1 ppm Cu	1500# 15% Sucrose	1500# Cu + Sucrose	3000# Control	3000# 1 ppm Cu	3000# 15% Sucrose	3000# Cu + Sucrose
RAW (Separated at 100-110°F.)			After 6 months at 0°F.											
		Glass	?	+++	-	++	-	+++	-	++	-	+++	-	++
		Paper	?	+++	-	++	-	+++	-	++	-	+++	-	++
	150°F.- 30 min.	Tin	?	+++	-	++	-	+++	-	++	-	+++	-	++
			After 12 months at 0°F.											
Tests:		Glass	+	+++	?	+++	-	+++	-	++	-	+++	-	++
Fat 50.0		Paper	+	+++	?	+++	-	+++	-	++	?	+++	-	++
Acid.		Tin	+	+++	-	+++	-	++	-	++	-	++	-	++
Flav.			After 6 months at 0°F.											
Caro-tene		Glass	-	++	-	+	-	++	-	*	-	++	-	+
Bact.		Paper	-	++	-	+	-	++	-	+	-	++	-	+
Misc.	165°F.- 15 min.	Tin	-	++	-	+	-	++	-	+	-	++	-	+
			After 12 months at 0°F.											
		Glass	-	+++	-	++	-	++	-	+	-	+++	-	++
		Paper	-	+++	-	++	-	++	-	+	?	+++	-	lost
		Tin	-	++	-	++	-	++	-	+	-	++	-	+
			After 6 months at 0°F.											
		Glass	-	++	-	+	-	++	-	+	-	++	-	*
		Paper	-	++	-	+	-	++	-	+	-	++	-	+
	185°F.- 5 min.	Tin	-	++	-	+	-	++	-	+	-	++	-	+ 54
			After 12 months at 0°F.											
		Glass	-	+++	-	++	-	++	-	+	-	++	-	+
		Paper	-	lost	-	++	-	++	-	+	-	++	-	+
		Tin	-	++	-	+	=	+	-	+	-	+	-	+

Table 17. The flavor of control cream samples in various containers when stored 6 months.

Month	Homogenization pressure (lbs.)	Oxidized flavor of cream when pasteurized at 150°F. - 30" and stored in glass	paper	tin	165°F. - 15" and stored in glass	paper	tin	185°F. - 5" and stored in glass	paper	tin
March	0	+	++	+	-	-	-	-	-	-
	1500	-	-	-	-	-	-	-	-	-
	3000	-	-	-	-	-	-	-	-	-
April	0	+	++	+	-	+	-	-	-	-
	1500	+	+	+	-	+	-	-	-	-
	3000	-	+	-	-	+	-	-	-	-
May	0	-	-	-	-	-	-	-	-	-
	1500	-	-	-	-	-	-	-	-	-
	3000	-	-	-	-	-	-	-	-	-
June	0	-	+	+	-	-	-	-	-	-
	1500	-	-	+	-	-	-	-	-	-
	3000	-	-	-	-	-	-	-	-	-
July	0	++	++	++	-	-	-	-	-	-
	1500	-	+	+	-	-	-	-	-	-
	3000	-	-	-	-	-	-	-	-	-
August (No tin or paper)	0	-			-			-		
	1500	-			-			-		
	3000	-			-			-		
September	0	-	-	-	-	-	-	-	-	-
	1500	-	-	-	-	-	-	-	-	-
	3000	-	-	-	-	-	-	-	-	-
October	0	-	+	-	-	-	-	-	-	-
	1500	-	+	-	-	-	-	-	-	-
	3000	-	-	-	-	-	-	-	-	-
November	0	-	-	-	-	-	-	-	-	-
	1500	-	-	-	-	-	-	-	-	-
	3000	-	-	-	-	-	-	-	-	-
December	0	-	-	-	-	-	-	-	-	-
	1500	-	-	-	-	-	-	-	-	-
	3000	-	-	-	-	-	-	-	-	-
January	0	-	-	-	-	-	-	-	-	-
	1500	-	-	-	-	-	-	-	-	-
	3000	-	-	-	-	-	-	-	-	-
February	0	-	-	-	-	-	-	-	-	-
	1500	-	-	-	-	-	-	-	-	-
	3000	-	-	-	-	-	-	-	-	-

Table 18. The flavor of copper treated cream samples in various containers when stored 6 months.

Month	Homogenization pressure (lbs.)	Oxidized flavor of cream when pasteurized at 150°F. - 30" and stored in glass	paper	tin	165°F. - 15" and stored in glass	paper	tin	185°F. - 5" and stored in glass	paper	tin
March	0	♦♦♦	♦♦♦	♦♦♦	♦♦♦	♦♦	♦♦	♦♦	♦♦	♦♦
	1500	♦♦	♦♦	♦♦	♦♦	♦	♦♦	♦♦	♦♦	♦♦
	3000	♦♦♦	♦♦	♦♦♦	♦♦	♦♦	♦♦	♦	♦♦	♦
April	0	♦♦	♦♦	♦♦	♦♦	♦♦	♦♦	♦	♦	♦
	1500	♦♦	♦♦♦	♦♦	♦♦	♦♦	♦♦	♦♦	♦♦	♦♦
	3000	♦♦	♦♦	♦♦	♦♦	♦♦	♦	♦♦	♦♦	♦♦
May	0	♦	♦	♦	♦♦	♦♦	♦♦	♦♦	♦	♦♦
	1500	♦	♦	♦	♦♦	♦♦	♦♦	♦♦	♦♦	♦
	3000	♦♦	♦	♦♦	♦♦	♦♦	♦♦	♦♦	♦	♦
June	0	♦♦♦	♦♦	♦♦♦	♦♦	♦♦	♦♦	♦♦	♦♦	♦♦
	1500	♦♦	♦♦♦	♦♦♦	♦♦	♦♦	♦♦	♦♦	♦♦	♦♦
	3000	♦♦	♦♦	♦♦	♦♦	♦♦	♦♦	♦♦	♦	♦♦
July	0	♦♦♦	♦♦♦	♦♦♦	♦♦	♦♦	♦♦	♦♦	♦♦	♦♦
	1500	♦♦	♦♦	♦♦♦	♦♦	♦♦	♦♦	♦♦	♦♦	♦♦
	3000	♦♦	♦♦	♦♦♦	♦♦	♦♦	♦♦	♦♦	♦♦	♦♦
August (No tin or paper)	0	lost			♦♦♦			♦♦		
	1500	♦♦♦			♦♦♦			♦		
	3000	♦♦♦			♦♦			♦		
September	0	♦♦♦	♦♦♦	♦♦♦	♦♦	♦♦	♦♦	♦	♦♦	♦♦
	1500	♦♦♦	♦♦♦	♦♦♦	♦♦	♦♦	♦♦	♦♦	♦	♦
	3000	♦♦♦	♦♦♦	♦♦♦	♦♦	♦♦	♦♦	♦♦	♦♦	♦♦
October	0	♦♦♦	♦♦♦	♦♦♦	♦♦	♦♦	♦♦	♦♦	♦♦	♦♦
	1500	♦♦♦	♦♦♦	♦♦♦	♦♦	♦♦	♦♦	♦♦	♦♦	♦♦
	3000	♦♦♦	♦♦♦	♦♦♦	♦♦	♦♦	♦♦	♦♦	♦♦	♦♦
November	0	♦♦	♦♦	♦♦	♦♦	♦♦	♦♦	♦♦	♦♦	♦♦
	1500	♦♦	♦♦	♦♦	♦♦	♦♦	♦♦	♦	♦	♦
	3000	♦♦♦	♦♦	♦♦	♦♦	♦♦	♦♦	♦	♦	♦
December	0	♦♦	♦♦♦	♦♦♦	♦♦	♦♦	♦♦	♦	♦	♦
	1500	♦♦	♦♦	♦♦	♦♦	♦♦	♦♦	♦	♦	♦
	3000	♦♦	♦♦	♦♦	♦♦	♦♦	♦♦	♦	♦	♦
January	0	♦♦♦	♦♦♦	♦♦♦	♦♦♦	♦♦♦	♦♦♦	♦♦	♦♦	♦♦
	1500	♦♦♦	♦♦♦	♦♦♦	♦♦	♦♦	♦♦	♦♦	♦♦	♦♦
	3000	♦♦♦	♦♦♦	♦♦♦	♦	♦♦	♦♦	♦	♦	♦
February	0	♦♦♦	♦♦♦	♦♦♦	♦♦	♦♦	♦♦	♦♦	♦♦	♦♦
	1500	♦♦♦	♦♦♦	♦♦♦	♦♦	♦♦	♦♦	♦♦	♦♦	♦♦
	3000	♦♦♦	♦♦♦	♦♦♦	♦♦	♦♦	♦♦	♦♦	♦♦	♦♦

Table 19. The flavor of sugared cream samples in various containers when stored 6 months.

Month	Homogenization pressure (lbs.)	Oxidized flavor of cream when pasteurized at 150°F. - 30" and stored in glass	paper	tin	165°F. - 15" and stored in glass	paper	tin	185°F. - 5" and stored in glass	paper	tin
	0	-	++	+	-	-	-	-	-	-
	1500	-	-	-	-	-	-	-	-	-
March	3000	-	+	-	-	-	-	-	-	-
	0	-	+	-	-	+	-	+	-	-
	1500	+	+	-	-	+	-	-	-	-
April	3000	-	-	+	-	+	-	-	-	-
	0	-	-	-	-	-	-	-	-	-
	1500	-	-	-	-	-	-	-	-	-
May	3000	-	-	-	-	-	-	+	-	-
	0	-	-	-	-	-	-	-	-	-
	1500	-	-	-	-	-	-	-	-	-
June	3000	-	-	-	-	-	-	-	-	-
	0	-	-	-	-	-	-	-	-	-
	1500	-	-	-	-	-	-	-	-	-
July	3000	-	-	-	-	-	-	-	-	-
(No tin or paper)	0	-			-			-		
	1500	-			-			-		
August	3000	-			-			-		
	0	-	-	-	-	-	-	-	-	-
	1500	-	-	-	-	-	-	-	-	-
September	3000	-	-	-	-	-	-	-	-	-
	0	-	-	?	-	-	-	-	-	-
	1500	-	-	?	-	-	-	-	-	-
October	3000	-	-	-	-	-	-	-	-	-
	0	-	-	-	-	-	-	-	-	-
	1500	-	-	-	-	-	-	-	-	-
November	3000	-	-	-	-	-	-	-	-	-
	0	-	-	-	-	-	-	-	-	-
	1500	-	-	-	-	-	-	-	-	-
December	3000	-	-	-	-	-	-	-	-	-
	0	-	-	?	-	-	-	-	-	-
	1500	-	-	-	-	-	-	-	-	-
January	3000	-	-	-	-	-	-	-	-	-
	0	-	-	-	-	-	-	-	-	-
	1500	-	-	-	-	-	-	-	-	-
February	3000	-	-	-	-	-	-	-	-	-

Table 20. The flavor of sugared and copper treated cream samples in various containers when stored 6 months.

Month	Homogenization pressure (lbs.)	Oxidized flavor of cream when pasteurized at 150°F. - 30" and stored in glass	paper	tin	165°F. - 15" and stored in glass	paper	tin	185°F. - 5" and stored in glass	paper	tin
March	0	++	++	+++	++	+	++	++	++	+
	1500	+++	++	++	+	++	+++	-	++	++
	3000	++	+	++	++	++	++	++	++	++
April	0	++	++	++	+	+	++	++	+	+
	1500	++	++	++	+	+	+	+	-	++
	3000	+	++	++	+	++	+	+	+	+
May	0	+	+	+	++	+	+	+	+	++
	1500	+	+	+	+	+	++	++	++	+
	3000	+	+	+	++	+	++	+	+	+
June	0	+++	+++	+++	+	+	+	++	+	++
	1500	++	++	++	+	+	+	+	+	+
	3000	++	+	+	+	+	++	+	+	+
July	0	+++	+++	+++	+	++	++	+	+	+
	1500	++	++	+++	+	++	++	+	+	+
	3000	++	++	++	+	++	++	+	++	+
August (No tin or paper)	0	+++			++			+		
	1500	+++			++			+		
	3000	+++			++			+		
September	0	+++	+++	+++	++	++	+	+	+	+
	1500	++	+++	++	++	++	+	+	+	+
	3000	++	++	++	++	++	+	+	+	+
October	0	+++	++	+++	++	+	++	+	+	+
	1500	+++	++	+++	++	+	++	++	+	++
	3000	+++	++	++	++	+	++	+	+	++
November	0	++	++	++	++	+	+	+	+	+
	1500	++	++	++	++	+	+	+	+	+
	3000	++	++	++	+	+	++	+	+	+
December	0	++	++	++	++	++	++	+	+	+
	1500	+	+	++	+	+	+	+	?	?
	3000	-	++	+	+	+	?	+	+	+
January	0	++	++	++	++	++	++	+	+	+
	1500	++	++	++	+	lost	lost	+	+	+
	3000	++	++	++	+	+	+	+	+	+
February	0	++	++	++	+	+	+	+	+	+
	1500	++	++	++	+	+	+	+	+	+
	3000	++	++	++	+	+	+	+	+	+

Table 21. The flavor of control cream samples in various containers when stored 12 months.

