

THE MANUFACTURE, USE, AND STORAGE
OF DEHYDRATED SWEETENED CONDENSED SKIMMILK

by

ARTHUR THOMAS MUSSETT

B. S., Kansas State College
of Agriculture and Applied Science, 1946

A THESIS

submitted in partial fulfillment of the
requirements for the degree of

MASTER OF SCIENCE

Department of Dairy Husbandry

KANSAS STATE COLLEGE
OF AGRICULTURE AND APPLIED SCIENCE

1947

1947
1948

Docu-
ment
LD
2668
.T4
1947
M8

TABLE OF CONTENTS

	Page
INTRODUCTION	1
REVIEW OF LITERATURE	2
Manufacture of Powder	2
Use of Powder	4
Storage of Powder	6
EXPERIMENTAL PROCEDURE	8
Manufacture of Powder	8
Use of Powder in Ice Cream.	9
Storage of Powder	14
EXPERIMENTAL RESULTS	15
Manufacture of Powder	15
Use of Powder in Ice Cream.	16
Storage of Powder	24
SUMMARY AND CONCLUSIONS.	30
ACKNOWLEDGMENTS.	32
LITERATURE CITED	33

12-12-57 J.R.

INTRODUCTION

During World War II, a number of new dairy products were developed. One of these new products was sweetened skimmilk powder. A skimmilk-sugar solution is dried to a powder which is designated as sweetened skimmilk powder. Several different drying methods are available and different kinds of sugar may be used as sweeteners for the powder. This new form of concentrated milk was used as a source of skimmilk solids and sugar in ice cream, candy and bakery products.

Sweetened skimmilk powder has certain advantages over sweetened condensed skimmilk. It required less storage space, is more convenient to handle and there is an additional saving in transportation cost. This new product also is desirable for small users because it can be merchandised more advantageously in much smaller quantities than sweetened condensed skimmilk which is usually packed in 600 pound barrels. A barrel of sweetened condensed skimmilk is a problem in moving due to its weight, and once opened, is susceptible to spoilage by fermentation.

To date no standards of identity have been formulated, nor is there information available regarding the methods for using of sweetened skimmilk powder.

This study was undertaken for the purpose of obtaining more information on methods of manufacturing the powder, how it compares with other sources of serum solids when used in ice cream and how it should be stored.

REVIEW OF LITERATURE

Manufacture of Powder

Drying Systems. The manufacture of dehydrated sweetened skimmilk powder entails the removal of all except a small percentage of water from a skimmilk-sugar solution by one of several methods of drying. The most popular and widely used system for drying other products such as eggs, fruit juices and milk is the pressure spray drier. Drying results from forcing the solution by means of a pump through an atomizing nozzle into a drying chamber. The pressure exerted by the pump in forcing the milk through the small opening in the nozzle, atomizes the solution into fog-like droplets. When the droplets come in contact with heated air which is forced into the drying chamber, practically all of the moisture is removed. The dried particles fall to the bottom of the chamber while the moisture laden air is released at the top of the drying chamber.

The Douthitt Gray-Jensen drier, the Rogers drier, and the Dick drier (7) are three of the several different commercial machines using the principle outlined above. Certain modifications in the design of the machines are covered by U. S. Patents.

Another system found in wide use for drying milk products is in the roller process (7). When this system is used the product to be dried is first condensed in a vacuum pan to approximately 40-60 percent total solids. After concentration, the condensed milk solids are then introduced onto a steam

heated drum. When dried, the thin film is removed from the rotating drum by means of a knife.

Recent application of cold temperatures in drying products have been successful (7). This method does not jeopardize the flavor of the product which is a distinct advantage over systems in which heat is used for drying.

Drying Sweetened Condensed Skimmilk. In the manufacture of dehydrated products, a large number of the present day practices in use as to drying temperatures, pressures and concentration of liquids to be dried have been developed by equipment manufacturers and plant operators.

It has been possible to secure some information from a few manufacturers who have had a limited amount of experience in the manufacture of sweetened condensed milk powder and similar products. Information furnished by Day (5) on the drying of "sugmisco" (a maltose syrup sweetened skimmilk powder) indicated that this product could be made by atomizing a liquid containing 30 percent total solids through a 0.061 inch nozzle, using 2000 pounds pressure per square inch and a temperature in the drying chamber of 185°F. Day further states it was necessary to reduce the inlet volume by using 4 or 5 of the 8 spraying nozzles on the drier. He reported when the concentration of the liquid before drying was increased from 30 to 40 percent and the other conditions remaining the same, some difficulty was encountered in drying due to the formation of a taffy-like mass on the floor of the drier. This mass consisted of an incompletely dried syrup-skimmilk mixture.

In the manufacture of milk powder it is important that the drying temperature and other conditions be such that the dried product will not have a burnt appearance and scorched taste. When the drying temperature is reduced it is necessary to reduce the inlet volume which results in a reduced capacity of the drier. Holm (6) stated that in drying milk the temperature of the air cannot be specified, but varies with the make of the drier and may be from 240°F. to 300°F. depending upon the efficiency of the spray, the rate of feed, degree of concentration of milk used and other factors.

When drying ice cream mix, a product similar to sweetened condensed skimmilk powder, Tracy (17) found that a caramel-like flavor was present in the product when the drying temperature was too high. To overcome this, he recommends the addition of only 25 percent of the total amount of sugar before drying.

Use of Powder

Being a comparatively new product, there is little published information available on the use of sweetened skimmilk powder. During the war the product was used by small ice cream manufacturers, candy makers and bakers as a source of milk solids and sugar.

Turnbow, Tracy and Raffetto (19) have suggested the possibility of the manufacture of special types of dry milk solids which would be particularly well suited for use in the ice cream industry. Such products should be of high solubility, be easily dispersed in the mix, impart good whipping qualities

to the mix, and have a good effect upon the body of the ice cream. Neither should they detract from the fine flavor of the finished ice cream.

