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The Effect of Cultures and the Relation of Acid Standardization to Several of the Physical and Chemical Properties of Ice Cream

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CONCLUSIONS

1. The use of high quality bacterial cultures offers a means of developing a distinctive and desirable "culture" flavor in ice cream.
2. A desirable "cultured" ice cream can be made by inoculating a small portion of the original mix with two per cent of high quality culture to make a "starter" mix. This starter mix should be incubated at 74 degrees Fahrenheit until the acidity reaches 0.85 per cent, at which time sufficient quantities can be added to the original mix before pasteurization.
3. That "cultured" ice cream has good keeping qualities is evidenced by the fact that after having been stored for five months the flavor was pleasant and desirable.
4. Standardizing the ice cream mix acidity below that which is normal for the mix requires more of the standardizing agent than theoretically should be necessary. This is, no doubt, due to the buffering capacity of the mix constituents.
5. Increasing the total food solids per gallon of ice cream by increasing the serum solids content resulted in a sweeter flavored ice cream with a more rapid and smoother meltdown, a closer texture.
6. Increasing the overruns excessively in the high serum solids ice creams resulted in an impairment of the texture and in an increase in the stability of the ice cream.
7. The standardization and subsequent development of acidity in the ice cream mix had no apparent effect upon the stability of the resultant ice creams.
8. Photographs of the internal structure of the ice creams indicated that acidity was not an important factor influencing the crystalline structure of ice cream. Increased serum solids resulted in slightly smaller ice crystals and in a more abundant matrix or non-frozen material surrounding the ice crystals. Increased overruns with an increase in serum solids increased the number of small air cells and the distance between ice crystals.
9. The temperature at which ice creams are dipped is probably the most important factor governing the number of dips obtained from a given volume of ice cream.
10. The acid standardizing agent used in this investigation apparently minimized the shrinkage of ice cream during storage. This was particularly apparent in the ice creams containing 13 and 15 per cent serum solids.

The Effect of Cultures and the Relation of Acid Standardization to Several of the Physical and Chemical Properties of Ice Cream

W. H. E. REID AND L. E. SMITH

INTRODUCTION

Bacterial cultures have been used for many years to control the flavor development of cheeses and to improve the flavor of butter and fermented milks. This investigation has been primarily concerned with an attempt to develop a desirable bacterial culture flavor in ice cream.

The improved processing and freezing methods used in the manufacture of ice creams have encouraged the manufacture of ice creams of higher serum solids content. This increase of serum solids content is accomplished by the addition of condensed or dried skimmilk to the mix. The increase in serum solids results in an increase in the titratable acidity of the mix due to the increase in the protein and acidic salts, namely citrates, phosphates, lactates, and in some cases, lactic acid. This increase in titratable acidity has suggested the possible advisability of standardizing the acidity of the ice cream mix to near the normal acidity of the fresh dairy products, by the addition of basic salts.

REVIEW OF LITERATURE

Hurlburt (1) reported that high acidity had a close relationship to the action of lactose, causing sandiness; and that the higher the milk solids-not-fat, the higher the acidity and the greater the danger of sandiness.

Masurovsky (2) published a report on the acidity phase of the ice cream mix in which he stated that the addition of starter to the ice cream mix and the subsequent acid development tends to increase the mix viscosity both before and during aging. Since the introduction of acidity to the mix may impart objectionable flavors and does not noticeably influence the physical make-up of the ice cream, it would not be a good practice to use dairy products of high acidity in ice cream making.

Mojonnier and Troy (3) pointed out the important role of acidity in ice cream mixes, by saying, "The acidity of the ice

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cream mix is an important factor in obtaining the most desirable flavor and texture in the finished product, and in controlling overrun. The acidity of the mix may be increased by adding cultured buttermilk to the mix. This will insure a good, sharp flavor and make possible the production of constant and ample viscosity."

Dahle (4) found that by increasing the acidity of the mix from 0.20 to 0.285 per cent a heavy, viscous mix resulted which was slow to whip. It was also found that decreasing the acidity of the mix below normal increased the whipping time.

Wahle, Budge, and Keith (5) made the observation that there were mixes high in titratable acidity, but low in actual acidity. In such mixes any attempts to standardize the acidity by usual plant methods may result in producing an alkaline mix. Knowledge of the serum solids content of a mix and of its titratable acidity are not sufficient to enable one to judge the correct point to which the acidity may be standardized. The acidity developed by a bacterial culture may be calculated as true acidity.

Turnbow and Raffetto (6) state that theoretically a 10 per cent serum solids mix should normally contain 0.18 per cent acid, but that in actual practice it is quite difficult to make such a mix and get less than 0.20 per cent acid because of the acid contained in the added milk solids and the buffer action of the added solids. It was found that by standardizing high acid mixes to 0.2 per cent the texture and stability of the resulting ice creams were improved.

Larson and White (7) state that the acidity of the ice cream mix may be reduced to 0.2 per cent without greatly impairing the flavor of the ice cream, but too great an addition of alkali to the mix must be avoided because of the abnormal flavor which may result.

Sommers (8) in commenting on the neutralization (standardization) of acidity in ice cream mixes, stated that a fairly safe rule to follow is "never to neutralize below the titratable acidity that is average and normal for the product."

It might be expected that altering the salt balance and acidity by neutralization would produce some effect on the texture. "The expectation is that a high calcium and magnesium content and a high acidity are detrimental to a smooth texture in ice cream because of the effect these factors are observed to have on limiting the hydration of the protein and on the clumping of fat globules. A high citrate or phosphate content and a low acid content would be expected to have the opposite effect. Actually, however, the effect is slight and may be overbalanced entirely if the other texture factors are favorable."

Corbett (9) using three common neutralizers (standardizers) sodium bicarbonate, a mixture of sodium hydroxide and sodium carbonate, and a mixture of calcium hydroxide and magnesium oxide showed that the three products had comparable effects on viscosity. Mixes neutralized with sodium salts had the best dispersion of the butterfat. Mixes neutralized with lime generally whipped to 100 per cent overrun in less time than did the mixes neutralized with the alkaline sodium salts. The body of the ice creams neutralized with lime was superior in nearly all cases, and was more resistant.

Dahle and Rivers (10) found that less alkali flavor was noticed in ice creams containing magnesium oxide than in those containing calcium hydroxide, and the melting ice cream had greater stability. Magnesium oxide, as the acid standardizing agent, gave a better flavored product than did calcium hydroxide, which was better than sodium hydroxide. When alkalies were used to lower the acidity of the mixes below the normal range, considerably more alkali was needed to cause a calculated reduction in acid. This was due to the buffering capacity of the system.

Reid, Decker, and Arbuckle (11) found that consumer preference was for ice creams standardized to a pH of 7, or slightly lower. Ice creams containing 1.77 pounds of total solids per gallon were preferred by consumers, and ice creams containing 1.90 pounds of total solids were next in preference. Ice creams having 0.12 per cent to 0.18 per cent acidity and a total solids weight per gallon of 1.77 pounds gave the most desirable texture.

Reid, Drew, and Arbuckle (12) found that increasing the serum solids of the mix caused a relative increase in the pH and viscosity. Ice cream containing 14 per cent fat, 13 per cent serum solids, and 14 per cent sugar was preferred of the series of mixes studied.

Roberts and Stoltz (13) conducted a quantity consumer preference experiment in ice cream and checked the results against the questionnaire and sample method. In all, 14 variables in vanilla ice cream were studied, and in general, it was found that the two methods gave similar results except in two cases. A preference was expressed for the higher serum solids ice cream (11-13 per cent) by the questionnaire and sample method, but when allowed to eat all the ice cream they wanted, the consumers ate more of the lower serum solids ice creams (9-11 per cent). The same contradiction occurred in the test in which corn sugar was used.

Bierman (14) in studying overrun, temperature, and composition of ice creams, found that ice creams having overruns of 60, 80, 90, 100 and 118 per cent dipped 17, 15.4, 14.4, 14.1, and 13.5 quarts respectively from five gallons of ice cream. Ice cream to possess the best dipping qualities, should have between 80 and 90 per cent overrun. Gelatin was found to have no effect on dipping, but high fat content, high sugar, and high serum solids caused greater losses.

Tracy (15) in a study of consumer opinions on ice cream, reported that high overrun not only detracts from the quality of the ice cream, but also causes a loss in consumer confidence. Extremely low overrun often causes a soggy type of body.

Reid (16) found that increasing the fat content of ice cream mixes, had no effect on the freezing temperature. Increasing the sugar content lowered the freezing point and resulted in a smother-bodied ice cream. An increase in the milk solids-not-fat lowered the freezing point, increased the viscosity of the mix, and improved the stability of the finished ice cream and the ability of the mix to absorb heat units rapidly.

Turnbow (17) stated that it was necessary to have proper proportions of ingredients in ice cream to control crystallization. An increase in total solids, rapid freezing and quick drawing from the freezer into pre-chilled containers, rapid hardening, and proper merchandising practices are necessary to insure the consumer of receiving smooth-textured ice cream.