Month	Homogenization pressure (lbs.)	Oxidized flavor of cream when pasteurized at 150°F. - 30" and stored in glass	paper	tin	165°F. - 15" and stored in glass	paper	tin	185°F. - 5" and stored in glass	paper	tin
	0	?	-	-	?	-	-	-	-	-
	1500	-	-	-	-	-	-	-	-	-
March	3000	-	-	-	-	-	-	-	-	-
	0	-	++	+	-	-	-	-	-	-
	1500	-	+	-	-	?	-	-	-	-
April	3000	-	+	-	-	-	-	-	-	-
	0	-	-	-	-	-	-	-	-	-
	1500	-	-	-	-	-	-	-	-	-
May	3000	-	-	-	-	-	-	-	-	-
	0	++	++	+++	?	+	+	-	-	-
	1500	+	++	++	-	+	+	-	-	-
June	3000	+	++	++	-	?	-	-	?	-
	0	+++	++	++	-	-	-	-	-	-
	1500	+	++	++	-	-	-	-	-	-
July	3000	+	+	++	-	-	-	-	-	-
(No tin or paper)	0	-			-			-		
	1500	-			-			-		
August	3000	-			-			-		
	0	-	-	-	-	-	-	-	-	-
	1500	-	-	-	-	-	-	-	-	-
September	3000	-	-	-	-	-	-	-	-	-
	0	++	++	++	-	-	-	-	-	-
	1500	-	-	-	-	-	-	-	-	-
October	3000	-	-	-	-	-	-	-	-	-
	0	?	++	++	-	-	-	-	-	-
	1500	-	-	-	-	-	-	-	-	-
November	3000	-	-	-	-	-	-	-	-	-
	0	+	+	+	-	-	-	-	-	-
	1500	?	+	-	-	-	-	-	-	-
December	3000	-	-	-	-	-	-	-	-	-
	0	+	++	+	-	?	-	-	-	-
	1500	+	+	+	-	-	-	-	-	-
January	3000	-	?	+	-	-	-	-	-	-
	0	+	+	+	-	-	-	-	-	-
	1500	-	-	-	-	-	-	-	-	-
February	3000	-	?	-	-	?	-	-	-	-

Table 22. The flavor of copper treated cream samples in various containers when stored 12 months.

Month	Homogenization pressure (lbs.)	Oxidized flavor of cream when pasteurized at 150°F. - 30" and stored in glass	paper	tin	165°F. - 15" and stored in glass	paper	tin	185°F. - 5" and stored in glass	paper	tin
March	0	♦♦♦	♦♦	♦♦♦	♦♦	♦♦	♦♦	♦♦	♦♦	♦♦
	1500	♦♦	♦♦	♦♦	lost	♦	♦	♦	♦	♦
	3000	♦♦	♦♦	♦♦	♦	♦	♦	♦	?	♦
April	0	♦♦♦	♦♦♦	♦♦♦	♦♦♦	♦♦♦	♦♦♦	♦♦♦	♦♦	♦♦
	1500	♦♦♦	♦♦♦	♦♦♦	♦♦	♦♦	♦♦♦	♦♦	♦♦	♦♦
	3000	♦♦♦	♦♦♦	♦♦♦	♦♦♦	♦♦	♦♦	♦♦	♦♦	♦♦
May	0	♦♦♦	♦♦♦	♦♦♦	♦♦♦	♦♦♦	♦♦♦	♦♦	♦♦	♦♦
	1500	♦♦♦	♦♦♦	♦♦♦	♦♦♦	♦♦	♦♦	♦	♦	♦♦
	3000	♦♦♦	♦♦♦	♦♦	♦♦	♦♦	♦♦	♦	♦	♦♦
June	0	♦♦♦	♦♦♦	♦♦♦	♦♦	♦♦♦	♦♦♦	♦♦	♦♦	♦♦
	1500	♦♦♦	♦♦♦	♦♦♦	♦	♦♦♦	♦♦♦	♦	♦♦	♦♦
	3000	♦♦♦	♦♦♦	♦♦♦	♦	♦	♦	♦	♦	♦
July	0	♦♦♦	♦♦♦	♦♦♦	♦♦♦	♦♦♦	♦♦♦	♦♦♦	♦♦♦	♦♦♦
	1500	♦♦♦	♦♦♦	♦♦♦	♦♦♦	♦♦♦	♦♦♦	♦♦♦	♦♦♦	♦♦
	3000	♦♦♦	♦♦♦	♦♦♦	♦♦♦	♦♦♦	♦♦♦	♦♦♦	♦♦♦	♦♦
August (No tin or paper)	0	♦♦♦			♦♦♦			♦♦♦		
	1500	♦♦♦			♦♦♦			♦♦♦		
	3000	♦♦♦			♦♦♦			♦♦♦		
September	0	♦♦♦	♦♦♦	♦♦♦	♦♦	♦♦	♦♦	♦♦	♦	♦♦
	1500	♦♦♦	♦♦	♦♦	♦♦	♦♦	♦♦	♦♦	♦	♦
	3000	♦♦♦	♦♦	♦♦	♦♦	♦♦	♦♦	♦♦	♦	♦
October	0	♦♦♦	♦♦♦	♦♦♦	♦♦♦	♦♦♦	♦♦♦	♦♦	♦♦	♦♦
	1500	♦♦♦	♦♦♦	♦♦♦	♦♦♦	♦♦♦	♦♦♦	♦♦	♦♦	♦♦
	3000	♦♦♦	♦♦♦	♦♦♦	♦♦♦	♦♦♦	♦♦♦	♦♦	♦♦	♦♦
November	0	♦♦♦	♦♦♦	♦♦♦	♦♦	♦	♦	♦	♦	♦
	1500	♦♦	♦♦	♦♦	♦	♦	♦	♦	♦	♦
	3000	♦♦	♦♦	♦♦	♦♦	♦	♦	♦	♦	♦
December	0	♦♦♦	♦♦♦	♦♦♦	♦♦	♦♦	♦♦	♦♦	♦♦	♦♦
	1500	♦♦♦	♦♦♦	♦♦♦	♦♦	♦♦	♦♦	♦♦	♦♦	♦♦
	3000	♦♦♦	♦♦♦	♦♦♦	♦	♦♦	♦♦	♦♦	♦♦	♦♦
January	0	♦♦♦	♦♦♦	♦♦♦	♦♦♦	♦♦♦	♦♦♦	♦	♦♦	♦♦
	1500	♦♦♦	♦♦♦	♦♦♦	♦♦	♦♦♦	♦♦	♦	♦	♦
	3000	♦♦♦	♦♦♦	♦♦♦	♦♦	♦♦♦	♦♦	♦	♦	♦
February	0	♦♦♦	♦♦♦	♦♦♦	♦♦♦	♦♦♦	♦♦	♦♦♦	lost	♦♦
	1500	♦♦♦	♦♦♦	♦♦	♦♦	♦♦	♦♦	♦♦	♦♦	♦
	3000	♦♦♦	♦♦♦	♦♦	♦♦♦	♦♦♦	♦♦	♦♦	♦♦	♦

Table 23. The flavor of sugered cream samples in various containers when stored 12 months.

Month	Homogenization pressure (lbs.)	Oxidized flavor of cream when pasteurized at 150°F. - 30" and stored in glass	paper	tin	165°F. - 15" and stored in glass	paper	tin	185°F. - 5" and stored in glass	paper	tin
March	0	-	-	-	-	-	-	-	lost	-
	1500	-	-	-	-	-	-	-	-	-
	3000	-	-	-	-	-	-	-	-	-
April	0	-	-	-	-	-	-	+	-	-
	1500	-	-	-	-	-	-	-	-	-
	3000	-	-	-	-	-	-	-	-	-
May	0	-	-	-	-	-	-	-	-	-
	1500	-	-	-	-	-	-	-	-	-
	3000	-	-	-	+	-	-	+	-	-
June	0	+	+	+	-	-	-	-	-	-
	1500	+	+	+	-	-	-	-	-	-
	3000	+	+	+	-	-	-	-	-	-
July	0	+	-	+	-	-	-	-	-	-
	1500	-	-	+	-	-	-	-	-	-
	3000	?	?	+	-	-	-	-	-	-
August (No tin or paper)	0	-			-			-		
	1500	-			-			-		
	3000	-			-			-		
September	0	-	-	-	-	-	-	-	-	-
	1500	-	-	-	-	-	-	-	-	-
	3000	-	-	-	-	-	-	-	-	-
October	0	+	+	+	-	-	-	-	-	-
	1500	-	-	-	-	-	-	-	-	-
	3000	-	-	-	-	-	-	-	-	-
November	0	?	?	+	-	-	-	-	-	-
	1500	-	-	-	-	-	-	-	-	-
	3000	-	-	-	-	-	-	-	-	-
December	0	+	+	+	-	-	-	-	-	-
	1500	?	?	-	-	-	-	-	-	-
	3000	?	-	-	-	-	-	-	-	-
January	0	?	+	+	-	-	-	-	-	-
	1500	-	-	?	-	-	-	-	-	-
	3000	++	-	-	-	-	-	-	-	-
February	0	?	?	-	-	-	-	-	-	-
	1500	-	-	-	-	-	-	-	-	-
	3000	-	-	-	-	-	-	-	-	-

Table 24. The flavor of sugared and copper treated cream samples in various containers when stored 12 months.

Month	Homogenization pressure (lbs.)	Oxidized flavor of cream when pasteurized at 150°F. - 30" and stored in glass	paper	tin	165° F. - 15" and stored in glass	paper	tin	185°F. - 5" and stored in glass	paper	tin
March	0	++	++	++	+	+	+	++	+	+
	1500	++	+	+	+	+	+	+	+	+
	3000	+	?	+	?	?	?	?	?	?
April	0	+++	++	+++	++	++	++	++	+	+
	1500	++	++	++	+	+	+	+	+	-
	3000	++	++	++	++	+	+	+	+	+
May	0	++	+++	+++	++	+	++	++	?	+
	1500	++	++	++	+	+	+	+	-	-
	3000	+++	++	++	+	+	+	-	-	-
June	0	+++	+++	++	++	++	++	+	+	+
	1500	++	++	++	+	+	+	+	+	+
	3000	+	+	+	+	+	+	+	+	+
July	0	+++	+++	+++	+++	++	+++	++	++	++
	1500	+++	+++	+++	+++	++	++	++	++	+
	3000	+++	++	+++	+++	++	+++	++	++	+
August (No tin or paper)	0	+++			+++		++			
	1500	+++			++		++			
	3000	+++			lost		++			
September	0	+++	++	++	+	+	+	+	+	+
	1500	++	++	++	+	+	+	+	+	+
	3000	++	+	+	+	+	+	+	+	+
October	0	+++	+++	+++	++	++	++	+	+	+
	1500	+	+	+	++	++	++	++	++	++
	3000	+	++	++	++	++	++	+	+	+
November	0	++	++	++	+	+	+	+	+	+
	1500	+	+	+	+	+	+	+	+	+
	3000	++	++	++	++	+	+	+	+	+
December	0	+++	+++	+++	++	++	++	++	++	++
	1500	+++	+++	++	++	++	++	++	++	++
	3000	+++	+++	++	++	++	++	++	++	++
January	0	+++	+++	+++	++	++	++	-	++	++
	1500	++	++	++	++	++	++	+	+	+
	3000	++	++	++	++	++	++	+	+	+
February	0	+++	++	++	++	++	++	++	++	+
	1500	++	++	++	+	+	+	+	+	+
	3000	++	++	++	++	lost	+	+	+	+

Table 25. A comparison of the carotene content and the intensity of oxidized flavor in the nonhomogenized samples over a 12 month period when pasteurized by three different exposures and stored for 6 months.

Month	The oxidized flavor and carotene content of cream pasteurized at 150°F. - 30"			treated with copper and sugar	165°F. - 15"			treated with copper and sugar	185° F. - 5"			treated with copper and sugar
	control	copper	sugar		control	copper	sugar		control	copper	sugar	
Mar.	+* 3.2**	+++ 3.2	- 3.5	++ 3.31	- 3.5	+++ 3.5	- 3.3	++ 3.21	- 2.9	++ 3.5	- 3.3	++ 3.16
Apr.	+ 2.6	++ 2.8	? 3.0	+++ 2.92	- 3.0	++ 3.0	- 3.0	+ 2.99	- 3.0	++ 2.9	- 3.0	++ 2.91
May	- 8.8	+ 8.4	- 9.1	+ 8.11	? 9.2	++ 7.7	- 8.9	++ 8.78	- 8.8	++ 7.8	? 9.3	+ 8.08
June	- 11.8	+++ 11.6	- 11.3	+++ 10.71	- 12.3	++ 11.7	- 11.5	+ 10.94	- 11.5	++ 11.2	- 11.4	++ 11.09
July	++ 11.9	+++ 10.9	- 9.3	+++ 10.02	- 11.4	++ 9.2	- 11.0	+ 9.95	- 11.2	++ 10.3	- 10.7	+ 9.81
August	- 9.8	+++ 9.6	- 11.0	+++ 11.3	- 10.9	+++ 9.5	- 10.1	++ 10.50	- 10.1	++ 10.1	- 9.7	+ 9.82
Sept.	- 11.3	+++ 11.0	- 11.3	+++ 10.86	- 11.1	++ 10.7	- 11.4	++ 10.84	- 11.2	+ 11.3	- 11.0	+ 10.71
Oct.	+ 12.0	+++ 11.4	? 11.9	+++ 11.24	- 12.6	++ 11.6	- 12.5	++ 11.83	- 11.8	++ 11.9	- 12.0	+ 12.14
Nov.	? 8.2	++ 9.1	- 8.5	++ 9.33	- 9.1	++ 9.1	- 8.8	++ 8.92	- 9.9	++ 8.9	- 9.1	+ 8.80
Dec.	- 5.9	++ 5.4	- 5.7	++ 5.57	- 5.9	++ 5.4	- 5.7	++ 5.62	- 5.8	+ 5.7	- 5.5	+ 5.66
Jan.	? 4.1	+++ 4.0	- 3.6	++ 3.55	- 3.9	+++ 4.1	- 3.9	++ 4.08	- 4.1	++ 3.9	- 3.7	+ 4.08
Feb.	? 3.4	+++ 3.1	- 3.3	++ 3.30	- 3.1	++ 3.1	- 3.3	+ 3.30	- 3.4	++ 3.4	- 3.3	+ 3.30