For the manufacture of ice cream of high quality Price and Whitaker (13) also emphasize the importance of proper dispersion of the dry ingredients in the liquid mix. They recommend the mixing of dry skimmilk with sugar and gelatin and then sprinkling the dry mixture in the cold liquid.

Considerable work has been reported on the effects of different ingredients upon the freezing properties of ice cream mixes.

When comparing the use of condensed skimmilk and spray process skimmilk powder in ice cream mixes, Lucas and Jensen (8) and Sommer (15) found no correlation between basic viscosity of the mixes and surface tension tests and whipping properties. They state that whipping ability of ice cream mixes cannot be explained on the basis of viscosity. Fat, sugar and gelatin are deterants to whipping, yet they also increase viscosity of the mix according to Sommer (15). Dahle and Kieth (3) and Dahle et al. (4) found slightly lower viscosities in mixes of the same composition made by spray process skimmilk powder than in the control containing condensed skimmilk.

In comparing dry skimmilk powders made by different processes and condensed skimmilk, Dahle et al. (4) obtained 100 percent overrun in slightly less time with spray process powder than with condensed skimmilk. This is supported by the report of Lucas and Jensen (8). In addition they found that mixes

made with butter in place of sweet cream required more time to develop a satisfactory overrun.

Turnbow, Tracy and Rafetto (19) showed that with either a high fat, high serum solids or high sugar content, a longer period of time is required to obtain the desired overrun.

Replacing part of the sucrose with corn sugar lowers the freezing point and requires a longer whipping time, Martin reported (9)

Using either skimmilk powder or condensed skimmilk, in making ice cream, Lucas and Jensen (8) obtained equally as good results on flavor and body and texture. When substituting butter of high quality for sweet cream, they found there was no practical difference in flavor scores; however, the body and texture scores were slightly lower.

Dahle (2), Dahle and Kieth (3), Dahle, Walts and Kieth, (4) Price and Whitaker (13), and Marquardt (10) have shown that dry skimmilk powder can be substituted for condensed skimmilk without noticeable difference in flavor and body and texture score.

Storage of Powder

Changes in the properties of condensed and dehydrated milks which take place during storage are of importance to the use of these products. In studying the effects of addition of sucrose on the keeping quality of whole milk powder, Hunziker (7) states that vacuum roller process powder, containing 13.7 percent fat and 14.24 percent sucrose did not show the slightest manifestation of tallowiness or other flavor defects when stored

in a tin for three years at room temperature ranging from 45 to 95°F. Samples of spray dried milk powder containing 15 percent milk fat, 57 percent milk solids not fat and 25 percent sucrose were held in glass jars with screw top caps, without protection from air, light and summer heat.

Marquardt (10) has shown a good quality ice cream can be made from dry skimmilk powder which had been stored in sealed containers for many months and that it was impossible to make ice cream of good quality from skimmilk powder which had been stored for more than 60 days in unsealed containers. According to Turnbow, Tracy, and Raffetto (19), dry skimmilk stored at room temperature of 60°F. or lower, a moisture content of 2.5 percent in the powder, and low humidities in the storage room are prerequisites for good keeping quality. Supplee and Bellis (16) concluded that there was a direct relationship between the moisture content during storage and quality of dry skimmilk.

Rancid flavors in sweetened condensed whole milk, according to Sommer (15), are usually caused by low forewarming temperature or allowing some of the milk to pass without forewarming so that the fat splitting enzyme, lipase, is not destroyed. In the storage of milk powder air should be excluded to prevent oxidation. Tallowiness in spray powder was attributed by Palmer and Dahle (12) to the presence of air within the granules. This contention is supported by Coulter and Jenness (1) who found the oxygen content of samples of powder gas-packed in nitrogen for 7 days was lower than that of the control samples.

Troy and Sharp (18) suggested that the caking of skimmilk

powder is the result of the following successions of reactions: 1. adsorption of moisture by the concentrated syrup, 2. adherence of milk particles to one another causing stickiness, and 3. solidification of the mass due to the crystallization of some of the lactose as alpha hydrate, causing caking. Webb and Hufnagel (20) found a paraffined lined, tight oak barrel was highly suitable for storing dried skimmilk. After four months' storage at 110°F. and 80 percent relative humidity, they reported only a one percent increase in moisture and no evidence of caking.

By increasing the moisture content of the powder, Supplee and Bellis (16) showed that the protein became progressively insoluble. These investigators, when maintaining the moisture content between three and five percent, found only a slight change in solubility of the powder when stored one year. Hunziker (7) reported roller-process dried whole milk containing as high as 3.7 percent moisture did not decrease in solubility in three and one half years, when stored at 59°F. However, when stored for long periods at 98°F. powders with as little as 2.4 percent moisture became completely insoluble. He attributed the hygroscopic properties of freshly-made powder to a change of lactose from hydride to a hydrate form.

EXPERIMENTAL PROCEDURE

Manufacture of Powder

This study was undertaken for the purpose of determining

the effects upon moisture content, flavor, color and texture of powder by temperature in the drying chamber atomizing pressure and total solids concentration of the skimmilk-sucrose solution before drying. In Table 1 is presented an outline of the experimental procedure used in this study.

Use of Powder in Ice Cream

The purpose of this phase of the experiment was to determine the suitability of sweetened condensed skimmilk powder as a source of serum solids for use in ice cream. This was accomplished by using it in standard ice cream mixes and comparing it with mixes in which the serum solids were furnished by sweetened condensed skimmilk or nonfat dry milk solids. Comparisons were made on the acidity, viscosity, visual sedimentation, and whipping properties of the mixes. Flavor and body and texture scores of the finished ice cream were compared.