Reid and Hales (18) using an improved method for microscopic examination of ice cream, reported that a fine texture is associated with the presence of a uniformly dispersed system of ice crystals and air cells. Improvement in texture was directly proportional to increased increments of fat, solids-not-fat, and sugar.

Reid, Drew, and Arbuckle (12) in later work on the microscopic examination of ice creams, found that as the percentage of fat, serum solids, sugar, and gelatin increased the ice crystals appeared relatively smaller.

Reid, Decker, and Arbuckle (11) in microscopic examinations of ice creams, found that a pH of 7 and a total solids weight of 1.77 to 1.90 pounds per gallon gave the smallest ice crystal.

PROCEDURE

This investigation has been conducted under commercial plant conditions, insofar as possible, so that the results obtained may be applicable to the ice cream industry.

The mixes used in this investigation were prepared from the same source of ingredients, which included cream, whole milk, skimmilk, dry milk solids, sucrose, a commercial product "De Raef minsol", and gelatin. The mixes were pasteurized at 155° F. for 30 minutes, homogenized at 2500 pounds pressure

(1500 pounds first stage and 1000 pounds second stage), cooled to 40° F., and aged 12 hours. All ice creams were frozen on a continuous freezer.

The acidities were determined by titration with N/10 sodium hydroxide, and the pH values determined by the use of a Beckman glass electrode potentiometer. Viscosity values were determined at 20 degrees Centigrade by the Ostwald viscosimeter and expressed in comparison with water.

For developing the bacterial culture flavor, three different butter cultures were used. Different methods of inoculation and acid development of the mix at 70 degrees Fahrenheit were used including (1) direct inoculation of the mix with 2 per cent butter culture and developing the acidity to the desired values; (2) a "starter" mix obtained by adding 2 per cent starter to a portion of the mix and developing it to 0.8 per cent acidity at 74 degrees Fahrenheit and using it to inoculate the remainder of the mix to develop the desired acidity values.

The samples were judged for flavor, body, texture and keeping quality after aging the ice cream one week, and one month respectively in the hardening room and tempering 24 hours in a dispensing cabinet at serving temperatures of 4 degrees Fahrenheit, 8 degrees Fahrenheit, and 12 degrees Fahrenheit.

Microscopic studies of texture of the ice creams were made by breaking in half a pint sample and taking photographs of the broken inner surface.

The crystalling and air cell structure of the ice creams were studied by making microscopic pictures of a thin section of each ice cream. Sections of the ice creams 5 to 10 microns in thickness were made with a modified microtone at a temperature of -10 degrees Fahrenheit, immersed in an immersion oil of refractive index 1.42 and photomicrographs taken at a magnification of 100 times.

In making the meltdown studies, one sample of each ice cream was tempered at 4 degrees Fahrenheit before being placed in the 85 degree Fahrenheit cabinet where moving pictures were made of the melting ice creams. Still pictures were also made at 10-minute intervals. The ice creams were photographed during an 80-minute period, and pictures were made of the final residues.

Each ice cream was dipped at temperatures of 4, 8, and 12 degrees Fahrenheit, using a size No. 24 Zeroll dipper. The ice creams were weighed, the number of dips in a 2½ gallon container determined, and the average weight per dip calculated. The package and bulk ice creams were drawn from the freezer at 100 per cent overrun with the exception of the ice creams in Series IV, which were drawn on a total solids per gallon basis.

EXPERIMENTAL BASIS

In this investigation 36 ice cream mixes were frozen.

Table 1 shows the composition, total solids per gallon, and the weight per gallon of each ice cream. In Series I and II the variable factor was acidity; in Series III the variable factors were acidity, and serum solids content; in Series IV acidity, serum solids, and overruns were the variable factors.

TABLE 1. THE COMPOSITION OF THE DIFFERENT ICE CREAM MIXES AND THE WEIGHT PER GALLON OF ICE CREAM

Mix Number	Fat Per Cent	Serum Solids Per Cent	Sugar Per Cent	Gelatin Per Cent	Specific Gravity	Overrun Per Cent	Solids Content per gallon of ice cream pounds	Weight per gallon of ice cream pounds
				Series I				
1 to 7	12	11	14	0.20	1.0820	100	1.70	4.57
				Series II				
7 to 13	12	11	14	0.20	1.0915	100	1.70	4.57
				Series III				
13a,13b,13c	12	9	14	0.20	1.0610	100	1.58	4.50
14a,14b,14c	12	11	14	0.20	1.0800	100	1.70	4.57
15a,15b,15c	12	13	14	0.20	1.1002	100	1.82	4.65
16a,16b,16c	12	15	14	0.20	1.1160	100	1.95	4.75
				Series IV				
17a,17b,17c	12	9	14	0.20	1.0613	85	1.709	4.86
18a,18b,18c	12	11	14	0.20	1.0783	100	1.699	4.57
19a,19b,19c	12	13	14	0.20	1.0981	115	1.699	4.35
20a,20b,20c	12	12	14	0.20	1.1172	130	1.699	4.13

Table 2 gives data on some of the chemical and physical properties of the ice cream mixes. The titratable acidities of the original mixes, after standardization and after starter development are shown. The pH and viscosity of each mix before freezing is also given.

Since the data for Series IV were practically identical with those for Series III, the data are not repeated in this paper. Controls were frozen of mixes at original and standardized acidities as well as at starter acidities. In Series III and IV, the mixes frozen at original acidities are identified by the letter (a), those frozen at standardized acidities, by the letter (b), and the "cultured" ice cream by (c). The data in this table show that the titratable acidity and the pH for the ice cream mixes depend largely upon the serum solids content of the mix. It may also be noticed that developed acidity had a marked influence upon the viscosity of the ice cream mix. Variable serum solids contents also caused variations in viscosity.

TABLE 2. THE CHEMICAL AND PHYSICAL PROPERTIES OF THE DIFFERENT ICE CREAM MIXES

	Acidities				
Mix Number	Original Per Cent	Standardized Per Cent	Starter Developed Per Cent	pH	Specific Viscosity
			Series I		
1	0.24	0.24		6.35	5.610
2	0.24	0.12		7.25	5.469
3	0.24	0.12	0.16	6.55	10.518
4	0.24	0.12	0.20	6.51	11.781
5	0.24	0.12	0.24	6.40	13.323
6	0.24	0.12	0.28	6.18	21.318
			Series II		
7	0.18	0.18		7.00	7.152
8	0.18	0.18	0.20	6.22	23.772
9	0.18	0.12		7.51	8.485
10	0.18	0.12	0.20	6.23	16.974
11	0.18	0.06		8.20	9.466
12	0.18	0.06	0.20	6.13	17.531
			Series III		
13a	0.22	0.22		6.70	6.311
13b	0.22	0.12		7.50	7.152
13c	0.22	0.12	0.20	6.90	8.485
14a	0.26	0.26		6.65	7.433
14b	0.26	0.12		7.45	7.293
14c	0.26	0.12	0.20	7.00	9.116
15a	0.29	0.29		6.63	8.415
15b	0.29	0.12		7.52	9.088
15c	0.29	0.12	0.20	7.10	9.817
16a	0.36	0.36		6.60	12.762
16b	0.36	0.12		7.50	11.781
16c	0.36	0.20	0.20	7.15	13.323
			Series IV		
14 to 17 inclusive	Data for this series are essentially the same as those given for Series III.				

The Relation of Acid Standardization and Acid Development to the Flavor, Body, and Texture of Ice Creams Served at Different Temperatures

Table 3 shows that the body and texture of the ice creams in Series I and II were not affected by acid development or by acid standardization as all the ice creams had a smooth, mellow body and close texture. In Series I the culture flavor was attained by using a "starter" mix, adding varying portions of it to the different mixes to increase the acidity of each mix to predetermined points. The ice creams from mixes 4 and 5

TABLE 3. THE RELATION OF ACID STANDARDIZATION AND ACID DEVELOPMENT TO THE FLAVOR, BODY, AND TEXTURE OF ICE CREAM SERVED AT DIFFERENT TEMPERATURES

	Flavor Observations				
	Serving Temperature in Degrees Fahrenheit				
	4	8	12	Texture	Body
			Series I		
1	mild pleasant	mild pleasant desirable	mild pleasant desirable	close	smooth and mellow
2	mild sl.unnatural	mild sl. unnatural	mild sl. unnatural	close	smooth and mellow
3	mild culture pleasant	mild culture pleasant	mild desirable culture	close	smooth and mellow
4	mild desirable culture	desirable culture	good culture	close	smooth and mellow
5	pronounced culture desirable	pronounced culture desirable	pronounced culture desirable	close	smooth and mellow
6	over-pronounced culture	over-pronounced culture	over-pronounced culture	close	smooth and mellow
			Series II		
7	mild lacking	mild cold pleasant	mild pleasant	close	smooth and mellow
8	mild lacking	very mild culture	very mild culture	close	smooth and mellow
9	lacking cold	mild to lacking	lacking	close	smooth and mellow
10	very mild culture	mild culture	high acid	close	smooth and mellow
11	mild to lacking sl. unnatural cold	lacking sl. unnatural	lacking sl. unnatural	close	smooth and mellow
12	culture pronounced undesirable	lacking undesirable culture	undesirable	close	smooth and mellow

having acidities increased from 0.12 per cent to 0.20 per cent and 0.24 per cent respectively, were judged as having very pleasant, desirable culture flavors. The ice cream from mix No.