*Intensity of Oxidized flavor

**Carotene content, gamma per gm. of fat

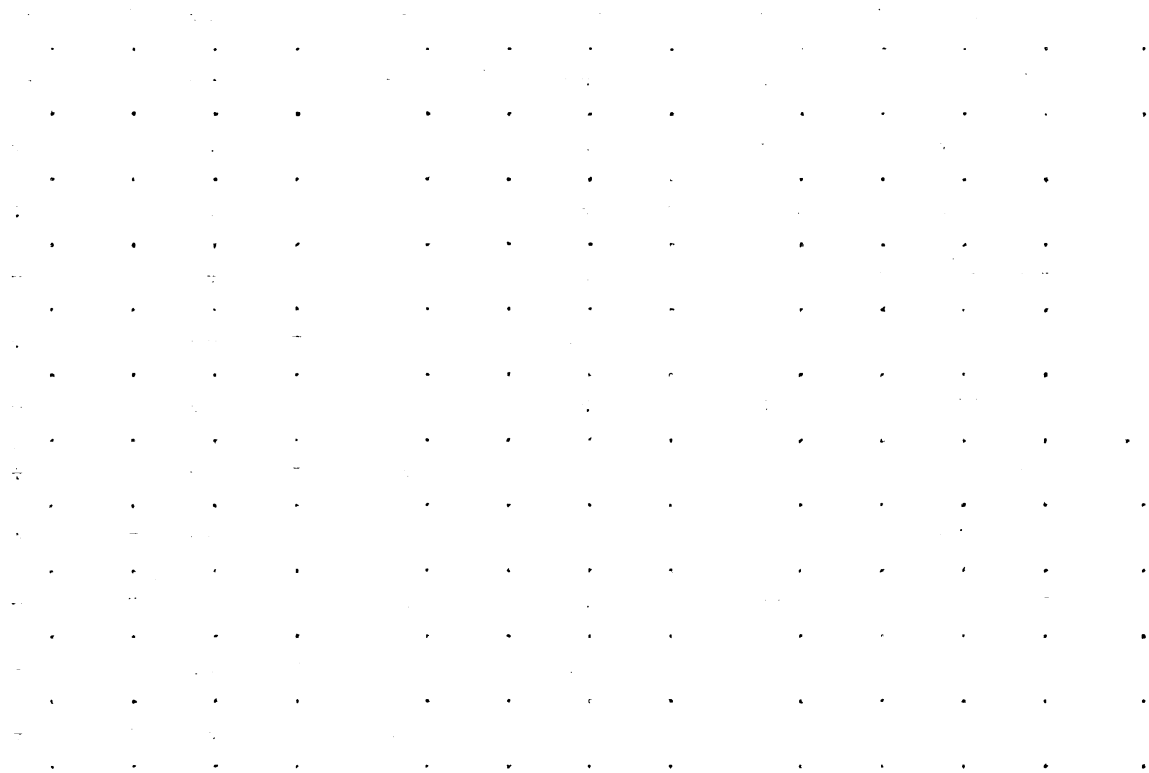

Table 26. The influence of the initial titratable acidity on the development of the oxidized flavor after 12 months' storage in the nonhomogenized glass container samples when pasteurized at three different exposures.

Month	Pasteurized at 150°F. - 30" control	150°F. - 30" copper	150°F. - 30" sugar	150°F. - 30" treated with copper and sugar	Pasteurized at 165°F. - 15" control	165°F. - 15" copper	165°F. - 15" sugar	165°F. - 15" treated with copper and sugar	Pasteurized at 185°F. - 5" control	185°F. - 5" copper	185°F. - 5" sugar	185°F. - 5" treated with copper and sugar
Mar.	?* .13**	♦♦♦ .12	- .11	♦♦ .11	- .13	♦♦ .13	- .11	♦ .11	- .13	♦♦ .13	- .11	♦♦ .105
April	♦ .12	♦♦♦ .12	- .10	♦♦♦ .10	- .12	♦♦♦ .11	- .10	♦♦ .10	- .12	♦♦♦ .12	- .10	♦♦ .105
May	? .13	♦♦♦ .13	? .12	♦♦ .12	- .13	♦♦♦ .13	- .12	♦♦ .115	- .12	♦♦ .13	- .11	♦♦ .11
June	♦♦ .17	♦♦♦ .17	♦ .16	♦♦♦ .165	? .15	♦♦ .18	- .155	♦♦ .17	- .16	♦♦ .16	- .15	♦ .155
July	♦♦♦ .18	♦♦♦ .18	♦ .18	♦♦♦ .17	- .18	♦♦♦ .18	- .17	♦♦♦ .17	- .18	♦♦♦ .18	- .18	♦♦ .17
August	? .11	♦♦♦ .10	- .10	♦♦♦ .10	- .11	♦♦♦ .11	- .09	♦♦♦ .09	- .11	♦♦♦ .11	- .10	♦♦ .09
Sept.	- .12	♦♦♦ .11	- .10	♦♦♦ .10	- .11	♦♦ .11	- .10	♦ .10	- .12	♦♦ .11	- .10	♦ .10
Oct.	♦♦ .13	♦♦♦ .13	♦ .13	♦♦♦ .12	- .13	♦♦♦ .13	- .12	♦♦ .13	- .13	♦♦ .13	- .12	♦ .12
Nov.	- .12	♦♦♦ .12	? .11	♦♦ .10	- .12	♦♦ .11	- .11	♦ .11	- .12	♦ .12	- .11	♦ .11
Dec.	- .13	♦♦♦ .13	♦ .12	♦♦♦ .12	- .13	♦♦ .13	- .13	♦♦ .13	- .13	♦♦ .13	- .12	♦♦ .13
Jan.	♦ .12	♦♦♦ .12	? .12	♦♦♦ .11	- .12	♦♦♦ .12	- .11	♦♦ .11	- .12	♦ .12	- .11	- .11
Feb.	♦ .11	♦♦♦ .11	? .10	♦♦♦ .10	- .11	♦♦♦ .11	- .10	♦♦ .10	- .11	♦♦♦ .11	- .10	♦♦ .105

*Intensity of oxidized flavor

**Per cent titratable acidity

Table 27. The influence of various methods of treatment and length of storage period on the hydrogen-ion concentration of the glass container samples when nonhomogenized and pasteurized at 165° F. for 15 minutes.

Month	The pH of cream when: Fresh and treated with: control	copper	sugar	copper and sugar	Fresh and treated with: control	copper	sugar	copper and sugar	Fresh and treated with: control	copper	sugar	copper and sugar
Mar.	6.50	6.51	6.51	6.40	6.60	6.95	6.73	6.95	6.05	6.05	5.85	5.80
Apr.	6.70	6.74	6.70	6.70	6.60	6.60	6.50	6.40	6.60	6.45	6.20	6.20
May	6.57	6.62	6.52	6.50	6.80	6.60	6.60	6.60	6.75	6.60	6.68	6.60
June	6.27	6.34	6.24	6.25	6.40	6.40	6.25	6.20	6.10	6.10	6.10	6.10
July	6.10	6.10	6.10	6.00	6.00	6.00	6.00	5.90	5.95	5.75	6.00	5.95
August	6.85	6.85	6.85	6.80	6.30	6.42	6.30	6.05	6.50	6.60	6.68	6.60
Sept.	6.68	6.68	6.60	6.60	6.15	6.15	6.15	6.15	6.63	6.35	6.68	6.50
Oct.	6.55	6.43	6.25	6.25	6.40	6.30	6.25	6.20	6.18	6.18	6.18	6.10
Nov.	6.68	6.60	6.45	6.43	6.75	6.75	6.68	6.68	6.35	6.35	6.50	6.50
Dec.	6.55	6.50	6.35	6.43	6.20	6.35	6.15	6.25	6.35	6.18	6.25	6.18
Jan.	6.50	6.50	6.45	6.40	6.55	6.50	6.40	6.50	6.43	6.43	6.35	6.18
Feb.	6.25	6.25	6.25	6.35	6.40	6.50	6.40	6.60	6.25	6.25	6.35	6.35

Table 28. The influence of various pasteurization exposures and length of storage period on the hydrogen-ion concentration of the glass container samples when nonhomogenized.

Month	The pH of cream when: Fresh after pasteurization at 150°F. 30"	Fresh after pasteurization at 165°F. 15"	Fresh after pasteurization at 185°F. 5"	Stored 6 mos. after pasteurization at 150°F. 30"	Stored 6 mos. after pasteurization at 165°F. 15"	Stored 6 mos. after pasteurization at 185°F. 5"	Stored 12 mos. after pasteurization at 150°F. 30"	Stored 12 mos. after pasteurization at 165°F. 15"	Stored 12 mos. after pasteurization at 185°F. 5"
Mar.	lost	6.50	6.50	6.73	6.50	6.50	6.05	6.05	5.75
Apr.	6.70	6.70	6.70	6.55	6.60	6.60	6.45	6.60	6.50
May	6.60	6.57	6.62	6.70	6.80	6.70	6.50	6.75	6.68
June	6.35	6.27	6.32	6.30	6.40	6.20	6.00	6.10	6.10
July	6.15	6.10	6.15	5.70	6.00	6.05	5.65	5.95	5.90
August	6.85	6.85	6.85	6.30	6.30	6.15	6.23	6.50	6.40
Sept.	6.68	6.68	6.80	6.15	6.15	6.18	6.80	6.68	6.80
Oct.	6.45	6.55	6.20	6.35	6.40	6.20	6.25	6.18	6.10
Nov.	6.60	6.68	6.60	6.75	6.75	6.75	6.60	6.35	6.43
Dec.	6.43	6.55	6.55	6.20	6.20	6.25	6.25	6.35	6.43
Jan.	6.40	6.50	6.45	6.50	6.55	6.50	6.18	6.43	6.50
Feb.	6.25	6.25	6.25	6.20	6.40	6.60	6.25	6.25	6.25

Table 29. The influence of method of treatment, pasteurization exposure and season of year upon the oxidation-reduction potential of nonhomogenized fresh cream.

Treatment of samples:	The Eh (volts) of fresh cream in Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.
Pasteurized at 150° F. 30 min.												
Control	.29	.29	.24	.30	.23	.29	.33	.33	.41	.38	.34	.37
Sugar	.31	.30	.28	.31	.30	.29	.35	.40	.42	.42	.39	.44
Copper	.29	.29	.23	.28	.26	.27	.34	.34	.41	.40	.36	.38
Copper and Sugar	.31	.32	.27	.29	.30	.29	.35	.36	.44	.42	.42	.43
Pasteurized at 165° F. 15 min.												
Control	.16	.24	.16	.22	.23	.23	.29	.34	.44	.39	.31	.38
Copper	.29	.38	.22	.26	.31	.31	.33	.40	.45	.42	.36	.44
Sugar	.17	.25	.15	.20	.27	.28	.24	.33	.43	.38	.32	.37
Copper and Sugar	.24	.34	.22	.26	.31	.31	.34	.38	.44	.42	.37	.42
Pasteurized at 185° F. 5 min.												
Control	.16	.24	.13	.19	.30	.27	.27	.32	.42	.35	.32	.36
Copper	.28	.34	.23	.28	.38	.29	.34	.43	.44	.42	.40	.43
Sugar	.20	.27	.15	.18	.28	.26	.28	.35	.43	.36	.35	.40
Copper and Sugar	.29	.36	.23	.27	.31	.32	.34	.38	.41	.41	.38	.45
Raw Control	.16	.35	.22	.27	.10	lost	.27	lost	lost	.40	.33	.38

Table 30. Oxidation-reduction potential (Eh) of homogenized cream samples when stored in glass for 12 months. (Average data from the 12 monthly samples).

Treatment of sample	The Eh of stored cream when											
	Pasteurized at 150° F. for 30 min.				Pasteurized at 165° F. for 30 min.				Pasteurized at 185° F. for 30 min.			
	control	copper	sugar	copper and sugar	control	copper	sugar	copper and sugar	control	copper	sugar	copper and sugar
Eh (volts)	.33	.35	.32	.35	.29	.35	.28	.34	.28	.35	.29	.35

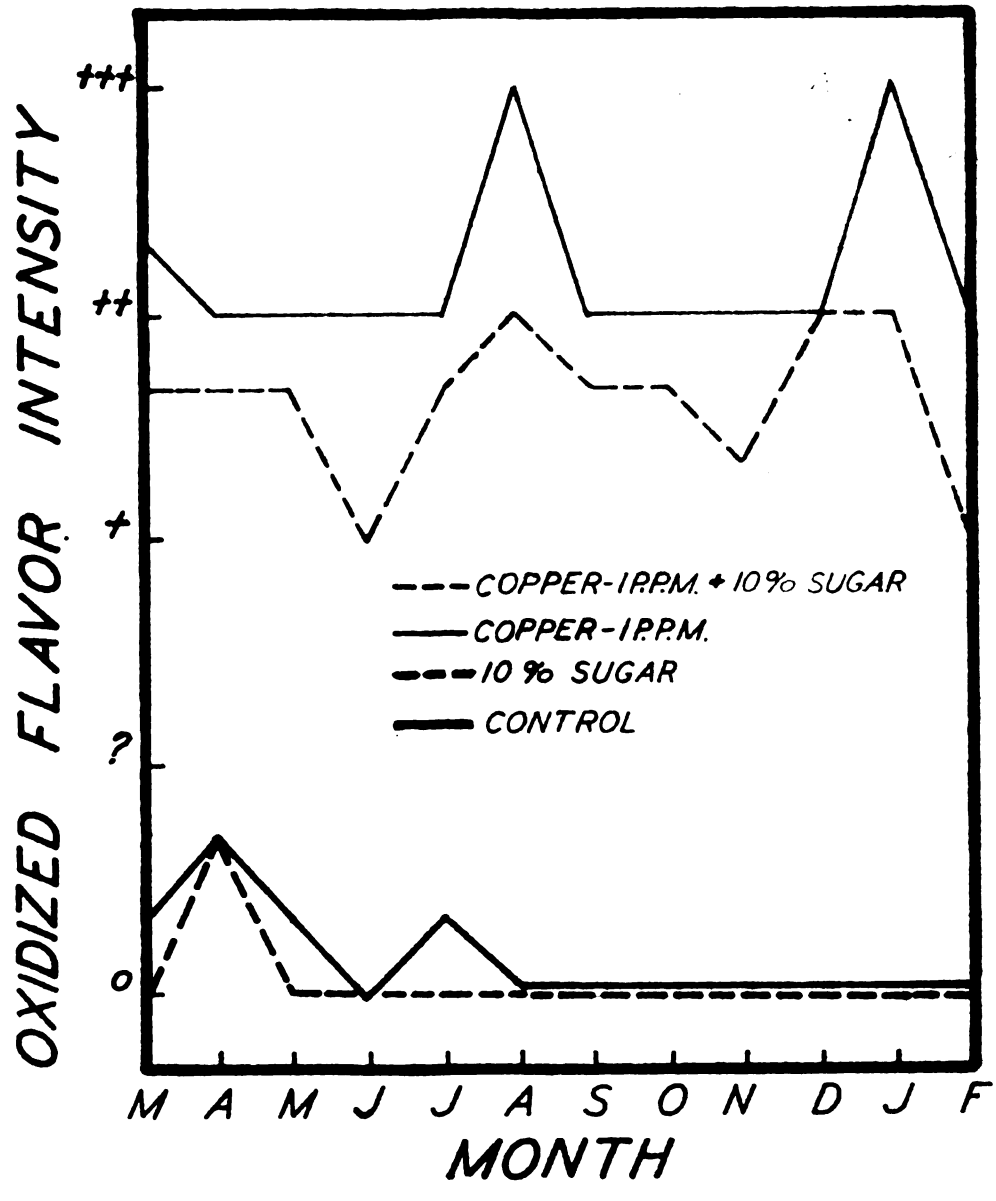

Fig. 1. The influence of various treatments on the development of the oxidized flavor during 6-months storage when nonhomogenized cream was pasteurized at 165° F. for 15 minutes. (Average of data from glass, paper and tin containers).

