

TOSHIHIDE MATSUI



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THE RELATION OF SUGAR CONTENT
OF THE ICE CREAM MIX TO
OVERRUN AND QUALITY OF
ICE CREAM

Thesis for Degree of M. S.

Toshihide Matsui

1926

THESIS

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INTRODUCTION

Ice cream has been defined as a frozen dairy product containing sugar, with or without natural flavoring, and containing a specified amount of butterfat as required by the laws or regulations of the various states and the Federal government.

It is unknown when, or by whom, ice cream was first made. Its origin is lost in antiquity. From the information available, however, it seems probable that recipes for water and milk ices were brought from Asia by Marco Polo, who visited Japan in the thirteenth century. They were introduced into France about 1550 by Catherine de Medici, and Frenchmen in turn brought them into England. In the United States the industry has been developed commercially to a much greater extent than in any other country. English "cream ice" was made by a French cook, Clement, and made from cream and milk, sugar, eggs, arrowroot or flour, and flavoring. In this country ice cream was first sold in New York by a Mr. Hall, but was first made commercially in 1851 by Jacob Fussel, a milk dealer of Washington and Baltimore, who began its manufacture as a side-line to his regular business.

From an humble beginning, the industry grew rather slowly until about 1900, when the production in the United States was about 25,000,000 gallons. Since then, due to mechanical refrigeration, improved machinery, and

a greater technical knowledge of the processes of manufacture, the business has increased tremendously until now there is an annual output of nearly 300,000,000 gallons.

It is one of the youngest of the world's manufactured dairy products. In less than a century, it has sprung from a rare delicacy to a nation-wide necessity, and enjoyed by practically everyone regardless of season. From a national industry in America, ice cream making has developed into an international one. Exporting of ice cream mix to the Orient has been carried on by manufacturers of the Pacific Coast for years. American machinery, flavors, etc., are going into Germany, Japan, and other countries each year.

"Japan has taken quickly to frozen cream products. Commercial Attache E.G. Babbitt says (1) there are several concerns manufacturing ice cream for wholesale distribution. As there is much milk produced around the district of Tokyo, the manufacturers find 'it more profitable to make and ship the ice cream into the city than to send in the milk.' There is a widely known drug store operated by a Japanese who learned his trade in Los Angeles. He is catering to the popular demand in making both ice cream and ices. 'Fresh milk and cream,' he states, 'form the basis of most of the ice cream manufactured, but there is much adultera-

tion. Cornstarch, gelatin, and ice cream powders are used to some extent; also eggs. The best is made with imported flavors. According to unofficial estimates there are 4,000 retail establishments with a total yearly consumption of 6,570,000 gallons.'"

According to the statistics of the Chiba Live Stock Experiment Station in 1924, the value of ice cream is estimated at nearly 3,500,000 yen. The history of milk in Japan is very short, dating back to not more than fifty years ago. It is told, however, that cow's milk and dairy products were introduced about 1,300 years ago through Korea, but they were used merely as medicine and not as foodstuffs. After the Meiji restoration cow's milk and dairy products were turned to account as foodstuffs. Ice cream is said to have been introduced by an American to Japan. In 1920 the first manufacturing plant was built in Tokyo by the Oriental Condensed Milk Co, and in 1921 the Kyokuto Condensed Milk Co.(Ltd.) started in this business on a large scale, using the American system, an example which was followed by entrepreneurs. The larger restaurants use electric power in the manufacture of ice cream, some hotels use the ammonia process, but the smaller employ hand turned freezers. The Japanese people are becoming educated to the use of ice cream as a staple food, and, as this process goes on, the

construction of large plants capable of producing ice cream in large amounts the year around, will be a natural development.

The ice cream industry offers an exceptionally good market for sugar. This material performs useful functions in ice cream.

In this experiment, sugar in ice cream was studied in its relation to the overrun, freezing point of the mixture, body and texture, and palatability of the final product.

Although sugar contributes to the food value of ice cream, its chief function is to properly sweeten the product and make it palatable. The sweetening value can be supplied by other food products than sugar. The amount of sugar is important because of its bulk; and its effect on rate of freezing and overrun. Sugar also acts as a slight preservative of the cream. Cane and beet sugar are identical in chemical composition and are the chief sources of sweetening in ice cream. These sugars are ordinarily used in the granulated form and should be clean and free from mold. Sometimes invert sugar syrups prepared by treating cane or beet sugar with tartaric or other acids, are used in the mix. Glucose and corn sugar were considered sugar substitutes by the Food Administration during the war, but invert sugar is not so considered because it is

manufactured from the same sources as sugar. Honey together with malt, maple and other syrups, are sometimes used as sweeteners.

REVIEW OF LITERATURE.

The ice cream industry has been developed so recently that research on its manufacture is very brief and practical in nature. Early methods in this industry were kept secret and scientific workers in educational institutions and private corporations that published their findings began their research work after the rudimentary methods of making ice cream were fairly well established.

Washburn (2) in 1910 published a very extensive article giving the results of investigations on ice cream which even today are of outstanding importance. He states in his bulletin entitled, "Principles and Practice of Ice Cream Making" that "being an American product, the literature on this subject is doubtless almost entirely in the English language. It is quite safe to say that there is no other American dairy industry representing so large an investment which has received so scant attention at the hands of investigators."

Until 1910, there were almost no articles treating ice cream making, save from the standpoint of the caterer. There were a few books, giving recipes of ice cream making in clumsily stated style and makeup, but they contain nothing regarding the principles of freezing, and, but little of methods.

Relation of Sugar to the Freezing Point.

Sugar goes into true solution and has a low molecular weight as compared with eggs or gelatin. Washburn (2) states the effect of increased sugar content is to depress the freezing point very materially and uniformly in proportion to its presence. Ice cream sweetened to average taste contains approximately fourteen per cent added sugar, and has a freezing point of about 28.5 F. He obtained the following data:

Table I:- Relation of Sugar to the Freezing Point of Ice Cream Mixes.

