CONDENSING WHOLE MILK WITH A VACREATOR

by

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To the Memory of

My Mother

Pat-Hong Kwai Lu

1888-1941

Whose Great Motherly Love

Inspired Me to Study

Dairy Science

This Thesis Is Dedicated

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CONDENSING WHOLE MILK WITH A VACREATOR

INTRODUCTION

The success of the processes of condensing milk into concentrated products for the purposes of long storage, economy of transportation, and the use in the manufacturing of other food products is the result of the combined efforts of modern sciences. Condensed milk and milk powder may be considered as the youngest twin brothers in the history of the development of the dairy industry. However, they have been progressing so fast and expanding so much that they have now become two strong branches of the industry. Hunziker (7) computed the statistics on the annual production of milk and manufactured dairy products supplied by the Bureau of Agricultural Economics, U. S. D. A., 1944, and 1945, and showed that there were tremendous increases in the percentage of production of all kinds of concentrated milk products in the period of 1941 to 1944 as compared to the period of 1937 to 1940. The figures are shown in the table below:

Milk Product	Average Annual Production For 4 Prewar Years 1937-1940 X 1000	Average Annual Production For 4 War Years 1941-1944 X 1000	Increase of Production
	pounds	pounds	percent
Dried whole milk	22,263	105,859	375.0
Sweetened condensed milk	46,418	108,141	133.0
Dried whey	65,325	121,876	86.0
Evaporated milk	2,160,503	3,313,170	53.0
Dried skimmilk	427,919	558,954	30.0

Condensing of milk is essentially a process of evaporation of milk through which the water content of the milk is lowered to its desired concentration. In order to hasten the process of condensing and to avoid over heating of the product, the milk is evaporated under partial vacuum at a temperature much lower than the normal boiling point of the milk. Based on this principle, different types of machines had been devised and used successfully. One of the most recent devices for the condensing of milk is the Vacreator. The Vacreator was devised by Mr. Lamont Murray and Mr. Frank S. Board of New Zealand, primarily for the pasteurization and the elimination of feed flavor of the cream (6). The machine is made up of 3 chambers (Fig. 1). The principle of high-temperature short-time treatment of the cream is applied in the pasteurization chamber, while steam distillation and evaporation under a series of vacuums for the removal of the feed flavor and the free water vapor, which, either derived from the injected steam or from the evaporation of the cream itself, are taking place in the second and third chambers. Because of high vacuum, the cream boils vigorously at a low temperature corresponding to the absolute pressure inside the Vacreator (Appendix Table XIV). It is based on this principle of boiling under partial vacuum that condensing of milk with Vacreator is made possible.

Owing to the high demand of concentrated milk products during the World War II period, Wilster (14), who introduced the first Vacreator into the United States, modified the vacreation process, and used it for condensing milk. The result was so remarkably successful that the process has been used as the standard procedure in the preparation

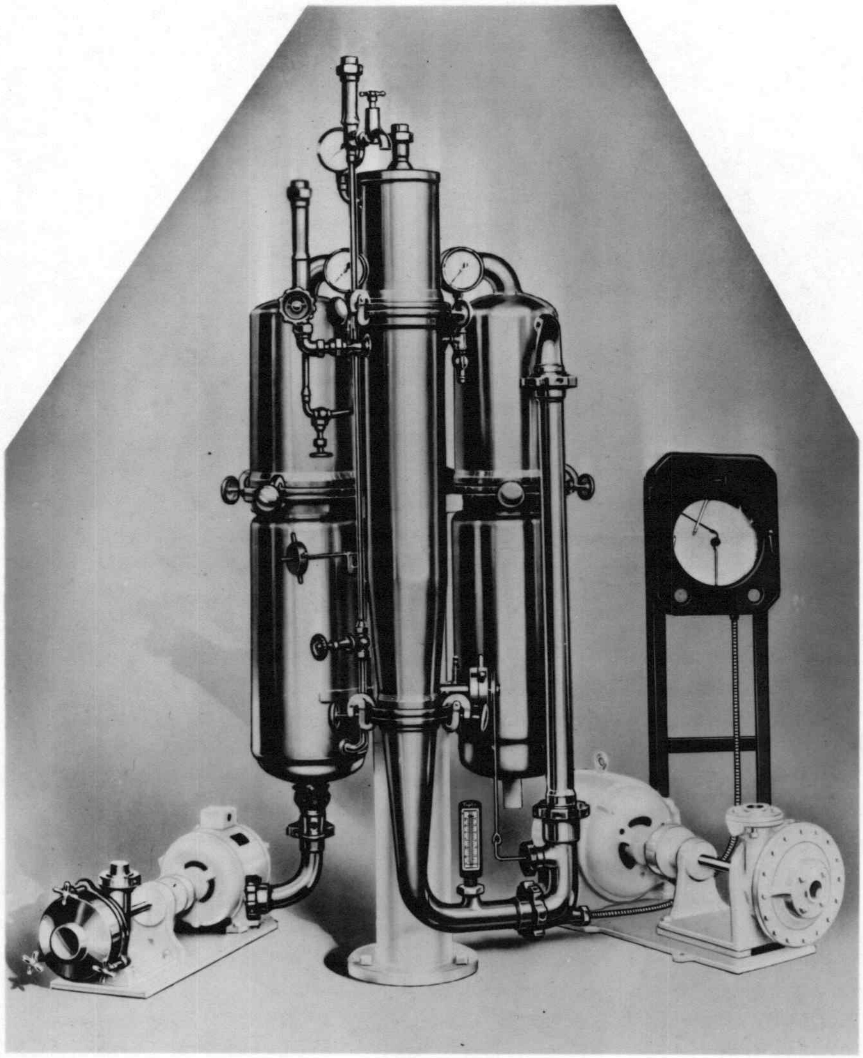

FIG. 1 THE "BABY" SIZE VACREATOR

of condensed milk for ice cream making at Oregon State College.

Because of the versatility of the Vacreator in dairy industry (15), there is an increasing demand for this machine as an important piece of equipment in dairy plants. Its application for condensing milk may eventually be widely adapted, especially in the field of ice cream manufacturing. It is the purpose of this paper to present a comprehensive idea about the condensing of whole milk with the Vacreator and its related problems.

One of the important problems in the condensing of whole milk for ice cream mix in a small plant is how can one know when the proper concentration has been reached during the condensing so that he can stop the process. Since the concentration of total solids of milk is increasing rapidly toward the end of the condensing process, a simple and rapid method must be used for the determination of its concentration so as to avoid unnecessary waste of time and energy due to over condensing. Furthermore, the concentration of condensed milk must be known before a proper ice cream mix can be intelligently prepared.

The use of the Mojonnier Tester (8) for analyzing condensed milk for its fat and total solids is commonly adapted in condenseries. Though it gives very accurate results, it requires a well trained technician to do a good job, and also takes a relatively long time to accomplish the complete process. The Mojonnier Tester is an expensive piece of equipment. It is not always economically possible for a small ice cream plant to possess this equipment.

With all these technical and economical backgrounds, the author has tried to work out some empirical formulae with which the percentage composition of condensed whole milk for total solids and fat can be easily and rapidly calculated through a known Baumé hydrometer reading.

The other important problems in relation to the use of the Vacreator as a whole milk condensing unit are the efficiency of the machine and the quality of the product. These were also studied in this research.

REVIEW OF LITERATURE

I. Development of the Condensed Milk Industry

According to Hunziker (7), the advent of condensed milk belongs to the 19th century. Toward the close of the 18th century and during the first half of the 19th century, the food scientists of France and England gave thought to the possibility of preserving milk in concentrated form. However, credit has been given to Nicolas Appert of Chalons-sur-Marne, France, as the first person who had successfully experimented with the condensing of milk following with the heat treatment of the concentrated products in a sealed container as a means of preservation. He condensed the milk by evaporating it in a water bath over a fire under atmospheric pressure to about two thirds of its original volume. He then sealed the condensed milk in glass bottles and heated in water bath to boiling for two hours as a means of sterilization.

Evaporation of milk under atmospheric pressure as used by Nicolas Appert is a long and uneconomical process. Gail Borden in America conceived the idea of evaporation of milk under partial vacuum as a means of hastening the process, saving of heat energy, and producing of better quality product. He had his ingenious process patented in 1856 under his claim of "producing concentrated sweet milk by evaporation in vacuo without the admixture of sugar or other foreign matter." It is his process that has made manufacturing of condensed milk commercially successful. He is honored as being the father of the modern condensed milk industry.

Preservation of the condensed milk is one of the important problems in the condensed milk industry. Gail Borden used sugar as a preservative in his sweetened condensed milk sold under the Eagle Brand, since micro-organisms generally do not grow in a strong sugar solution or syrup. John B. Meyenberg of Switzerland conceived the idea of sterilization of condensed milk in its sealed container by steam under pressure as a means of preserving this product without the addition of preservatives of any form and also without the necessity of keeping it cold. He experimented with this over a period of three years, 1880 to 1883 (7). He designed the revolving sterilizer, the principle of which is now still in use in condenseries.

The invention of the homogenizer by August Gaulin of Paris, France, in 1899 (13) and its introduction into the manufacturing process of condensed milk has solved the problem of fat separation which was a serious trouble in condensed whole milk. Newer knowledge of the control of viscosity and heat stability has also greatly improved the quality of condensed milk.

Different types of vacuum pans have been designed after the basic idea of evaporation under partial vacuum developed by Gail Borden. Many improvements have been made by modern engineers as to the efficiency and capacity of the machine, economy of fuel, protection of the milk against heat damage, and the use of stainless steel in the place of copper. The vacuum pans now in common use are, as follows: the Single-Effect Vacuum Pan, the Double-Effect Buflovak Vacuum Milk Evaporator, the Kestner Vertical Film Evaporator, the Mojonnier Tubular Evaporator, the Scott Forced-Circulation Evaporator, and the Peebles Single-Pass Evaporator. During World War II, a new type of vacuum evaporator has been developed. It is the Vacreator(14).