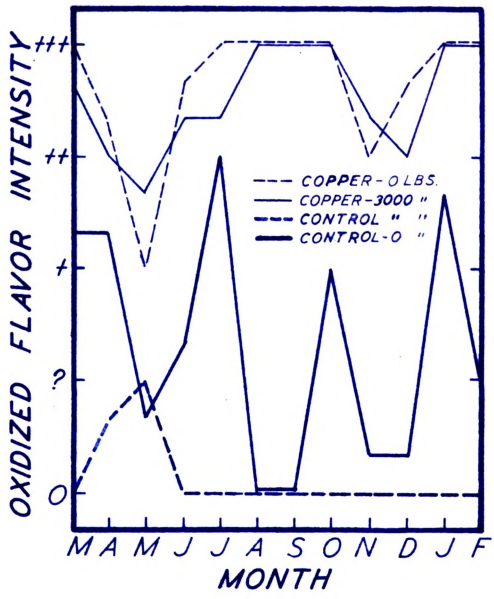

Fig. 2. The effect of homogenization upon the development of the oxidized flavor in the control and copper treated cream during 6-months storage when the cream was pasteurized at 150° F. for 30 minutes. (Average of data from glass, paper and tin containers).

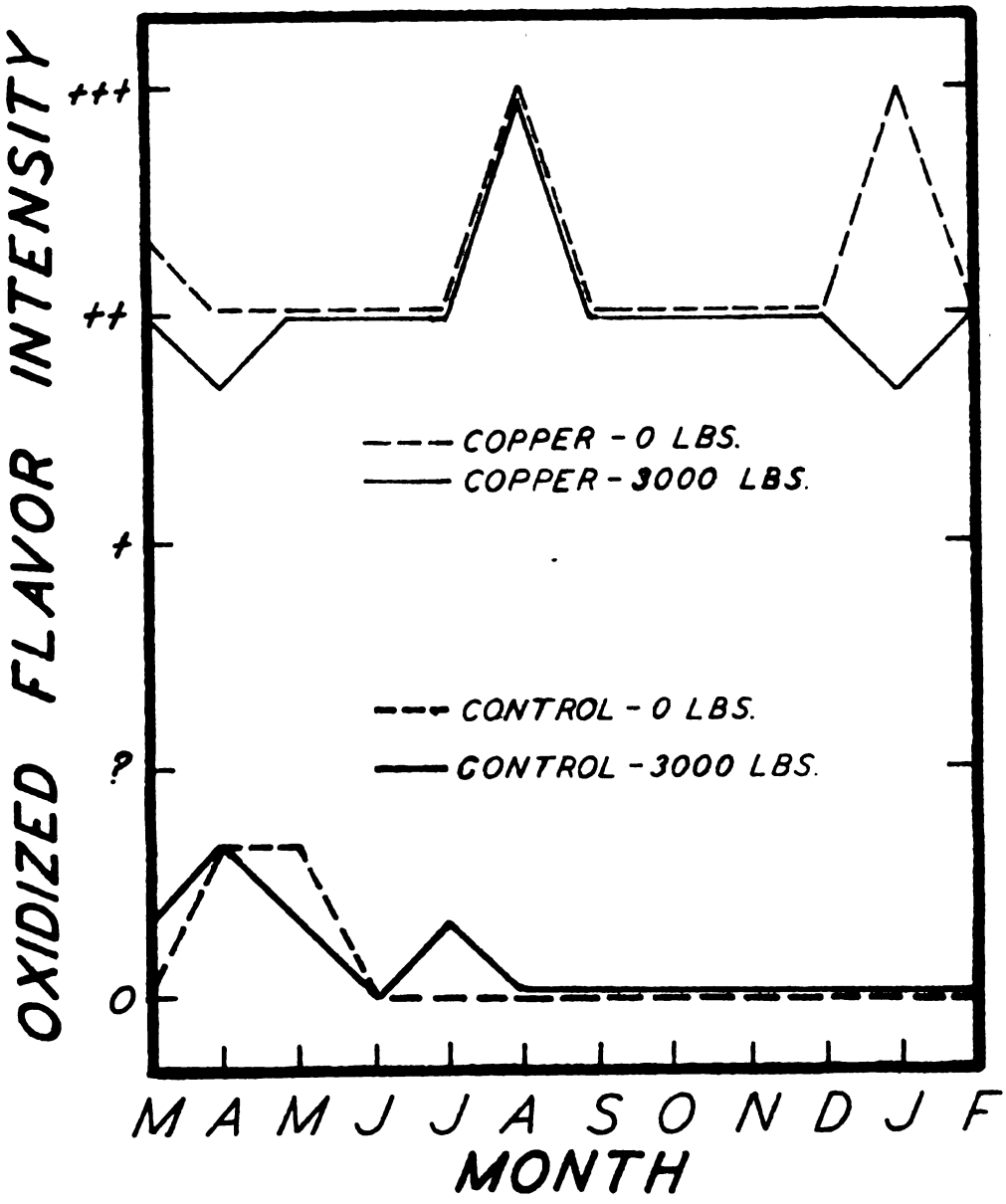

Fig. 3. The effect of homogenization upon the development of the oxidized flavor in the control and copper treated cream during 6-months storage when the cream was pasteurized at 165° F. for 15 minutes. (Average of data from glass, paper and tin containers).

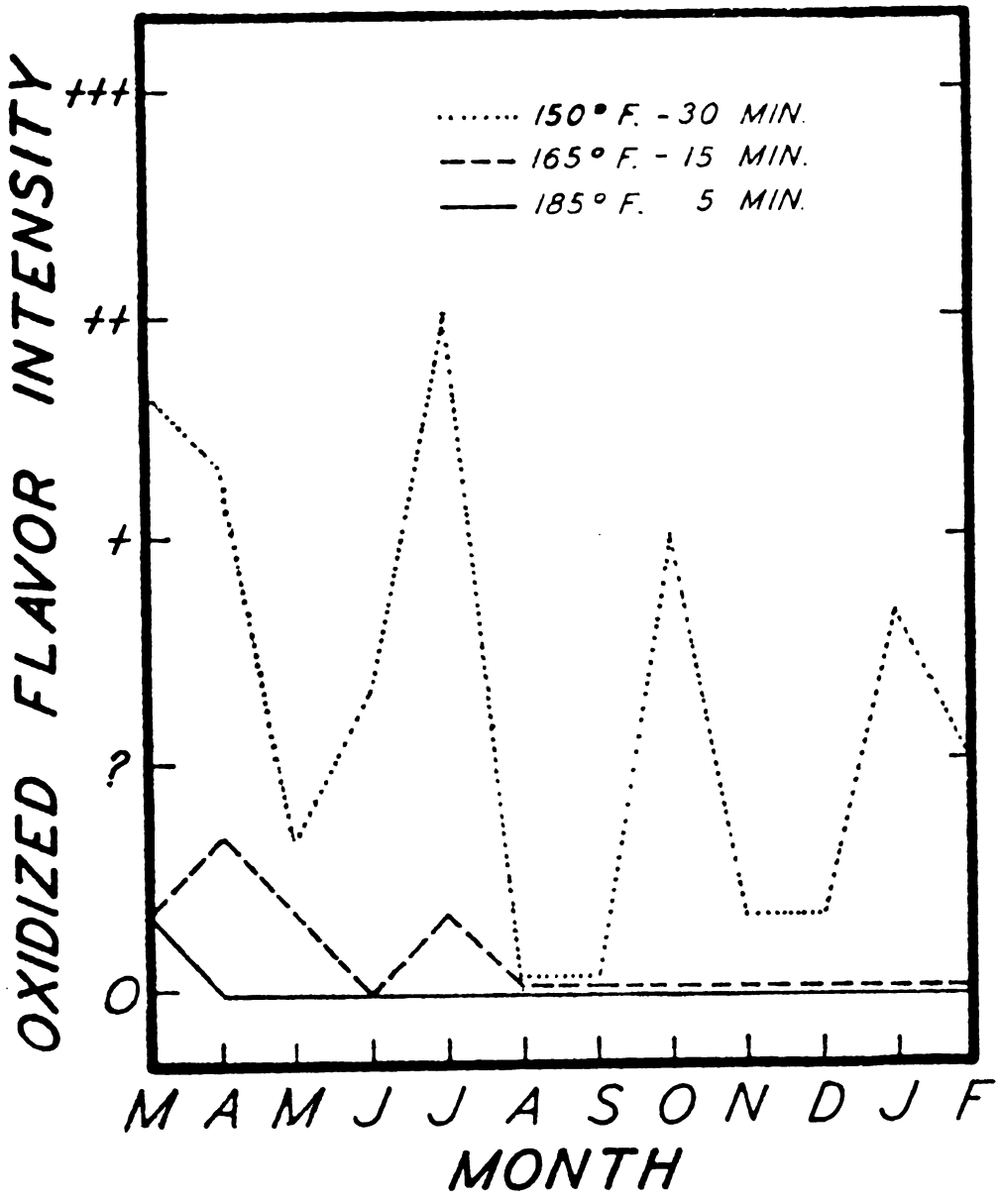

Fig. 4. The influence of the various pasteurization exposures upon the development of the oxidized flavor in the control cream during 6-months storage when the cream was nonhomogenized. (Average of data from glass, paper and tin containers).

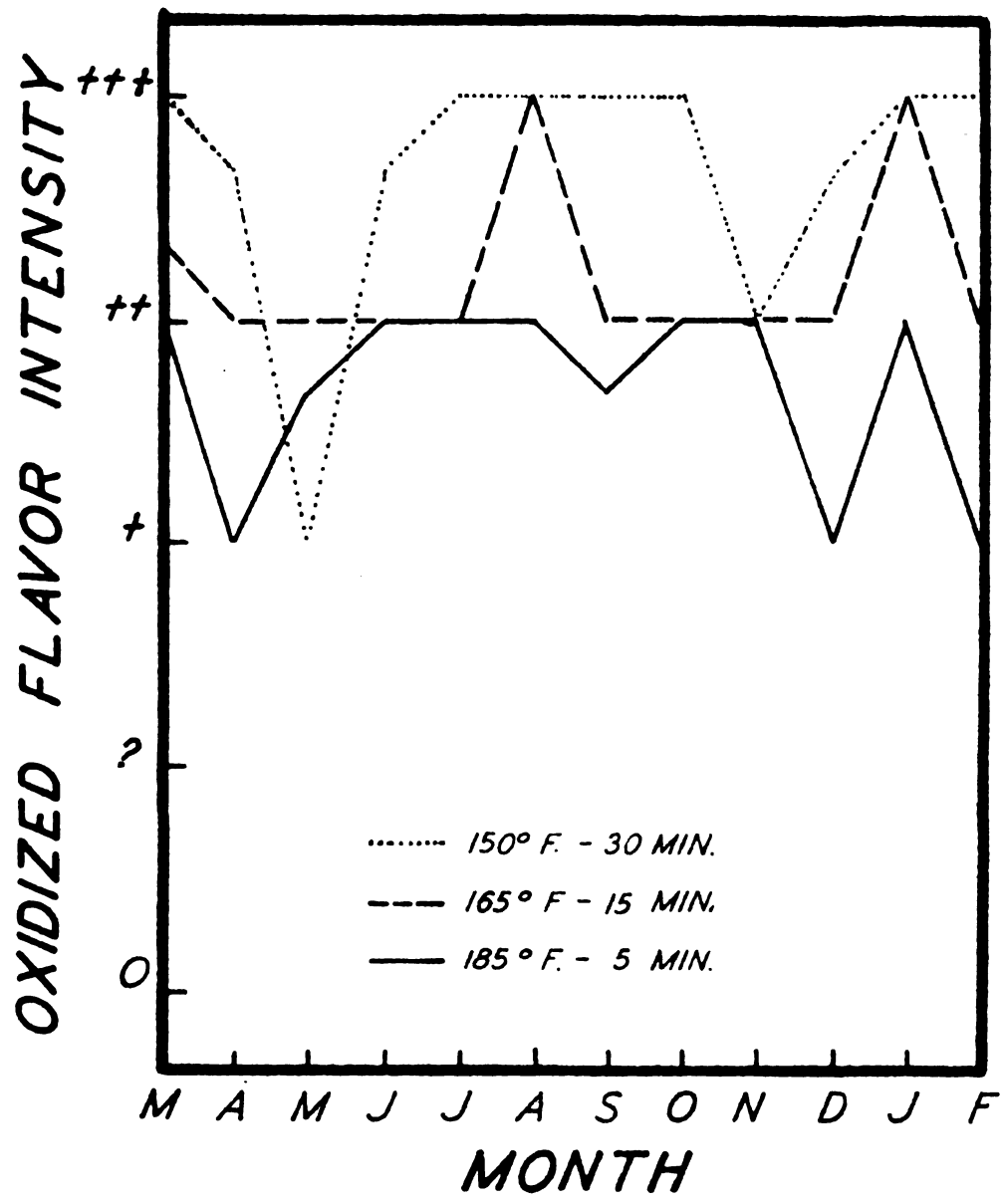

Fig. 5. The influence of the various pasteurization exposures upon development of the oxidized flavor in the copper treated cream during 6-months storage when the cream was nonhomogenized. (Average data from glass, paper and tin containers.