The sweetened skimmilk powder used in this study was obtained from three sources. A sucrose sweetened skimmilk powder was obtained from the Hershey Creamery Company, Chambersburg, Pa. A maltose syrup sweetened skimmilk powder manufactured by the Bennett Creamery Company, Ottawa, Kansas and obtained from the Dessendorf Brokerage Company, Kansas City, Mo. A sucrose sweetened skimmilk powder was made in the Chemical Engineering laboratory at Kansas State College. The composition of the powders according to the analysis furnished by the manufacturer was approximately 40 percent serum solids and 60 percent sugar (moisture content disregarded). Three series of experiments,

Table 1. Experimental procedure outline for determining certain effects upon sweetened skimmilk powder by methods of drying.

Percent total solids of skimmilk-sucrose solution before drying											
14			22			22*					
Temperatures in drying chamber											
325°F.		375°F.		325°F.		375°F.		325°F.		375°F.	
Atomizing pressure in pounds per square inch											
750		1200		750		1200		750		1200	

*Diluted sweetened condensed skimmilk

the first consisting of three trials, the second consisting of one trial and the third series consisting of three trials, were made. The experimental procedure outline for the comparisons of ice cream is presented in Table 2.

The composition of Series I and II was selected as a typical ice cream mix used by ice cream manufactures during normal times.

Sugar shortages and high butterfat costs necessitated certain changes in the composition of ice cream during and since the war. The composition of series III was chosen as representative of a low fat, low sugar, high serum solids mix which was brought into use during the post war.

Mixing. The dry ingredients, including the sugar, the stabilizer and the skimmilk powder when used were mixed and sifted into the liquid ingredients when the temperature reached 120°F. The liquid ingredients were agitated vigorously during the addition of the dry ingredients to insure thorough dispersion. The size of the mixes was 50 pounds each. Observations were made on the ease and thoroughness of incorporation of the several different powders.

Pasteurization and Homogenization. The mixes were pasteurized in 10 gallon milk cans by placing the cans in a tank of hot water and stirring the contents until they reached a temperature of 155°F.

At the end of the 20 minute holding period at 155°F, the mixes were homogenized at 2000 pounds per square inch pressure using a single stage Creamery Package homogenizer, followed by

Table 2. Experimental procedure outline for comparisons of various ingredients used in ice cream.

Composition of experimental mixes						
	12 % fat	:	10 % fat			
	10.5% serum solid	:	12 % serum solids			
	14 % sugar	:	13 % sugar			
	0.3% stabilizer	:	0.3% stabilizer			
	Cream as source of fat, Series I	:	Butter as source of fat, Series II	:	Cream as source of fat, Series III	
Mix	Source of serum solids : and sugar	No. : : trials	Source of serum : solids and sugar	No. : : trials	Source of serum : solids and sugar	No. : : trials
A	Control-liquid sweet- ened condensed skimmilk	3	Same as A	1	Same as A	3
B	Skimmilk powder and su- crose	3	Same as B	1	Same as B	3
C	Skimmilk and sucrose pulverized together	3	Same as C	1	Same as C	3
D	Skimmilk powder sweet- ened with sucrose before drying	3	Same as D	1	Same as D	3
E	Skimmilk powder sweetened with maltose before dry- ing	3	Same as E	1	Same as E*	3

*Kansas State sucrose sweetened skimmilk powder substituted for maltose sweetened powder

cooling to 40°F. over a surface cooler. The mixes were held at 40°F. for 24 hours prior to freezing.

Analyses. The ice cream mixes were tested for butterfat by the Minnesota (19) method, and for total solids by the Mojonnier and Troy (11) method. The McMichael viscosimeter with No. 30 wire was used to measure the viscosity of the mixes. The acidity of the mixes was determined by titrating a nine gram sample, with N/10 NaOH, using phenolphthalein as a color indicator. A sample of each mix was placed in a 100 milliliter graduated cylinder and allowed to stand at 40°F. for 48 hours and observation made on sedimentation and destabilization.

Freezing. The mixes were frozen in a 40 quart direct expansion Creamery Package Batch freezer. A preliminary freezing was made prior to freezing the experimental mixes to standardize freezing condition. The amount of overrun and the temperature of the mixes was recorded at minute intervals throughout the freezing period, using a Mojonnier overrun scale and Weston dial thermometer.

Sampling and Storing of Ice Cream. When the desired overrun (approximately 100 percent) was reached, samples of the ice cream were taken direct from the freezer into pint Sealright containers and placed in a hardening room at -15°F. After 24 hours and 48 hours in the hardening room, the samples were removed, placed in an insulated ice cream shipping bag and allowed to temper for one hour. After tempering, they were examined organoleptically for flavor and body and texture by two qualified judges. The American Dairy Science score card which

allowed a total of 45 points for flavor and 30 points for body and texture was used for scoring the ice cream.

Storage of Powder

This phase of the experiment was designed to measure some of the chemical and physical changes which sweetened condensed skimmilk powder undergoes while in storage. A study of the effects of length of time in storage, storage temperature and type of container on the percent moisture, percent acidity, solubility index, flavor score, and texture of sweetened condensed skimmilks was made. Samples of the sweetened condensed skimmilk powders were placed in four ounce glass jars with screw caps, one quart tin cans with tightly fitting closures, one pint Sealright containers sealed with scotch tape and one pint Sealright containers lined with moisture resistant paper. One set of samples was stored at room temperature and the other at 40°F. for a period of two months.

The powders were analyzed for moisture content, tested for acidity, and solubility and scored for flavor at the start of the storage period and again after one month and two months in storage.

The acidity was determined by titrating an 18 gram sample of reconstituted powder with N/10 NaOH using phenolphthalein as a color indicator.

The method for determining the solubility of nonfat dry milk solids as outlined by the American Dry Milk Institute (21)

was followed with the exception that a Hamilton Beach malt mixer was substituted for the Dumore mixer No. 6.

The sweetened condensed skimmilk powders were reconstituted to the composition of skimmilk and scored for flavor by two judges using the American Dairy Science score card for the examination of milk which allows 45 points for a perfect flavor score.

EXPERIMENTAL RESULTS

Manufacture of Powder

The results obtained from a study of methods of drying skimmilk powder sweetened with sucrose before drying is presented in Table 3.