Material	Observed freezing point
Plain skimmilk.....	31.03 F.
5% Solution in skimmilk.....	30.40 F.
10% " " " 	29.70 F.
14% " " " 	28.60 F.
25% " " " 	27.07 F.

The more sugar there is in any ice cream, the lower the freezing point and the more difficult it is to hold it frozen hard.

In 1921 Reid (3) found that increase of sugar content from ten to twelve per cent changed the freezing time from fifteen to sixteen minutes; while raising the

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sugar content from fourteen to sixteen per cent resulted in an increase in time of freezing from eighteen to twenty three minutes. That is, an increase of sugar increased the time required to freeze, and this proved to be greater with the higher percentages than with the lower percentages of sugar.

Relation of Sugar to Overrun.

Yield or overrun applied to ice cream has been defined as "the volume of ice cream obtained over the volume of mix before freezing." It is the result of expansion, due chiefly to the air which is incorporated by the violent agitation during the freezing process.

Factors affecting overrun may be divided into two general classes according to Fisk(4): I. Kind and preparation of materials used, II. Manner or method of freezing. Gregory and Manhart(5) divide these factors into three general classes: I. Composition of the mix. II. Preparation and treatment of the mix. III. Freezing conditions.

Fisk(4) illustrated these factors as follows:

(A), Age, Viscosity, acidity, and fat-content of milk and cream; (B), Size of fat globules in cream; (C), Aging of mix; (D), Pasteurization of milk and cream; (E), Use of homogenizer and emulsor; (F), Method of mixing; (G), Use of condensed mix; (H), Amount of

sugar; (I), Different kinds of flavoring; (J), Fillers and binders; (K), Total solids in mix.

Thomas (6) thinks that the sugar is a much more important factor in controlling overrun than is milk solids.

Sugar being the cheapest solid used in the ice cream mix, the manufacturer naturally endeavors to use the largest amount possible, yet not an excessive amount so that quality of the product will be impaired. There is an optimum amount or combination of sugar to use with the other constituents of the mix for the best results.

Davis(7) in 1916 reports that decreasing the amount of sugar in the ice cream mix below normal increased the per cent of swell; while increasing the amount of sugar in the ice cream mix above normal decreased the per cent of swell.

Williams(8) classifies sugar as one of the major deterrents of overrun. He states that, "sugar increases the density of the mix. This increase in density is one of the principal means of retarding the abnormal overrun that otherwise would be obtained. In mixes containing thirteen and sixteen per cent sugar, high overruns can be obtained and the final overruns are about the same for both mixes."

1. The first step in the process of the scientific method is to make an observation or ask a question. For example, a scientist might observe that a plant grows better in one type of soil than another.

2. The second step is to form a hypothesis, which is a prediction or an educated guess about the outcome of an experiment. For example, a scientist might hypothesize that a plant will grow taller in soil A than in soil B.

3. The third step is to design an experiment to test the hypothesis. This involves setting up a controlled experiment where only one variable is changed at a time. For example, the scientist might plant the same type of seed in two different soils and measure the height of the plants after a certain period of time.

4. The fourth step is to collect data and analyze the results. The scientist would measure the height of the plants in both soils and compare the results. If the plants in soil A are significantly taller than the plants in soil B, the hypothesis is supported.

5. The fifth step is to draw a conclusion based on the results of the experiment. If the hypothesis is supported, the scientist might conclude that soil A is better for growing this type of plant. If the hypothesis is not supported, the scientist might conclude that soil B is better for growing this type of plant.

6. The final step is to communicate the results of the experiment to other scientists. This can be done through a presentation, a poster, or a published paper.

Reid(3) conducted an experiment to determine the direct relation of sugar content to the ultimate swell or overrun of the finished ice cream. Five different mixtures were used, the percentage of sugar varying from eight to sixteen per cent. There was an increase of four and three tenths per cent in overrun of the mixture containing but eight per cent sugar. A loss of four and three tenths per cent overrun was noted in comparing mixtures containing twelve to sixteen per cent sugar, due to the use of the larger amount. Maximum swell was obtained when twelve per cent of sugar was added to the mixture. He further states that the difference in temperature of brine did not effect the relative curve of the maximum swell, and that sugar was the principal factor influencing the swell of the mixture.

According to Manhart and Gregory's (5) investigation into ice cream commercial practices, the data collected from forty seven ice cream plants, do not show a lower overrun in those mixes containing the higher percentage of sugar. The mixes were divided into three groups according to sugar content, as I, containing twelve and two tenths per cent of sugar; II, thirteen and one tenth per cent; and III, fourteen and two tenths per cent. The average per cents overrun for groups I. II. III. were ninety four,

ninety and five tenths, and ninety and seven tenths, which would indicate that as high as fifteen per cent sugar when in proper proportion with other constituents of the mix will not necessarily cause a low overrun.

Reid (12) ran a second experiment to determine the relation of sugar to overrun. He found that overrun increased up to twelve per cent with each addition of sugar. When more sugar was added, the overrun decreased with the same rapidity as it had increased, until the maximum decrease was reached. This shows that the amount of sugar that can be added to a mixture and assure an increase in overrun is limited. This result is the same as the one he published in 1921(3).

Relation of Sugar to Quality.

The quality of sugar in ice cream is varied in commercial practice according to the sweetness desired, but such variations effect the quality of ice cream in different ways.

In discussing the factors which improve the smoothness of ice cream, Washburn (2) enumerated several, but no mention is made especially of sugar. That sugar is essential to a smooth texture is known in the industry and has been demonstrated by Davis (7). In 1916, he reports that decreasing the amount of sugar in the ice

cream mix below normal increased the per cent of swell, but produced a favorable effect upon the finished product from the standpoint of flavor and texture, while increasing the amount of sugar in the ice cream mix above normal decreased the per cent of swell, and, while it produced a better texture, resulted in ice cream which was too sweet.