II. Development of the Vacreator as a Milk Evaporator

The Vacreator was invented in 1923 by H. L. Murray and F. S. Board of New Zealand. It was originally designed for pasteurization of cream under vacuum with the idea of driving off the feed flavor present in the cream through the combined action of vacuum evaporation and steam distillation. Since high vacuo are used and vigorous evaporation does take place in the vacreation process, Wilster conceived the idea of modifying it for the evaporation of milk as early as 1939 (14). However, it was because of the shortage of condensed milk and milk powder during the war time for the United States domestic ice cream making that Wilster and his co-workers carried on their experiments in modifying the vacreation process into milk condensing process. Wilster (14) preheated the milk to about 200° F. by means of a flash heater before it entered the Vacreator. In contrast to the vacreation of cream, no steam was admitted into the Vacreator during the condensing process. The hot preheated milk boils instantaneously under the partial vacuum condition of the evaporation chamber of the machine. Thus, the hot milk gives off much water vapor which is condensed and carried away by the water of the ejector-condenser. The result was so remarkably successful that since 1943 the Dairy Products Laboratory at Oregon State College has been using the Vacreator for condensing milk. Skim milk was used in their early experiments, and later, in the I. N. Hagan Ice Cream Factory, Uniontown, Pennsylvania, whole milk was used under the supervision of Wilster. The flavor and texture of ice cream made from Vacreator-condensed milk are so fine that there is a possibility that many ice cream factories will make their own condensed milk with the Vacreator.

III. The Condensing Cycle When Using the Vacreator as a Milk Evaporator

The process of condensing milk with a Vacreator is carried on by first placing the milk in a storage vat and then pumping it through a flash preheater, heating it to 200° F. ± 5° F. and then evaporating under two different degrees of partial vacuums in the Vacreator. The partially concentrated milk is then pumped from the Vacreator and returned to the storage vat. The detail and the mechanism of the process is stated below:

The Vacreator proper consists of three vacuum chambers (Fig. 1 and Fig. 2). Vacuum is developed by a strong jet of water under a pressure of about 110 pounds per square inch shooting through a fixed vertical nest of cones, the orifice of each being slightly larger than the preceding one. This vertical nest of cones is housed in a cylindrical casing. It also serves as the condenser of the Vacreator and is called the Ejector-Condenser. Both the second and the third vacuum chambers are directly connected to this Ejector-Condenser through two separate pieces of goose-neck pipe over their tops respectively. Thus, the moisture and gases evaporated in the vacuum chambers are carried away together with the high-speed Ejector-Condenser water. During the condensing process, the vacuum in the second chamber is maintained at 24 inches, and in the third chamber at 28 inches or higher. This difference of 4 inches of vacuum causes the milk to pass rapidly from one chamber to another through the Vacreator. The vacuum in the second chamber is adjusted by means of a "Snifter" valve located at the side of the Ejector-Condenser which regulates the admission of air into the condenser. Milk at a temperature of about 200° F. $\pm 5^{\circ}$ F. is being conducted into the Vacreator through a perforated spray pan over the top of the first chamber. Under the partial vacuum condition of the first chamber, these hot milk droplets evaporate instantaneously and vigorously. By gravitation and the higher vacuum in the second chamber, this mixture of milk droplets, water vapor, and some other gases go down to the bottom of the first chamber and are carried up to the second chamber through an up-take pipe. The inlet of the up-take pipe into the second chamber is tangentially located. Owing to the suction of the higher vacuum in the second chamber, the milk enters the top of the chamber with a high speed at a tangent angle and then spirals down by gravity over the inside surface of the vacuum chamber. While spiralling down, the milk continues to boil vigorously, since the absolute pressure is lower here, and the milk is still very hot. The centrifugal force developed by the spiral movement of the milk throws the heavier concentrated fluid milk against the wall and leaves the much lighter water vapor and other gases at the center space of the chamber. These water vapor and gases are then sucked out and condensed in the Ejector-Condenser. The partially concentrated milk is then similarly drawn tangentially into the third chamber and gives out more water vapor for there a still higher vacuum, usually about 28 inches, is maintained. An intermediate float valve is located at the bottom of the second chamber. It controls the flow of milk from the second to the third chamber, and also serves as a seal-valve for maintaining a higher vacuum in the third chamber. The spiral movement of milk is finally cut off by a vertical plate at the middle of the bottom of the last chamber. The concentrated milk product is pumped out from the last chamber back to the storage vat.

Between the storage vat and the Vacreator is installed a flash preheating unit (Fig. 2). The flash pasteurizer and tubular heater have been successfully used. The purpose is to bring the temperature of milk immediately up to about 200° F. before it enters the first chamber of the Vacreator. In order to render the flash preheater to function properly, that is to bring the temperature immediately up to 200° F., it is usually necessary to heat the milk in the storage vat to a temperature of about 130° F. The milk is continuously circulated around through the three units, namely, the storage vat, flash preheater, and the Vacreator until the desired concentration is reached. The flow cycle of condensing milk with the Vacreator is illustrated in the diagram of Figure 2, in which:

<u>1</u> is the first vacuum chamber maintained at about 18 to 20 inches of vacuum;

<u>2</u> is the second vacuum chamber maintained at 24 inches of vacuum;

3 is the third vacuum chamber maintained at 28 inches of vacuum or higher;

F is a flash preheater or tubular heater maintained at 200° ± 5° F.;

V is a storage vat maintained at about 130° F.;

E is the Ejector-Condenser;

X is a milk feeding pump;

Y is a concentrated milk discharging pump;

Z is a water pressure pump, giving a pressure of about 110 lbs. per square inch.

For a proper operation of the flash preheater, that is to maintain a constant temperature of 200° F., it is necessary to have an automatic pressure reducing valve on the main steam pipe so that the variation of steam pressure in the boiler will not affect the steam pressure on the equipment used during the operation. A reduced pressure of 35 pound gauge is desirable for the operation of the Vacreator. (1)

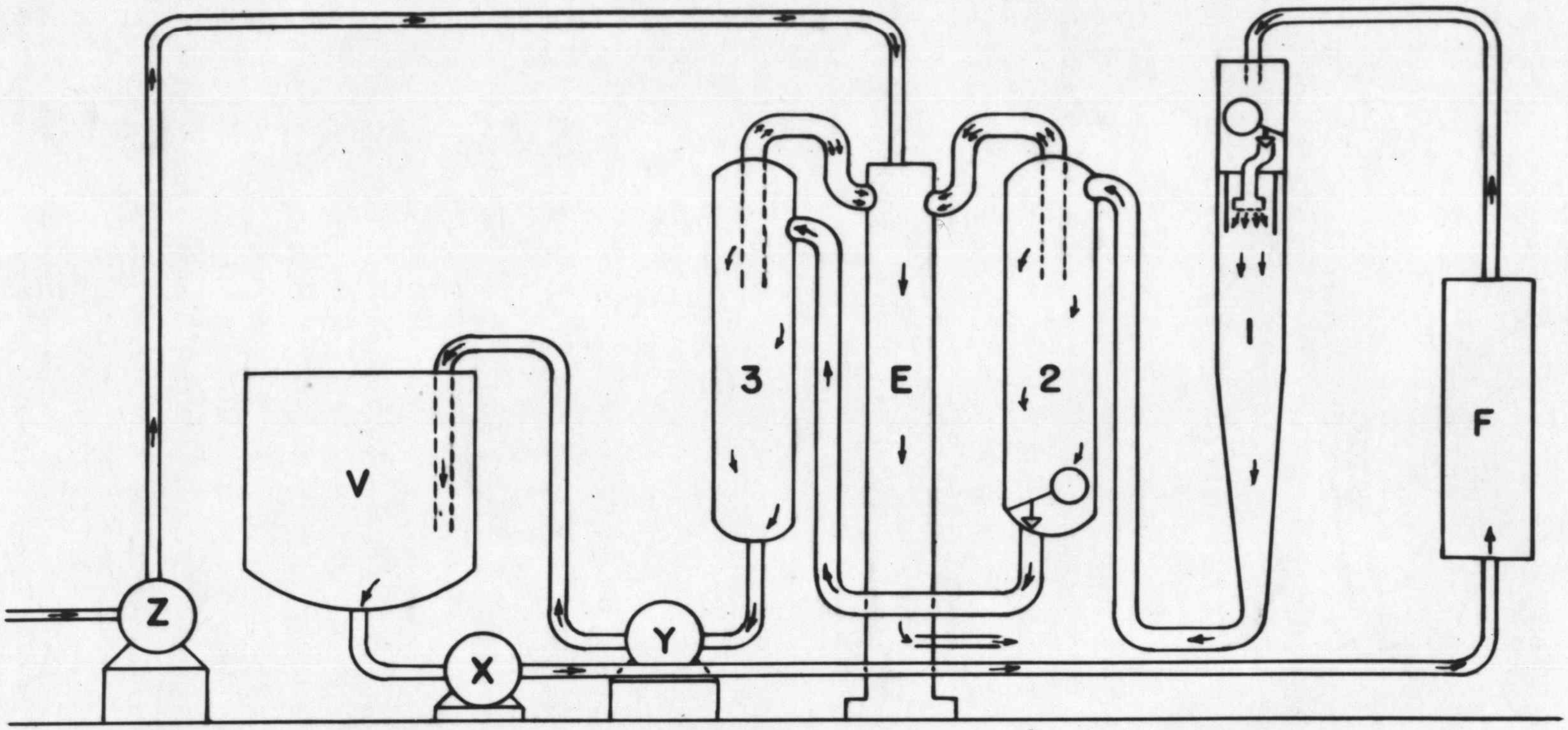

FIG. 2 DIAGRAM ILLUSTRATING FLOW CYCLE OF CONDENSING MILK WITH VACREATOR

IV. The Efficiency and Economic Aspect of the Vacreator as a Milk Evaporator

There are three sizes of stainless steel Vacreators manufactured by the Murray Company of New Zealand. The Cherry-Burrell Dairy Machinery Co. has manufactured some recently, but they are of slightly different specifications. The specifications for the present machines are, as follows (14):

	"Baby" size	"Junior" size	"Senior"
Capacity, pounds per hour when pasteurizing	2,500 (cream)	5,000 (cream)	12,000 (cream) 15,000 (milk)
Water required in the Ejector-Condenser when pasteurizing - U. S. gallons per minute	18-24	29-42	35-51
Motor requirements			
Water pump	3-5 hp	5 hp	7.5 hp
Discharge pump	2 hp	2 hp	3 hp
Shipping weight (without motor)	1,350 lb	2,000 lb	3,700 lb

Wilster's experiment on condensing skim milk with the "Baby" size Vacreator showed that its water-evaporating capacity ranged from 300 to 500 pounds per hour with an average of 400 pounds (14). With the "Junior" size, the water-evaporating capacity ranged from 700 to 1000 pounds per hour, with an average of 900 pounds for skim milk, and 700 to 850 pounds with an average of 750 pounds for whole milk. These variations in water-evaporating capacity are mainly due to the variation of the inflow of milk into the Vacreator from the flash preheater. Later, this point is proved experimentally in this research.