6 having the acidity increased from 0.12 per cent to 0.28 per cent was judged as having an over-pronounced "culture" flavor. After one month of storage all the culture flavors in this series were found to be pleasant and desirable.

In Series II the culture flavor was developed by adding 2 per cent butter culture directly to the mix and developing the acidity from 0.18 per cent to 0.20 per cent in mix No. 8, from 0.12 per cent to 0.20 per cent in mix No. 10, and from 0.06 per cent to 0.20 per cent in mix No. 12.

The "cultured" ice creams in Series II were judged as lacking in desirable culture flavor. Standardization of the ice cream mix acidity below 0.12 per cent was observed to result in giving the ice cream an unnatural flavor.

In Series III and IV, four basic mixes were used of varied serum solids contents for each series. Each of the basic mixes

TABLE 4. THE RELATION OF ACID STANDARDIZATION AND DEVELOPMENT TO THE FLAVOR, BODY AND TEXTURE OF ICE CREAMS OF DIFFERENT SERUM SOLIDS AND SERVED AT DIFFERENT TEMPERATURES.

Mix Number	Acidity Per Cent	Serum Solids Per Cent	Overrun Per Cent	Flavor Observations — Serving Temperature in Degrees Fahrenheit 4	8	12	Texture	Body
				Series III				
13a	0.22	9	100	pleasant, lacking	pleasant, lacking	pleasant, mild	med. close	smooth, lacks resistance
13b	0.12	9	100	pleasant, lacking	pleasant, lacking	pleasant, mild	med. close	smooth, lacks resistance
13c	0.20	9	100	pleasant, mild culture	pleasant, mild cutlure	pleasant, mild culture	med. close	smooth, lacks resistance
14a	0.26	11	100	pleasant	pleasant	pleasant	close	smooth, mellow
14b	0.12	11	100	mild	mild	mild	close	smooth, mellow
14c	0.20	11	100	mild culture	mild culture	mild culture	close	smooth
15a	0.29	13	100	dairy products, sweet	dairy products, sweet	dairy products, sweet	close to v. close	smooth
15b	0.12	13	100	sl. unnatural	sl. unnatural	sl. unnatural	close to v. close	smooth
15c	0.20	13	100	dairy products, culture lacking	dairy products, culture	dairy products, culture	close	smooth
16a	0.36	15	100	dairy products, sweet	dairy products, sweet	dairy products, sweet	v. close	smooth, sl. soggy
16b	0.12	15	100	dairy products, sl.unnatural	dairv products, sl. unnatural	dairy products, sl. unnatural	v. close	smooth, sl. soggy
16c	0.20	15	100	lacking culture	sweet, lacking culture	sweet, lacking culture	v. close	smooth, sl. soggy

was divided into three parts, (a) frozen at the original acidity, (b) was standardized to 0.12 per cent acid and frozen at that acidity, and (c) was standardized to 0.12 per cent acidity, then "starter" mix was added to develop the acidity to 0.20 per cent at which acidity it was frozen. Table 4 gives the observations of the ice creams in Series III in which the serum solids contents varied from 9 to 15 per cent. The ice creams of 9 per cent serum solids had a medium close texture and smooth body but lacked resistance. The flavor was lacking in the (a) and (b) mixes, but the (c) had a desirable culture flavor. The ice creams containing 11 per cent serum solids were judged as having a desirable texture, body and fuller flavor. Increasing the serum solids to 15 per cent resulted in an ice cream having a very close texture and a slightly soggy body. The high serum solids ice creams had a dairy products flavor.

The cultured flavor of the 13 and 15 per cent serum solids mixes was less pronounced showing that an increase in serum solids partially submerged the cultured flavor.

The Relation of Acid Standardization and Development to the Flavor, Body, and Texture of Ice Creams of Varying Overruns Served at Different Temperatures

Table 5 shows the effect of variable overruns and serum solids in maintaining a constant food solids weight per gallon of 1.70 pounds to the flavor, body, and texture of ice creams. As the serum solids and the overrun were increased, a sweet dairy products flavor became apparent. As the overrun was increased from 85 to 130 per cent and the serum solids increased from 9 to 15 per cent the body changed from smooth and mellow to smooth and weak while the texture changed from very close to slightly open.

Relation of Acidity, Per Cent Serum Solids and Per Cent Overrun to the Texture of Ice Cream

Figures 1 and 2 show the texture of ice creams in Series I and II. When the broken surfaces of these twelve ice creams were examined, no consistent difference, if any, was noticed, and all were considered to be very desirable and close textured. Figure 3 illustrates the improvement in the texture of the ice creams containing increased increments of serum solids with constant overruns. With each additional increment of serum solids the texture becomes closer. Variation in the acidity of the ice cream mixes had no apparent effect upon the texture except on the instance of the ice cream containing 9 per cent solids

TABLE 5. THE RELATION OF ACID STANDARDIZATION AND DEVELOPMENT TO THE FLAVOR, BODY, AND TEXTURE OF ICE CREAMS OF VARYING OVERRUNS SERVED AT DIFFERENT TEMPERATURES

Mix Number	Acidity Per Cent	Serum Solids Per Cent	Overrun Per Cent	Flavor Observations Serving Temperature in Degrees Fahrenheit 4	8	12	Texture	Body
				Series IV				
17a	0.22	9	85	lacking	pleasant, sl. lacking	pleasant, mild	very close	smooth, mellow
17b	0.12	9	85	lacking	pleasant, sl. lacking	pleasant, mild	very close	smooth, mellow
17c	0.20	9	85	mild culture	mild culture	pleasant, mild culture	very close	smooth, mellow
18a	0.26	11	100	pleasant	pleasant, desirable	pleasant, desirable	close	smooth, mellow
18b	0.12	11	100	pleasant	pleasant, desirable	pleasant, desirable	close	smooth, mellow
18c	0.20	11	100	mild culture	mild culture	mild culture	close	smooth, mellow
19a	0.29	13	115	dairy products	dairy products	dairy products	med. close	smooth, lacks resistance
19b	0.12	13	115	dairy products	dairy products	dairy products	med. close	sl. weak smooth
19c	0.20	13	115	lacking culture	mild culture	mild culture	close	sl. weak gummy
20a	0.36	15	130	sweet, dairy products	sweet, dairy products	sweet, dairy products	sl. open	smooth weak
20b	0.12	15	130	sweet, sl. unnatural	sweet, sl. unnatural	sweet, unnatural	sl. open	smooth, weak
20c	0.20	15	130	lacking, culture	mild culture	mild culture	sl. open	smooth, weak

with a starter developed acidity appears to have a finer texture than the ice cream of original acidity.

Figure 4 shows that a close to medium close texture is maintained with increased overruns and a compensating increase of serum solids to maintain the same total food solids weight per gallon. The variation in the acidity of the ice cream mixes had no appreciable effect upon the texture of the ice creams although it seems that ice cream containing 9 per cent solids, 85 per cent overrun and a starter developed acidity of .20 has a closer texture than the ice cream with an original acidity of .22 per cent.