According to an experiment of Reid (3), to determine the effect of an increased percentage of sugar on the hardness of ice cream, he found that there was a gradual reduction in hardness with each additional two per cent of sugar. The depth of penetration of a standard needle when sixteen per cent sugar was added to the mixture was nearly double that secured when eight per cent sugar was used. The greatest resistance was offered when eight per cent sugar was added to the mixture; the least when sixteen per cent was added. He also found that ten per cent of sugar gave an ice cream that offered the maximum resistance to a standard summer temperature. Each additional per cent of sugar added to the mixture lessened its resistance.

It is the opinion of Zoller (10) that "Whereas the proteins and fat in the ice cream mix readily gave up their water in the form of ice, the sugar tended to hold a portion of water with great resistance,

because of their molecular structure. " He (9) also found that sugar increased the extent of super-cooling during the freezing process.

In summing up his work, Dahlberg (11) states that sugar improved the texture of ice cream by reducing the amount of ice that was formed. The water partially froze out leaving a very concentrated or super-saturated sugar solution which did not freeze due to its low congealing point.

Reid (12) tried scoring the mixtures made up of eight to sixteen per cent of sugar. The score after a one-day and a seven-day period would indicate that the product containing twelve per cent sugar was superior in body, texture, and flavor, the eight per cent **present-**ing an open texture and the sixteen per cent a rather close texture and firm body. An ice cream containing twelve per cent sugar is the more desirable, the eight per cent lacking in sweetness, and the sixteen per cent proving somewhat excessive.

To show the public's preference for ice cream of varying richness in butterfat, sweetness, and fineness, Williams and Campbell (13) of the United States Department of Agriculture, made ice cream of different compositions and sold them on a market where about fifty daily purchasers had an opportunity to choose from three

different kinds without knowing anything of the ingredients contained. More than sixty per cent chose ice cream containing nineteen per cent sugar; nearly thirty per cent preferred a sugar content of sixteen per cent, and ten per cent selected the product with thirteen per cent sugar. In other words, about ninety per cent of the consumers indicated a preference for ice cream containing sixteen per cent or more of sugar.

It has been stated often that sucrose, glucose, and corn syrup in the mix would tend to inhibit sandiness.

Dahle (14) showed that where different sugars were used as inhibiting factors, there was no pronounced effect. It has been stated by practical investigators that high sugar content caused the precipitation of lactose to become less and in some instances prevented it entirely. This view was not borne out in his experiment.

Sugar Substitutes.

Cane sugar or beet sugar is the most satisfactory sweetening agent for ice cream. None of its substitutes will satisfactorily replace more than about fifty per cent of the cane sugar in the mix. When the supply of cane sugar is low and the price high, such products as malt sugar, corn sugar, corn syrup, invert sugar, and honey may profitably be used. As compared with cane sugar, the

sweetening power of invert sugar seems to vary from eighty five to a hundred twenty per cent, corn sugar seventy per cent, and corn syrup from fifty to sixty per cent.

Frandsen, Rovner, and Luithly (15) investigated substitutes used for conservation of sugar in ice cream making, and found that none of the substitutes tested would satisfactorily replace all the cane sugar in the ice cream mix. They worked out four formulas which save from thirty to fifty per cent of cane sugar in the mix, lower the cost of sweetening per gallon of ice cream, and produce ice cream of satisfactory flavor and texture. Corn sugar can replace fifty per cent of cane sugar in the mix. Corn syrup dissolves with difficulty in cold cream, but when added to cream before pasteurizing, it dissolves readily. It is thought that hydrolyzing corn syrup in the presence of an acid will enhance its sweetening properties. These experiments were performed during the war, when prices were abnormal and at variance with their usual relation. They have but little value under present conditions.

EXPERIMENTAL WORK

Plan of Experiment.

Object.

The object of this investigation was, mainly, to determine the effect of the different percentages of sugar on the physical properties of ice cream.

The observations were as follows:

(1) The effect of the sugar content of the mix upon the maximum swell obtained,

(2) The effect of the sugar content of the mix upon the quality of the ice cream,

(3) The effect of the sugar content of the mix upon its freezing point,

(4) The effect of the sugar content of the mix upon the specific gravity, and,

(5) The effect of the sugar content of the mix upon the resisting power to a standard summer temperature.

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- Journal of Management Studies*, 19(6), 701-718.

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General Plan.

The Mixes.

Before beginning the actual experimental work, it was deemed advisable to adopt standard mixes. Five different mixtures were used in conducting the experiments. In these, all ingredients remained constant except sugar, the latter being used in the following amounts: eleven, thirteen, fifteen, seventeen, and nineteen per cents. The calculated composition of the mixes is given in the following table:

Table II:- Calculated Composition of the Experimental Mixes.

Calculated Composition.

		Per Cent Fat	Per Cent M.S.N.F.	Per Cent Sugar.	Per Cent Total Solids.
Mix No.	I.	12	10	11	33.7
Mix No.	II.	12	10	13	35.4
Mix No.	III.	12	10	15	37.2
Mix No.	IV.	12	10	17	38.9
Mix No.	V.	12	10	19	40.6

Table III:-Analysis of Materials Used in Experimental Mixes.

Percentage Composition			
<u>Materials</u>	<u>Fat</u>	<u>M.S.N.F.</u>	<u>Total Solids</u>
Sweetcream	20	6.30	26.30
Milk	3	8.73	11.73
Skimmilk powder	-	95.00	95.00
Sugar	-	-	95.00
Gelatin	-	-	90.00

Table IV:- Composition of Mixes.

Forty-five pounds of these were used in each mix.

