T H E S I S

on

THE MANUFACTURE OF BUTTER FROM REFRIGERATED CREAM

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I. INTRODUCTION

A recently conducted survey (1) by the Oregon Agricultural Experiment Station has shown that a large percentage of the butter made in Oregon is of a mediocre quality and that considerable of the butter is of a low grade. The survey indicated that if there is to be made any great improvement in Oregon's butter it must be brought about through improved methods of manufacture and the improvement in the quality of the raw material.

A large amount of the cream received at the Oregon creameries comes from small or medium size dairy herds. Very often it is not possible or economical because of high transportation costs to ship the cream to the creamery oftener than once, twice, or three times a week. Holding the cream for long periods of time on the farm may cause a lowering of the quality of the cream because most of the farms do not have facilities for properly cooling and storing it, and it may mean a reduction in the price which the producer is receiving for cream, especially when he is sending cream to a creamery which pays a premium for higher grade cream. In order to maintain a high quality it is necessary either to increase the size of the herds so that frequent deliveries, such as daily or every other day, are possible, coupled, of course, with the observation of proper sanitary methods of production and the protection of cream during transit, or to use improved methods of cooling and storing of cream on the farms. If cream can be kept at temperatures which will largely prevent the development of bacteria, yeasts and molds, the growth of which may cause serious deterioration in the quality of the cream through the development of acidity and undesirable flavors and odors, it would seem

that it would be possible to hold cream for three to four days without any significant decrease in the quality.

The average score of Oregon's butter is now approximately 90.5. (2) The demand for higher scoring butter is increasing, especially in California, and higher prices are paid for the higher grades. The production of butter in Oregon in 1930 was 26,725,350 pounds (3). The average wholesale price for 92 score butter, according to the United States Department of Agriculture, on the San Francisco market, for the year 1930, was 3.04 cents higher than the average price for 90 score butter. If one-half of Oregon's butter scores 90.50 and below, and the score of this amount was raised to a uniform 92.00, on the basis of 3.04 cents per pound difference between the two scores it would result in an increased income to the creameries of over $406,000. The production of higher quality butter would probably stimulate consumption and create a greater demand for it on out of state markets.

The California market is the principal outlet for surplus butter from the Northwest and Intermountain states. Oregon ships most of its surplus butter to San Francisco or Los Angeles. It comes into competition there with butter manufactured in California and in other states. The buyers are anxious to secure representative lots of butter scoring 92.00 and higher.

Sweet cream, if of a good flavor, using the best manufacturing methods, should result in the production of butter scoring 92.00 to 93.00, whereas high acid, yeasty, or otherwise badly fermented cream usually results in butter scoring 88.00 to 89.00. There was an average difference of 3.74 cents in the price paid for 88.00 and 92.00 score

butter on the New York and Chicago markets in 1930 (4). This means a difference of 4.64 cents in the value of a pound of butterfat. The proper checking of microbial fermentations in cream by refrigeration may mean the raising of the quality of much of the second-grade cream, which is now received at the creameries, and bringing it into the first grade and sweet cream classes.

II. HISTORICAL AND REVIEW OF LITERATURE

A. Refrigeration

1. History of refrigeration

The following references to the early use of refrigeration were mentioned by Riek (5) and Hull (6).

"The word refrigeration is derived from the Latin word "frigus", meaning frost. Present usage has it, however, that refrigeration is the cooling of a body by the transfer of a portion of its heat to another, which needs to be, of course, a cooler body. The ancient Egyptians, Greeks, and Romans made use of this fact by placing their jars of wine and water in porous water filled vessels which extracted some of the heat from the liquids through evaporation."

"Simonides of Keos, an early Greek lyric poet, who lived about 500 B.C., mentioned, in one of his odes, the cooling of wine."

"Alexander the Great, King of Macedon (B.C. 336-323), had trenches dug and then filled with snow. He used this to cool hundreds of kegs of wine which were given to his soldiers on the eve of battle."