Baker and Arents (14) reported that the cost of removing one pound of water from skim milk would be about 0.112 cent with the "Baby" size Vacreator and 0.109 cent with the "Junior" size, provided the condensate would be returned to the boiler.

V. Determination of the Total Solids Content of Condensed Milk

The gravimetric method for the determination of the total solids of condensed milk by means of the Mojonnier Tester is accurate. However, it takes time and expensive equipment to do the job. The other methods are the use of a Baumé hydrometer and the pycnometer. Wilster has worked out a table (14) showing the relation of degree Baumé to total solids in unsweetened condensed skim milk. The table ranges from 8.3 degrees Baumé to 9.45 with their corresponding total solids in percentage. The Baumé readings are made at 60° F. (See Table V.). This table shows that there is a definite correlation between Baumé degree and the percentage of total solids content of the condensed skim milk. A mathematical equation to represent their relation is of scientific interest, and may be of practical value.

There is a definite relation between the specific gravity of fresh whole milk and its percentage of fat and total solids. The mathematical formulae for computing the percentage of total solids of a given milk of known specific gravity and fat test were first worked out by Fleischmann of Germany in 1882 (2), (12), as below:

$$T = 0.2665 \frac{100\ S - 100}{S} + 1.2\ F$$

where T is the total solids of the whole milk, S is its specific gravity at 15° C., and F is its fat test.

Richmond (2), (12) modified the formula into:

$$T = 0.25\ L + 1.2\ F + 0.14$$

in which L is the Quevenne lactometer reading and 0.14 is a correcting factor.

Babcock (12) further simplified it into:

$$T = 0.25\ L + 1.2\ F$$

Overman, Davidson and Sanmann (9) made an extensive comparison of the total solids as determined by Babcock's equation, and total solids determined by the official gravimetric method. They developed the formula, as follows:

$$T = 0.25\ L + 1.2\ F + 0.105$$

Sharp and Hart (5) in 1936 published their equations, as follows:

$$\text{Total solids} = 1.2648 \text{ Fat} + 0.2586 \text{ Lactometer}$$

$$\text{Total solids} = 1.2537 \text{ Fat} + 0.2680 \frac{\text{Lactometer}}{\text{Sp. gr. milk}}$$

Herrington (5) in 1946 checked Sharp and Hart's equations by means of calculation and revised them into a new equation based on Quevenne lactometer reading at 30° C.:

$$\text{Total solids} = 1.2648 \text{ Fat} + 0.2594 \ (Q + 3)$$

The Baumé hydrometer test is commonly used for the density test of condensed milk. However, Hunziker (7) stated that: "Information is needed as to the correct Baumé reading for any desired composition or concentration of the finished product. In such a case, the availability of a suitable specific gravity formula is of tangible assistance."

The relation of Baumé degree (°Bé.) and specific gravity for liquids heavier than water is represented by the following formula:

$$145 - \frac{145}{\text{Specific gravity at } 60^\circ \text{ F.}} = \text{Bé. at } 60^\circ \text{ F.}$$

The Baumé reading varies with the temperature. The deviation factor for each degree Fahrenheit different from the standard temperature is $\pm$ 0.03 depending on whether it is above or below it.

Doan (14) worked out a formula showing the relation of the total solids content of condensed skim milk and its corresponding specific gravity at 60° F., as follows:

$$\frac{(\text{sp. gr. at } 60^\circ \text{ F.} \times 100 - 100) \times 2.751}{\text{sp. gr. at } 60^\circ \text{ F.}} = \text{per cent total solids}$$

This formula can be converted into Baumé reading at 60° F.:

$$\text{Total solids} = \frac{275.1 \times \text{degree Baumé at } 60^\circ \text{ F.}}{145}$$

The above review of literature shows that the relation of total solids in fresh whole milk to fat and specific gravity of the milk, and also in condensed skim milk to its specific gravity, can be mathematically represented in some equations. Does such a similar relationship exist in condensed whole milk? This is a question of both scientific and practical interest.

VI. Micro-Organisms in Condensed Milk

Hunziker (7) stated: "The food sanitation literature appears to be devoid of recorded epidemics of consumer illness traced to any form of concentrated milk, or to the recovery of disease germs from such milks. This is as might be expected for, in every form of concentrated milk, the temperature-time ratio of forewarming appears ample to destroy any micro-organisms of milk-borne diseases, should such germ life be present in the fresh milk received by the condensery." However, some micro-organisms do exist in condensed milk if the condensing process is not followed with sterilization. Ruehe (10) reported that plain condensed milk, freshly manufactured, from the ordinary vacuum pan had a minimum bacterial count of 2,200 per cc. and a maximum of 145,000 with an average of 27,000.

Wilster (14) reported the number of bacteria present in the finished condensed milk from the Vacreator ranged from 0 to 600 per ml. Wilster also reported that the phosphatase test of condensed milk from the Vacreator was negative.

VII. Quality of Condensed Whole Milk Made with a Vacreator

Wilster (14) reported: "The flavor of the condensed milk (made with a Vacreator) was excellent. There was no trace of either a feed flavor or a cooked or scorched flavor. An outstanding characteristic was a smooth and quite 'heavy' body . . . . There are two explanations for the production of this excellent body. One is the greater dispersion of the fat globules in the condensed milk. A microscopic examination showed the condensed milk to contain fat globules of small size with an absence of clumps . . . . Apparently the process used had a homogenizing effect on the milk. Another reason for the superior body of the condensed milk may be that a superheating effect probably took place during the heating in the continuous heater . . . . The keeping quality of the condensed milk was excellent. There was no development of any undesirable flavor, such as for instance an oxidized flavor, after storage for a number of days . . . . The vacuum treatment resulted . . . . in less cooked flavor, probably because of the removal of some of the sulfur odors." The cooked flavor, as found by Gould and Sommer (4) is caused by the formation of certain sulphydryl compounds in the milk by the action of heat. Therefore, evaporation under partial vacuum favors the removal of this sulfur compound, and thus improves the flavor of the Vacreator-condensed milk.

STATEMENT OF THE PROBLEM

I. To Study the Efficiency of the Vacreator as a Condensing Unit.

Although the efficiency of a Vacreator as a condensing unit has been studied by Wilster, a further study as to its improvement by increasing the rate of inflow of milk is of practical importance.

II. To Determine the Total Solids of Condensed Whole Milk.

With the new application of a Vacreator in the field of the condensed milk industry, especially for the self-supply of this concentrated product for the ice cream plant, the problem of a simple and reliable method for the determination of the total solids content of the finished product is of practical importance. The Review of Literature shows that there is a definite relation between the total solids and specific gravity in fresh whole milk and also in condensed skim milk. Whether such a condition holds true in condensed whole milk has to be proved experimentally since the Review of Literature has shown that no such work has been done on condensed whole milk. If such a condition does exist, the total solids content of a condensed whole milk sample could be easily determined by means of a Baumé hydrometer. Furthermore, some mathematical equations to represent the relationship between the fat, total solids, and Baume reading would be of scientific interest and also of practical value.

III. To Study the Destruction of Micro-organisms During the Condensing Process of Milk with a Vacreator

The bacterial count of the condensed milk made from a Vacreator as shown by Wilster (14) is much lower than the conventional vacuum pan product as reported by Ruehe (10). It is of interest to know the whole picture of the destruction of the micro-organisms during the processing period and also the point at which the greatest drop in number of micro-organisms takes place.

IV. To Determine the Keeping Quality Test of the Vacreator-Condensed Milk

The problem of the keeping quality is important in all kind of dairy products. How well will this condensed milk keep under various conditions is of practical importance.

OUTLINE OF THE EXPERIMENTAL METHOD

I. The Condensing Process

The "Baby size Vacreator was used as a vacuum evaporator for condensing whole milk. About 1,200 pounds of fresh whole milk was preheated in a 200-gallon size revolving coil vat to about 130° F. (See Figure 2 of the flow cycle) and then continuously pumped into a flash heater or a tubular heater where it was immediately heated to about 200° F. This heated milk was continuously conducted to the Vacreator wherein it was subjected to a series of vacuum evaporation treatments. The low vacuum side (the second and the first chamber) was maintained at 24 inches of vacuum, while the high vacuum side (the third chamber) was held at 28 inches or higher. The temperature of the outgoing milk was about 110° F., since some heat had been lost through the partial vacuum evaporation in the Vacreator. This outgoing milk of reduced temperature was piped back to the storage vat to be reheated and recirculated through the Vacreator for further condensing. Thus, the milk was continuously circulating through the vat, preheater, and Vacreator until the desired concentration was obtained. The efficiency of the process with two different ingoing milk rates, namely, 85 lbs. per minute and 105 lbs. per minute, is shown in Table I.

II. Determination of the Total Solids of the Condensed Whole Milk

Two types of whole milk were used separately; namely, high testing milk, such as Jersey milk with an average fat test of about 5 per cent, and low testing milk, such as Holstein milk, with an average of about 3.4 per cent. When the evaporation process was going on, samples of partially condensed milk were taken from the vat at several intervals toward the last one third of the condensing period. Samples were immediately cooled to 60° F., by means of an ice water bath and the specific gravity, as well as the Baumé reading were determined. On the same day, the samples were analyzed for fat and total solids by the Mojonnier method. The data were finally subjected to statistical analysis. The simple correlation between each two variables of fat, Baumé, and total solids, and the multiple correlation of these three variables together were worked out. (Table III, IV, and V.)

III. Destruction of Micro-Organisms During Several Stages When Condensing Milk With a Vacreator

The following samples were taken, held in ice water, and plated immediately after collection, according to the standard methods for the determination of dairy products;

(a) Sample of raw milk before prewarming.

(b) Sample of raw milk after having been warmed to 130° F. in the storage vat.

(c) Sample of heated milk from the outlet of preheater when condensing has just started.

(d) Sample from the outlet of the Vacreator before milk enters the storage vat when condensing has just started.

(e) Samples collected from the storage vat, at the outlet of flash preheater, and also at the outlet of the Vacreator respectively at 30-minute intervals during the condensing process until it was completed.

Standard Tryptone-glucose-extract-milk agar was used for all the determinations. All the agar plates were incubated at 37° C. for 48 hours and then counts were made. The results are shown in Table VI.

IV. Keeping Quality Tests of the Vacreator-Condensed Whole Milk

A. Storage of Plain Vacreator-Condensed Milk

Samples of plain Vacreator-condensed milk were collected directly from the outlet of the Vacreator into sterilized metal cap bottles. One set was stored at 80° F. and the other at 44° F. Observations on the physical appearance of the stored samples and their flavor were made at intervals of every 12 hours for the high-temperature storage and every 7 days for the cold storage sets.