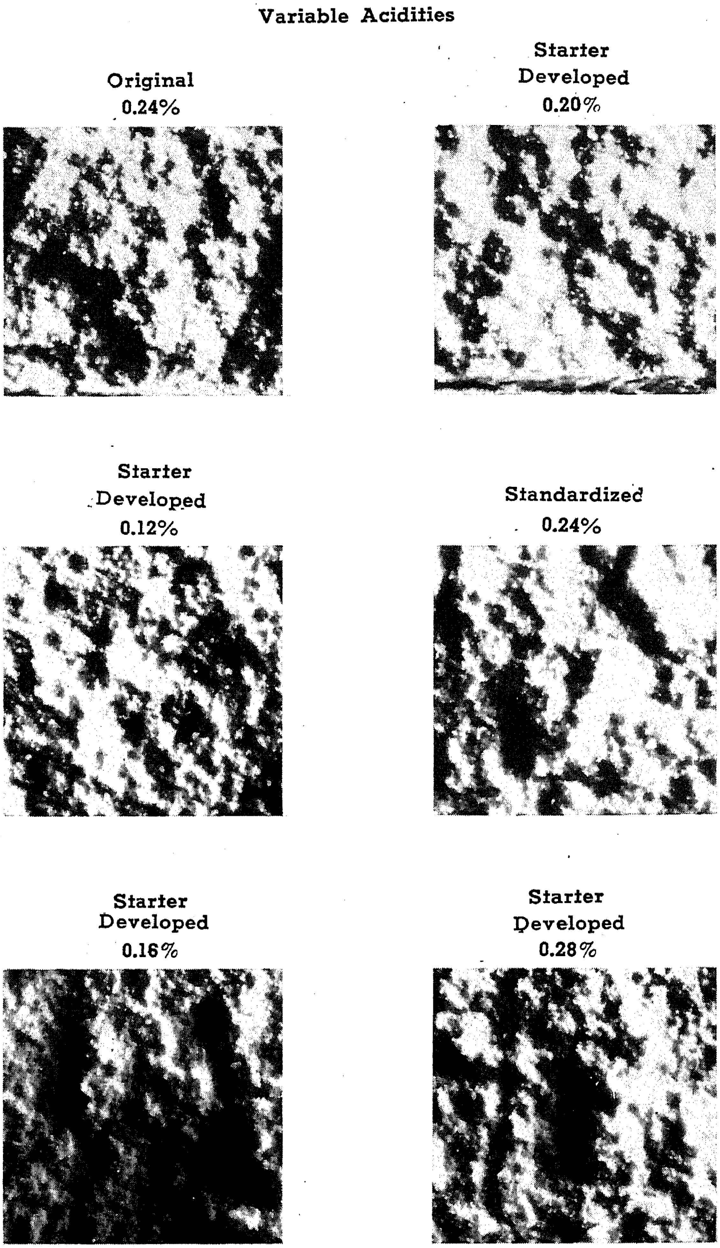


Fig. 1.—The relation of acid standardization and development to the texture of ice cream.

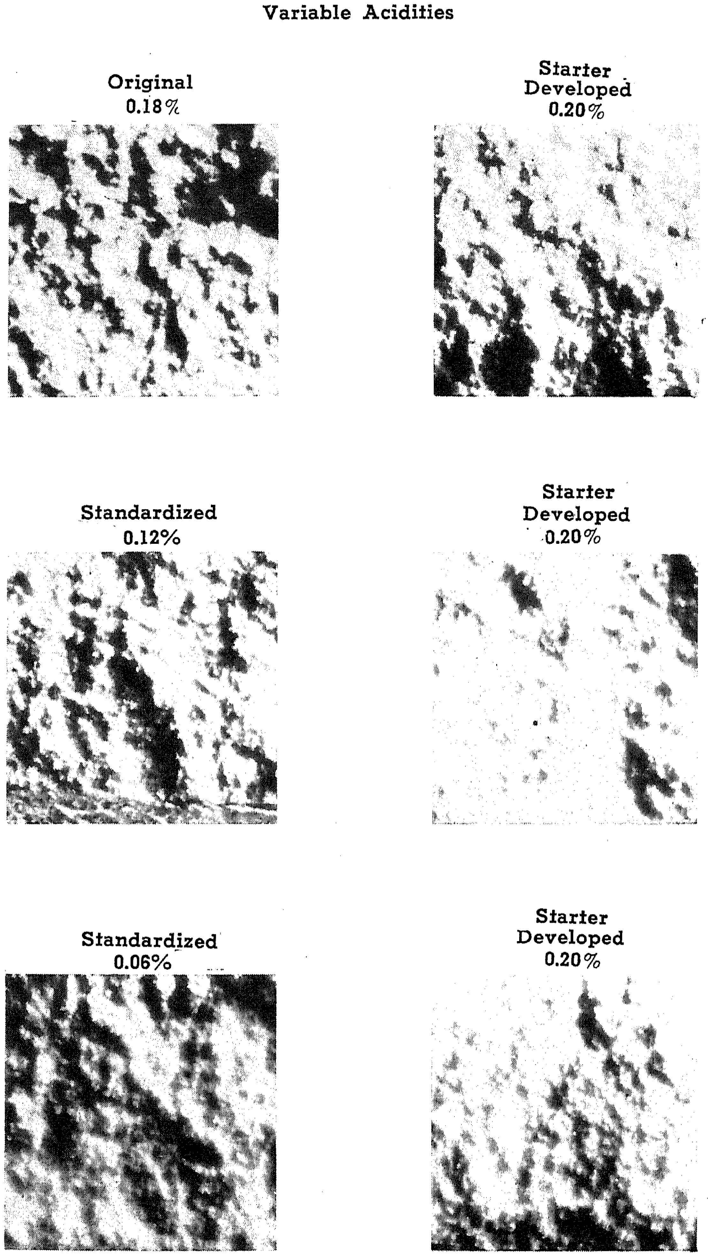


Fig. 2.—The relation of acid standardization and development to the texture of ice cream.

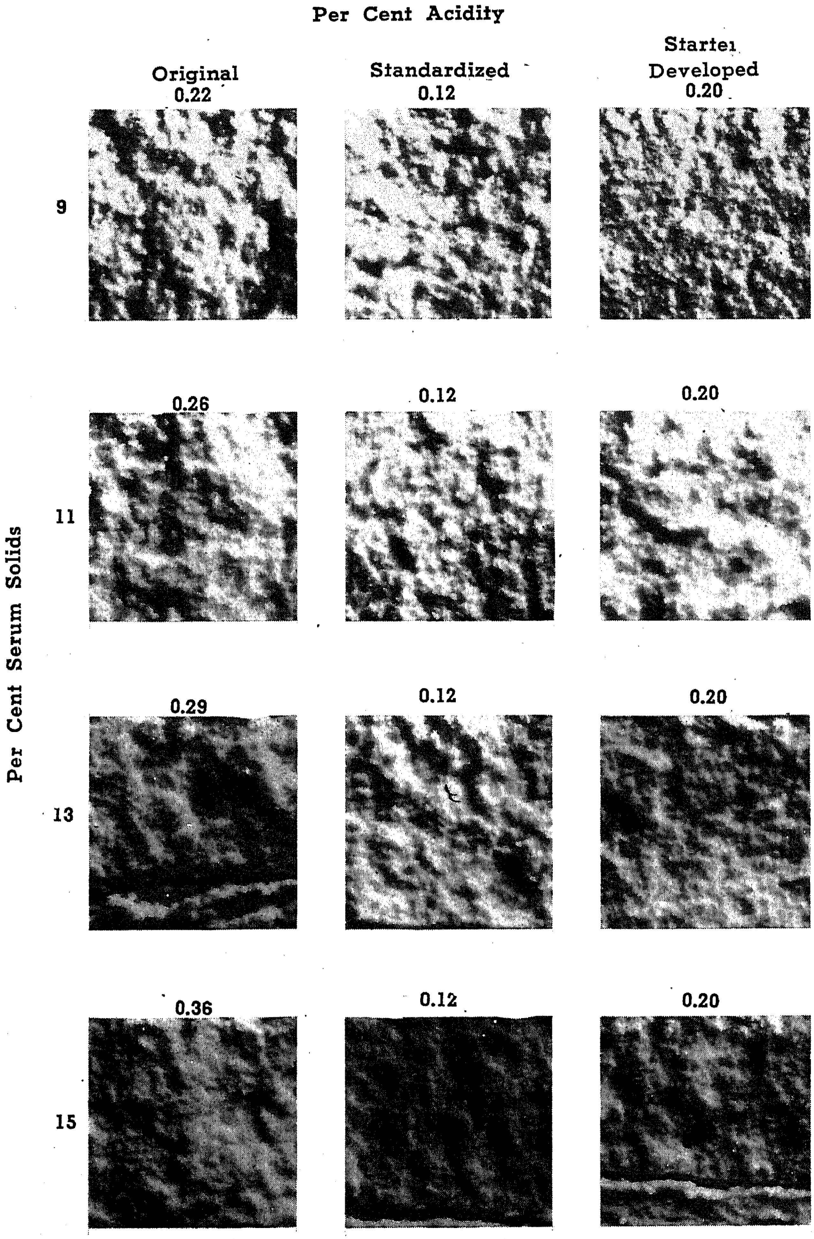


Fig. 3.—The effect of variations in serum solids contents and in acidities upon the texture of ice cream.