Using 325°F. drying temperature, 750 pounds per square inch atomizing pressure and a concentration of 14 percent total solids, the powder obtained had a lower moisture content than the same temperature, same degree of concentration and 1200 pounds per square inch pressure. With the same conditions except using a concentration of 22 percent total solids before drying, the moisture content was at a higher level. When 375°F. was used with identical conditions to 325°F. a powder resulted with a lower moisture content.

When considering the flavor of the powder, 325°F. gave satisfactory results with either 750 or 1200 pounds pressure and either a concentration of 14 or 22 percent, while a drying

temperature of 375°F. gave unsatisfactory results because of the cooked flavor imparted to the powder.

With a drying temperature of 325°F. and either 750 or 1200 pounds of pressure per square inch and with 14 or 22 percent total solids concentration, a desirable color was obtained while the higher temperature (375°F.) with other conditions being the same resulted in powder with a scorched color (Table 3.)

The texture of the powder was satisfactory except when a concentration of 22 percent solids, at 1200 pounds pressure and either 325°F. or 275°F. The chief objection in texture was the formation of carmelized, sticky, taffy-like masses caused by the product sticking to the periphery of the cyclone and then being detached by the force of the heated air. Dropping from the bottom of the cyclone into the powder container, these gummy sticky balls never became completely dehydrated.

The best drying conditions from a standpoint of the finished powder as measured by flavor, color and texture were a temperature of 325°F. in the drying chamber, 750 pounds per square inch pressure and a concentration of either 14 or 22 percent total solids before drying.

Use of Powder in Ice Cream

The results obtained from a comparison of several sources of serum solids and sugar in ice cream are presented in Tables 4 and 5.

Analysis of Mixes. In Series I, II and III the average butterfat content in percent varied only 0.2 of a point and the

Table 3. The effect of different dehydrating temperatures and pressures upon certain properties of sweetened skimmilk powder.

Percent total solids concentration of liquid before drying	Inlet pressure in lbs. per sq. in.	Percent moisture		Flavor		Color		Texture	
		325°F.	375°F.	325°F.	375°F.	325°F.	375°F.	325°F.	375°F.
14	750	1.89	1.53	Satisfactory	Cooked	Satisfactory	Scorched	Satisfactory	
	1200	2.47	2.06	do	do	do	do	do	do
22	750	3.50	2.70	do	do	do	do	do	do
	1200	6.97	3.64	do	do	do	do	do	Carmelized
22*	750	3.26	2.76	do	do	do	do	Satisfactory	
	1200	8.14	3.94	do	do	do	do	Carmelized	

*Diluted sweetened condensed skimmilk

total solids only 0.5 of a point from the calculated percentage of 12, 12 and 10 percent fat and 36.8, 36.8 and 35.3, respectively, for the series.

The average titratable acidity of the mixes in Series I ranged from 0.24 to 0.36 percent, for Series II from 0.20 to 0.28 percent and for Series III from 0.25 to 0.28 percent. All of the mixes with the exception of the ones containing maltose sweetened skim milk powder were within the expected range of acidities (0.18 - 0.26 percent) for mixes of these compositions. However, the acidities (average of 0.36 percent) of the mixes which contained the maltose sweetened skim milk powder were much higher than the other mixes in Series I. Such high acidity may have resulted from an excessive amount of acid in the skim milk or maltose syrup used in the manufacture of the powder. The acidities of the mixes in Series III averaged in percent approximately 0.3 of a point higher than the acidities of Series I. This was to be expected since the serum solids content of the mixes in Series II was 10.5 and that of the mixes in Series I was 12 percent. When considering acidities of mixes containing sucrose sweetened skim milk powder produced acidities which were lower than the control mixes and approximately equal to mixes containing nonfat dry milk solids while maltose sweetened skim milk powder resulted in acidities which were much higher

The viscosity in the control mix in Series II was 190 McMichael centipoise, which is somewhat higher than the 153 average for the corresponding mixes in Series I. This was to be

expected since it is known that mixes in which butter is used as a source of fat are always higher in viscosity than mixes in which sweet cream is used. The other mixes in Series II which contained butter were comparatively higher in viscosity than in corresponding mixes in Series I in which sweet cream was used as a source of fat.

The average viscosity of the control mixes of Series I was 153 McMichael centipoise. The average viscosities of the other mixes in Series I ranged from 133 in the mixes containing a pulverized skimmilk powder-sucrose mixture to 175 in the mix containing the maltose sweetened condensed skimmilk powder. In Series III the average viscosity of the control mix was 74 McMichael centipoise and for the other mixes in this series it ranged from 40 in the mix containing the pulverized skimmilk powder-sucrose mixture to 74 for the control mix. The lower viscosities in Series II mixes was due to the lower total solids content of the mixes. The higher acidities in the mixes containing maltose sweetened condensed skimmilk powder was probably the cause of the higher viscosities in those mixes. Resulting viscosities of all the mixes were for all practical purposes equal.

Observations made on the ease with which the different powders were incorporated into the mix indicated that the sucrose and maltose sweetened skimmilk powder was more easily and completely dispersed in the mix than were the nonfat dry milk solids or the pulverized nonfat dry milk solids-sucrose mixture.

All of the powders used were completely dispersed after pasteurization and homogenization and there was no settling out or sedimentation in any of the samples after standing in graduated cylinders at 40°F. for 48 hours. As indicated in Table 4, there was no tendency for protein destabilization during processing and storage of the mixes.

Drawing Temperature and Percent of Overrun. None of the ingredients used in these mixes exerted any marked change in the drawing temperatures of the ice cream (Table 5). The drawing temperatures of the ice cream in Series III averaged about 1°F. lower than those in Series I which was probably due to the fact that the mixes in Series III had a lower total solids content making it possible to freeze them to a slightly lower temperature than the mixes in Series I.