B. Storage of Frozen Condensed Milk With and Without Addition of Sucrose

One-quart samples of condensed milk were obtained from the storage vat immediately after the conclusion of the condensing process. The samples were cooled in the quart bottles with ice water to about 40° F. Four hundred grams of each condensed milk sample was weighed out in a "Sealright" one-pint paper container. Enough space was left for the expansion of the product during freezing. To the four different containers, 0 per cent, 2.5 per cent, 5 per cent, and 7.5 per cent of sucrose were added and mixed well with the condensed milk until dissolved. The samples were then placed near the fan in the hardening room of the refrigerator at 0° to 10° F. After storage of several weeks, the samples were thawed at room temperature. The physical appearance of the thawed samples and the flavor of the reconstituted milk was observed.

RESULTS OF EXPERIMENTS

I. The Efficiency of the Vacreator as a Whole Milk Condensing Unit

The efficiency of the Vacreator as a condensing unit is shown on the following page (Table I).

TABLE I

Data Showing the Efficiency of the Vacreator as a Condensing Unit for the Condensing of Whole Milk
(a) With a Flash Pasteurizer* as a Flash Preheater, the Milk Capacity of Which is About 85 Pounds Per Minute or 5,100 Pounds Per Hour

Whole Milk	Condensing Time	Ejector Water Used During Condensing	Whole Milk		Finished Condensed Milk		Ratio of Concentration	Water Removed From Whole Milk		Pounds Water Removed	
			Fat Test	Total Solids	Fat Test	Total Solids		Per Cent	Total	Per Minute	Per Hour
lbs.	min.	cu.ft.	%	%	%	%		%	lbs.	lbs.	lbs.
1200	102	283	4.02	13.17	8.65	26.71	2.03	50.7	608.4	5.96	357.6
1200	105	318	4.50	13.75	9.90	28.43	2.07	51.7	620.4	5.91	354.6
1200	105	308	4.60	14.18	10.01	29.36	2.07	51.7	620.4	5.91	354.6
1200	105	302	4.42	13.50	9.24	28.25	2.09	52.1	625.2	5.95	357.0
1200	105	315	4.43	13.61	9.63	29.58	2.17	54.0	648.0	6.17	370.2
1200	90	275	4.08	13.39	9.65	28.43	2.12	52.8	633.6	7.04	422.4
1200	90	305	4.74	13.66	10.12	29.26	2.14	53.3	639.6	7.11	426.6
1230	95	285	4.83	13.67	10.29	29.14	2.13	53.1	653.1	6.87	412.2
1230	100	311	5.09	14.38	11.71	32.32	2.25	55.6	683.9	6.84	410.4
1190	100	285	4.82	13.81	9.95	28.89	2.09	52.1	620.0	6.20	372.0
1270	100	310	4.53	13.46	9.93	29.44	2.19	54.3	689.6	6.89	413.4
1270	120	346	4.71	13.90	10.03	28.27	2.03	50.7	643.9	5.37	322.2
1270	105	318	5.04	14.16	11.44	32.53	2.30	56.5	717.6	6.83	409.8

* Creamery package type, 22 inches inside height, 11.5 inches inside diameter.

TABLE I (continued)

Data Showing the Efficiency of the Vacreator as a Condensing Unit for the Condensing of Whole Milk
(b) With a Tubular Heater* as a Flash Preheater, the Milk Capacity of Which is About
105 Pounds Per Minute or 6,300 Pounds Per Hour

Whole Milk	Condensing Time	Ejector Water Used During Condensing	Whole Milk		Finished Condensed Milk		Ratio of Concentration	Water Removed From Whole Milk		Pounds Water Removed	
			Fat Test	Total Solids	Fat Test	Total Solids		Per Cent	Total	Per Minute	Per Hour
lbs.	min.	cu.ft.	%	%	%	%		%	lbs.	lbs.	lbs.
1220	80	247	3.41	12.47	7.43	27.69	2.22	54.95	670.4	8.38	502.8
1220	90	274	3.21	11.44	7.29	26.17	2.29	56.33	687.2	7.64	458.4
1220	90	270	3.22	11.45	8.72	28.40	2.48	59.67	728.0	8.09	485.4

* Cherry-Burrell Co. 12 tubes, each tube 11 ft. in length and 1 and 3/4 inches of inside diameter

Comparison of the data (a) and (b) of Table I shows the difference in efficiency between the use of the flash pastuerizer and the tubular heater as a preheater. The results are shown in Table II, below:

TABLE II

Comparison of Data (a) and (b) of Table I

	Flash Pasteurizer	Tubular Heater	Difference
Rate of Milk Inflow Per Minute	85 lbs.	105 lbs.	20 lbs.
Average Amount Whole Milk Used in Each Batch Condensed	1,220 lbs.	1,220 lbs.	
Average Time Required For Each Batch Condensed	101.6 min.	86.7 min.	14.9 min.
Average Amount Ejector Water Used During Condensing Period	304.7 cu.ft.	263.7 cu.ft.	41.0 cu.ft.
Average Amount Water Removed From Each Batch of Milk	644.9 lbs.	695.2 lbs.	50.3 lbs.
Average Amount Water Removed Per Minute From the Milk	6.39 lbs.	8.04 lbs.	1.65 lbs.
Average Amount Water Removed Per Hour From the Milk	383.4 lbs.	482.2 lbs.	98.8 lbs.
Average Amount Ejector Water Used Per Minute During Condensing Period or	3 cu.ft. 197.29 lbs.	3 cu.ft. 197.29 lbs.	
Average Amount Ejector Water Used to Remove Pound of Water From the Milk	30.87 lbs.	24.54 lbs.	6.33 lbs.
Average Ratio of Concentration	2.13 : 1	2.33 : 1	0.2

II. Determination of the Total Solids, Fat, and Baumé Reading of Condensed Whole Milk and the Statistical Analyses of the Data

The results of the determinations for fat, total solids, and the corresponding Baumé reading of condensed whole milk samples of different concentrations are shown in Table III and Table IV. The statistical analyses (3), (11) for their relationship follows each table. For the interest of comparison between condensed whole milk and condensed skim milk with respect to their relation between total solids and Baumé reading, the data in Table V obtained by Wilster (4) on condensed skim milk of different concentrations are subjected to a similar statistical analysis.

The symbols used in the statistical analyses are, as follows:

X denotes Baumé reading at $60^\circ/60^\circ$ F.

Y denotes per cent total solids

Z denotes per cent fat

$\bar{X}$ is the mean of X

$\bar{Y}$ is the mean of Y

$\bar{Z}$ is the mean of Z

N denotes the number of samples analyzed

r denotes the correlation coefficient between two variables studied

R denotes the multiple correlation coefficient among three variables studied

Σ denotes summation

S denotes standard error of estimate

U denotes the ratio of fat to total solids

$\bar{U}$ denotes the mean of U

Y_E denotes the Y value calculated from the regression equation

Z_E denotes the Z value calculated from the regression equation

σ^2 denotes variance

σ denotes standard deviation

A. Condensed Whole Milk Made from High Testing Milk

The results of the determination of the total solids, fat, and Baumé reading of condensed whole milk of various concentrations made from high testing milk are shown in Table III.

TABLE III

Data of the Total Solids, Fat, and Baumé Reading of Condensed Milk of Various Concentrations Made From High Testing Milk

Batch No.	Total Solids (Y) %	Fat (Z) %	Baumé Reading (X) At 60° F.
1	17.26	5.67	5.7
	19.58	6.37	6.4
	21.92	7.14	7.2
	21.11	8.22	8.3
	28.25	9.24	9.3
2	16.94	5.49	5.7
	19.53	6.35	6.6
	22.08	7.09	7.4
	25.28	8.18	8.3
	29.58	9.63	9.7
3	17.61	5.88	5.9
	20.91	7.00	6.8
	24.16	8.16	7.9
	28.43	9.65	9.3
4	18.12	6.26	5.7
	21.67	7.45	6.8
	25.00	8.71	7.8
	29.26	10.12	9.1
5	17.36	6.11	5.6
	20.90	7.17	6.5
	23.63	8.30	7.3
	27.65	9.69	8.6
	29.14	10.29	9.1

(continued from previous page)

TABLE III

Data of the Total Solids, Fat, and Baumé Reading

of Condensed Milk of Various Concentrations

Made From High Testing Milk

Batch No.	Total Solids (Y) %	Fat (Z) %	Baumé Reading (X) At 60° F.
6	17.82	6.32	5.4
	20.93	7.55	6.3
	24.11	8.65	7.2
	27.73	10.04	8.3
	32.32	11.71	9.4
7	17.10	6.08	5.6
	20.01	6.99	6.5
	23.47	7.96	7.4
	26.70	9.25	8.5
	28.89	9.95	9.2
8	17.14	5.73	5.7
	19.72	6.63	6.6
	22.27	7.62	7.4
	26.59	8.97	8.6
	29.44	9.93	9.5
9.	17.34	6.03	5.6
	19.30	6.67	6.2
	21.27	7.34	6.8
	23.22	8.01	7.4
	25.80	8.90	8.2
	28.27	10.03	9.1
10	18.46	6.46	5.8
	21.74	7.60	6.8
	24.42	8.58	7.6
	28.19	9.90	8.7
	32.53	11.49	10.0

Statistical Analysis of Table III

$N = 49$

$\Sigma Y = 1,144.15$ $\Sigma Z = 392.56$ $\Sigma X = 368.8$

$\Sigma Y^2 = 27,675.0737$ $\Sigma Z^2 = 3,269.8944$ $\Sigma X^2 = 2,802.86$

$\Sigma (YZ) = 9,507.8067$ $\Sigma (XZ) = 3,021.046$ $\Sigma (XY) = 8,802.018$

$(\Sigma Y)^2 = 1,309,079.2225$ $(\Sigma Z)^2 = 154,103.3536$ $(\Sigma X)^2 = 133,079.04$

$(\Sigma Y)(\Sigma Z) = 449,147.524$ $(\Sigma X)(\Sigma Z) = 143,205.888$ $(\Sigma X)(\Sigma Y) = 417,385.920$

$\frac{(\Sigma Y)^2}{N} = 26,715.9025$ $\frac{(\Sigma Z)^2}{N} = 3,144.9664$ $\frac{(\Sigma X)^2}{N} = 2,715.8988$