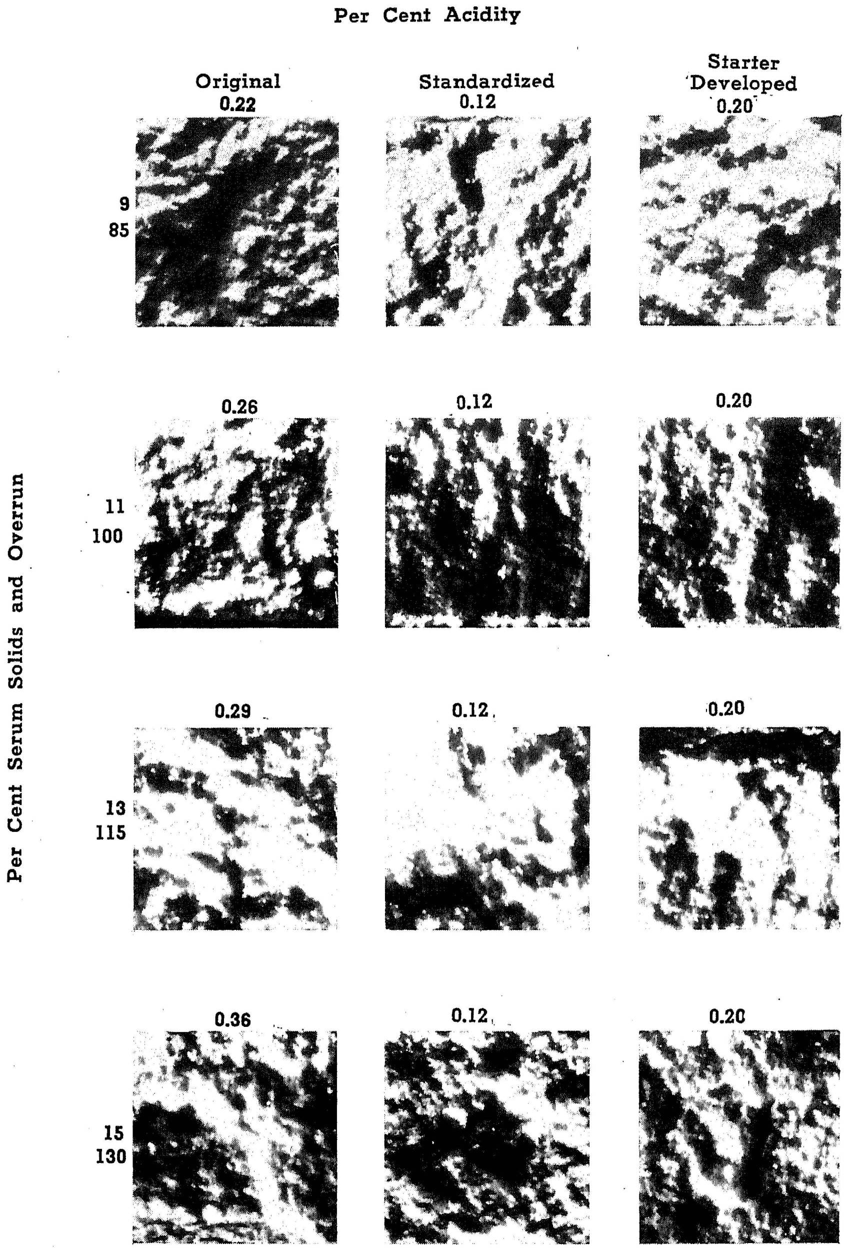


Fig. 4.—The effect of variations in serum solids contents, overruns, and acidities upon the texture of ice cream.

Relation of Acidity, Serum Solids Content and Per Cent Overrun to the Internal Structure of Ice Cream

The photomicrographs of the crystalline structure of ice creams, Figures 5, 6, and 7, show the relation of acid standardization and development to the size of ice crystals, air cells, and the amount of bounding material or matrix. These photomicrographs show that a variation in the acidity did not have any appreciable effect upon the microscopic crystalline structure of ice cream. The number and size of the ice crystals and air cells appear to be uniform irrespective of the acidity of the mixes.

Figure 8 shows the effect of varying serum solids and overruns in ice cream of varying acidities. It is quite apparent that the acidity did not affect the microscopic structure. However, it does appear that as the serum solids are increased and the overrun held constant there is a tendency toward a slightly smaller ice crystal with relatively greater amounts of bounding material or matrix. Increasing the overruns of the high serum solids resulted in a smaller ice crystal and increased the number of air cells. The increase in serum solids depressed the freezing point of the mix resulting in a softer ice cream. Increasing the overrun of these high serum solids ice creams seemed to counteract the effect of the depressed freezing point.

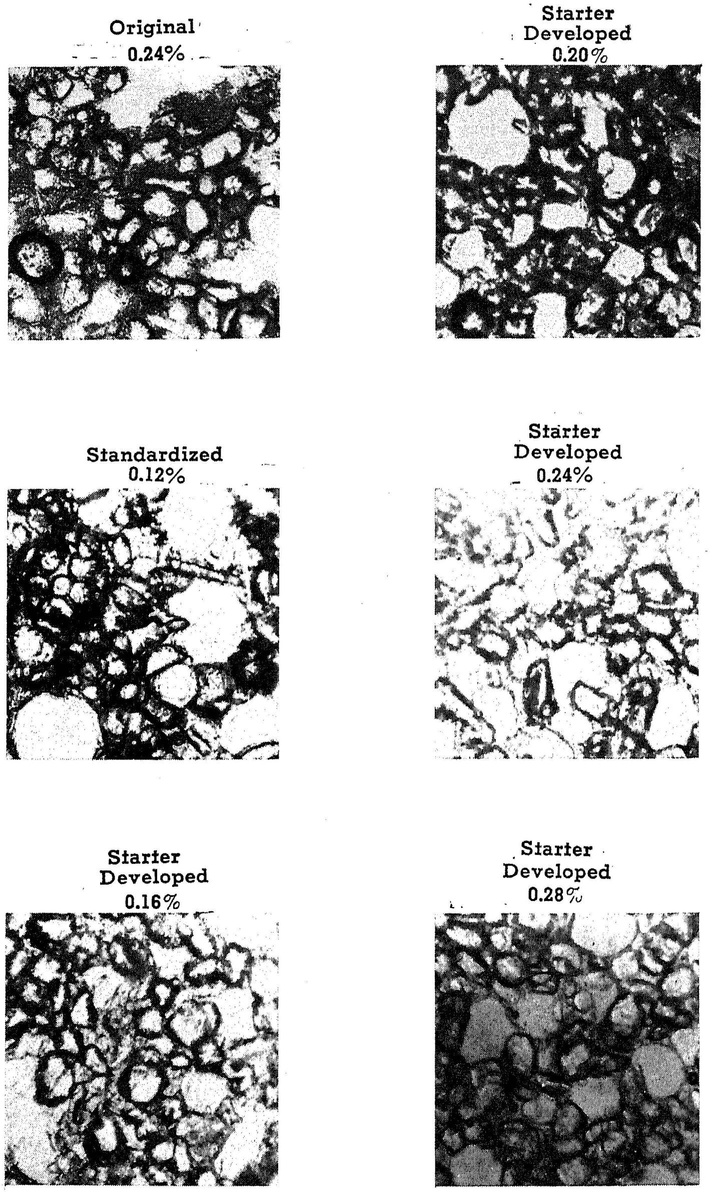


Fig. 5.—The effect of acid standardization and development upon the microscopic structure of ice cream.

Variable Acidities

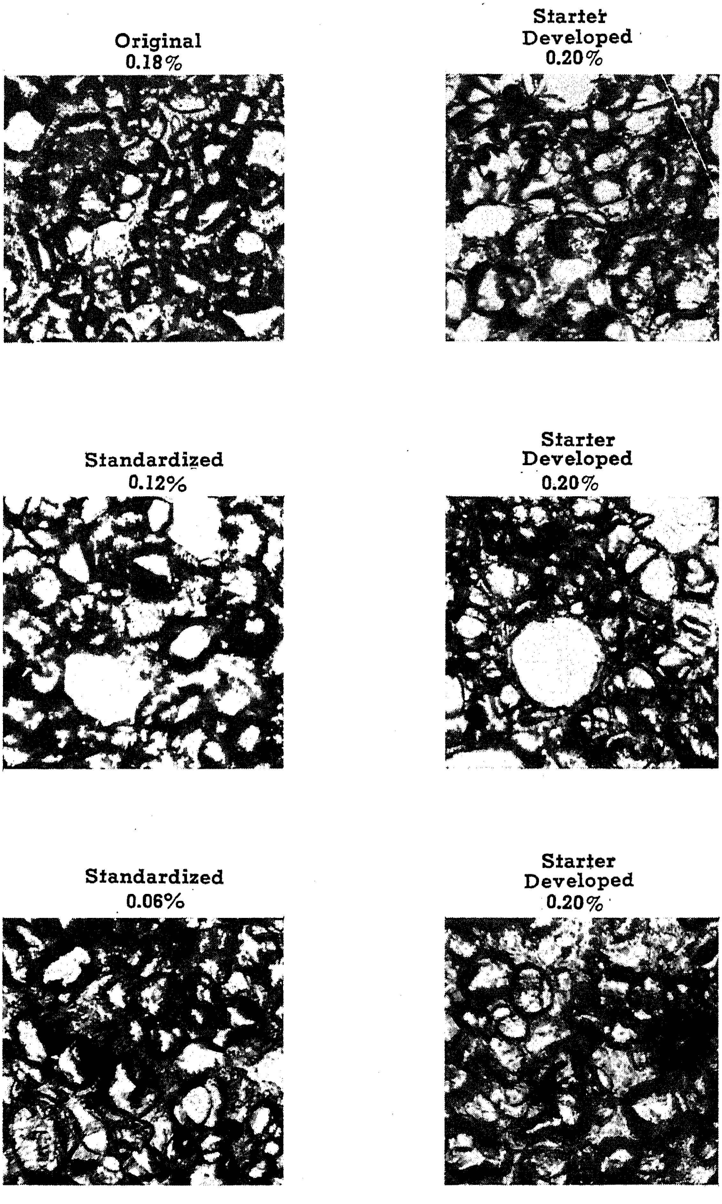


Fig. 6.—The effect of acid standardization and development upon the microscopic structure of ice cream.