Mix I.

<u>Materials</u>	<u>Pounds</u>
Cream	55.79
Milk	28.14
Sugar	11.00
Skimmilk Powder	4.47
Gelatin	.60
Total	100.00

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- **Figure 1** ■ **Percentage of respondents who reported that they had been exposed to a natural disaster in the past 10 years**

1. *Chlorophyll a* and *Chlorophyll b* were determined by the method of Arar and Collins (1987).

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Table IV:- Continued, Composition of Mixes.

Mix II.

<u>Materials</u>	<u>Pounds.</u>
Cream	55.91
Milk	26.02
Sugar	13.00
Skimmilk powder	4.47
Gelatin	.60
Total	100.00

Mix III.

<u>Materials</u>	<u>Pounds</u>
Cream	56.42
Milk	23.51
Sugar	15.00
Skimmilk powder	4.47
Gelatin	.60
Total	100.00

Table IV:- Continued, Composition of Mixes.

Mix IV.

<u>Materials</u>	<u>Pounds</u>
Cream	56.84
Milk	21.09
Sugar	17.00
Skimmilk powder	4.47
Gelatin	.60
Total	100.00

Mix V.

<u>Materials</u>	<u>Pounds</u>
Cream	57.18
Milk	18.75
Sugar	19.00
Skimmilk powder	4.47
Gelatin	.60
Total	100.00

Preparing the Mixes.

The mixtures were carefully standardized as follows. First, the cream was standardized to twelve per cent fat with milk, and weighed into five gallon cans numbered to correspond to the number of the mix. Then sugar, gelatin, and skimmilk powder, which had been carefully weighed and well mixed together, was slowly added to each can. After these materials had been added to each can, they were well mixed by agitating with a stirring rod. These cans were placed in a hot water tank where they were pasteurized at a temperature of one hundred forty five degrees Fahrenheit and held for twenty five minutes. The mixes were constantly agitated with stirring rods. At the end of twenty five minutes the mixes were immediately cooled down to one hundred ten degrees Fahrenheit and then viscolized at a pressure of a thousand five hundred pounds. From the viscolizer the mixes flowed over a surface coil cooler, the top section of which was cooled with water and the bottom section cooled with brine. In each case, the mixes were entirely emptied from the supply tank and the pipes. They were then held in a cold room at about thirty two to thirty five degrees Fahrenheit and aged forty eight hours.

Method of Freezing.

The same freezer was used for each experiment. The type of freezing machine used was a United States fifty-quart-batch horizontal brine freezer. Freezing was done by circulating brine cooled by an ammonia refrigerating machine.

First the brine pump was run and after the brine temperature became constant, by closing the freezing valve, and opening the freezing valve long enough to chill the freezer, the dasher was started. The temperature of the brine varied somewhat from day to day, but the five batches in the experiment were frozen at nearly the same temperature. The temperature of all mixes before freezing was about thirty five degrees Fahrenheit. The brine was shut off at the same time on each series, and two ounces of vanilla flavor was added as soon as brine was shut off. Records of the overrun were taken at two minutes intervals.

Methods of Testing.

Cream and milk test.

The samples were tested by the Babcock Method.

Pasteurization.

This was done in a tank where each mix was heated to one hundred forty five degrees Fahrenheit for twenty five minutes and cooled immediately to one hundred ten degrees Fahrenheit, and then viscolized.

Viscolization.

Temperature of the mixes at viscolization was one hundred ten degrees Fahrenheit and a pressure of one thousand five hundred pounds used.

Aging.

The mixes placed in the cold room were kept at between thirty two to thirty five degrees Fahrenheit and aged forty eight hours.

Specific gravity.

A piconometer was used. All mixes were weighed at the temperature of 15.55 degrees Centigrade.

Freezing point.

The freezing point was taken by a Hortvet Cryoscope and determined to the third decimal point.

Overrun test.

The records of overrun were taken at two minutes intervals and continued until the maximum overrun was

obtained. A Mojonnier overrun tester was used. The overrun cup was adjusted each time before using.

Resistance test for standard summer temperature.

Five one quart samples were drawn into cartons for brick ice cream, when seventy five per cent overrun had been obtained. For the melting test a cheese making vat was used to maintain a constant temperature of eighty six degrees Fahrenheit, which is considered average summer temperature. Rectangular pieces of wood, the size of brick ice cream, having a nail driven up through the center, were used to hold the ice cream. Pictures of the melting bricks were taken at the end of five hours exposure and six and seven hours exposure.

Scoring the ice cream.

One pint samples were drawn when the overrun reached to seventy five per cent. These samples were scored by Professor P.S. Lucas and the writer. Body and texture only were judged. Twenty five points were allowed as a perfect score.

Experimental Data.

Table V:- Relation of Sugar Content of Mixes to Specific Gravity at 15.55 Degrees C.

<u>Per Cent Sugar</u>	<u>Specific Gravity</u>	<u>Per Cent Sugar</u>	<u>Specific Gravity</u>
Mix I.		Mix II.	
11%	1.0550	11%	1.0532
13%	1.0560	13%	1.0585
15%	1.0626	15%	1.0609
17%	1.0668	17%	1.0674
19%	1.0723	19%	1.0715
Mix III.		Mix IV.	
11%	1.0520	11%	1.0555
13%	1.0574	13%	1.0607
15%	1.0622	15%	1.0634
17%	1.0655	17%	1.0674
19%	1.0724	19%	1.0720
Mix V.		Average <u>Specific Gravity</u>	
11%	1.0543	11%	1.0540
13%	1.0582	13%	1.0590
15%	1.0622	15%	1.0623
17%	1.0672	17%	1.0669
19%	1.0727	19%	1.0721