$\frac{(\Sigma Y)(\Sigma Z)}{N} = 9,166.2760$ $\frac{(\Sigma X)(\Sigma Z)}{N} = 2,922.5691$ $\frac{(\Sigma X)(\Sigma Y)}{N} = 8,518.0800$

$\bar{Y} = 23.3500000$ $\bar{Z} = 8.0114286$ $\bar{X} = 7.4448980$

$\Sigma (Y-\bar{Y})^2 = \Sigma Y^2 - \frac{(\Sigma Y)^2}{N}$ $\Sigma (Z-\bar{Z})^2 = \Sigma Z^2 - \frac{(\Sigma Z)^2}{N}$ $\Sigma (X-\bar{X})^2 = \Sigma X^2 - \frac{(\Sigma X)^2}{N}$

$= 959.1712$ $= 124.8280$ $= 86.9612$

$\Sigma (Y-\bar{Y})(Z-\bar{Z}) = \Sigma YZ - \frac{(\Sigma Y)(\Sigma Z)}{N}$ $\Sigma (Z-\bar{Z})(X-\bar{X})$ $\Sigma XZ - \frac{(\Sigma X)(\Sigma Y)}{N}$

$= 341.5307$ $= 98.4769$

$\Sigma (X-\bar{X})(Y-\bar{Y}) = \Sigma XY - \frac{(\Sigma X)(\Sigma Y)}{N}$

$= 283.9380$

$U = \frac{Z}{Y}$ $\Sigma U = 16.7922$ $\Sigma U^2 = 5.7607116$

$\frac{(\Sigma U)^2}{N} = 5.75465267$ $(\Sigma U)^2 = 281.97798084$

$\Sigma (U-\bar{U})^2 = U^2 - \frac{(\Sigma U)^2}{N} = 0.0060549$

(1) Relationship of Baumé Reading and Total Solids Of Condensed Whole Milk

(a) Correlation Coefficient:

$$r_{XY} = \frac{\Sigma(X-\bar{X})(Y-\bar{Y})}{\sqrt{\Sigma(X-\bar{X})^2 \Sigma(Y-\bar{Y})^2}} = \frac{283.9380}{\sqrt{86.9612 \times 959.1712}}$$

0.9831

(b) Regression Equation:

$$Y_E = bX + a$$

$$b = \frac{\Sigma(X-\bar{X})(Y-\bar{Y})}{\Sigma(X-\bar{X})^2} = \frac{283.9380}{86.9612}$$

$$= 3.2651113$$

$$a = \bar{Y} - b\bar{X}$$

$$= 23.3500000 - 3.2651113 \times 7.4448980$$

$$= -0.9584$$

$$Y = 3.2651X - 0.9584$$

(c) Standard Error of Estimate, S_Y

$$S_Y = \sqrt{\frac{\Sigma(Y-\bar{Y})^2 (1-r^2)}{N-2}}$$

$$= \sqrt{\frac{959.1712 \times (1-0.9831339^2)}{49-2}}$$

$$= 0.8262$$

(2) Relationship of Baumé Reading and the Percentage of Fat Content of Condensed Whole Milk Made from High Testing Milk

(a) Correlation Coefficient:

$$r_{XY} = \frac{\Sigma(X-\bar{X})(Z-\bar{Z})}{\sqrt{\Sigma(X-\bar{X})^2\Sigma(Z-\bar{Z})^2}} = \frac{98.4769}{\sqrt{86.9612 \times 124.8280}}$$

$$= 0.9450$$

(b) Regression Equation:

$$Z = bX + a$$

$$b = \frac{\Sigma(X-\bar{X})(Z-\bar{Z})}{\Sigma(X-\bar{X})^2} = \frac{98.4769}{86.9612}$$

$$= 1.1324$$

$$a = Z - bX$$

$$= 8.0114286 - 1.1324 \times 7.4448980$$

$$= - 0.4193$$

$$\therefore Z = 1.1324X - 0.4193$$

(c) Standard Error of Estimate, S_Z

$$S_Z = \sqrt{\frac{\Sigma(Z-\bar{Z})^2(1-r^2)}{N-2}}$$

$$= \sqrt{\frac{124.8280 \times (1.0.9450^2)}{49-2}}$$

$$= 0.5332$$

(3) Ratio of Fat and Total Solids of Condensed Whole Milk Made From High Testing Milk

$\Sigma U = 16.7922$

Mean of the Ratio, $\bar{U} = \frac{\Sigma U}{N} = \frac{16.7922}{49}$

$= 0.3427$

or

34.27% of the total solids of the condensed milk is fat.

Variance, $\sigma^2 = \frac{\Sigma (U-\bar{U})^2}{N-1}$

$= \frac{0.0060549}{49-1}$

$= 0.00012621854$

Standard Deviation, $\sigma = \sqrt{\frac{(U-\bar{U})^2}{N-1}}$

$= \sqrt{0.00012621854}$

$= 0.0112347$

or 1.123%

(4) Relationship of Total Solids to Fat and Baumé Reading of Condensed Whole Milk Made from High Testing Milk

(a) The Regression Equation:

$$Y_E = b_1X + b_2 + a$$

Here, b_1 and b_2 are the regression coefficients of X and Z respectively. By the principle of least squares, the regression coefficients, b_1 and b_2, are the solutions of the following two normal equations:

$$\Sigma(X-\bar{X})^2 b_1 + \Sigma(X-\bar{X})(Z-\bar{Z})b_2 = \Sigma(X-\bar{X})(Y-\bar{Y}) \quad \ldots\ldots\ldots\ldots (1)$$

$$\Sigma(X-\bar{X})(Z-\bar{Z})b_1 + \Sigma(Z-\bar{Z})^2 b_2 = \Sigma(Z-\bar{Z})(Y-\bar{Y}) \quad \ldots\ldots\ldots\ldots (2)$$

$$\therefore 86.9612b_1 + 98.4769b_2 = 283.9380 \quad \ldots\ldots\ldots\ldots (1)$$

$$98.4769b_1 + 124.8280b_2 = 341.5307 \quad \ldots\ldots\ldots\ldots (2)$$

Solving equation (1) and (2) simultaneously:

$b_1 = 1.564189$ and $b_2 = 1.502020$

a is a constant

$$a = \bar{Y} - b_1\bar{X} - b_2\bar{Z}$$

$$= 23.3500000 - 1.564189 \times 1.448980 - 1.502020 \times 8.0114286$$

$$= -0.3286$$

$$Y_E = 1.5642X + 1.5020Z - 0.3286$$

(b) Multiple Correlation Coefficient:

$$R = \sqrt{\frac{\Sigma(Y_E - \bar{Y})^2}{\Sigma(Y - \bar{Y})^2}}$$

$$\Sigma(Y_E - \bar{Y})^2 = b_1\Sigma(X-\bar{X})(Y-\bar{Y}) + b_2\Sigma(Z-\bar{Z})(Y-\bar{Y})$$

$$= 1.564189 \times 283.9380 + 1.50202 \times 341.5307$$

$$= 957.11864$$

$$\Sigma(Y-\bar{Y})^2 = 959.1712$$

$$R = \sqrt{\frac{957.11864}{959.17120}} = 0.9989$$

(c) Standard Error of Estimate

$$S = \sqrt{\frac{\Sigma(Y - Y_E)^2}{N-3}}$$

$$\Sigma(Y - Y_E)^2 = 2.0526$$

$$S = \sqrt{\frac{2.0526}{49-3}}$$

$$= 0.2112$$

(B) Condensed Whole Milk Made From Low Testing Milk

The results of the determination of the total solids, fat, and Baumé reading of various concentrations of condensed whole milk made from low testing milk are shown in Table IV.

TABLE IV

Data of the Total Solids, Fat, and Baumé Reading

of Condensed Whole Milk Made From

Low Testing Milk

Batch No.	Total Solids (Y) %	Fat (Z) %	Baumé Reading (X) At 60° F.
1	15.11	4.22	5.7
	16.88	4.61	6.2
	17.68	4.95	6.7
	19.21	5.43	7.2
	20.28	5.75	7.7
2	20.81	5.74	7.6
	23.92	6.36	8.3
	25.57	6.78	8.8
	27.69	7.43	9.4
3	18.09	5.14	6.9
	20.41	5.82	7.7
	22.26	6.38	8.5
	24.00	6.83	9.0
	26.17	7.29	9.8
4	18.89	5.76	7.0
	20.96	6.14	7.7
	22.54	6.62	8.3
	23.70	6.97	8.7
	25.13	7.38	9.2
5	19.42	5.92	6.8
	20.96	6.39	7.3
	24.27	7.36	8.4
	26.84	8.24	9.3
	28.40	8.72	10.4

Statistical Analysis of Table IV

$N = 24$

$\Sigma Y = 529.19$ $\quad \Sigma Z = 152.23$ $\quad \Sigma X = 192.6$

$\Sigma Y^2 = 11,961.9563$ $\quad \Sigma Z^2 = 993.2013$ $\quad \Sigma X^2 = 1,577.84$

$\Sigma(YZ) = 3,442.8877$ $\quad \Sigma(XZ) = 1,249.638$ $\quad \Sigma(XY) = 4341.349$

$(\Sigma Y)^2 = 280,042.0561$ $\quad (\Sigma Z)^2 = 23,173.9729$ $\quad (\Sigma X)^2 = 37,094.76$

$(\Sigma Y)(\Sigma Z) = 80,558.5937$ $\quad (\Sigma X)(\Sigma Z) = 29,319.498$ $\quad (\Sigma X)(\Sigma Y) = 101.921.994$

$\frac{(\Sigma Y)^2}{N} = 11,668.419$ $\quad \frac{(\Sigma Z)^2}{N} = 965.582$ $\quad \frac{(\Sigma X)^2}{N} = 1,545.612$

$\frac{(\Sigma Y)(\Sigma Z)}{N} = 33,566.08070$ $\quad \frac{(\Sigma X)(\Sigma Z)}{N} = 1,221.64575$ $\quad \frac{(\Sigma X)(\Sigma Y)}{N} = 4,246.74975$

$\bar{Y} = 22.0496$ $\quad \bar{Z} = 6.3846$ $\quad \bar{X} = 8.025$

$\Sigma (Y-\bar{Y})^2 = \Sigma Y^2 - \frac{(\Sigma Y)^2}{N}$, $\quad \Sigma (Z-\bar{Z})^2 = \Sigma Z^2 - \frac{(\Sigma Z)^2}{N}$, $\quad \Sigma (X-\bar{X})^2 = \Sigma X^2 - \frac{(\Sigma X)^2}{N}$