"The use of salt petre for cooling liquids was known and practiced at an early date in India. Tancrelus, in 1607, mentions the freezing of water by a mixture of salt petre and snow."

"Iced fruits were brought to the table in Italy during the beginning of the Seventeenth Century."

"Lord Francis Bacon, prominent English philosopher and statesman (1561-1626), realized the importance of refrigeration and what a boon to

mankind it would be, once control could be made of it."

"In the early part of the 19th century, the ice box came into use. Naturally frozen ice obtained from ponds was placed in the ice compartment, and the melting of the ice produced a circulation of cold air which cooled the foods."

"Reference is made in 1799 to the first cargo of ice sent from New York to Charleston."

"Credit for one of the first commercial machines to freeze water is given to the Carre' Brothers. This was the ammonia absorption type and appeared about the middle of the 19th century."

"In 1824 reference is made to a machine by Vallance of France which is closely followed in 1834 by Jacob Perkins. Perkins' ether-compression machine is the forerunner of the modern compression type."

The next important step was the use of manufactured ice. In 1922, dairy refrigerating plants alone produced 126,000,000 tons of ice, as reported by Hull (5). Hull (5) stated, "during the last twenty-seven years, the household refrigerating machine has been under rapid development. It is only within the last twelve years, however, that machines have been manufactured in quantities and proven a commercial success."

The use of cooling processes on dairy farms has been restricted to the use of water, natural ice, and ice and salt, though at an early date the value of small artificial refrigerating machines for cooling milk and cream was recognized and their use predicted for the future. Stewart and Atwood in 1908 (7) stated that "small refrigerating plants have a big field of usefulness on the better class of dairy farms which supply milk and cream to our towns and cities for direct consumption."

This is the earliest mention found of the refrigeration of cream. Since that time several workers have recognized the value of the small refrigerator on the farm. Bowen in 1914 (8) discussed size and cost of plants, cooling cream on the farm and at the receiving stations, and keeping the cream cold during transportation.

Studies were made by Hunziker, Mills, and Switzer (9) in 1916 on the cooling of cream by running water on the farm. The cream produced on twenty farms located near Purdue University was used in this work. Half of the Producers held the cream on the farms in cooling tanks with water at temperatures ranging from 54 deg. to 68 deg. Fah. and averaging 58.8 deg. Fah. while the other half held the cream under atmospheric temperature conditions with the temperature ranging from 42 to 87 deg. Fah., and mean daily temperature ranging from 56 deg. to 75 deg. Fah. The cream was gathered by the creamery truck twice weekly. The tank cream had an average acidity during the experiment of .38 per cent, and the no-tank cream an acidity of .52 per cent. The tank cream contained an average of 147,125,000 bacteria per cc. when delivered to the creamery, and the no-tank cream contained 226,750,000 per cc. The average score of the butter made from the tank-cooled cream was 90.69 and that of the butter made from the no-tank cream was 88.36. There was a difference of one cent a pound in the price obtained for the two classes of butter. The investigators stated, "the quality of the butter on the market depends more on the quality of the cream from which it is made than on any other condition incident to production, manufacture, and transportation of the butter. In order that the cream may arrive at the creamery in good condition it must be cooled promptly and be kept cool until it leaves

the farm."

The literature reveals that very little experimental work has been conducted to ascertain the influence of keeping cream on the farm at various temperatures upon the bacterial flora and upon the butter made from it. There has also been a remarkable lack of experimental data on the use of the small refrigerator on farms for the cooling of milk and apparently none on the cooling of cream till the year 1928. The reason why more experimental work in this field has not been done can be attributed to several causes: (1) high cost of refrigeration equipment, (2) competition in the field of buying cream, (3) a general lack of the purchase of cream according to grades, (4) the basing of cream quality on the physical condition, chemical composition (including acidity), and flavor, with little regard to the types of microorganisms present. There is at present a tendency to improve the quality of cream and to manufacture a higher scoring butter. Cream producers are therefore becoming interested in the methods to use in the production and storing of cream so as to obtain the highest price.