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	100	101	102	103	104	105	106	107	108	109	110	111	112	113	114	115	116	117	118	119	120	121	122	123	124	125	126	127	128	129	130	131	132	133	134	135	136	137	138	139	140	141	142	143	144	145	146	147	148	149	150	151	152	153	154	155	156	157	158	159	160	161	162	163	164	165	166	167	168	169	170	171	172	173	174	175	176	177	178	179	180	181	182	183	184	185	186	187	188	189	190	191	192	193	194	195	196	197	198	199	200	201	202	203	204	205	206	207	208	209	210	211	212	213	214	215	216	217	218	219	220	221	222	223	224	225	226	227	228	229	230	231	232	233	234	235	236	237	238	239	240	241	242	243	244	245	246	247	248	249	250	251	252	253	254	255	256	257	258	259	260	261	262	263	264	265	266	267	268	269	270	271	272	273	274	275	276	277	278	279	280	281	282	283	284	285	286	287	288	289	290	291	292	293	294	295	296	297	298	299	300	301	302	303	304	305	306	307	308	309	310	311	312	313	314	315	316	317	318	319	320	321	322	323	324	325	326	327	328	329	330	331	332	333	334	335	336	337	338	339	340	341	342	343	344	345	346	347	348	349	350	351	352	353	354	355	356	357	358	359	360	361	362	363	364	365	366	367	368	369	370	371	372	373	374	375	376	377	378	379	380	381	382	383	384	385	386	387	388	389	390	391	392	393	394	395	396	397	398	399	400	401	402	403	404	405	406	407	408	409	410	411	412	413	414	415	416	417	418	419	420	421	422	423	424	425	426	427	428	429	430	431	432	433	434	435	436	437	438	439	440	441	442	443	444	445	446	447	448	449	450	451	452	453	454	455	456	457	458	459	460	461	462	463	464	465	466	467	468	469	470	471	472	473	474	475	476	477	478	479	480	481	482	483	484	485	486	487	488	489	490	491	492	493	494	495	496	497	498	499	500	501	502	503	504	505	506	507	508	509	510	511	512	513	514	515	516	517	518	519	520	521	522	523	524	525	526	527	528	529	530	531	532	533	534	535	536	537	538	539	540	541	542	543	544	545	546	547	548	549	550	551	552	553	554	555	556	557	558	559	560	561	562	563	564	565	566	567	568	569	570	571	572	573	574	575	576	577	578	579	580	581	582	583	584	585	586	587	588	589	590	591	592	593	594	595	596	597	598	599	600	601	602	603	604	605	606	607	608	609	610	611	612	613	614	615	616	617	618	619	620	621	622	623	624	625	626	627	628	629	630	631	632	633	634	635	636	637	638	639	640	641	642	643	644	645	646	647	648	649	650	651	652	653	654	655	656	657	658	659	660	661	662	663	664	665	666	667	668	669	670	671	672	673	674	675	676	677	678	679	680	681	682	683	684	685	686	687	688	689	690	691	692	693	694	695	696	697	698	699	700	701	702	703	704	705	706	707	708	709	710	711	712	713	714	715	716	717	718	719	720	721	722	723	724	725	726	727	728	729	730	731	732	733	734	735	736	737	738	739	740	741	742	743	744	745	746	747	748	749	750	751	752	753	754	755	756	757	758	759	760	761	762	763	764	765	766	767	768	769	770	771	772	773	774	775	776	777	778	779	780	781	782	783	784	785	786	787	788	789	790	791	792	793	794	795	796	797	798	799	800	801	802	803	804	805	806	807	808	809	810	811	812	813	814	815	816	817	818	819	820	821	822	823	824	825	826	827	828	829	830	831	832	833	834	835	836	837	838	839	840	841	842	843	844	845	846	847	848	849	850	851	852	853	854	855	856	857	858	859	860	861	862	863	864	865	866	867	868	869	870	871	872	873	874	875	876	877	878	879	880	881	882	883	884	885	886	887	888	889	890	891	892	893	894	895	896	897	898	899	900	901	902	903	904	905	906	907	908	909	910	911	912	913	914	915	916	917	918	919	920	921	922	923	924	925	926	927	928	929	930	931	932	933	934	935	936	937	938	939	940	941	942	943	944	945	946	947	948	949	950	951	952	953	954	955	956	957	958	959	960	961	962	963	964	965	966	967	968	969	970	971	972	973	974	975	976	977	978	979	980	981	982	983	984	985	986	987	988	989	990	991	992	993	994	995	996	997	998	999	1000	1001	1002	1003	1004	1005	1006	1007	1008	1009	1010	1011	1012	1013	1014	1015	1016	1017	1018	1019	1020	1021	1022	1023	1024	1025	1026	1027	1028	1029	1030	1031	1032	1033	1034	1035	1036	1037	1038	1039	1040	1041	1042	1043	1044	1045	1046	1047	1048	1049	1050	1051	1052	1053	1054	1055	1056	1057	1058	1059	1060	1061	1062	1063	1064	1065	1066	1067	1068	1069	1070	1071	1072	1073	1074	1075	1076	1077	1078	1079	1080	1081	1082	1083	1084	1085	1086	1087	1088	1089	1090	1091	1092	1093	1094	1095	1096	1097	1098	1099	1100	1101	1102	1103	1104	1105	1106	1107	1108	1109	1110	1111	1112	1113	1114	1115	1116	1117	1118	1119	1120	1121	1122	1123	1124	1125	1126	1127	1128	1129	1130	1131	1132	1133	1134	1135	1136	1137	1138	1139	1140	1141	1142	1143	1144	1145	1146	1147	1148	1149	1150	1151	1152	1153	1154	1155	1156	1157	1158	1159	1160	1161	1162	1163	1164	1165	1166	1167	1168	1169	1170	1171	1172	1173	1174	1175	1176	1177	1178	1179	1180	1181	1182	1183	1184	1185	1186	1187	1188	1189	1190	1191	1192	1193	1194	1195	1196	1197	1198	1199	1200	1201	1202	1203	1204	1205	1206	1207	1208	1209	1210	1211	1212	1213	1214	1215	1216	1217	1218	1219	1220	1221	12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Table VI:- Relation of Sugar to Freezing Point.