$= 293.5373$ $\quad = 27.6191$ $\quad = 32.225$

$\Sigma (Y-\bar{Y})(Z-\bar{Z}) = \Sigma YZ - \frac{(\Sigma Y)(\Sigma Z)}{N}$, $\quad \Sigma (Z-\bar{Z})(X-\bar{X}) = \Sigma XZ - \frac{(\Sigma X)(\Sigma Z)}{N}$,

$\Sigma (X-\bar{X})(Y-\bar{Y}) = \Sigma XY - \frac{(\Sigma X)(\Sigma Y)}{N}$

$= 86.2796$ $\quad = 27.99225$ $\quad = 94.59925$

$U = \frac{Z}{Y} \times 100$ $\quad \Sigma U = 687.92$ $\quad \Sigma U^2 = 19,762.351$

$(\Sigma U)^2 = 473,233.9264$ $\quad \frac{(\Sigma U)^2}{N} = 19,718.0803$

$\Sigma (U-\bar{U})^2 = \Sigma U^2 - \frac{(\Sigma U)^2}{N} = 44.3427$

(1) Relationship of Baumé Reading and Total Solids Of Condensed Whole Milk Made From Low Testing Milk

(a) Correlation Coefficient:

$$r_{XY} = \frac{\Sigma (X-\bar{X})(Y-\bar{Y})}{\sqrt{\Sigma (X-\bar{X})^2 \Sigma (Y-\bar{Y})^2}} = \frac{94.59925}{\sqrt{32.225 \times 293.5373}}$$

$$0.9727$$

(b) Regression Equation:

$$Y_E = bX + a$$

$$b = \frac{\Sigma (X-\bar{X})(Y-\bar{Y})}{\Sigma (X-\bar{X})^2} = \frac{94.59925}{32.225}$$

$$= 2.935585725$$

$$a = \bar{Y} - b\bar{X}$$

$$= 22.04958333 - 2.935585725 \times 8.025$$

$$= - 1.5085$$

$$\therefore Y_E = 2.9356X - 1.5085$$

(c) Standard Error of Estimate, S_Y

$$S_Y = \sqrt{\frac{\Sigma (Y-\bar{Y})^2 (1-r^2)}{N-2}}$$

$$= \sqrt{\frac{293.5373 \times (1-0.9727^2)}{22}}$$

$$= 0.8480$$

(2) Relationship Between Baumé Reading and the Percentage of Fat Content of the Condensed Whole Milk Made From Low Testing Milk

(a) Correlation Coefficient:

$$r_{XZ} = \frac{\Sigma(X-\bar{X})(Z-\bar{Z})}{\sqrt{\Sigma(X-\bar{X})^2\Sigma(Z-\bar{Z})^2}}$$

$$= \frac{27.99225}{\sqrt{32.225 \times 27.6191}}$$

$$= 0.9383$$

(b) Regression Equation:

$$Z = bX + a$$

$$b = \frac{\Sigma(X-\bar{X})(Z-\bar{Z})}{\Sigma(X-\bar{X})^2} = \frac{27.99225}{32.225}$$

$$= 0.8687$$

$$a = \bar{Z} - b\bar{X}$$

$$= 6.38458333 - 0.86865 \times 8.025$$

$$= -0.5863$$

$$\therefore Z = 0.8687X - 0.5863$$

(c) Standard Error of Estimate, S_Z

$$S_Z = \sqrt{\frac{\Sigma(Z-\bar{Z})^2\ (1 - r^2)}{N - Z}}$$

$$= \sqrt{\frac{27.6191\ (1-0.9383^2)}{24 - 2}} = 0.3875$$

(3) Ratio of Fat and Total Solids of Condensed Whole Milk

Made From Low Testing Milk

$\Sigma U = 687.92$

Mean of the ratio, $\bar{U} = \frac{\Sigma U}{N} = \frac{687.92}{24}$

$= 28.66\%$

28.66% of the total solids of the condensed milk is fat.

Variance, $\sigma^2 = \frac{\Sigma (U-\bar{U})^2}{N-1}$

$= \frac{44.3427}{24-1}$

$= 1.92794$

Standard Deviation, $\sigma = \sqrt{1.92794}$

$= 1.388\%$

(4) Relationship of Total Solids to Fat and Baumé Reading of Condensed Whole Milk Made From Low Testing Milk

(a) The Regression Equation:

$$Y_E = b_1X + b_2Z + a$$

Here, b_1 and b_2 are the regression coefficients of X and Z respectively. By the principle of least squares, the regression coefficients b_1 and b_2 are the solutions of the following two normal equations:

$$\Sigma(X-\bar{X})^2 b_1 + \Sigma(X-\bar{X})(Z-\bar{Z})b_2 = \Sigma(X-\bar{X})(Y-\bar{Y}) \quad \ldots\ldots\ldots\ldots \quad (1)$$

$$\Sigma(X-\bar{X})(Z-\bar{Z})b_1 + \Sigma(Z-\bar{Z})^2 b_2 = \Sigma(Z-\bar{Z})(Y-\bar{Y}) \quad \ldots\ldots\ldots\ldots \quad (2)$$

$$\therefore\ 32.225b_1 + 27.99225b_2 = 94.59925 \quad \ldots\ldots\ldots\ldots \quad (1)$$

$$27.99225b_1 + 27.61910b_2 = 86.2796 \quad \ldots\ldots\ldots\ldots \quad (2)$$

Solving equations (1) and (2) simultaneously:

$$b_1 = 1.8560$$

$$b_2 = 1.2429$$

$$a = Y - b_1\bar{X} - b_2\bar{Z}$$

$$= 22.0496 - 1.8560 \times 8.025 - 1.2429 \times 6.3846$$

$$= -0.7802$$

$$Y_E = 1.8560X + 1.2429S - 0.7802$$

(b) The Multiple Correlation Coefficient

$$R = \sqrt{\frac{\Sigma (Y_E - \bar{Y})^2}{\Sigma (Y - \bar{Y})^2}}$$

$$\Sigma (Y_E - \bar{Y})^2 = b_1 \Sigma (X-\bar{X})(Y-\bar{Y}) + b_2 \Sigma (Z-\bar{Z})(Y-\bar{Y})$$

$$= 1.8560 \times 94.59925 + 1.2429 \times 86.2796$$

$$= 282.807863$$

$$\Sigma (Y-\bar{Y})^2 = 293.5373$$

$$R = \sqrt{\frac{282.807863}{293.5373}} = 0.9816$$

(c) Standard Error of Estimate

$$S = \sqrt{\frac{\Sigma (Y-Y_E)^2}{N-3}}$$

$$\Sigma (Y-Y_E)^2 = 10.729437$$

$$S = \sqrt{\frac{10.729437}{24 - 3}}$$

$$= 0.5109$$

(C) Condensed Skim Milk

The data of the total solids content of various concentrations of condensed skim milk and their corresponding Baumé reading obtained by Wilster (14) are quoted in Table V and subjected to similar statistical analysis.

TABLE V

Data Showing the Relation of Baumé Reading To Total Solids In Condensed Skim Milk

Baumé degrees at 60° F. (X)	Total Solids (Y) Per Cent	Baumé degrees at 60° F. (X)	Total Solids (Y) Per Cent
8.30	15.75	9.50	18.02
8.35	15.84	9.55	18.12
8.40	15.94	9.60	18.21
8.45	16.03	9.65	18.31
8.50	16.13	9.70	18.40
8.55	16.22	9.75	18.50
8.60	16.32	9.80	18.59
8.65	16.41	9.85	18.69
8.70	16.51	9.90	18.78
8.75	16.60	9.95	18.88
8.80	16.70	10.00	18.97
8.85	16.79	10.05	19.07
8.90	16.89	10.10	19.16
8.95	16.98	10.15	19.26
9.00	17.08	10.20	19.35
9.05	17.17	10.25	19.45
9.10	17.26	10.30	19.54
9.15	17.36	10.35	19.64
9.20	17.45	10.40	19.73
9.25	17.55	10.45	19.83
9.30	17.64	10.50	19.92
9.35	17.74	10.55	20.02
9.40	17.83	10.60	20.11
9.45	17.93		

Statistical Analysis of Table V

$N = 47$

$\Sigma Y = 842.67$ $\qquad \Sigma X = 444.15$

$(\Sigma Y)^2 = 710{,}092.7289$ $\qquad (\Sigma X)^2 = 197{,}269.2225$

$(\Sigma X)(\Sigma Y) = 374.271.8805$

$\frac{(\Sigma Y)^2}{N} = 15{,}108.35593$ $\qquad \frac{(\Sigma X)^2}{N} = 4{,}197.21175$

$\frac{(\Sigma X)(\Sigma Y)}{N} = 7{,}963.2315$

$\Sigma Y^2 = 15{,}186.5305$ $\qquad \Sigma X^2 = 4{,}218.8375$

$\Sigma XY = 8{,}004.3455$

$\bar{Y} = 17.929149$ $\qquad \bar{X} = 9.45$

$\Sigma(Y-\bar{Y})^2 = \Sigma Y^2 - \frac{(\Sigma Y)^2}{N}$ $\qquad \Sigma(X-\bar{X})^2 = \Sigma X^2 - \frac{(\Sigma X)^2}{N}$

$= 78.17457$ $\qquad = 21.62575$

$$\Sigma(X - \bar{X})(Y - \bar{Y}) = \Sigma XY - \frac{(\Sigma X)(\Sigma Y)}{N} = 41.114$$

Relationship of Baumé Reading To The Total Solids

Content of Condensed Skim Milk

(a) Correlation Coefficient:

$$r_{XY} = \frac{\Sigma(X-\bar{X})(Y-\bar{Y})}{\sqrt{\Sigma(X-\bar{X})^2 \Sigma(Y-\bar{Y})^2}} = \frac{41.114}{\sqrt{21.62575 \times 78.17457}}$$

$$0.9999$$

(b) Regression Equation:

$$Y_E = bX + a$$

$$b = \frac{\Sigma(X-\bar{X})(Y-\bar{Y})}{\Sigma(X-\bar{X})^2} = \frac{41.114}{21.62575}$$

$$= 1.9012$$

$$a = \bar{Y} - b\bar{X}$$

$$= 17.929149 - 1.9012 \times 9.45$$

$$= -0.0368$$

$$\therefore Y_E = 1.9012X - 0.0368$$

(c) Standard Error of Estimate, S_{Y_E}

$$S_{Y_E} = \sqrt{\frac{\Sigma(Y-\bar{Y})^2 (1-r^2)}{N-2}}$$

$$\sqrt{\frac{78.17457 \times (1-0.9999^2)}{47-2}} = 0.0151$$

(D) Comparison and Checking of the Equations

The results of the above statistical analysis are summarized, checked, and compared with each other in Tables VI, VII, VIII and IX.