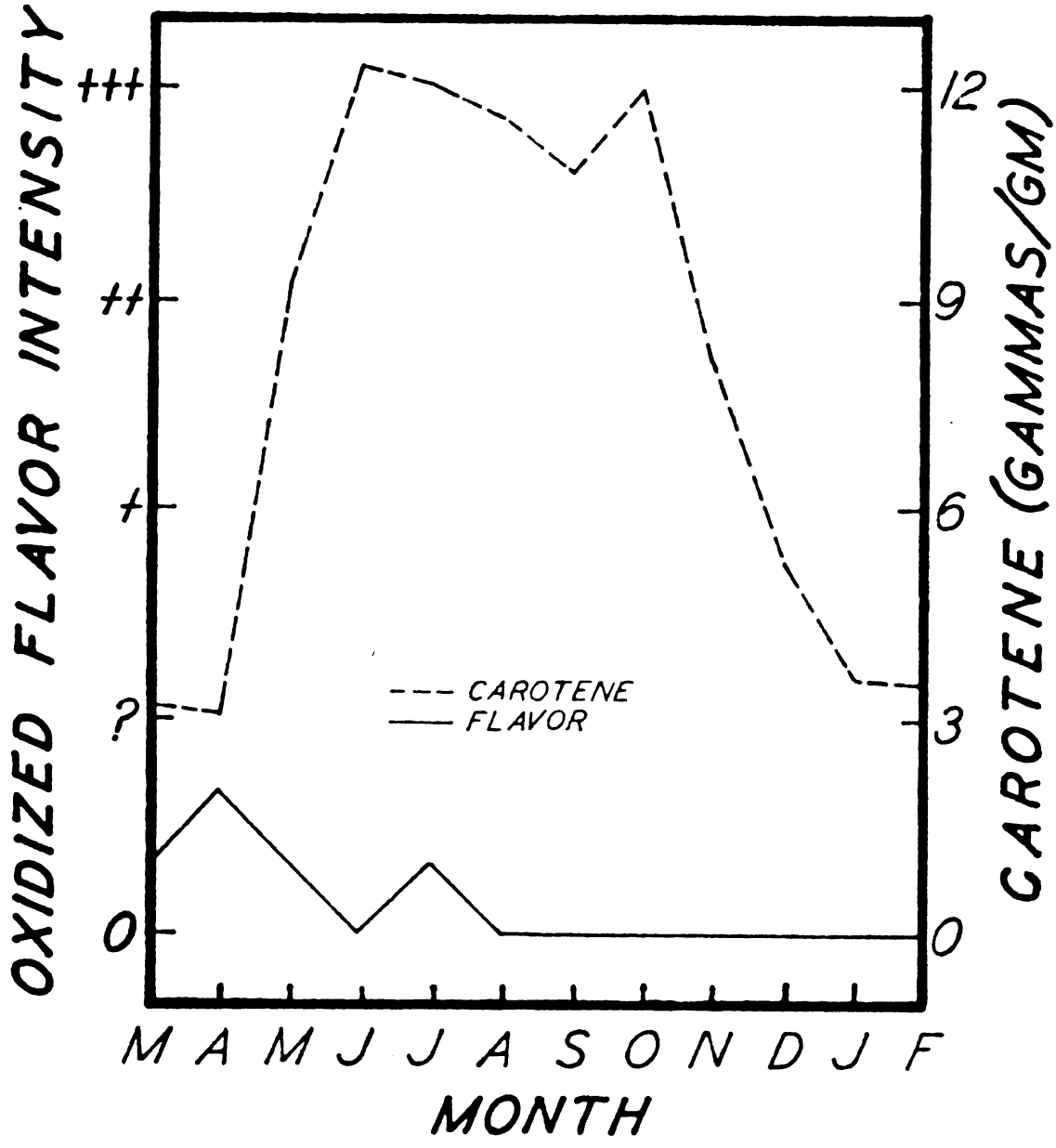

Fig. 6. The effect of carotene content due to season of the year upon development of the oxidized flavor in the control cream during 6-months storage in glass containers when nonhomogenized and when pasteurized at 165° F. for 15 minutes.

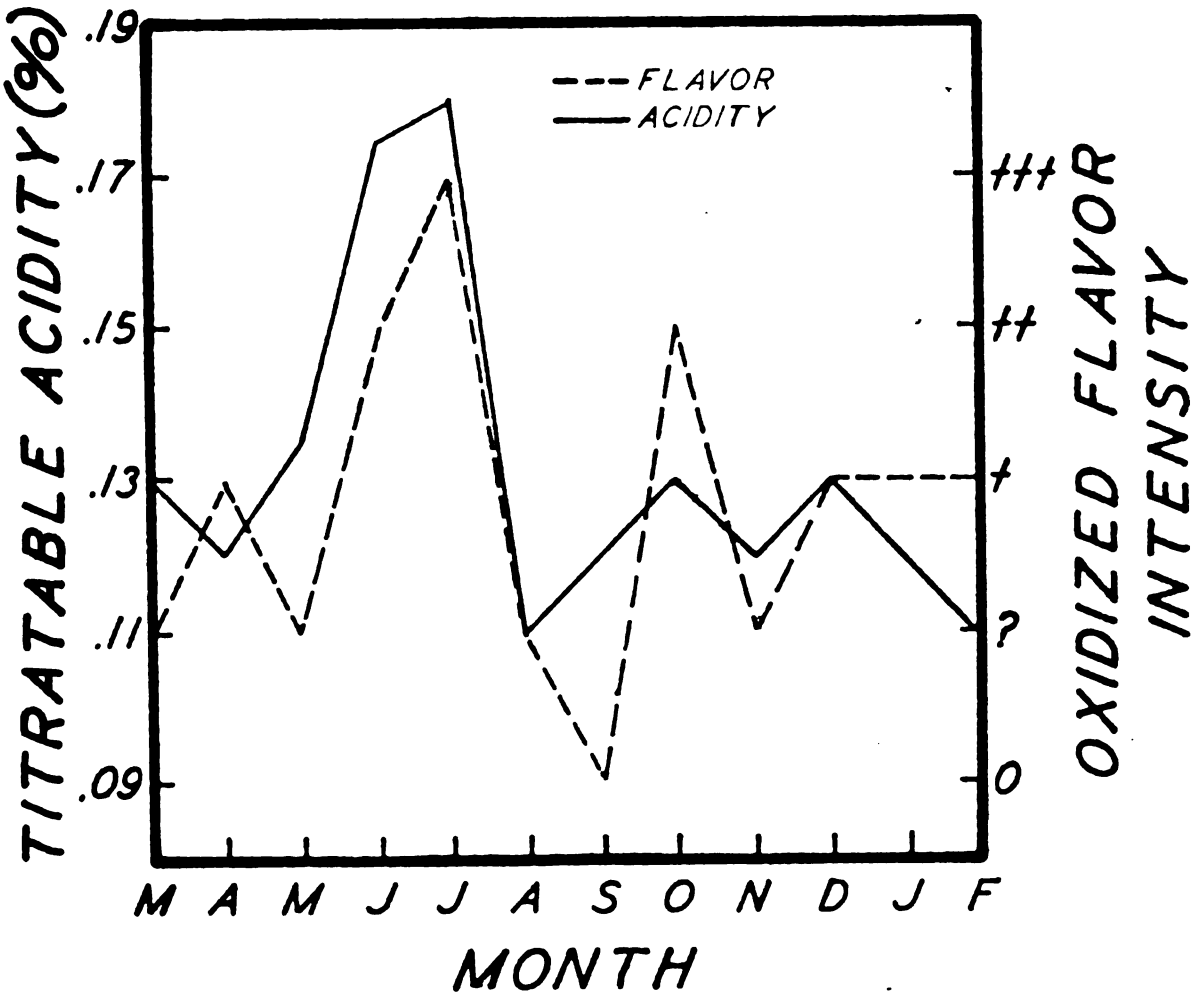

Fig. 7. The influence of initial titratable acidity upon the development of the oxidized flavor in the control cream after 12-months storage in glass containers when nonhomogenized and when pasteurized at 150° F. for 30 minutes.

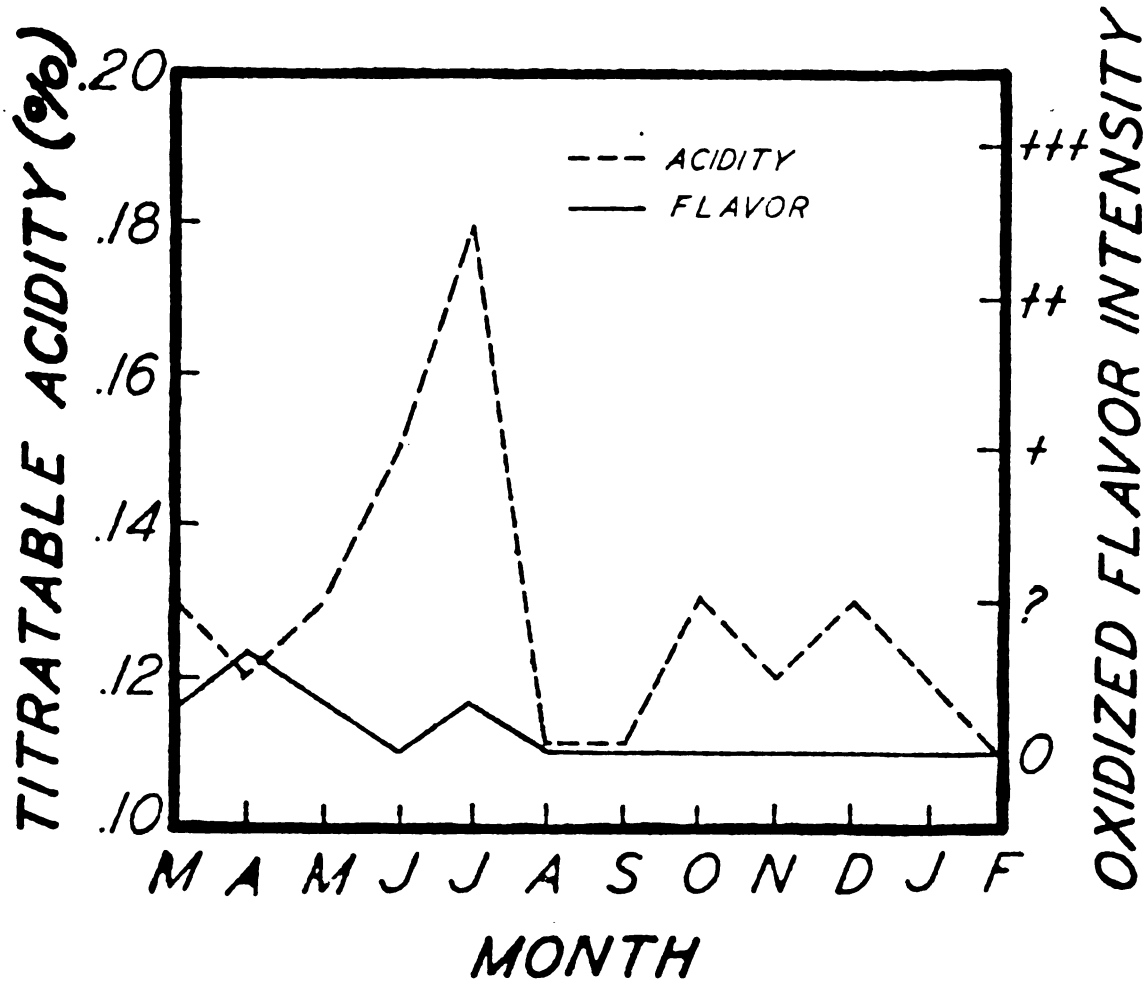

Fig. 8. The influence of initial titratable acidity upon the development of the oxidized flavor after 6-months storage when the cream was nonhomogenized and when pasteurized at 165° F. for 15 minutes. (Average data on flavor from glass, paper and tin containers).