Temperature is given in Degrees Centigrade.

<u>Per Cent</u> <u>Sugar</u>	<u>Freezing</u> <u>Point</u>	<u>Per Cent</u> <u>Sugar</u>	<u>Freezing</u> <u>Point</u>
Mix I.		Mix II.	
11%	-2.175°	11%	-2.170°
13%	-2.504°	13%	-2.512°
15%	-2.872°	15%	-2.865°
17%	-3.082°	17%	-3.090°
19%	-3.225°	19%	-3.210°
Mix III.		Mix IV.	
11%	-2.160°	11%	-2.173°
13%	-2.515°	13%	-2.522°
15%	-2.875°	15%	-2.882°
17%	-3.080°	17%	-3.090°
19%	-3.220°	19%	-3.215°
Mix V.		Average <u>Freezing Point</u>	
11%	-2.172°	11%	-2.170°
13%	-2.515°	13%	-2.514°
15%	-2.870°	15%	-2.873°
17%	-3.095°	17%	-3.087°
19%	-3.232°	19%	-3.220°

Overrun.

Although the freezing process was conducted for each series under almost identical conditions, the time required to reach the maximum overrun was different in each. Consequently there were slight differences in the amount of maximum overruns tabulated in Table XII, giving the mean per cent overrun at every other minute, and in Table XIII, giving the average maximum overruns of the different per cents sugar batches.

Figure I, shows very clearly the results of maximum overruns taken on by the different batches.

**Table VII:- Per Cents Overrun by Two Minute Intervals
for Mix I.**

Maximum Swell is underlined.

Time (Minutes)	No.I.	No.II.	No.III.	No.IV.	No.V.	Per Cent Sugar Brine Tempt. F.
	11%	13%	15%	17%	19%	
	9	9	11	11	11	
0	0	0	0	0	0	
2	21	32	31	21	34	
4	56	71	50	33	50	
6	79	76	68	55	62	
8	81	81	75	60	66	
10	85	87	78	65	68	
12	<u>89</u>	89	80.5	69	71	
14	87	<u>93.5</u>	<u>86</u>	74	74	
16		87	84	<u>78</u>	<u>76</u>	
18				76	74	

Table VIII:- Per Cents Overrun by Two Minute Intervals
for Mix II.

Time (Minutes)	No.I.	No.II.	No.III.	No.IV.	No.V.	Per Cent Sugar Brine Tempt. F.
	11%	13%	15%	17%	19%	
	6	4	4	4	5	
0	0	0	0	0	0	
2	55	40	28	23	18	
4	78	59	59	39	46	
6	81	68	71	59	53	
8	85	74	79	63	64	
10	88	79	82	71	73	
12	<u>90</u>	<u>92</u>	84	76	78	
14	89	89	<u>87</u>	<u>81</u>	<u>79</u>	
16			85	75	78	

Table IX:- Per Cents Overrun by Two Minute Intervals
for Mix III.

Time (Minutes)	No.I.	No.II.	No.III.	No.IV.	No.V.	Per Cent Sugar Brine Tempt. F.
	11%	13%	15%	17%	19%	
	12	13	12	12	13	
0	0	0	0	0	0	
2	15	17	14	15	17	
4	30	22	22	25	23	
6	57	32	32	32	27	
8	75	72	62	40	36	
10	84	82	70	69	41	
12	86	90	78	73	58	
14	<u>90</u>	<u>93</u>	<u>83</u>	78	66	
16	89	90	81	<u>79</u>	<u>73</u>	
18				77	70	

**Table X:- Per Cents Overrun by Two Minute Intervals
for Mix IV.**

Time (Minutes)	No.I.	No.II.	No.III.	No.IV.	No.V.	Per Cent Sugar Brine Tempt. F.
	11%	13%	15%	17%	19%	
	7	10	9	8	8	
0	0	0	0	0	0	
2	25	24	21	17	16	
4	40	35	42	39	24	
6	68	69	66	65	46	
8	74	77	79	75	64	
10	85	83	86	79	76	
12	<u>93</u>	91	<u>90</u>	81	81	
14	92	<u>96</u>	88	<u>84</u>	<u>82</u>	
16		93		82	80	

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Table XI:- Per Cents Overrun by Two Minute Intervals
for Mix V.

Time (Minutes)	No.I.	No.II.	No.III.	No.IV.	No.V.	Per Cent Sugar Brine Tempt. F.
	11%	13%	15%	17%	19%	
	5	5	4	5	5	
0	0	0	0	0	0	
2	54	45	45	38	41	
4	84	75	64	59	61	
6	88	79	77	64	70	
8	89	88	80	69	74	
10	<u>90</u>	92	82	72	77	
12	85	<u>95</u>	<u>83</u>	76	78	
14		93	81	<u>79</u>	<u>79</u>	
16				77	77	

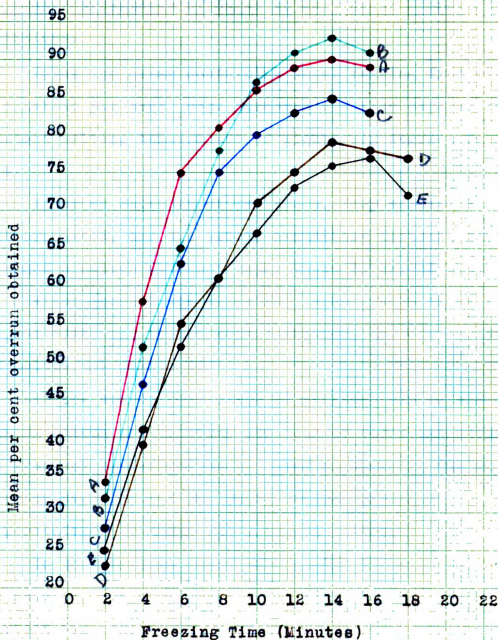
Table XII:- Mean Per Cent Overrun of Five Mixes.