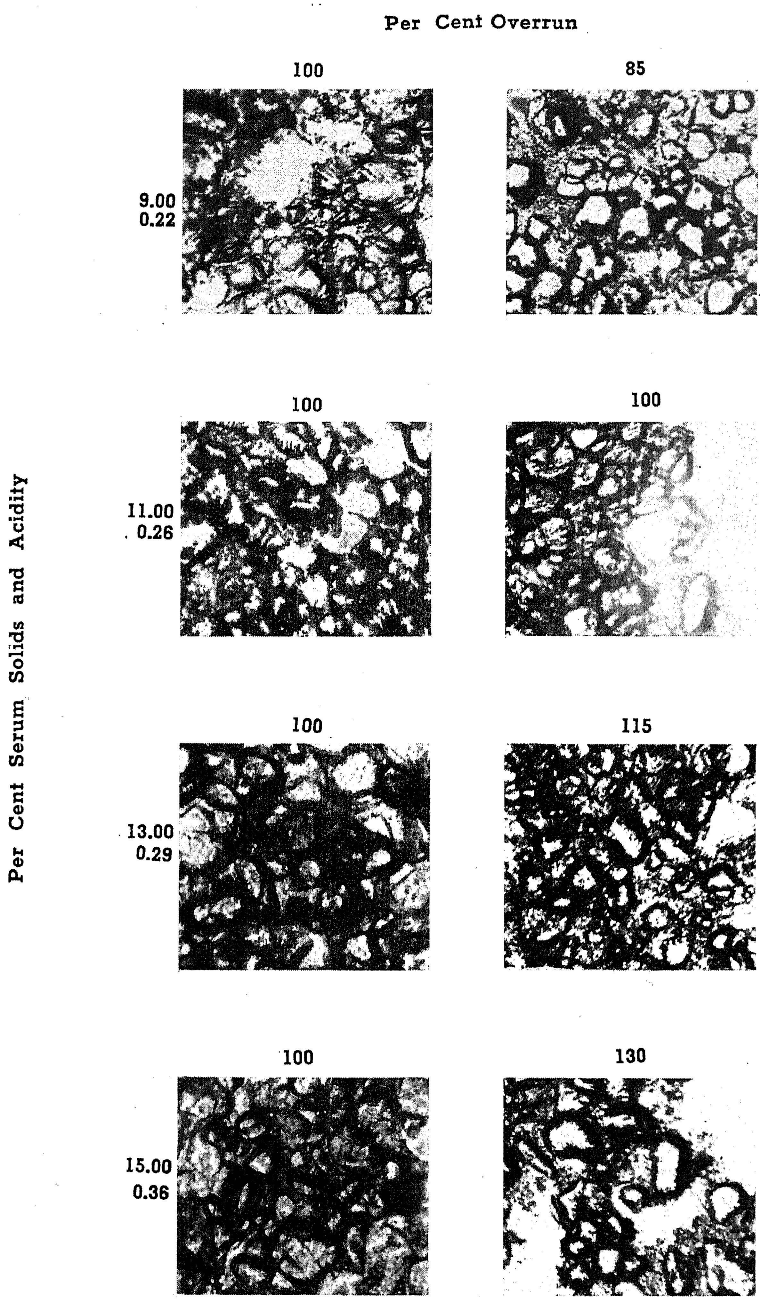
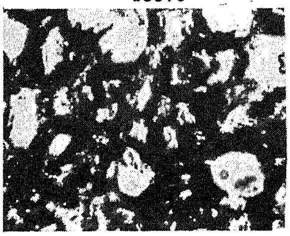


Fig. 7.—The effect of variable serum solids and variable overruns upon the microscopic structure of ice cream.

Overruns

100%

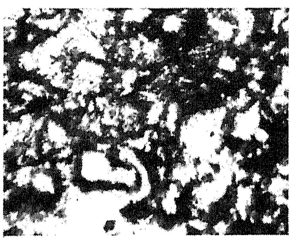


0.36%

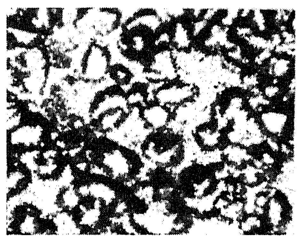
130%

0.36%

Original Acidity

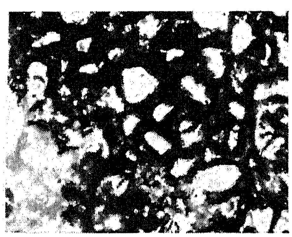


0.12%

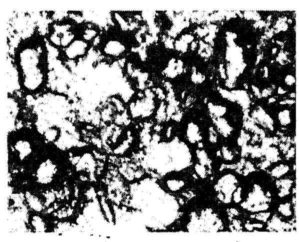


0.12%

Standardized Acidity



0.20%



0.20%

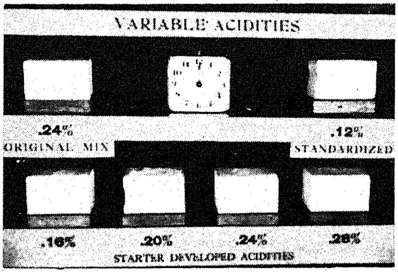
Starter Developed Acidity

Fig. 8.—The effect of acid standardization and development and of varying overruns upon the microscopic structure of 15% serum solids ice creams.

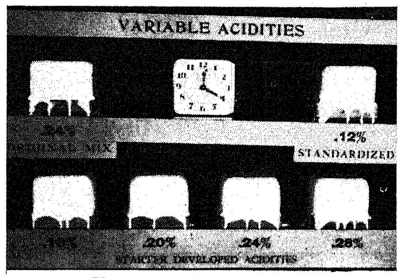
Relation of Acidity, Variable Serum Solids and Overruns to the Stability of Ice Cream

Figure 9 shows the effect of variable acidities upon the stability of the ice cream in Series I. The ice creams in this series, during the melting period, had a smooth, bright luster. Those ice creams containing the acid standardizing agent were slightly less stable which was probably caused by the small increase in total solids resulting from the addition of the standardizing agent. The variation in the acidity of the mixes had no marked influence on stability of the ice cream. Figure 10 illustrates the meltdowns of the ice creams in Series II with the acidity of the mixes being the only variable factor. The addition of an excess of stabilizer caused these ice creams to melt down slower than usual. The ice creams in this series did not have the smooth meltdowns of those in Series I. However, no significant differences were apparent between the ice creams of different acidities. Figure 11 shows that the ice creams containing 13 and 15 per cent of serum solids had more rapid, smoother meltdowns than did the ice creams of lower serum solids. The stabilities of these ice creams were apparently not affected by the variations in acidity.

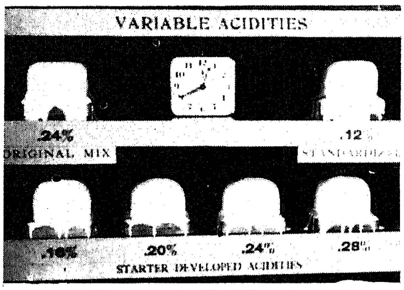
Figure 12 shows the effect of increasing overruns upon the stability of ice creams varying serum solids content and different acidities. Ice creams containing 13 and 15 per cent serum solids and drawn from the freezer at 115 and 130 per cent overrun respectively were more stable and had a fluffy, foamy appearance during the melting period. In this series as in the previous series, acidity apparently had no effect upon the stability and meltdown properties of the different ice cream.



Original Ice Cream



Exposed 20 Minutes



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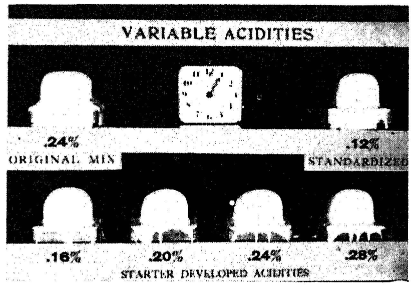
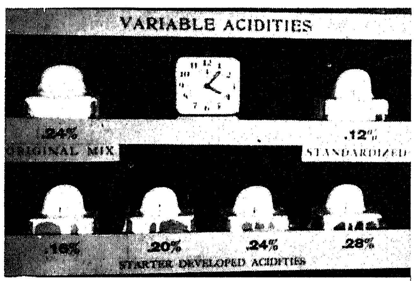
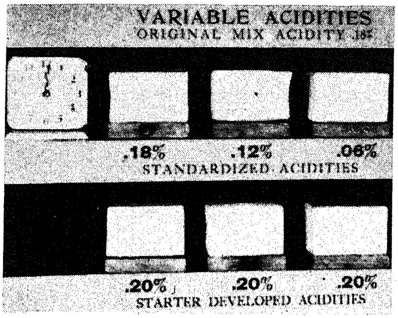


Exposed 60 Minutes

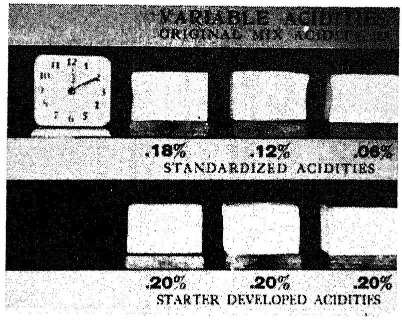


Exposed 80 Minutes

Fig. 9.—The relation of acid standardization and development to the stability of ice cream.