TABLE VI

Summary of the Statistical Analysis of Condensed Whole Milk and Condensed Skim Milk

	Condensed Whole Milk Made From High Testing Milk	Condensed Whole Milk Made From Low Testing Milk	Condensed Skim Milk
Regression Equation for Total Solids and Baumé Reading	$Y_E = 3.2651X - 0.9584$	$Y_E = 2.9356X - 1.5085$	$Y_E = 1.9012X - 0.0368$
Correlation Coefficient	$r = 0.9831$	$r = 0.9727$	$r = 0.9999$
Standard Error of Estimate	$S = 0.8262$	$S = 0.8480$	$S = 0.0151$
Regression Equation for Fat and Baumé Reading	$Z_E = 1.1324X - 0.4193$	$Z_E = 0.8687X - 0.5863$	
Correlation Coefficient	$r = 0.9450$	$r = 0.9383$	
Standard Error of Estimate	$S = 0.5332$	$S = 0.3875$	
Mean of Ratio of Fat Over Total Solids	$\bar{U} = 34.27\ \%$	$\bar{U} = 28.66\ \%$	
Standard Deviation	$\sigma = 1.123\ \%$	$\sigma = 1.388\ \%$	
Regression Equation For Total Solids, Fat, and Baumé Reading	$Y_E = 1.5642X + 1.5020Z - 0.3286$	$Y_E = 1.8560X + 1.2429Z - 0.7802$	
Multiple Correlation Coefficient	$R = 0.9989$ $S = 0.2112$	$R = 0.9816$ $S = 0.5109$	

TABLE VII

Comparison of Calculated and Actual Per Cent Total Solids in Condensed Whole Milk

Condensed Whole Milk Made From	Baume′ Reading (X)	Actual Fat % (Z)	Total Solids % (Y_E) Calculated By Equation		Actual Total Solids % (Y)	Difference in Per Cent of Total Solids	
			(1)	(2)		(1)	(2)
High Testing Milk	7.4	7.09	23.21	21.90	22.08	+ 1.13	- 0.18
	9.3	9.65	29.41	28.72	28.43	+ 0.98	+ 0.29
	8.5	9.25	26.78	26.86	26.70	+ 0.09	+ 0.16
	10.0	11.49	31.69	32.57	32.53	- 0.84	+ 0.04
	9.7	9.63	30.71	29.31	29.58	+ 1.13	- 0.27
			(3)	(4)		(3)	(4)
Low Testing Milk	7.7	5.75	21.10	20.66	20.28	+ 0.82	+ 0.38
	9.0	6.83	24.92	24.41	24.00	+ 0.92	+ 0.41
	8.3	6.62	22.86	22.85	22.54	+ 0.32	+ 0.31
	8.7	6.97	24.03	24.03	23.70	+ 0.33	- 0.33

Note (1) $Y_E = 3.2651X - 0.9584$ (3) $Y_E = 2.9356X - 1.5085$

(2) $Y_E = 1.5642X + 1.5020Z - 0.3286$ (4) $Y_E = 1.8560X + 1.2429Z - 0.7802$

TABLE VIII

Comparison of Calculated and Actual Per Cent Fat in Condensed Whole Milk

Condensed Whole Milk Made From	Baume´ Reading (X)	Actual Fat % (Z)	Actual Total Solids % (Y)	Per Cent Fat (Z_E) Calculated By Equation		Difference in Per Cent of Fat	
				(1)	(2)	(1)	(2)
High Testing Milk	9.3	9.24	28.25	10.09	9.68	+ 0.85	+ 0.44
	7.8	8.71	25.00	8.41	8.57	- 0.30	- 0.14
	8.5	9.25	26.70	9.21	9.15	- 0.04	- 0.10
	8.7	9.90	28.19	9.43	9.66	- 0.47	- 0.24
	9.1	10.03	28.27	9.89	9.69	- 0.14	- 0.34
				(3)	(4)	(3)	(4)
Low Testing Milk	7.7	5.75	20.28	6.10	5.81	+ 0.35	+ 0.06
	9.8	7.29	26.17	7.93	7.50	+ 0.64	+ 0.21
	8.7	6.97	23.70	6.97	6.79	- 0.00	- 0.18
	9.3	8.24	26.84	7.49	7.69	- 0.75	- 0.55

Note (1) $Z_E = 1.1324X - 0.4193$

(2) $Z_E = Y \times 34.27\%$

(3) $Z_E = 0.8687X - 0.5863$

(4) $Z_E = Y \times 28.66\%$

TABLE IX

Comparison of Calculated and Actual

Per Cent Total Solids

in Condensed Skim Milk

Baumé Reading at 60°/60°F.	Calculated Total Solids By Equation (1)	Calculated Total Solids By Equation (2)	Actual Total Solids	Difference In Per Cent of Total Solids (1)	Difference In Per Cent of Total Solids (2)
8.5	16.123	16.126	16.13	- 0.007	- 0.004
8.7	16.504	16.506	16.51	- 0.006	- 0.004
9.0	17.074	17.075	17.08	- 0.006	- 0.005
9.3	17.644	17.644	17.64	+ 0.004	+ 0.004
9.9	18.785	18.783	18.78	+ 0.005	+ 0.003

Note (1) $Y_E = 1.9012X - 0.0368$

(2) $\text{Total Solids} = \frac{275.1 \times \text{degree Baumé at } 60^\circ \text{ F}}{145}$

III. Destruction of the Micro-Organisms During the Condensing Process

The results of the determination of the destruction of micro-organisms present in the whole milk during the condensing process with the Vacreator are in the following tables:

TABLE X

Data Showing the Reduction of Bacterial Counts During the Condensing Process of Whole Milk with the Vacreator

Trial 1

Jan.25,1946 Samples	Temp. °F.	Bacterial Counts Per ml. 0 min.	30 min.	60 min.	90 min.	120 min.	130mi.
Raw	44	410,000					
Coil Vat	130-140	480,000	1,750	200	100	90	
Preheater	190-200	1	3	20	160	60	
Vacreator	100-110	10	8	80	10	80	
Finished Condensed Milk	130-140						190

Trial 2

Jan.30,1946 Samples	Temp. °F.	Bacterial Count Per ml. 0 min.	30 min.	60 min.	90 min.	120 min.	130mi.
Raw	44	20,000					
Coil Vat	130-140	24,000	7,400	230	300		
Preheater	190-200	10,000	1,050	100	100		
Vacreator	100-110	22,000	4,100	200	70		
Finished Condensed Milk	130-140					130	

Trial 3

Feb.15,1946 Samples	Temp. °F.	Bacterial Count Per ml. 0 min.	30 min.	60 min.	90 min.
Raw	48	8,000			
Coil Vat	130-140	26,000	200	200	
Preheater	190-200	310	900	200	
Vacreator	100-110	600	100	120	
Finished Condensed Milk	130-140				70

TABLE X (continued)

Trial 4

Feb.28,1946 Samples	Temp. °F.	Bacterial Count Per ml. 0 min.	30 min.	60 min.	90 min.	120 min.
Raw	44	500,000				
Coil Vat	130-140	200,000	3,400	3,200	1,400	
Preheater	190-200	6,000	180	200	1,000	
Vacreator	100-110	6,000	2,100	1,200	1,000	
Finished Condensed Milk	130-140					500

Trial 5

Mar.6,1946 Samples	Temp. °F.	Bacterial Count Per ml. 0 min.	30 min.	60 min.	90 min.
Raw	46	140,000			
Coil Vat	140-150	12,000	800	280	
Preheater	185-195	140	350	270	
Vacreator	100-110	220	340	210	
Finished Condensed Milk	140				300

TABLE XI

Logarithmic Average of Trials in Table X

Samples	Temp. °F.	Bacterial Count Per ml. 0 min.	30 min.	60 min.	90 min.	
Raw	45	85,590				
Coil Vat	135	59,070	1477	383	244	
Preheater	195	304	178	116	212	
Vacreator	105	705	319	217	88	
Finished Condensed Milk	135					191

IV. Keeping Quality Test of Vacreator-Condensed Whole Milk

A. Plain Vacreator-Condensed Whole Milk Stored at 80° F. and 44° F.

The results of the keeping quality of plain Vacreator-condensed whole milk stored at 80° F. and 44° F. are shown in Table XII.

TABLE XII

Data Showing the Flavor of Vacreator-Condensed Whole Milk Stored at 80° F. and at 44° F. Respectively

Trial No.	Storage Temperature °F.	Flavor 12 hr.	24 hr.	36 hr.	48 hr.	7 days	14 days	21 days
1	80	-	-	-	x			
	44	-	-	-	-	-	-	x
2	80	-	-	-	x			
	44	-	-	-	-	-	-	x
3	80	-	x					
	44	-	-	-	-	-	x	
4	80	-	-	x				
	44	-	-	-	-	-	x	
5	80	-	-	-	x			
	44	-	-	-	-	-	x	

Notes: - denotes satisfactory flavor
x denotes undesirable flavor which may be sour, bitter, or cheesy

B. Frozen Vacreator-Condensed Whole Milk With and Without Addition of Sucrose

The results of the keeping quality of frozen Vacreator-condensed whole milk are shown in Table XIII.