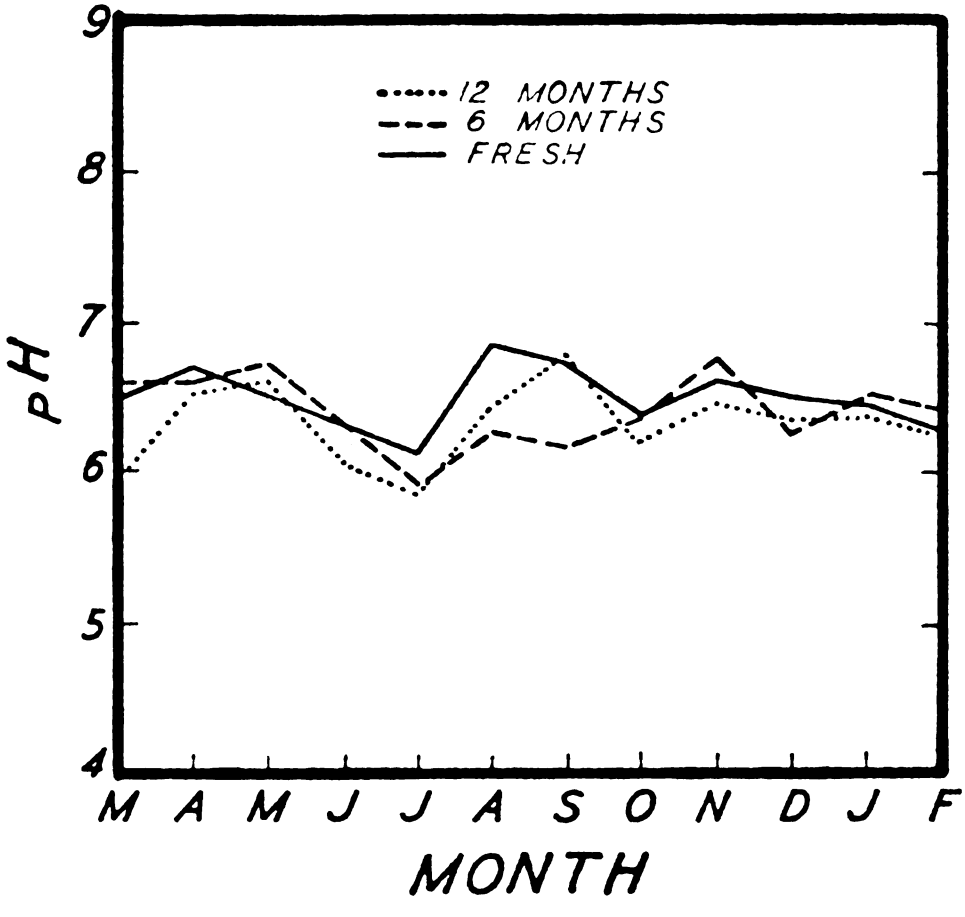

Fig. 9. The influence of length of storage period on the hydrogen-ion concentration of the nonhomogenized cream in glass containers. (Average data from 3 pasteurization exposures).

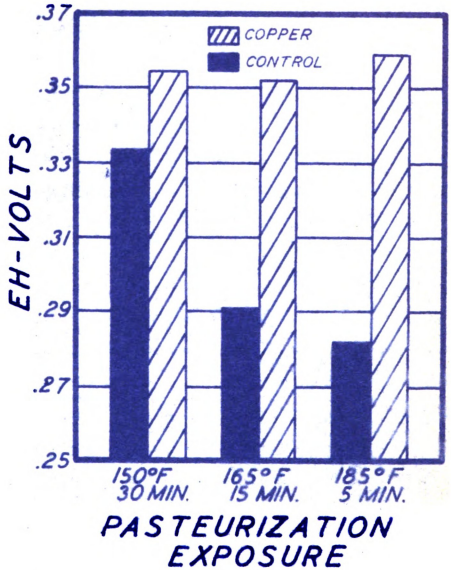

Fig. 10. The influence of copper treatment on the oxidation-reduction potential of fresh nonhomogenized cream when pasteurized at different exposures. (Average data from 11 monthly samples).

PART I.

B. The Influence of Several Factors upon Stability of Fat Emulsion.

Nine-gram lots of each of the samples of cream stored during the months of December, January and February were weighed out into regulation 9-gram, 50 per cent cream test bottles and tested for stability of fat emulsion according to the method outlined in the "Experimental". The tests on each sample were made when fresh, and after having been frozen in a -10° F. hardening room and held 1, 90, 180 and 360 days. The data secured are presented in tables 31 and 32.

1. Influence of homogenization on the free fat separation of cream.

The ability of the homogenizer to stabilize the fat emulsion in a nonfrozen product is well recognized. In view of this fact, the effects of homogenization on the stability of the fat emulsion in both frozen and nonfrozen cream were especially interesting.

The data show that homogenization had a very definite stabilizing effect upon the fat emulsion of the fresh, nonfrozen cream. In fact, the oiling-off in the nonfrozen product was practically eliminated in fresh cream upon the use of either 1500 or 3000 pounds pressure, but without homogenization a 50 per cent cream yielded about 20 per cent free fat by the method of testing employed.

On the other hand, the data show that freezing almost entirely destroyed the effects of homogenization on the fat emulsion stability. Analysis of these data reveals that nothing is gained by homogenization insofar as fat emulsion stability is concerned if the cream is to be frozen.

2. Effect of sugar on free fat separation of defrosted frozen cream.

Sugar has been used with varying degrees of success by previous workers as an aid in stabilizing the fat emulsion of the defrosted cream, and as this

experiment included samples containing ten per cent sugar, analyses were made on these samples at the same intervals of storage as those just previously mentioned.

Data in table 31 show that the addition of sugar to nonhomogenized nonfrozen cream caused only a slight decrease in the per cent oiling-off. This decrease was no greater than the amount of fat displaced by the addition of the sugar. Sugar partially stabilized the fat emulsion against the effects of freezing when held frozen only 24 hours. The combination of homogenization and sugar seemed to be more beneficial than either process when used singly in preventing oiling-off, regardless of length of storage.

As the length of frozen storage extended, the influence of sugar in stabilizing the fat emulsion was lessened. At the 3 and 12 month storage periods, sugar had no appreciable effect on the stability of the fat emulsion according to the method used in this experiment.

3. Effect of fat content on stability of fat emulsion of defrosted frozen cream. A study was made of the relationship between the fat content of the cream and its susceptibility to oiling-off upon freezing and defrosting. The data secured are presented in table 32.

The amount of fat destabilized was found to increase as the per cent fat in the cream increased. The data showed also that as the fat content was increased, the percentage of the total fat which was destabilized was greater.

4. Influence of length of storage period of cream on stability of the fat emulsion of defrosted frozen cream. Fresh cream not frozen was found to be more stable than that which had been frozen. However, according to the rigorous method of testing employed there was considerable oiling-off even in the fresh, nonfrozen cream.

The cream frozen only 24 hours showed less fat destabilization than did that which had been frozen for either 3, 6 or 12 months (Tables 31 and 32). In this respect there was no appreciable difference in the samples stored frozen either at 3, 6 or 12 months, the three-months period seeming to be more than sufficient to complete destructive effects to the fat emulsion by the freezing process.

5. Effect of pasteurization exposure on free fat separation of defrosted frozen cream. Data showing the effect of the pasteurization exposure upon the destabilization of the fat emulsion in the nonhomogenized cream after six months are presented in table 32. Apparently, no significant differences occur in oiling-off of fat as a result of the particular pasteurization exposures with the possible exception that the 165° F.-15 minute exposure seemed to be slightly less severe than the other two exposures.

Data on a larger number of samples held various periods of time, and presented in table 31, show largely the same trend. Undoubtedly, the more stable emulsion of the 165° F. pasteurization temperature may be accounted for by the lessened agitation than that of the 150°F. and the less heat than at the 185° F. exposure.

On the other hand a slight increase in oiling-off as the temperature of pasteurization was increased was noted in the nonfrozen group.

6. Effect of speed of freezing on stability of fat emulsion of defrosted frozen cream. Samples of cream containing over 50 per cent fat were weighed out into regulation 9-gram test bottles and were frozen by various methods in order to ascertain the effect of the speed of freezing upon the destabilization of the fat emulsion. The data are presented in table 33 and shown graphically in figure 11. Despite the fact that fast freezing partially prevented destabilization of the fat, there was not the differ-

ence in per cent oiling-off between fast and slow freezing as might be expected in view of the great difference in freezing time of the samples. However, there appeared to be a significant difference in the stability of the fat emulsion between each of the four respective rates of freezing.

Table 31. The influence of sugar, homogenization, pasteurization, freezing process and length of storage period on stability of fat emulsion. Figures represent fat column readings. (Average data of three trials; cream averaging 50% fat).

Pasteurization exposure	The per cent free fat in cream when homogenized at (lbs.) 0 and treated with: control	copper	sugar	copper and sugar	1500 and treated with: control	copper	sugar	copper and sugar	3000 and treated with: control	copper	sugar	copper and sugar
150° F.					Unfrozen							
30"	18.2	18.0	18.0	16.8	5.0	1.0	2.5	2.5	2.0	0.5	2.5	2.0
165° F.												
15"	20.0	17.0	17.0	18.8	1.2	1.2	1.8	2.2	1.0	0.5	1.3	1.0
185° F.												
5"	24.0	29.0	18.0	18.0	2.3	1.0	2.0	1.0	2.2	2.0	2.8	0.7
Av.	20.7	21.3	18.0	18.0	2.8	1.1	2.1	2.2	1.7	1.0	2.2	1.2
					Frozen 24 hours							
150° F.												
30"	43.0	31.5	29.2	29.5	35.8	25.0	15.8	15.8	33.0	15.5	13.8	14.5
165° F.												
15"	33.0	33.0	26.0	25.0	33.0	22.0	7.0	14.0	35.0	17.0	10.0	13.0
185° F.												
5"	37.0	35.0	31.0	33.0	33.0	27.0	13.5	14.5	32.0	14.5	9.0	11.5
Av.	38.0	38.0	28.7	29.0	33.6	25.0	12.1	14.4	33.3	16.0	10.9	13.3
					Frozen 3 months							
150° F.												
30"	46.0	46.0	41.0	41.0	43.0	45.0	37.0	38.0	42.0	41.0	35.0	34.0
165° F.												
15"	42.0	40.0	38.0	37.0	41.0	42.0	35.0	33.0	41.0	38.0	34.0	30.0
185° F.												
5"	46.0	46.0	42.0	41.0	39.0	39.0	33.0	31.0	37.0	38.0	36.0	34.0
Av.	45.0	44.0	40.0	40.0	41.0	42.0	35.0	34.0	40.0	39.0	35.0	33.0
					Frozen 12 months							
150° F.												
30"	41.0	42.0	39.0	40.0	42.0	42.0	38.0	35.0	41.0	37.0	36.0	32.0
165° F.												
15"	39.0	37.0	37.0	35.0	39.0	39.0	33.0	36.0	39.0	39.0	36.0	37.0
185° F.												
5"	43.0	41.0	41.0	41.0	39.0	41.0	36.0	37.0	35.0	37.0	37.0	33.0
Av.	41.0	40.0	39.0	39.0	40.0	41.0	36.0	36.0	38.0	38.0	36.0	34.0

Table 32. The influence of fat content on stability of fat emulsion in nonhomogenized cream stored for 6 months. Figures represent fat column readings.

Pasteurization exposure	The per cent of free fat in cream testing (% butterfat)											
	45 and treated with				50 and treated with				54 and treated with			
	control	copper	sugar	copper and sugar	control	copper	sugar	copper and sugar	control	copper	sugar	copper and sugar
150° F. 30"	41	40.5	35	35	46	45	42	40	50	49	48.5	48
165° F. 15"	32	33.5	28	25	44	38	39	38	50	50	46.0	47
185° F. 5"	40	41.0	38	37.5	47	45.5	41	41	49.5	50	49.0	47
Av.	38	38	34	33	46	43	41	40	50	50	48	47

Table 33. Influence of speed of freezing on the stability of the fat emulsion. Figures represent fat column readings.

Trial	Per cent free fat in cream at 3 months storage when frozen in: Dry Ice and alcohol (3")	Dry Ice (15")	-10° F. room (20")	Jiffy Bag in -10°F. room (180")	Dry Ice and alcohol (3")	Dry Ice (15")	-10° F. room (20")	Jiffy Bag in -10° F. room (180")
	Series I - 52% cream				Series II - 53% cream			
1	47.5	50.0	52.0	51.0	44.0	49.0	51.0	52.0
2	47.0	50.0	50.5	51.0	43.0	49.0	52.0	52.0
3	46.0	49.0	51.0	51.0	44.0	48.0	51.0	52.0
4	46.0	48.0	50.0	51.0	45.0	50.0	50.0	53.0
5	47.5	50.0	49.5	51.5	44.0	50.0	51.0	53.0
6	47.5	49.5	50.5	51.0	43.0	49.0	51.0	53.0
7	46.5	49.0	50.5	51.0	44.0	49.0	51.0	53.0
8	46.0	49.5	50.0	51.0	44.0	50.0	51.0	52.0
9	47.5	49.5	50.0	50.0	45.0	49.0	51.0	52.0
10	45.0	49.5	50.0	51.0	44.0	49.0	51.0	53.0
Av.	46.6	49.4	50.45	51.05	44.00	49.2	51.0	52.5

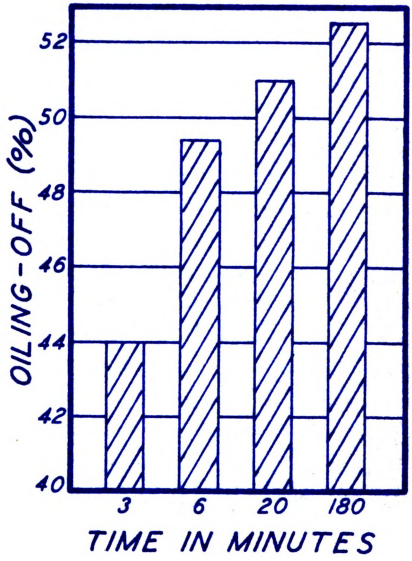

Fig. 11. The effect of the speed of freezing on stability of the fat emulsion. (Average 10 trials, 53-per cent, November cream).

PART II.

UTILIZATION OF FROZEN CREAM IN THE ICE CREAM MIX

The Influence of Certain Factors on the Whipping Ability of Frozen Cream Mixes and the Flavor of the Resulting Ice Cream. Duplicate lots of fresh, sweet cream were stored in forty-pound, lard-type tin containers 6, 3 and 1 month previous to the freezing trials. Ten per cent sucrose was added to one lot of the cream prior to freezing. Dried egg yolk was added to mixes made from both sugared and nonsugared frozen cream, the whipping ability of which was compared with that of like mix containing no added egg yolk. Fresh cream mixes were frozen as controls.

Flavor determinations were made at regular intervals on representative samples of all ice cream frozen.