Original Ice Cream



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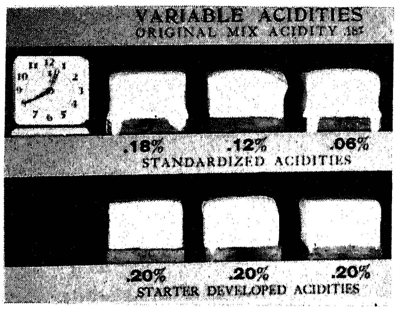

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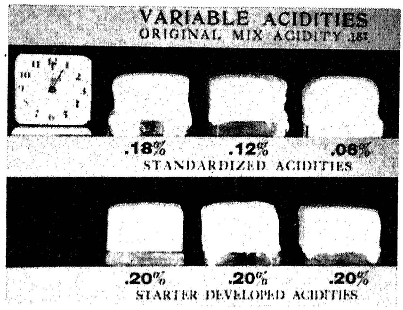
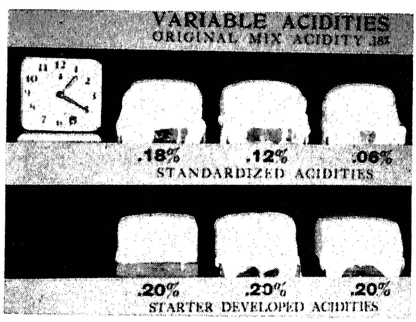


Exposed 60 Minutes



Exposed 80 Minutes

Fig. 10.—The relation of acid standardization and development to the stability of ice cream.

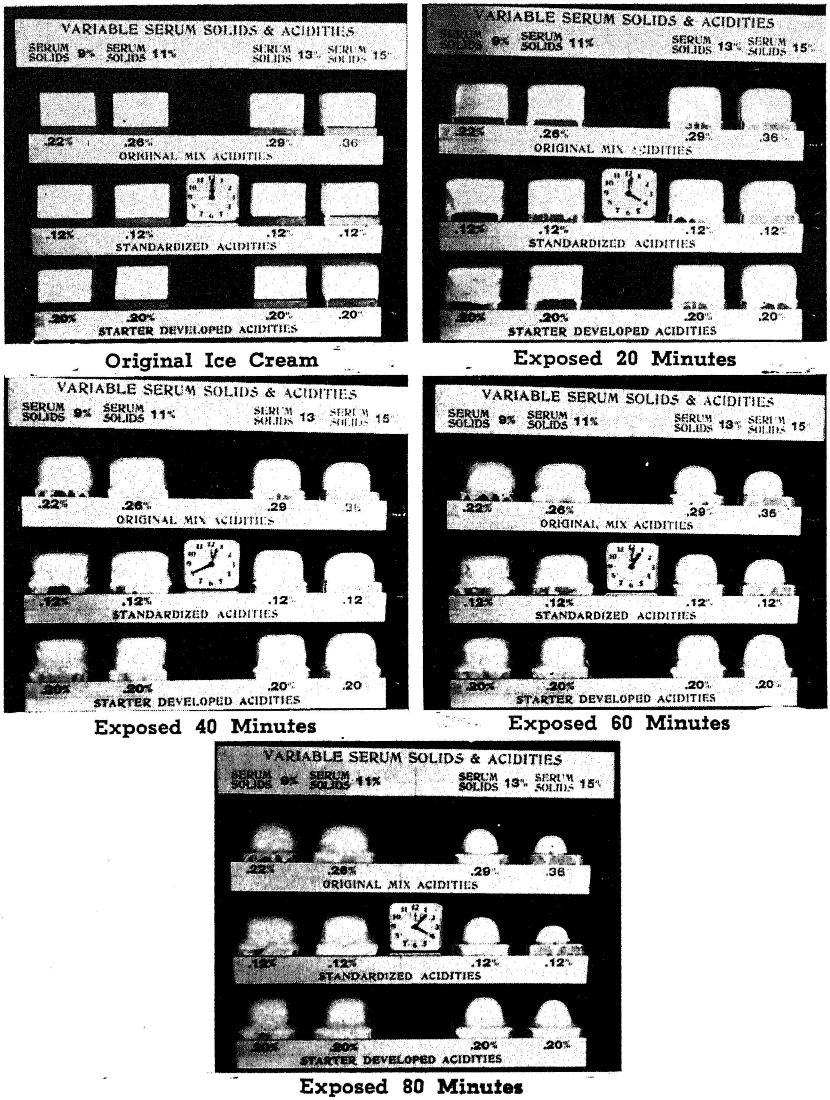
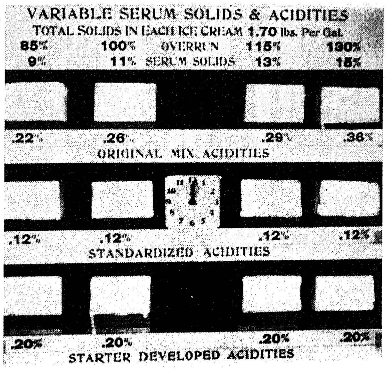
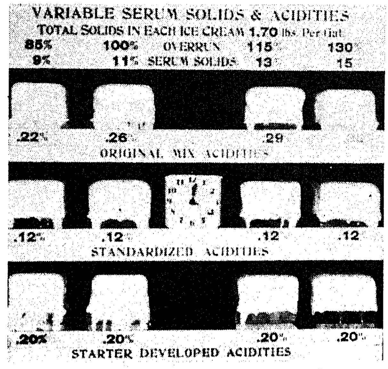


Fig. 11.—The relation of acid standardization and acid development to the stability of ice cream of different serum solids content.



Original Ice Cream



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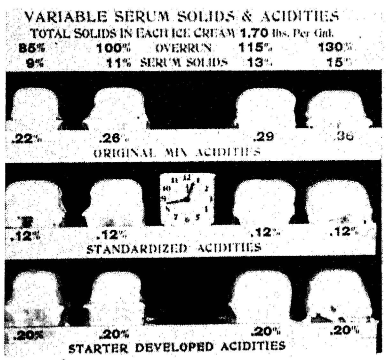

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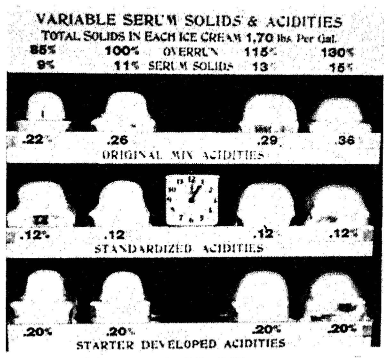
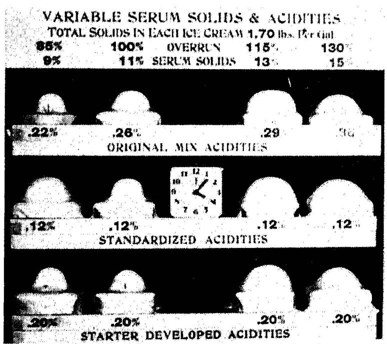


Exposed 60 Minutes



Exposed 80 Minutes

Fig. 12.—The relation of acid standardization and acid development to the stability of ice creams of varying serum solids and overruns.

Relation of Acidity, Per Cent Serum Solids and Per Cent Overrun to the Dipping Properties of Ice Creams

The ice creams were dipped, at each of the three temperatures, 4, 8, and 12 degrees Fahrenheit. The relation of acidity and dipping temperature to the weight per dip of ice cream, the number of dips per gallon of ice cream and the condition of the dipped ice cream are shown in Table 6. It may be seen that although there are variations between ice creams of different acidities, the variations are not consistent.