TABLE XIII

Data Showing the Flavor of Frozen Vacreator-Condensed Whole Milk With and Without Addition of 2.5%, 5.0%, and 7.5% of Sucrose

Trial No.	Storage Period Days	Physical Appearance of Thawed Out Condensed Whole Milk				Flavor of Reconstituted Milk			
		Per Cent Sucrose				Per Cent Sucrose			
		0.0%	2.5%	5.0%	7.5%	0.0%	2.5%	5.0%	7.5%
1	8	s	s	s	s	fine	fine	fine	fine
	19	c	st	s	s	fine*	fine	fine	fine
	34	c	t	s	s	fine*	fine	fine	fine
2	6	s	s	s	s	fine	fine	fine	fine
	19	t	st	s	s	fine	fine	fine	fine
	34	c	t	s	s	fine*	fine	fine	fine

Notes: s denotes a smooth and creamy appearance
c denotes curdled condition
st denotes slightly thickening
t denotes a thickened condition
* denotes flavor was fine but the texture was poor due to curdled particles

DISCUSSION OF THE EXPERIMENTAL RESULTS

I. The efficiency of the Vacreator as a whole milk condensing unit was studied. The use of a tubular heater instead of a flash pasteurizer had greatly increased the rate of condensing. The average rate of condensing or the speed of the removal of water from the whole milk was 6.39 lbs. per minute when the flash preheater was used, and 8.04 lbs. per minute when the tubular heater was used. A difference of 1.65 lbs. per minute in favor of the tubular heater was evident, due mainly to the difference in the rate of ingoing milk through the heater into the Vacreator, as all other conditions regarding vacuum and temperature were the same. With the flash preheater, the rate of inflow was only about 85 lbs. per minute. When the tubular heater was used, it was 105 lbs. per minute. A difference of 20 lbs. per minute in the rate of ingoing milk results in an important difference in the efficiency of the machine as a condensing unit. An effort had been made to increase the rate of inflow of milk to the Vacreator. It was found that 105 lbs. per minute, or 6,300 lbs. per hour, was the average maximum intake capacity of the Vacreator. Therefore, it may be concluded that, for the optimum operation of the "Baby" size Vacreator as a condensing unit, the following conditions must be observed:

(1) The ingoing rate of milk should be maintained at 105 lbs. per minute;

(2) the milk entering the Vacreator should be maintained at 200° F. ± 5° F.;

(3) the vacuum of the second chamber should be maintained at 24 inches and the third chamber at 28 inches, or higher. To maintain the proper vacuum and also for condensing the water vapor, the speed of the ejecting water passing through the Ejector-condenser, as usually used at the Dairy Products Laboratory, Oregon State College, is about 3 cu. ft. per minute or 197.29 lbs. per minute.

II. The statistical analysis of the relationship of total solids (Y), fat (Z), and Baumé reading (X) of condensed whole milk made from both high and low testing milk, and also the total solids and Baumé reading of condensed skim milk, shows that there are certain definite correlations between each of the two factors and also among the three factors together. Their correlation coefficients range from 0.9383 to 0.9999. Such a high correlation coefficient indicates they are closely related to each other, and each one of them can be served as an index for the measuring of the other. For the convenience of comparison, the results of the statistical analyses were summarized in Table VI. Judging from the data in Table VI, it is evident that the regression coefficients of fat (Z) and Baumé reading (X) for the three different types of condensed milk products, namely,

(1) Condensed whole milk made from high testing milk

(2) Condensed whole milk made from low testing milk

and (3) Condensed skim milk,

in all the four different cases of correlation are widely apart in their figurative values. This indicates that, for different types of condensed milk products, different corresponding regression equations should be used. To prove the usefulness of the equations, data selected at random from Tables III, IV, and V were used to check with the calculated value. Tables VII, VIII, and IX, presented previously, show the results of comparison.

It is noted that the differences of the calculated values and the actual values obtained by gravimetric method are within the standard error estimated for each equation. It seems that, of all the equations, obtained, the regression equation

$$Y_E = 1.5642X + 1.5020Z - 0.3286,$$

with a standard error of estimate of 0.2112 for the condensed whole milk made from the high testing milk and also the regression equation

$$Y_E = 1.9012X - 0.0368$$

with a standard error of estimate of 0.0151 for the condensed skim milk are most accurate. The results obtained when they are used, compared with those obtained from the actual determinations, show practically no difference. Therefore, the above two stated equations appear to be reliable for practical application. The formula developed by Doan (14) for the calculation of the total solids of condensed skim milk is practically identical with the formula derived in this research. Although the formulae, other than the above two as listed in Table VI, are not quite so accurate, they do show a certain relationship between the different factors. They could be used for an approximate determination. Further work should be done to improve their accuracy, as their correlation coefficients are quite high.

III. The efficiency of the destruction of micro-organisms during the condensing process by the Vacreator was studied. The results were summarized in Table XI. It was found that a considerable decrease in the bacterial count took place after 30 minutes of processing. The high-temperature, short-time heating treatment was the one that destroyed most of the micro-organisms. This was clearly illustrated by the fact that the bacterial count dropped rapidly from 59,070 per ml. in the raw milk in the holding vat to 304 per ml. of the milk from the flash preheater. This tendency of drop in count holds true throughout the whole process. There was a slight increase in count when milk passed through the Vacreator. The logarithmic average of the bacterial count of the finished condensed milk was about 200 per ml. Further experiments on the identification of the survival of micro-organisms would be of considerable interest.

IV. The keeping quality of plain Vacreator-condensed whole milk was studied under two different temperature conditions. Data in Table XII shows that the plain condensed whole milk can be stored at 80° F. for a maximum possible period of 48 hours. However, the safety margin storage period was only 12 hours. Storage at 44° F. was more satisfactory. The maximum possible storage period was 21 days, but 7 days was the probable safety period.

The flavor study of frozen condensed whole milk with and without the addition of sucrose shows that addition of a small percentage of sucrose definitely improved its keeping quality. It seems that sugar has a stabilizing effect on the protein and thus prevents early thickening of the condensed milk. Five percent of sucrose seems to be the proper amount for a storage period of 34 days. Although 7.5 per cent sucrose showed the same result, it is not economical to add more sucrose than it requires. Furthermore, the extra sweetness may not be liked by those who prefer a plain fresh whole milk flavor.

SUMMARY

1. The use of a Vacreator as a whole milk condensing unit was successfully demonstrated. Weekly since 1945 1200 pounds of whole milk was condensed with a "Baby" size Vacreator to about 2.1 : 1 concentration for use in ice cream mix at the Dairy Products Laboratory of Oregon State College. This is about the same condensing factor as when manufacturing commercial evaporated milk.

2. With an ingoing rate of milk at 105 pounds per minute, or 6300 pounds per hour, an average of 8.04 pounds per minute, or 482.4 pounds per hour, of water could be removed from the whole milk with the "Baby" size Vacreator. The temperature of the ingoing milk was maintained at about 200° F., the low vacuum side of the Vacreator was maintained at 24 inches of vacuum, and the high vacuum side at 28 inches or higher.

3. An increase in the rate of milk inflow up to the intake capacity of the Vacreator increased the speed of condensing when all other conditions were the same.

4. The average amount of water used by the Ejector-condenser during the condensing period was 3 cu. ft., or 197.29 lbs. per minute.

5. The relation of total solids (Y), fat (Z), and Baumé reading (X) at 60° F. of unsweetened condensed whole milk made from high testing milk (e.g. Jersey milk) can be represented by the following equations:

(a) The relation of total solids and Baumé reading:

$Y_E = 3.2651X - 0.9584$

whose correlation coefficient, $r = 0.9831$

standard error of estimate, $S = 0.8262$

(b) Relation of fat and Baumé reading:

$Z_E = 1.1324X - 0.4193$

whose correlation coefficient, $r = 0.9450$

standard error of estimate, $S = 0.5332$

(c) The ratio of fat over total solids:

The mean of $\frac{Z}{Y} = 0.3427$ or 34.2%

standard deviation, $\sigma = 1.123\%$

(d) The multiple relation of total solids, fat, and Baume

$Y_E = 1.5642X + 1.5020Z - 0.3286$

whose multiple correlation coefficient, $R = 0.9989$

standard error of estimate, $S = 0.2112$

6. The relation of total solids (Y), fat (Z), and Baumé reading (X) of unsweetened condensed whole milk made from low testing milk (e.g. Holstein milk) can be represented by the following equations:

(a) The relation of total solids and Baumé reading:

$Y_E = 2.9356X - 1.5085$

whose correlation coefficient, $r = 0.9727$

standard error of estimate, $S = 0.8480$

(b) The relation of fat and Baumé reading:

$Z_E = 0.8687X - 0.5863$

whose correlation coefficient, $r = 0.9383$

standard error of estimate, $S = 0.3875$

(c) The ratio of fat over total solids:

The mean of $\frac{Z}{Y} = 0.2866$ or 28.66%

standard deviation $\sigma = 1.388\%$

(d) The multiple relation of total solids, fat, and Baumé:

$Y_E = 1.8560X + 1.2429Z - 0.7802$

whose multiple correlation coefficient, R 0.9816

standard error of estimate, $S = 0.5109$

7. The relation of total solids (Y) and Baumé reading (X) of unsweetened condensed skim milk can be represented by the equation below:

$Y_E = 1.9012X - 0.0368$

whose correlation coefficient, $r = 0.9999$

standard error of estimate, $S = 0.0151$

8. The bacterial count of milk in the milk storage vat gradually decreased throughout the condensing process, but the decrease was especially rapid during the first 30 minutes. At the end of the first 30 minutes, the average bacterial count of the partially condensed milk in the vat was 1500 per ml.

9. The average bacterial count of the milk directly from the Vacreator was approximately 100 per ml.

10. The average bacterial count of the finished Vacreator-condensed whole milk in the storage vat was about 200 per ml.

11. Plain Vacreator-condensed whole milk could be satisfactorily stored at 80° F., for about 12 hours, and at 44° F. for about 7 days.

12. When 5.0 per cent sucrose was added to the condensed milk, this could be stored satisfactorily for about 34 days at 0° to 10° F. without protein destabilization taking place.

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RELATION OF PRESSURE TO THE BOILING POINT OF WATER

TABLE XIV

Boiling Point of Water at Different Partial Vacuums

Vacuum Gauge Inches	Boiling Point Degrees F.	Vacuum Gauge Inches	Boiling Point Degrees F.
0	212.0	23.5	143.4
1	210.2	24.0	140.4
2	208.6	24.5	136.9
3	207.0	25.0	133.2
4	204.8	25.5	129.2
5	203.0	26.0	124.7
6	201.0	26.5	119.7
7	198.9	27.0	114.1
8	196.7	27.5	107.6
9	194.5	28.0	99.9
10	192.2	28.1	98.1
11	189.7	28.2	96.3
12	187.2	28.3	94.3
13	184.6	28.4	92.1
14	181.8	28.5	90.0
15	178.9	28.6	87.6
16	175.8	28.7	85.3
17	172.6	28.8	82.6
18	169.0	28.9	80.4
19	165.2	29.0	76.6
20	161.2	29.1	73.2
20.5	159.1	29.2	69.3
21.0	156.7	29.3	64.9
21.5	154.4	29.4	59.9
22.0	151.9	29.5	54.1
22.5	149.2	29.6	46.9
23.0	147.2	29.7	37.0

Zero inch mercury on vacuum gauge = 760 mm. mercury column or 14.7 pounds per square inch absolute.

29.92 inches mercury on vacuum gauge = zero mm. mercury column or total vacuum.