1. Influence of sugar in frozen cream upon whipping ability and flavor of frozen-cream ice cream. Sugar was added to the cream prior to freezing to ascertain the effect of sugar on the properties of the mix made from that cream. Ten per cent sugar was added to the cream and the remainder added in the manufacture of the ice cream mix. Data secured on the freezing trials are included in table 34 and presented graphically in figures 12, 13 and 16. Sugar incorporation into the cream prior to freezing not only hastened freezing but also increased the maximum overrun obtainable when compared to that of the cream stored without the previous sugar addition. However, there was no significant flavor difference observed in the ice cream made from the sugared or nonsugared frozen cream mixes either when fresh or after 18-weeks storage. Similarly, no material body differences in the ice cream from the two mixes were noted.

2. Influence of dried egg yolk upon whipping ability of frozen cream mixes. To another series of mixes similar to those just previously discussed but from another lot of cream, 0.35 per cent egg yolk was added both to the previously sugared and to the nonsugared frozen cream mixes to ascertain the effect of dried egg yolk addition to the whipping properties of the mixes. The data secured are presented in table 35 and figures 14, 15 and 16.

These data show a marked improvement both in the speed of obtaining and in the maximum overrun obtained as a result of the addition of egg yolk to frozen cream mixes. Of especial interest was the fact that while the incorporation of 10 per cent sugar to the frozen cream considerably improved the whipping characteristics of that mix, (Table 34), the same did not hold true of the mix wherein the egg yolk was added (Table 35).

Figure 16 graphically shows that the addition of egg yolk to the ice cream mix resulted in improved whipping ability to the mix when compared to both the plain and the sugared mixes. However, it will be noted also that the egg yolk addition did not restore the whipping properties of the mix so that it compared favorably with the fresh cream mix (Figure 16).

3. The influence of egg yolk upon flavor of frozen-cream ice cream. A sufficient supply of the ice cream samples previously discussed under "Influence of dried egg yolk upon whipping ability of frozen cream mixes" was secured that individual samples might be examined at definite intervals for 18 weeks. The data are presented in tables 36 and 37.

The data showed no material difference in the flavor of the fresh-cream ice cream. However, comparing the flavor data of the ice cream with-

out egg (Table 36) with those of egg ice cream (Table 37) the flavor of the egg samples was more desirable than that of the nonegg samples. While it must be remembered that these do not represent the same original batch of cream, at least one can conclude that the addition of egg does not prove a flavor deterrent in the case of frozen cream.

4. Influence of length of frozen cream storage on whipping ability of mixes. The cream samples used in these mix freezing trials were 6-, 3- and 1-month stored frozen and a fresh control. The data presented in tables 34 and 35 show no significant difference in the whipping ability of the mix due to the length of the storage period of the frozen cream, when the fat of the mix was supplied by frozen cream.

Figure 13 points out graphically the comparative whipping ability of the frozen cream mixes from cream stored for the various periods of time.

Obviously from these trials, the freezing process rather than the length of storage period of the cream is the factor responsible for the inferior whipping ability of a frozen cream mix.

5. Flavor of frozen-cream ice cream upon storage. In order that a flavor study might be made from these mixes, regular vanilla ice cream was made and sufficient samples were saved to flavor each week for 8 consecutive weeks as well as at 12 and 18 weeks storage.

The samples were scored "blind" by two experienced judges, who were designated as A and B. Judge A indicated the intensity of any oxidized flavor present as in the judging of the cream while Judge B gave a numerical score to the flavor of the ice cream. Body scores were given numerical ratings in both cases.

The data included in table 36 show little difference between the flavor or body scores of the fresh-cream or frozen-cream ice cream either

when fresh or at the end of the 18-week holding period. Apparently, therefore, there could be no objection to using frozen cream of good quality in ice cream from the standpoint of body and flavor criticism.

Likewise, data presented in table 37 from cream which had dried egg yolk added to all but the fresh sample, showed no significant difference between the flavor of the fresh and the frozen-cream ice cream. However, as a rule, the egg samples were slightly more desirable in both body and flavor than the group of samples containing no egg (Table 36). This condition is not considered to be of significance, however, inasmuch as the initial cream was not the same, although it was very similar.

Data in tables 36 and 37 show that the storage period of the cream up to six months did not affect the body or flavor of the resulting ice cream.

6. Bacteria count of frozen-cream ice cream. The bacteria plate count of ice cream samples was made at 18-weeks storage. Analyses were made according to standard procedure.

The data included in table 38 show the bacteria plate count of the two groups of samples to be extremely low. Although the October (egg) series had a slightly higher plate count there seemed to be no material difference in any single sample of either group.

These very low bacterial counts of the frozen-cream ice cream indicate that the use of frozen cream in mix might not raise the bacteria count of the resultant ice cream if the original cream were of good quality.

Since low bacteria count in milk is often associated with oxidized flavor it is not improbable that such might be the case in ice cream. At any rate, it is considered worthy of mention that had the bacteria count been normal, some of the old, stale, flavors particularly in the September (nonegg) series might not have appeared.

Table 34. The influence of the addition of 10 per cent sugar to cream prior to freezing on the whipping properties of the resulting mixes. (Average data from 2 trials).

Whipping properties	The whipping properties of high-testing cream frozen in March and stored 6 mos.		June and stored 3 mos.		August and stored 1 mo.		September fresh
	without sugar	with sugar	without sugar	with sugar	without sugar	with sugar	
Freezing time (min.)	12:22	11:50	13:26	10:17	13:17	10:18	8:14
Maximum overrun obtainable	113	113	98	105	98	110	125

Table 35. The influence of the addition of 0.35 per cent egg yolk to the whipping properties of plain and sugared cream mixes. (Average data from 2 trials).

Whipping properties	The whipping properties of high-testing cream frozen in April and stored 6 mos.		July and stored 3 mos.		September and stored 1 mo.		October fresh
	without sugar	with sugar	without sugar	with sugar	without sugar	with sugar	
Freezing time (min.)	8:44	9:00	9:10	9:18	8:30	8:20	8:20
Maximum overrun obtainable	120	120	119	120	118	120	125

Table 36. Body and flavor scores of ice cream after various periods of storage.

Cream used	The body and flavor of ice cream after									
	1 week		4 weeks		8 weeks		12 weeks		18 weeks	
	Body	Flavor	Body	Flavor	Body	Flavor	Body	Flavor	Body	Flavor
Judge A										
March (6 mos.)	*	**								
Without sugar	23.5	-	24	-	23	-	23	-	22.5	-
With sugar	23.5	-	23.5	-	23.5	-	23	-	22.5	-
June (3 mos.)										
Without sugar	23.5	?	23.5	+	22		23		22.5	+
With sugar	23.5	?	24	-	22	-	23	-	22.5	-
August (1 mo.)										
Without sugar	23.0	-	23.5	+	22.5	-	23	-	22.5	-
With sugar	23.5	-	23.5	-	22.5	+	23	-	22.5	-
September										
Fresh	23.5	+	23.5	+	22	+	23	+	22.5	
Judge B										
March (6 mos.)		*								
Without sugar	23.5	44.5	22.5	43	23.5	44	23.5	43	22.5	42
With sugar	23	44.5	22.5	43.5	23.5	43	22.5	43	23	43
June (3 mos.)										
Without sugar	23	43.5	22.5	44	23.5	44.5	22	43	21.5	43
With sugar	23	43.5	22.5	43.5	23.5	44.5	22.5	43	21.5	43
August (1 mo.)										
Without sugar	23	44	22.5	43	23.5	42	22.5	43	22.5	43
With sugar	22.5	44	22.5	44	23.5	44.5	22.5	43	21.5	42
September										
Fresh	23	44	22.5	43.5	23.5	42.5	22.5	43	21.5	42

*Based upon former ice cream score card - body 25 points; flavor 50 points.

**Intensity of oxidized flavor.

Table 37. Body and flavor scores of ice cream after various periods of storage.

Cream used	The body and flavor of ice cream after 1 week		4 weeks		8 weeks		12 weeks		18 weeks	
	body	Flavor	Body	Flavor	Body	Flavor	Body	Flavor	Body	Flavor
Judge A										
April (6 mos.)	*	**								
Without sugar	24	-	23	-	23	-	23	-	23	-
With sugar	24	-	23	-	23	-	23	-	23	-
July (3 mos.)										
Without sugar	24	-	23	-	23	-	23	-	23	-
With sugar	23	?	23	-	23	-	23	-	23	-
Sept. (1 mo.)										
Without sugar	23	+	23	-	23	+	23	-	23	-
With sugar	23.5	-	23.5	-	23	-	23	-	23	-
October										
Fresh	23	-	23	-	23	+	23	-	23	-
Judge B										
April (6 mos.)		*								
Without sugar	23	45	22.5	43.5	22.5	44	22.5	44	23	43.5
With sugar	23	45	22.5	43.5	22.5	44	22.5	44	23	43.5
July (3 mos.)										
Without sugar	23	45	22.5	43.5	23	44	23	43.5	23	43.5
With sugar	22.5	45	22.5	43.5	22.5	44	23	44	22.5	43.5
Sept. (1 mo.)										
Without sugar	23	45	22.5	43.5	23	44	22.5	44	23	43.5
With sugar	23	44	22.5	43.5	23	44	22.5	44	23	43.5
October										
Fresh	23	45	22.5	43.5	22	44	22.5	44	22	43.5

*Based upon former ice cream score card - body 25 points; flavor 50 points.

**Intensity of oxidized flavor.

Table 38. The bacterial quality of 18-weeks old ice cream made from fresh and from frozen cream held for various storage periods.

Ice cream	Standard plate count of ice cream made from fresh and frozen cream after 18-weeks storage when						
	Stored 6 mos.		Stored 3 mos.		Stored 1 mo.		
	Without sugar	With sugar	Without sugar	With sugar	Without sugar	With sugar	Fresh
Without egg	800	900	500	300	450	1,000	1,000
With egg	3,000	2,500	1,200	1,500	3,400	2,400	1,300

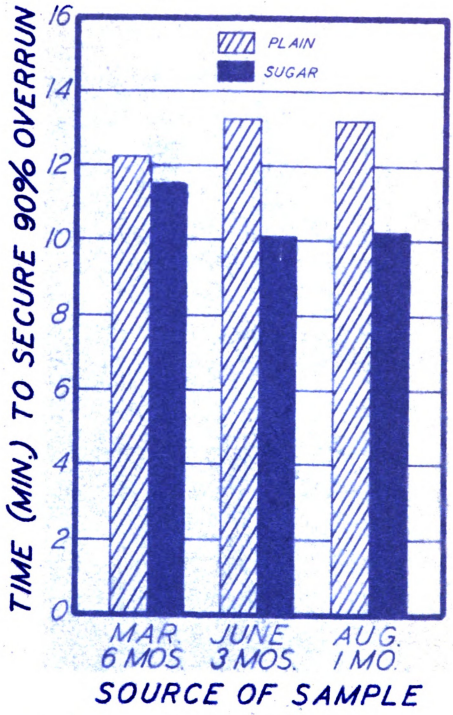

Fig. 12. The effect of the addition of 10 per cent sugar to cream prior to freezing on the speed of the ice cream mix made therefrom. (Average data from 2 trials).

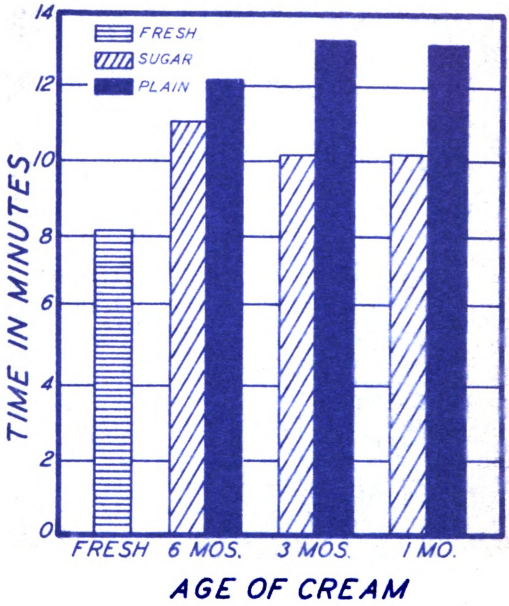

Fig. 13. A comparison of the speed of freezing of mixes made from sugared and nonsugared frozen cream and from fresh cream. (Average date from 2 trials).

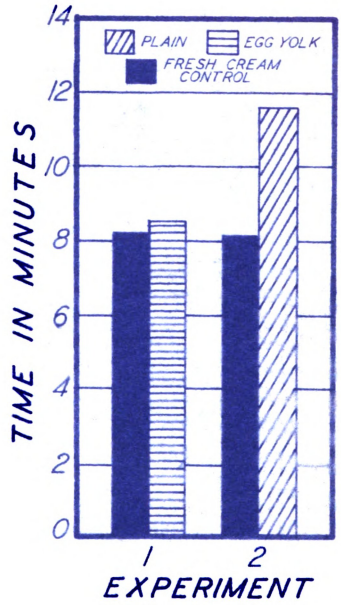

Fig. 14. The influence of the addition of 0.35 per cent dried egg yolk to frozen cream mix on maximum overrun obtainable. (Average data from 6 trials in frozen cream mixes).

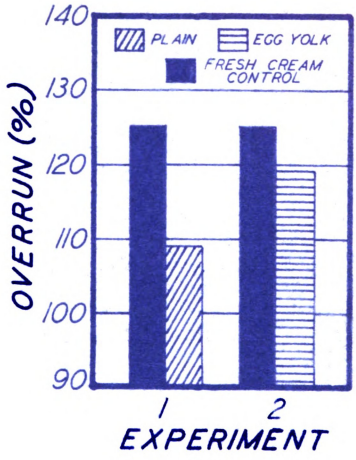

Fig. 15. The influence of the addition of 0.35 per cent dried egg yolk to frozen cream mix on the maximum overrun obtainable. (Average data from 6 trials in frozen cream mixes).