There was considerable variation in the percent of overrun in the ice cream at the end of an eight minute period in the freezer. For either the control mixes or the mixes containing sucrose sweetened skimmilk powder, the average overrun obtained in eight minutes was 94 percent in Series I, and in Series III it was 94 and 93 respectively (Table 5). The mixes in Series I, containing skimmilk powder, a pulverized skimmilk-sucrose mixture, and maltose sweetened skimmilk powder contained less overrun at the end of eight minutes than did the controls. The reverse was true in Series III.

The amount of overrun in all the mixes in Series II, which contained butter and either skimmilk powder or sweetened powder, was considerably less than the control.

Table 4. Comparison of certain properties of ice cream mixes made with various sources of serum solids and sugar.

Trial no.	Mix*	Percent			Acidity	Viscosity : McMichael centipoise	Indication : of destab- ilization during processing	Sedimentation : or destabil- ization 100 ml. grad.
		Fat	solids	Total				
Series I								
1	A	11.8	37.07	0.24	167	none	none	
	B	12.0	37.15	0.24	144	do	do	
	C	11.8	37.11	0.25	128	do	do	
	D	11.8	37.08	0.24	156	do	do	
	E	11.9	37.00	0.36	190	do	do	
2	A	12.1	36.89	0.25	141	do	do	
	B	11.9	37.24	0.24	149	do	do	
	C	12.0	36.42	0.26	133	do	do	
	D	12.0	36.53	0.24	135	do	do	
	E	11.9	36.56	0.36	185	do	do	
3	A	11.7	36.98	0.25	150	do	do	
	B	11.7	36.72	0.26	135	do	do	
	C	11.9	36.59	0.23	138	do	do	
	D	12.1	36.82	0.23	149	do	do	
	E	11.8	36.51	0.34	151	do	do	
Average of Trial 1, 2 and 3	A	11.9	36.98	0.25	153	do	do	
	B	11.8	37.40	0.24	140	do	do	
	C	11.9	37.70	0.24	133	do	do	
	D	12.0	36.81	0.24	146	do	do	
	E	11.9	36.69	0.36	175	do	do	
Series II								
1	A	11.7	37.12	0.20	190	none	none	
	B	12.0	36.85	0.22	160	do	do	
	C	11.9	36.95	0.22	141	do	do	
	D	11.8	36.70	0.21	160	do	do	
	E	11.8	37.00	0.28	205	do	do	
Series III								
1	A	9.8	32.29	0.28	61	none	none	
	B	9.8	35.54	0.27	39	do	do	
	C	10.0	35.48	0.28	32	do	do	
	D	9.6	35.16	0.27	71	do	do	
	E**	10.1	35.10	0.28	59	do	do	
2	A	10.0	35.63	0.28	68	do	do	
	B	10.1	35.20	0.27	45	do	do	
	C	10.0	35.37	0.28	30	do	do	
	D	10.2	35.38	0.26	60	do	do	
	E**							
3	A	9.7	35.19	0.28	94	do	do	
	B	9.9	34.95	0.29	65	do	do	
	C	9.8	35.56	0.28	58	do	do	
	D	9.8	35.00	0.27	88	do	do	
	E**							
Average of Trial 1, 2 and 3	A	9.8	35.37	0.28	74	do	do	
	B	9.9	35.34	0.27	47	do	do	
	C	9.8	35.54	0.28	40	do	do	
	D	9.8	35.18	0.27	70	do	do	
	E**	10.1	35.10	0.28	59	do	do	

*A Control-liquid sweetened condensed skim milk
 B Skimmilk powder and sucrose
 C Skimmilk and sucrose pulverized together
 D Skimmilk powder sweetened with sucrose before drying
 E Skimmilk powder sweetened with maltose before drying
 ** Only one trial made

Table 5. Comparison of certain properties of ice cream made with various sources of serum solids and sugar.

Trial no.:	:Source :of serum: :solids*:	:Temp. of :ice cream: :when	:Percent :overrun :at end of:	: Flavor score		: Body and texture		: Remarks
				: 24 hrs.:	: 48 hrs.:	: 24 hrs.:	: 48 hrs.:	
		drawn	°F.:	8 minutes:				Flavor criticisms
Series I								
1	A	23	90	42.25	41.5	29.0	28.75	
	B	23	85	41.5	41.5	28.75	28.5	
	C	23	78	41.5	41.25	28.75	28.5	
	D	24	85	42.5	42.0	29.25	29.0	
	E	23	76	31.0	31.0	29.0	28.5	Malt
2	A	24	95	37.5	37.75	27.75	27.75	Slightly oxidized
	B	23	98	37.5	37.5	27.0	27.5	Slightly oxidized
	C	24	93	37.5	37.75	27.25	27.5	Slightly oxidized
	D	24	98	41.0	41.25	28.75	28.5	
	E	24	90	31.0	31.0	28.25	28.0	Malt
3	A	23	98	41.5	41.75	29.0	28.75	
	B	23	90	39.5	40.0	28.75	28.5	
	C	24	98	41.5	41.25	28.0	28.25	
	D	24	100	40.5	41.25	28.25	28.5	
	E	24	90	31.0	31.0	29.0	29.0	Malt
Average of 1, 2 and 3	A	23	94.3	40.4	40.5	28.6	28.5	
	B	23	91	39.5	39.7	28.2	28.2	
	C	24	89.7	39.2	39.5	28.2	28.1	
	D	24	94.3	40.3	40.5	28.8	28.5	
	E	24	85.3	31.0	31.0	28.8	28.5	
Series II								
1	A	22	98.0	37.0	38.5	29.0	28.75	Old ingredients
	B	23	90	34.5	34.5	27.5	28.0	Old ingredients
	C	22	80	35.0	34.5	27.0	28.0	Old ingredients
	D	22	85	37.0	36.5	28.5	28.0	Old ingredients
	E	24	70	31.0	31.0	27.0	27.0	Malt
Series III								
1	A	23	100	39.0	40.5	28.75	29.0	Lacks sweetness***
	B	23	97	37.5	38	29.0	28.75	Old ingredients
	C	23	90	36.5	36.5	27.5	27.25	Old ingredients
	D	23	97	38.0	38.0	29.0	28.75	Slightly cooked
	E**	22	95	37.5	38.0	27.75	28.0	Slightly cooked
2	A	23	92	39.0	39.0	28.0	28.25	Old ingredients
	B	23	88	35.5	36.5	28.0	27.75	Slightly cooked
	C	22	85	36.0	36.0	27.75	27.25	Old ingredients
	D	23	88	38.5	38.5	27.75	27.75	Slightly cooked
	E**							
3	A	23	100	39.0	40.0	28.5	28.25	Old ingredients
	B	23	100	36.5	37.5	27.5	27.5	Old ingredients
	C	22	94	36.0	36.0	27.5	27.0	Old ingredients
	D	22	94	38.5	39.0	28.25	28.5	Slightly cooked
	E**							
Average of 1, 2 and 3	A	23	94	39.0	39.8	28.4	28.5	
	B	23	95	36.5	37.3	28.2	28.0	
	C	22	94	36.2	36.2	27.5	27.3	
	D	23	93	38.3	38.5	28.3	28.3	
	E	22	95	37.5	38.0	27.75	28.0	