TABLE 6. THE RELATION OF ACID STANDARDIZATION AND DEVELOPMENT TO THE DIPPING PROPERTIES OF ICE CREAMS DIPPED AT DIFFERENT TEMPERATURES

		Dipping Temperature, 4°F.			Dipping Temperature, 8°F.			Dipping Temperature, 12°F.		
Mix Number	Acidity Per Cent	Dips per gallon ice cream	Average Weight per dip ounces	Dipping Condition	Dips per gallon ice cream	Average Weight per dip ounces	Dipping Condition	Dips per gallon ice cream	Average Weight per dip ounces	Dipping Condition
					Series I					
1	0.20	50.9	1.42	Hard	47.2	1.52	Excellent	48.5	1.49	Soft
2	0.12	50.5	1.43	"	48.5	1.49	"	47.5	1.52	"
3	0.16	48.2	1.50	"	50.5	1.43	"	48.2	1.50	"
4	0.20	48.2	1.50	"	47.5	1.52	"	46.6	1.55	"
5	0.24	49.1	1.47	"	47.2	1.53	"	46.8	1.56	"
6	0.28	51.2	1.41	"	48.2	1.50	"	47.5	1.52	"
					Series II					
7	0.18	47.2	1.53	Hard	44.6	1.62	Excellent	42.0	1.72	Soft
8	0.20	46.4	1.57	"	44.7	1.61	"	44.7	1.61	"
9	0.12	47.9	1.51	"	45.7	1.58	"	43.0	1.68	"
10	0.20	47.5	1.52	"	45.2	1.60	"	44.3	1.63	"
11	0.06	47.5	1.52	"	46.0	1.57	"	40.6	1.78	"
12	0.20	47.9	1.51	"	45.7	1.58	"	42.3	1.71	"

The temperature at which the ice creams were dipped was an important factor in determining the number of dips obtained from a gallon of ice cream and the average weight of dips. A significant trend was noted in all four series, that as the temperature was increased from 4 to 8 and 12 degrees respectively, the average weight per dip increased, Table 7 and 8.

Table 7 shows the effect of varying serum solids and dipping temperatures upon the number of dips per gallon of ice cream, the weight per dip, and the condition of the dipped ice cream. The data, Series III, shows that as the per cent of serum solids increased there was a slight decrease in the number of dips per gallon of ice cream. This was true of ice creams dipped at the

TABLE 7. THE RELATION OF VARIABLE SERUM SOLIDS CONTENTS AND OVERRUNS TO THE DIPPING PROPERTIES OF ICE CREAM

				Dipping Temperature, 4°F			Dipping Temperature, 8°F			Dipping Temperature, 12°F		
Mix Number	Serum Solids Per Cent	Overrun Per Cent	Weight per gallon pounds	Dips per gallon	Average weight per dip ounces	Dipping Condition	Dips per gallon	Average weight per dip ounces	Dipping Condition	Dips per gallon	Average weight per dip ounces	Dipping Condition
						Series III						
13	9	100	4.50	51.0	1.41	Good	48.3	1.49	Excellent	45.6	1.58	Good
14	11	100	4.57	48.1	1.52	Good	44.6	1.64	Excellent	43.0	1.70	Soft
15	13	100	4.65	45.9	1.62	Sl. sticky	43.8	1.70	Sticky	42.5	1.75	Sticky
16	15	100	4.75	45.5	1.67	Sticky	44.1	1.72	V. sticky	40.2	1.89	V. Sticky
						Series IV						
17	9	85	4.86	53.6	1.45	Hard	52.1	1.49	Hard	52.1	1.49	Excellent
18	11	100	4.57	48.8	1.50	Excellent	46.5	1.57	Good	45.7	1.60	Soft
19	13	115	4.35	46.7	1.49	Sl. soft	44.0	1.58	Soft	41.9	1.66	Sticky
20	15	130	4.13	41.5	1.59	Sticky	40.4	1.63	Sticky & Spongy	39.2	1.68	V. spongy

three different serving temperatures, and was probably due to the increased weight per gallon as the serum solids content was increased above 11 per cent. Although the average weight per dip in Series IV decreased with increased serum solids content and overruns as compared to Series III, the same trend was present in that with increased serum solids the average weight per dip increased. The ice creams of high overruns, and high serum solids were somewhat difficult to dip at 12 degrees Fahrenheit. The ice creams of low overrun gave the largest number of dips per gallon and were in excellent dipping condition even at 12 degrees Fahrenheit.

Relation of Variable Serum Solids Content and Variable Overruns to the Weight of Each Ingredient in the Ice Cream

Table 8 shows the per cent of ingredients in the ice creams of Series III drawn from the freezer at 100 per cent overrun while the ice creams of Series IV were drawn on the basis of total solids which were maintained at 1.70 pounds by increasing the serum solids with the increased overruns from 85 to 130 per cent. Thus as the overrun was increased, the total food solids weight per gallon which would normally also decrease was maintained constant at 1.70 pounds per gallon by increasing the amount of serum solids proportionately which is essentially a replacement by weight of the sugar, gelatin, and fat with ser.ım solids. With increased overrun a part of the water is replaced with air resulting in a lower weight per gallon of ice cream.

TABLE 8. THE RELATION OF VARIABLE SERUM SOLIDS CONTENT AND VARIABLE OVERRUNS TO THE WEIGHT OF EACH INGREDIENT IN THE ICE CREAM

	Ingredients Per Cent	Ingredients per gallon of mix pounds	Ingredients per gallon of ice cream pounds Series III	Ingredients per gallon of ice cream pounds Series IV
Mix Number			13b	17b
Overrun			100%	85%
Fat	12.0	1.080	0.540	0.590
Serum Solids	9.0	0.810	0.405	0.430
Sugar	14.0	1.260	0.630	0.680
Gelatin	0.2	0.018	0.009	0.009
Total Solids	35.2	3.168	1.584	1.709
Water	64.8	5.832	2.916	3.151
Total	100.00	9.000	4.500	4.860
Mix Number			14b	18b
Overrun			100%	100%
Fat	12.0	1.100	0.550	0.550
Serum Sloids	11.0	1.000	0.500	0.500
Sugar	14.0	1.280	0.640	0.640
Gelatin	0.2	0.018	0.009	0.009
Total Solids	37.2	3.393	1.699	1.699
Water	62.8	5.757	2.871	2.871
Total	100.0	9.150	4.570	4.570
Mix Number			15b	19b
Overrun			100%	115%
Fat	12.0	1.112	0.560	0.520
Serum Solids	13.0	1.210	0.605	0.560
Sugar	14.0	1.300	0.650	0.610
Gelatin	0.2	0.018	0.009	0.009
Total Solids	39.2	3.648	1.824	1.699
Water	60.8	5.652	2.826	2.651
Total	100.0	9.300	4.650	4.350
Mix Number			16b	20b
Overrun			100%	130%
Fat	12.0	1.140	0.570	0.490
Serum Solids	15.0	1.420	0.710	0.620
Sugar	14.0	1.320	0.660	0.680
Gelatin	0.2	0.019	0.009	0.009
Total Solids	41.2	3.899	1.949	1.699
Water	58.8	5.601	2.801	2.431
Total	100.0	9.500	4.750	4.130

DISCUSSION

The most desirable culture flavor was obtained by the use of "starter" mix which had been aged at 74 degrees Fahrenheit to an acidity of 0.8 per cent or a pH of about 4.0. The associative organisms of the culture evidently were not active in producing the volatile substances desired in a starter except at a pH below 4.5. The sugar and serum solids content of the "starter" mix seem to increase the production of the volatile flavor compounds, diacetyl and acetylmethylcarbinol, and apparently do not lessen the rate of acid production by S. lactic. Some of the "starter" mixes used had an aroma and flavor suggestive of di-acetyl, which became very apparent in some of the ice creams. However, after aging for three months, the flavor of these ice creams was described as very pleasant and desirable.

The "cultured" ice cream having an acidity developed by the addition of "starter" mix to 0.24 per cent from a standardized acidity of 0.12 per cent was judged as having the most desirable "culture" flavor. "Cultured" ice creams having acidities developed by the addition of 2 per cent of culture and allowed to age until the desired acidity was reached were lacking in a desirable "culture" flavor.

There was some shrinkage of the ice cream containing 15 per cent serum solids frozen at the original acidity and aged five weeks, however, this was not true of the ice creams the acidity of which had been standardized to 0.12 per cent. A slight shrinkage was also noticed in the 13 per cent serum solids ice cream of original acidity only. This suggests the possibility that the standardizing agent may have a stabilizing effect on the serum solids.

The ice creams in Series III of 13 per cent and 15 per cent serum solids were somewhat less stable than the ice creams containing 9 and 11 per cent serum solids which may be attributed to the different crystalline and air cell structure of the ice creams.

Increasing the serum solids content and the overrun of ice creams as a means of maintaining a constant food solids content per gallon improved the stability of the ice creams and gave a close texture, however, the body of the melted ice creams with overruns of 115 and 130 per cent lacked resistance, although the food solids per gallon were held constant at 1.70 pounds.

Increased overruns gave greater stability or retarded the melting of the ice creams and presumably resulted from the insulating effect of the increased air content. The meltdowns of the high overrun ice creams, however, were soft and fluffy in appearance.

When reducing the acidity of ice cream mixes below the normal acidity an excess of the standardizing agent was required because of the buffering action of the mix constituents. The titratable acidity of a mix depends largely on its serum solids content. Ice creams of 9, 11, 13, and 15 per cent serum solids had titratable acidities of 0.22, 0.26, 0.29, and 0.36 per cent and pH values of 6.60. 6.63. 6.65, and 6.70 respectively. This would indicate that in standardizing mix acidities the serum solids content should be known.

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