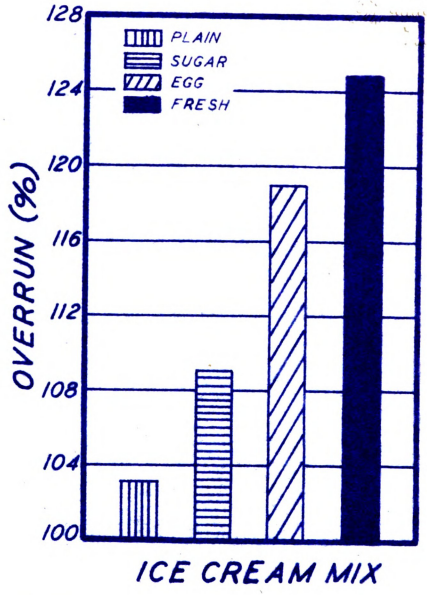

Fig. 16. A comparison of the maximum overrun obtained in mixes made from various lots of cream.

DISCUSSION

Copper contamination had long been recognized as the predominant cause of oxidized flavor development of fresh cream. There has been, however, a great variety of preventive methods that would retard oxidized flavor development after the copper has already been absorbed by the cream.

Copper in the strength of 1 part per million gave a very definite off-flavor at three months storage which aging only intensified. Of course, it was recognized that it was very unlikely for any cream to be contaminated to that extent with copper in normal plant operations, but on the other hand if by some processing method, the oxidized flavor could be inhibited in cream containing that amount of copper, certainly the method would be of considerable value to creamerymen.

The addition of sugar to cream prior to freezing had been advocated by numerous workers but the findings of this experiment were not fully in agreement with them. Particularily was this true concerning flavor. While it was shown that the flavor of the cream containing sugar and no copper was equally as good as that of the control, no major benefit was derived by the addition of the sugar to the copper sample in an attempt to "mask" the oxidized flavor which might have developed.

McFarland and Burgwald (1940) showed that homogenization at 2300 to 2500 pounds pressure prevented the development of oxidized flavor in cream containing 3 parts per million copper, after 26 weeks storage. The results presented herein were quite contradictory to that finding. In fact, these findings revealed that homogenization had only a very slight detrimental effect on the development of the oxidized flavor even in cream con-

taining 1 part per million copper, and by no means inhibited the oxidized flavor development entirely.

Of the three types of containers used, glass, paper and tin, each had its advantages. The glass container was probably the most desirable from the standpoint of flavor alone. The tin showed good flavor and handled easily while the paper container was the most easily removed from the frozen cream, but in some cases seemed to give a slight off-flavor to the control samples.

However, the glass was obviously not desirable from the standpoint of breakage as well as cost so it appeared that either the paper or the lacquered tin container would have in most cases, proven satisfactory. Nevertheless, it was conceivable that a glass-lined receptacle would prove ideal for cream storage.

Gould and Sommer (1939) showed the effect of high temperature pasteurization in sulfhydryl production and the consequent reduction in tendency toward oxidation of fats or fat-like substances. McFarland and Burgwald (1940) showed that pasteurization at 172° F. for 5 minutes prevented development of oxidized flavor in frozen cream after 26 weeks storage even in the presence of 2.5 parts per million copper.

These findings were in partial agreement with the previous experiment but neither 165° F. for 15 minutes nor 185° F. for 5 minutes showed such inhibitory action as that cited by McFarland and Burgwald (1940). In fact, these temperatures showed much improvement over 150° F. for 30 minutes yet neither inhibited the oxidation in cream which contained 1 part per million copper even in the short three-month storage period. Unquestionably, however, high temperature pasteurization was very essential for cream designed for frozen storage.

The season of year in which most cream would be stored was of course during the flush season, or in the early spring and summer months. However, if one wished to store cream at any other period of year, it would keep equally well, as it apparently made very little difference whether winter or summer cream was stored.

Ordinarily it was considered that frozen cream would be used after only a few months of storage. The logical assumption was that cream would be stored in the early summer surplus period and used later when the pastures are drier and production was not so great. However, in view of the fact that all of the stored cream might not be used or perhaps with the idea that it might be put up regularily for much longer storage periods, the cream was held in this experiment up to one year and in another experiment for two years.

Upon the completion of the one year storage period, it was concluded that cream could be held that length of time without an appreciable loss of quality providing the initial quality was good and the processing methods optimum. Various workers such as Newlander and Ellenberger (1929) and Mack (1931) indicated that cream would keep well up to six months, but hesitated to recommend a storage period of a full year. Dahle (1941) agreed that cream could be stored as long as one year and perhaps 18 months.

Carotene content of cream apparently had very little effect upon the flavor of frozen cream either with or without copper contamination. Carotene had been cited as an oxidative inhibitory agent in numerous instances but while that condition existed in milk, it obviously did not apply to cream when subjected to the conditions of this experiment.

The carotene content of cream varied quite materially with the season of the year yet in no case was there correlation between the amount

of carotene due to season of the year and the presence or absence of the oxidized flavor.

The best cream for frozen storage was that with a low initial acidity. However, in view of the findings of this experiment, it appeared that most workers have over-stressed the quality angle from the titratable acidity standpoint. Dahle and Josephson (1939) contended that exceptional quality was desired in cream which was to be frozen. While a low initial acidity was desired in all fresh cream to be frozen, it did not follow that cream of higher acidity, yet sweet, and free from off odors and flavors could not be successfully held as frozen cream.

These findings showed that relatively high initial acidity might be particularily detrimental to flavor if pasteurized at low temperatures, but no necessarily so when high temperature pasteurization was used. In view of that fact, it appeared that while low acidity was desirable, one should not refrain from storing cream merely on the basis that the initial acidity was slightly higher than normal.

The use of pH as an indicator of quality of high testing cream designed for frozen storage appeared to be of no special value. While an idea of the initial quality could be obtained, there were other tests which were much simpler and more inexpensive than a measurement of the hydrogen-ion concentration by the potentiometer.

The fact that after 6-months storage, the hydrogen-ion concentration of the cream increased or the pH decreased was in agreement with the findings of other workers. Dahle, Lawhorn and Barnhart (1940) showed that aging of cream caused a decrease in titratable acidity which was particularily interesting in view of the fact that they also found a slight decrease in pH over the same aging period.

As Eh measurements showed quite readily the effect of copper additions to fresh cream, it appeared that the Eh value might have been beneficial in predicting the keeping quality of fresh cream, when considering the fact that the production of sulfhydryls or anti-oxidants of the cream produced an opposite effect on the Eh value.

However, there were certain limitations to the use of Eh, and workers hesitated to recommend it as a conclusive test for cream quality prior to or during frozen storage. The fact that Eh varied greatly with the season of the year as well as certain unexplainable actions in the relationship of the oxidants to reductants was quite largely responsible for the failure of Eh to be used commercially as a method of predicting the keeping quality of cream.

As homogenization stabilized the fat emulsion of nonfrozen dairy products, it was only natural to assume that it might have like effect upon frozen cream. However, such was not the case. In fact, Dahle and Josephson (1936) pointed out that homogenization was not beneficial in preventing oiling-off of cream and even caused greater oiling-off than in the case of nonhomogenized cream. These findings agreed with the previous work in that homogenization did not prevent oiling-off of the defrosted frozen cream, however, homogenization did not appear to facilitate the free fat separation.

Webb and Hall (1935) noted that homogenization of low-fat cream reduced fat separation. However, they also showed that increasing milk solids-not-fat decreased the per cent fat separation so perhaps the lessened fat separation of the low-fat cream might have been in part due to the larger portion of milk solids as well as the homogenization procedure.

These findings agreed with other workers in that the addition of sugar reduced somewhat the amount of free fat separation. However, these results showed less benefits to be derived from sugar additions than did other workers, but in heating the mixes there was decidedly less oiling-off observed in the sugared than in the nonsugared frozen cream mixes. Probably less difference in these experiments in oiling-off as a result of the addition of sugar than that noted by other workers was due to the extremely rigorous testing method used. Certainly the greater whipping ability of the sugared frozen cream mixes was further proof that the sugaring of cream prior to freezing markedly reduced the per cent of free fat separation.

While it was not economical to store low fat cream by freezing it would have been better from the standpoint of the stability of the fat emulsion of the defrosted cream. These findings are in agreement with Webb and Hall (1935) who showed less oiling-off in low than in high fat cream. This condition was considered to be due to greater solids-not-fat in the low testing cream as well as the greater fat content in the high testing cream, both of which had inverse relationships toward stability of the fat emulsion.

The findings in these studies did not agree with Webb and Hall (1935) that the fat was destabilized at once by the freezing process. A comparison of the samples of this experiment showed that while there was no greater fat emulsion destabilization either at 6 or 12 months than at 3 months, still there was greater free fat separation at 3 months than at 24 hours. While it was agreed that the fat emulsion destabilization was brought about shortly, it was considered that the destruction of the fat emulsion was not accomplished immediately by the freezing process, but

rather requires a few days although not nearly so long as the precipitation of proteins in a frozen milk product.

The temperature of pasteurization of the cream was of no material concern in the freezing of cream insofar as the effect that it had on the stability of the fat emulsion. However, there was slightly less free fat separation in this experiment due to the 165° F. for 15 minute heat treatment than to either 150° F. for 30 minutes or 185° F. for 5 minutes, due perhaps to the greater holding and agitation time of the former and greater heat of the latter exposure.

Numerous workers had shown that the speed of freezing affected the degree of free fat separation of defrosted cream. These findings agreed that faster freezing was beneficial in preventing oiling-off of the cream. The fact that samples frozen in three minutes showed greater difference in fat separation between it and the six and one-half minute cream than did the six and one-half to the one-hundred and eighty minute sample, appeared to be significant. One could readily deduct from these findings that the speed of freezing should be as near instantaneous as possible inasmuch as each successive longer freezing time gave greater free fat separation of the defrosted cream.

Addition of ten per cent sugar to cream prior to freezing proved beneficial both to speed of whipping and to maximum overrun obtainable, but did not prove beneficial from the standpoint of flavor of the resulting ice cream as had been indicated by previous workers. Neither was there any significant difference in the body scores of the ice cream from sugared and nonsugared frozen cream.

The addition of dried egg yolk to the mixes made from sugared and nonsugared frozen cream showed that sugar had no beneficial effect on speed of

whipping and maximum overrun obtainable when 0.35 per cent egg yolk was used. Experiments with the use of egg yolk by other workers also showed that egg yolk was beneficial in restoring whipping ability of frozen cream mixes. However, these findings showed that egg yolk did not restore the whipping ability of frozen cream mixes to such an extent that they would compare favorably with the mix of fresh cream. Nevertheless, it was believed that the whipping ability of frozen cream mixes was sufficiently restored by egg yolk additions to meet all practical purposes of commercial dairy plants. That the egg yolk was not a deterrent to flavor and body in ice cream either fresh or after 18 weeks storage was further proof that egg yolk was a very practical method of restoring the whipping ability of frozen cream mixes.

Periods of storage of cream up to six months were not more detrimental than one month from the standpoint of whipping or of flavor of the resulting ice cream. Therefore, it seemed logical that one might use cream which had been stored for one year with equal success as that stored for one month providing the processing had been such that the flavor was not affected by the longer period of storage. Obviously, the freezing process rather than the length of frozen storage was responsible for the loss of the whipping properties of frozen cream.

The flavor of frozen-cream ice cream both with and without egg yolk proved to be as good as that of the fresh product when fresh and after 18 weeks storage. The fact that very little work was on record of other experiments on the keeping quality of frozen-cream ice cream prevents a comparison having been made of these and other findings on the flavor of frozen-cream ice cream after an appreciable period of storage. At any rate, there can be no objection to the use of frozen cream mixes on the basis of

flavor deterioration of the resulting ice cream due to prolonged storage, if one observed the processing precautions as outlined in this experiment.

The bacteria count of the ice cream made from frozen cream showed no material difference to that of the fresh-cream ice cream. However, there was a slightly higher count in the ice cream containing the egg yolk but bacteriologically speaking, it was of no significance. The fact that all frozen-cream ice cream showed a very low bacteria plate count after 18 weeks of frozen storage demonstrated from the bacteriological standpoint that frozen cream might be used in the ice cream mix.

SUMMARY

Samples of high-testing cream, averaging throughout the year 52.5 per cent fat, were processed, frozen and stored at -10° F. and were examined at 3, 6 and 12 months to note the development of the oxidized flavor.

A pasteurization exposure of 150° F. for 30 minutes was found inadequate to protect the cream against the development of off-flavors. Exposures of either 165° F. for 15 minutes or 185° F. for 5 minutes were sufficient to inhibit staling of copper-free cream upon prolonged frozen storage. However, the higher pasteurization exposure was slightly more beneficial than the exposure of 165° F. for 15 minutes.

The presence of 1 part per million copper added to the cream after pasteurization resulted in the development of a very undesirable oxidized flavor in all samples upon storage regardless of the method of processing.

The addition of 10 per cent sugar to the cream aided in stabilizing the fat emulsion but did not necessarily prove beneficial to flavor.

Homogenization was slightly beneficial in inhibiting the development of the oxidized flavor, but did not stabilize the fat emulsion against free fat separation upon defrosting. However, fast freezing although not a complete preventive of oiling-off was beneficial in stabilizing the fat emulsion of frozen cream.

Cream could be stored equally well in glass, paper or tin containers insofar as development of off-flavors was concerned. However, the lacquered tin container seemed to be the most practical from a commercial standpoint as a container for cream storage although paper was believed to be quite satisfactory.

Cream might be stored equally well at any season of the year and might remain stored for a year or more with no apparent loss of quality to the cream if the proper processing methods were used.

Carotene had no inhibitory effect on the development of copper-induced oxidized flavor in high testing cream.

The initial titratable acidity should be low in cream intended for frozen storage.

The hydrogen-ion concentration of fresh, sweet cream furnished little information of practical value in predicting the keeping quality of the cream.

While oxidation-reduction measurements increased with copper contamination and decreased with high-temperature pasteurization, they were not conclusive indicators of the future keeping quality of the cream.

Sugar additions to cream prior to freezing were beneficial to whipping ability of the resulting ice cream mixes.

Egg yolk was found to aid greatly in restoring the whipping properties of frozen cream mixes.

Neither sugar nor egg yolk greatly affected the flavor of ice cream upon storage.

Bacteria counts of the frozen cream mixes were quite low.

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