*A Control-liquid sweetened condensed skimmilk
 B Skimmilk powder and sucrose
 C Skimmilk and sucrose pulverized together
 D Skimmilk powder sweetened with sucrose before drying
 E Skimmilk powder sweetened with maltose before drying

**Only one trial made

***Criticism of all samples in Series III

Ice cream made from mixes containing sucrose sweetened skim-milk powder was as satisfactory as the control mix containing liquid sweetened condensed skimmilk when viewed from the standpoint of the percent of overrun obtained at the end of eight minutes.

Scoring Flavor and Body and Texture. The data obtained from scoring the various ice creams of Series I, II and III is recorded in Table 5.

In comparison of the various flavor scores, it will be noted with few exceptions in Table 5 that the scores at the end of 48 hours were approximately 0.5 of a point higher than at 24 hours for the respective ice creams. This slight increase probably can be accounted for by the fact that the added vanilla flavor had more time to permeate throughout the ice cream. For the purposes of comparison of flavors, the 48 hour score will be used. The ice cream containing sucrose sweetened skimmilk powder mix of Series I, II and III was equal in score to the control ice cream (mix A) in Series I, each with a score of 40.5 out of a possible 45 points for flavor. Ice cream made from the control mixes in the remaining two series was slightly higher in score than that made from sucrose sweetened powder. When ice cream was made from mixes containing maltose sweetened powder (mix E, Series I and II), a pronounced malt flavor was present resulting in an average score of 31 points. The remaining ice cream made from mixes containing skimmilk powder and pulverized skimmilk-sucrose mixture (mixes B and C, Series I, II and III) had average scores slightly under that of the con-

trol ice cream (mix A same Series) and sucrose sweetened powder (mix D same Series).

On a basis of flavor score for ice cream, sucrose sweetened powder used in mixes produced results equally as good as liquid sweetened condensed skimmilk used in mixes (control mix).

Maltose sweetened powder when used in ice cream mixes produced an ice cream which was considerably lower in score than the control mixes.

There was no marked change in body and texture of the various ice creams when scored at the end of 24 and 48 hours. Ice cream in the three series made with skimmilk powder or pulverized skimmilk powder-sucrose mixture had body and texture scores which were slightly lower than mixes made with sweetened condensed skimmilk. Ice cream made with sucrose and maltose sweetened powder for all practical purposes equaled the body and texture score of the control ice cream which averaged 28.5, 28.75 and 28.5 points for Series I, II and III, respectively.

Storage of Powder

The data obtained from the study of the effects upon the moisture content, acidity, solubility index and flavor by type of container, storage temperature and storage period are presented in Tables 6 and 7. When considering the percent moisture, glass and tin containers were more suitable than paper containers. Commercial sweetened powder had an initial moisture content of 2.36 percent and at the end of two months when stored in tin was as low as 1.57 percent. In several cases there were

Table 6. Effects of certain containers and storage temperatures upon the moisture, acidity, and solubility index of dehydrated sweetened powder.

Kind of powder	Type of container*	Storage temperature	Percent moisture			Percent acidity			Solubility index (ml.)		
			Beginning	1 Mo.	2 Mo.	Beginning	1 Mo.	2 Mo.	Beginning	1 Mo.	2 Mo.
Sucrose	1	Room	2.36	0.15	2.53	0.16	0.16	0.16	0.1	0.1	0.1
do	1	40°F.	do	1.53	2.44	do	do	do	do	do	do
do	2	Room	do	2.34	2.17	do	do	do	do	do	do
do	2	40°F.	do	1.45	1.57	do	do	do	do	do	do
do	3	Room	do	6.80	6.41	do	do	do	do	0.5	0.8
do	3	40°F.	do	8.40	10.52	do	do	do	do	do	do
do	4	Room	do	6.18	6.53	do	do	do	do	do	do
do	4	40°F.	do	9.54	9.75	do	do	do	do	do	do
Maltose	1	Room	3.25	3.09	3.62	0.23	0.23	0.23	0.1	0.1	0.1
do	1	40°F.	do	3.80	3.89	do	do	do	do	do	do
do	2	Room	do	3.27	3.29	do	do	do	do	do	do
do	2	40°F.	do	3.09	3.05	do	do	do	do	do	do
do	3	Room	do	5.39	7.47	do	do	do	do	0.75	1.25
do	3	40°F.	do	8.43	8.30	do	do	do	do	do	do
do	4	Room	do	6.97	8.06	do	do	do	do	do	do
do	4	40°F.	do	10.09	13.65	do	do	do	do	do	do
Kansas State	1	Room	3.86	4.29	4.47	0.17	0.17	0.17	0.1	0.1	0.1
Col. Sucrose	1	40°F.	do	3.76	3.38	do	do	do	do	do	do
do	2	Room	do	2.47	2.16	do	do	do	do	do	do
do	2	40°F.	do	3.40	3.17	do	do	do	do	do	do
do	3	Room	do	6.51	7.00	do	do	do	do	1.0	1.75
do	3	40°F.	do	10.99	11.47	do	do	do	do	do	do
do	4	Room	do	7.56	7.17	do	do	do	do	do	do
do	4	40°F.	do	11.57	13.49	do	do	do	do	do	do

*1. glass 2. tin 3. paper lined Sealright 4. Sealright

Table 7. Effects of certain containers and storage temperatures upon the flavor score of sweetened powders.