Time (Minutes)	No.I.	No.II.	No.III.	No.IV.	No.V.	Per Cent Sugar
	11%	13%	15%	17%	19%	
0	0	0	0	0	0	
2	34	32	28	23	25	
4	58	52	47	39	41	
6	75	65	63	55	52	
8	81	78	75	61	61	
10	86	87	80	71	67	
12	89	91	83	75	73	
14	<u>90</u>	<u>93</u>	<u>85</u>	<u>79</u>	76	
16	89	91	83	78	<u>77</u>	
18				77	72	

**Table XIII:- Average Maximum Obtained from
Each Series.**

Per Cent Sugar	Per Cent Overrun
11%	90
13%	94
15%	86
17%	80
19%	78

FIGURE I. THE RELATION OF SUGAR TO OVERRUN OBTAINED



Key:-

A	I.	—●—●—	Ice cream containing 11% sugar
B	II.	—●—●—	" " " 13% "
C	III.	—●—●—	" " " 15% "
D	IV.	—●—●—	" " " 17% "
E	V.	—●—●—	" " " 19% "

Determination of the Time Required for Ice Cream with
Different Percentages of Sugar to Melt Under Summer
Conditions.

Brick ice cream containing sugar ranging from eleven to nineteen per cent were hardened and then exposed to a constant melting temperature of eighty six degrees Fahrenheit.

After an exposure of two hours, they assumed a honeycomb appearance, and the bricks containing fifteen, seventeen and nineteen per cent sugar began to spread out.

After three hours exposure, large cracks appeared on all surfaces, all bricks were flattened, and the corners had melted and fallen off.

At the end of four hours of melting, the bricks containing eleven and thirteen per cent of sugar had offered the greatest resistance to the heat as shown in the pictures on pages 41 and 42. These bricks containing the higher percentages of sugar had sloughed greatly.

In the pictures which were taken at the end of six and seven hours, the bricks which contained eleven and thirteen per cent sugar retained better form, especially in the picture taken at the end of seven hours. The bricks containing eleven per cent sugar showed best standing-up qualities. The remainder of the bricks had almost melted away. This standing-up property decreased as the content of sugar increased.

Figure II. Showing the five bricks of ice cream after melting four, six, and seven hours at a temperature of 86 F.

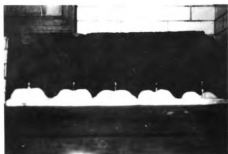
Bricks were arranged corresponding to their per cent of sugar, left to right, beginning with the smallest percentage.



Mix No.V: After four hours exposure.

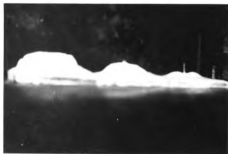


Mix No.I: After four hours exposure.



Mix No.II: After six hours exposure.

Figure II. Continued. Showing the five bricks of ice cream after melting four, six, and seven hours at a temperature of 86 F.



Mix No.III: After seven hours exposure.

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The Effect of Different Percentages of Sugar on the Body and Texture of Ice Cream.

The hardened ice cream was judged and scored by Professor P.S.Lucas and the writer. Only body and texture of the ice creams of different per cent of sugar, were scored.

The following score-card, used in the New York State College of Agriculture at Cornell University, was adopted in judging body and texture. In this score-card twenty five points were allowed as a perfect score for body and texture.

Flavor	40
Body and texture	25
Bacterial count	15
Richness	10
Appearance	5
Package	5
Total	100

The results were as follows:

The mix containing eleven per cent sugar was open, porous and coarse in texture, giving a rough feeling to the tongue, and was icy. It was not sweet enough for the average taste.

The mix containing thirteen per cent sugar had a closer texture as compared with the one containing eleven per cent sugar, but was a trifle coarse. Sweetness was about to the average taste.

The samples of ice cream having fifteen and seventeen per cent sugar showed the best qualities. There was a noticeable improvement in both body and texture over the former mixtures. The texture was smooth, desirable, and medium close, mellow and firm body, free from iciness, but a little too sweet, especially the latter.

The mix containing nineteen per cent sugar had the firmer body and closer texture, but was rather sticky and a trifle too sweet.

The following table shows by scores the body and texture of the ice creams containing different per cents of sugar.

Table XIV:- Scores of the Body and Texture of Ice Cream.

Per Cent Sugar	Mix I.	Mix II.	Mix III.	Mix IV.	Mix V.
11%	20	21	21	20	21
13%	22	22	21.5	20.5	21.5
15%	24	23	23	23.5	23
17%	24	23	24	23	24
19%	22.5	23.5	23.5	23	22.5

1. The first step in the process of the scientific method is to ask a question. This question should be based on observation and should be specific and measurable. For example, "Does the amount of sunlight affect the growth of a plant?"

2. The second step is to form a hypothesis. A hypothesis is a statement that can be tested. It should be based on the question and should be a prediction of the outcome. For example, "If a plant receives more sunlight, then it will grow taller." This hypothesis is testable because it can be measured and compared.

3. The third step is to design an experiment. The experiment should be designed to test the hypothesis. It should include a control group and an experimental group. The control group is the group that does not receive the treatment, and the experimental group is the group that does receive the treatment. In this case, the control group would be plants that receive a normal amount of sunlight, and the experimental group would be plants that receive more sunlight.

4. The fourth step is to collect data. Data is the information that is gathered during the experiment. In this case, the data would be the height of the plants in both the control and experimental groups.

5. The fifth step is to analyze the data. This step involves looking at the data and seeing if it supports the hypothesis. In this case, the data would be analyzed to see if the plants in the experimental group grew taller than the plants in the control group.

6. The sixth step is to draw a conclusion. A conclusion is a statement that summarizes the results of the experiment. It should be based on the data and should answer the original question. For example, "The data shows that plants that receive more sunlight grow taller than plants that receive a normal amount of sunlight." This conclusion supports the hypothesis.

7. The seventh step is to communicate the results. This step involves sharing the results of the experiment with others. This can be done through a presentation, a poster, or a paper. Communicating the results allows others to see if the experiment was done correctly and if the results are valid.

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Summary.

The study of the effect of sugar upon the quality of ice cream is an important problem from the economical standpoint to the manufacturer of commercial ice cream, since it affects the quality of his finished product.

The results show that the addition of sugar to the mix decreases the per cent of swell. Table XIII showed that maximum swell was obtained when thirteen per cent of sugar was added to the mixture. A less per cent of swell was obtained from the mixture containing eleven per cent sugar. The per cent swell of those mixtures containing more than thirteen per cent sugar gradually decreased. There was a decrease of sixteen per cent in overrun in those mixtures, containing nineteen per cent sugar over those mixtures containing but thirteen per cent sugar.

Table IV showed that the freezing point of the finished ice cream lowered as the percentage of sugar was increased.

The specific gravity of different mixes increased uniformly by the addition of sugar to the mixes.

The determination of the rapidity with which the bricks of ice cream containing different percentages of sugar melted when exposed to summer temperatures demonstrated that increase in sugar lowers standing-up properties.

Ice creams containing eleven per cent sugar showed the highest resisting power to a standard summer temperatures.

Ice creams, containing eleven and thirteen per cent of sugar had rather coarse and open textures, were icy, and were not sweet enough; while the mixtures containing fifteen and seventeen per cent sugar showed much smoother texture and were medium close. Ice cream containing nineteen per cent of sugar were rather sticky in texture and firm in body. Sweetness was excessive.

Judging from these data a mixture containing thirteen to fifteen per cent sugar seems to be the most desirable ice cream to manufacture. Such ice creams had the most desirable body and texture, resistance, overrun, and freeze more quickly.

CONCLUSIONS

1. An addition of sugar above thirteen per cent decreases the per cent of overrun. Maximum overrun can be obtained when thirteen per cent of sugar is added to the mixture.
2. Increased sugar tends to depress the freezing point of the mix; that is, the more sugar there is in the ice cream the lower the freezing point.
3. Creams containing eleven per cent sugar have the greatest resistance to standard summer temperatures. The resistance of ice cream to summer temperatures decreases with further addition of sugar to the mixture above eleven per cent.
4. Ice creams containing eleven and thirteen per cent of sugar usually have a coarse, open texture and are not sweet enough. An ice cream containing fifteen and seventeen per cent sugar has a smoother and closer texture, and firm body. An ice cream containing nineteen per cent sugar has a firmer body and closer texture, but is sticky and too sweet.
5. The addition of sugar to the mix, uniformly increases the specific gravity of the mix.

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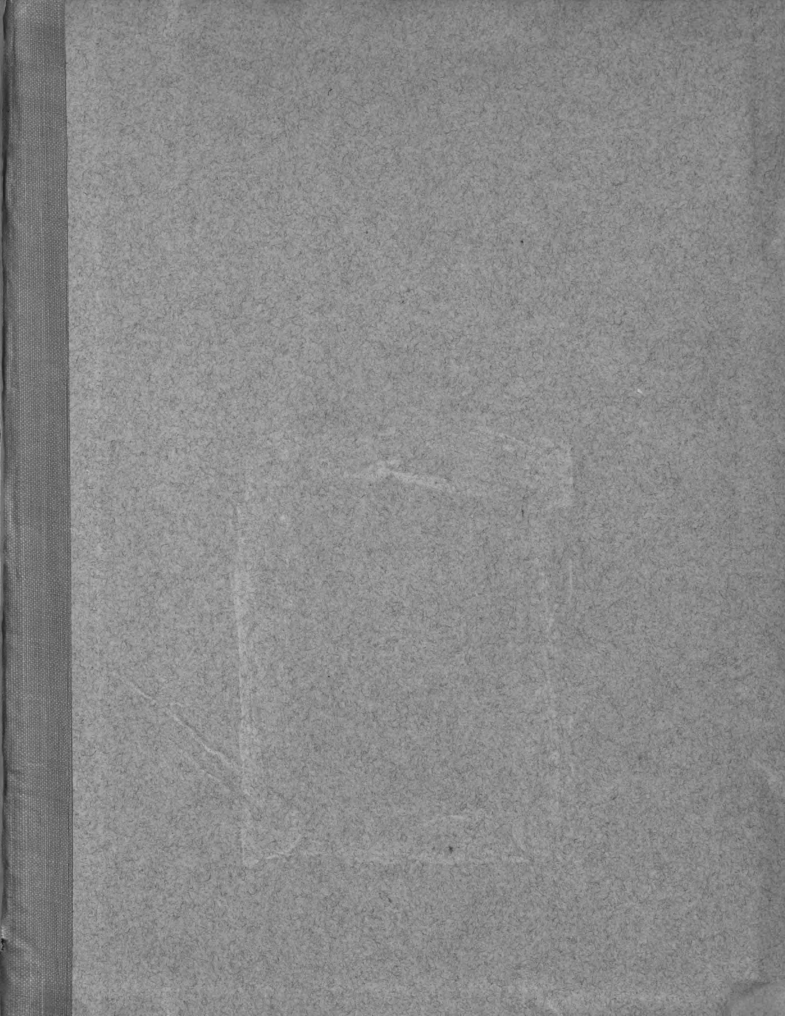
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