Kind of powder	:Type of : :contain-: :er**	: Storage : : tempera-: : ture :	Flavor score and criticism*		
			Beginning	1 month	2 months
Sucrose sweetened	1	Room	38 Sl.*** cooked	38 Sl. cooked	37 Sl. cooked
do	1	40°F.	38 Sl. cooked	38 Sl. cooked	Sl. tallowy
do	2	Room	38 Sl. cooked	38 Sl. cooked	37 Sl. cooked
do	2	40°F.	38 Sl. cooked	38 Sl. cooked	Sl. tallowy
do	3	Room	38 Sl. cooked	37 Sl. storage	37 Sl. cooked
do	3	40°F.	38 Sl. cooked	38 Sl. cooked	Sl. tallowy
do	4	Room	37 Sl. cooked	37 Sl. cooked	36 paper taste
do	4	40°F.	38 Sl. cooked	37 Sl. storage	33 pronounced cappy
Maltose sweetened	1	Room	29 pronounced malt	29 pronounced malt	35 Sl. rancid
do	1	40°F.	do	do	29 paper taste
do	2	Room	do	do	29 malt flavor
do	2	40°F.	do	do	29 masks others
do	3	Room	do	do	do
do	3	40°F.	do	do	do
do	4	Room	do	do	do
do	4	40°F.	do	do	do
Kansas State sucrose	1	Room	35 cooked	35 cooked	33 stale cooked
do	1	40°F.	do	do	34 stale cooked
do	2	Room	do	do	33 stale cooked
do	2	40°F.	do	do	34 stale cooked
do	3	Room	do	34 Sl. storage cooked	32 cappy papery
do	3	40°F.	do	35 cooked	33 cappy
do	4	Room	do	34 Sl. storage cooked	32 cappy
do	4	40°F.	do	35 cooked	33 cappy

*All samples had a sweetish taste

**1. glass 2. tin 3. paper lined Sealright 4. Sealright

***Throughout this table the word Sl. appears and is an abbreviation for the adjective "slightly"

slight reductions in the moisture content at the end of two months when stored in glass and tin at either room temperature or 40°F. while in other instances there were slight increases. The increase in moisture content of the glass and tin may be explained by faulty sealing of the closure which allowed for moisture to be absorbed from the outside air, while the loss in moisture content was due to the sugar changing from a hydride to a hydrate form (7) by absorbing free moisture from within the container. Sweetened powders stored in either Sealright or moisture resistant paper lined Sealright container showed higher increases in moisture when stored at 40°F. than when stored at room temperature. The extreme gain in moisture content was in the case of Kansas State College sweetened powder when it increased from 3.86 percent to 13.49 percent at the end of two months when stored in a Sealright container at 40°F. The samples which were stored in paper containers were highly caked at the end of the storage period while those in glass and tin containers were not affected. The caking was the result of an increase in the moisture content of the sugar. The increases at both temperatures, however, were sufficient to eliminate paper as a type of container for sweetened powder unless a paper container is developed which is more moisture resistant and which has more efficient closures.

There was no significant change in the percent of acidity of any of the powders in the different containers used or at the different storage temperatures. The acidities at the end of two

months of storage at either temperature were sucrose sweetened condensed powder 0.15 percent, Kansas State College sweetened powder 0.17 percent and maltose sweetened powder 0.22 percent.

The initial solubility index of the powders expressed in milliliters was less than 0.1 for sucrose sweetened condensed skimmilk powder to 0.1 for Kansas State sucrose sweetened condensed skimmilk powder. Again glass and tin gave equally as good results with no loss of solubility at either temperature and at the end of two months' time. The solubility index increased particularly with a high moisture content and after extended storage. At the end of two months of storage, the solubility index of Kansas State sweetened powder increased from 0.1 milliliter to 1.7 milliliters. Commercial sucrose sweetened powder and maltose sweetened powder followed the same general trend but not at such a high level.

The initial flavor scores given to the powder were: 1. commercial sweetened powder (Hershey's) 38 points, 2. maltose sweetened powder (Bennett's) 29 points, and 3. Kansas State College Sucrose sweetened powder 35 points. All powders were criticized for being too sweet, and in addition commercial and Kansas State sucrose sweetened powder for being slightly cooked. The maltose sweetened powder was criticized for its strong malt flavor.

When stored in glass and tin containers there was approximately one point decrease in flavor scores of the various powders after two months of storage, when stored at either room temperature or 40°F. When stored in paper containers, there was

a two point decrease at 40°F. and three point decrease at room temperature at the end of two months. At the end of the storage period, criticisms of powders in paper containers were the development of storage, cappy and tallowy flavors. Maltose sweetened powder was given the same score at each examination since the malt flavor masked other developed flavors.

SUMMARY AND CONCLUSIONS

This study was undertaken for the purpose of obtaining more information on methods of manufacturing sweetened skimmilk powder, the comparison with other sources of serum solids when used in ice cream and the manner of storage.

In the phase concerning manufacture, the factors studied were the temperature in the drying chamber, atomizing pressure and degree of concentration of the liquid to be dried and their effects upon moisture content, flavor, color and texture of the finished product. Twelve small lots of powder were made in an experimental drier under the different conditions being studied.

A study to determine the suitability of sweetened powders in ice cream was made by comparing them with other sources of serum solids and sugar. A total of 33 mixes and ice creams were made to obtain data as a basis for the study.

The storage study was conducted to determine the most suitable conditions under which to store the sweetened skimmilk powders. Powders were stored in different containers and at different temperatures.

Conclusions made from this study of manufacture, use and storage of sweetened powders are as follows:

1. The best drying conditions from the standpoint of the finished powder as measured by flavor, color and texture resulted when using a temperature of 325°F. in the drying chamber, 750 pounds per square inch atomizing pressure and a concentration

of 14 or 22 percent total solids in the liquid before drying.

2. When a temperature of 375°F. was substituted for a temperature 325°F. in the drying chamber a lower moisture content was obtained but the powder had an objectionable flavor and color.

3. From the standpoint of acidities, mixes containing sucrose sweetened powder produced results which were more desirable than the control mixes while mixes containing maltose sweetened powder resulted in acidities which were much higher.

4. There were no significant differences in the viscosities of any of the mixes in the three series when considered from a practical basis.

5. Observations made on the ease with which the different powders were incorporated into the mix indicated that sucrose and maltose sweetened skim milk powder were more easily and completely dispersed in the mix than were either skim milk powder or the pulverized skim milk powder-sucrose mixture.

6. When selecting ice cream on the basis of flavor, body and texture and the amount of overrun at the end of eight minutes, mixes containing sucrose sweetened powders made ice cream equally as satisfactory as the control.

7. Maltose sweetened powder when used in ice cream, resulted in a lower percent overrun obtained at the end of eight minutes and a lower flavor score than the control or sucrose sweetened ice cream, however, the body and texture score equalled that of the control ice cream when using mixes containing maltose sweetened powder.

8. In studying the effects upon moisture content, acidity, solubility index and flavor by type of container, storage temperature and storage period, the best results were obtained when sweetened skimmilk powders were stored in glass or tin containers at either room temperature or 40°F. when stored for two months.

ACKNOWLEDGMENTS

The author wishes to express his appreciation to Prof. W. H. Martin for guidance and help received during the course of this work and to associate Professor J. L. Barnhart for aid in scoring samples of ice cream.

The author is also indebted to the Chemical Engineering Department of the College for the use of the pressure spray drier used in this study, to Mr. C. A. Day of the Bennett Creamery Company, Ottawa, Kansas for valuable information about drying milk and to the Hershey Creamery Company, Chambersburg, Pennsylvania for furnishing the dehydrated sucrose sweetened powder used in this study.

LITERATURE CITED

- (1) Coulter, S. T. and R. Jenness.
Oxygen retained in powder...Minn. Agr. Expt. Sta. Tech. Bul. 167. 27 p. 1945.
- (2) Dahle, C. D.
Dry skimmilk in ice cream. The Am. Dry Milk Inst. Publication. 23 p. 1933.
- (3) Dahle, C. D. and J. I. Keith.
Studies on the use of dry skimmilk in manufacturing ice cream. The Ice Cream Trade Jour. 27:33-35. Jan. 1931.
- (4) Dahle, C. D., C. C. Walts and J. I. Keith.
Dry skimmilk in ice cream. Penn. State Col. Agr. Expt. Sta. Tech. Bul. 271. 27 p. 1931.
- (5) Day, Clarence A.
Drying sweetened skimmilk. Information from a personal interview. Bennett Creamery Co., Ottawa, Kans. June, 1947.
- (6) Holm, George E.
Dried milks. U. S. Dept. Agr. BDIM-Inf. 25 p. June, 1945.
- (7) Hunziker, O. F.
Condensed milk and milk powder, ed. 6. La Grange, Ill. Published by the author, 560 p. 1946.
- (8) Lucas, P. S. and J. Jensen
Limitations to the use of skimmilk powder and butter in the ice cream mix. Mich. Agr. Expt. Sta. Quart. Bul. 19(3) 9 p. 1947.
- (9) Martin, W. H.
Sugars in ice cream mix...Ice Cream Trade Jour. 23:44. Mar. 1927.
- (10) Marquardt, J. C.
The utilization of dry skimmilk in the manufacture of ice cream and cheese. N. Y. State Agr. Expt. Sta. Tech. Bul. 174. 23 p. Mar. 1931.
- (11) Mojonnier, M. S. and H. C. Troy.
The technical control of dairy products, ed. 2. Mojonnier Brothers Company. 935 p. 1925.

- (12) Palmer, L. S. and C. D. Dahle.
Structure of powdered milk and its possible relation to
keeping quality of whole milk powders. Jour. Dairy Sci.
5:240-245. 1922.
- (13) Price, Walter V. and Randall Whitaker.
Dry skimmilk in ice cream. Cornell Univ. Agr. Expt. Sta.
Bul. 516. 37 p. March, 1931.
- (15) Sommer, Hugo H.
The theory and practice of ice cream making. Madison.
Published by the author. 628 p. 1932.
- (16) Supplee, G. C. and B. Bellis.
The solubility of milk powder as affected by moisture
content. Jour. Dairy Sci. 8:39-46. 1925.
- (17) Tracy, P. H.
Powdered whole milk and mix. Ice Cream Trade Jour.
41:22. April, 1945.
- (18) Troy, H. C. and P. F. Sharp.
Alpha and Beta lactose in some milk products. Jour.
Dairy Sci. 13:140-157. 1930.
- (19) Turnbow, G. D., P. H. Tracy and L. A. Raffetto.
The ice cream industry, ed. 2. New York. John Wiley.
654 p. 1947.
- (20) Webb, B. H. and C. F. Hufnagel.
Compressing spray-dried milk to save shipping space.
Food Ind. 15:72-74. Sept. 1943.
- (21) _____.
The grading of nonfat dry milk solids. Am. Dry Milk
Inst. Bul. 911. 20 p. 1944.