The improvement in quality of the cream through the use of a mechanical refrigerator may be limited in the high altitude sections of the state to from three to five months during the warm season of the year, because of the availability of naturally cold water and low atmospheric temperatures in those sections for a large part of the year. With a combination household and cream refrigerator, however, farmers in those sections would undoubtedly find it advantageous to use a mechanical refrigerator of that type. Price and Hurd (10) of the Oregon Agricultural

Experiment Station have designed a combination household and cream refrigerator which has an investment cost of very little more than the dairy refrigerator alone.

2. Object of refrigeration.

As milk and cream are cooled, bacterial rates of increase are diminished accordingly until, at about 40 degrees to 50 degrees Fah., multiplication is so slow that at or below these temperatures reasonably long periods of storage are practical.

"Bacterial growth", stated White (11), "is most rapid at temperatures of from 70 degrees to 100 degrees Fah., and while such growth practically stops at the freezing point of water or 32 deg. Fah. (very few being killed), a few even at this temperature continue to develop although rather slowly. When temperature conditions again become favorable activity is resumed. Actual freezing of milk must, of course, be guarded against because of resulting changes in physical characteristics and greatly impaired quality. On many farms the time between cream shipments is close to a week and the cooling and storage temperature under such conditions is about 33 deg. Fah."

Price and Hurd (12), who have made an intensive study of cream refrigeration, reported that cream must be cooled below 40 deg. Fah. in two to four hours if excessive bacterial growth during the first day is to be prevented; in fact, even with rapid cooling to 40 deg. Fah. and storage at 36 deg. Fah. the bacterial counts increased greatly at the end of 90 hours. However, cream in wet storage below 40 deg. Fah. for 4 days

could not be distinguished in flavor and general quality from the same grade 6 hours old. Cream cooled to 36 deg. Fah. in 3 hours and stored at 33 deg. Fah. or less had a bacterial count below the initial count at the end of 90 hours. Even when cream was cooled slowly (to 44 deg. Fah. in 12 hours and held at 36 deg. Fah. after 24 hours) it graded "No. 1 sweet" for butter at the end of 90 hours. When cream is held for twice weekly delivery, as stated by the workers, rapid cooling and low temperature storage is essential if the best quality cream is to be produced.

"Where milk or cream is shipped in cans for any considerable distance the temperature rise in uninsulated cans may be excessive. In such cases cans which are jacketed or otherwise insulated should be used," concluded Gamble and Bowen (13).

3. Types of milk and cream cooling boxes and tanks and refrigerating units.

Refrigerated storage, as described by White (11) and Nicholas (14), may be either of the "dry" or "wet" type. The use of tanks containing refrigerated water is especially favored by dairymen who wholesale their milk or cream in cans, considerable refrigeration being stored, and the first cost being lower than for equivalent dry storage. Available data does not indicate any necessity for forced circulation of water, but milk cools more rapidly when water agitation is employed. Milk also cools more rapidly in the wet type cooler when the ratio of water to milk is large.

"A dry storage box should have an allowance in floor space of 15

x 15 inches for each 10 gallon container that is to be stored, or where the milk is in quart bottle cases a space of 16 x 20 x 21 inches for each case," stated White (11).

White (11) explained that dry storage boxes are cooled in two general ways: (a) by the brine system, and (b) by the direct expansion system. The direct expansion system is generally more efficient than the brine system, but since it does not build up a reserve of cold as does the brine system, it has a lower rating under ordinary operating conditions. Under the first system there should be from 1.5 to 2 gallons of brine per gallon of milk cooled daily; the strength and nature of the brine (usually calcium chloride) is specified by the refrigeration equipment manufacturers.

In describing refrigerating media White (11) mentioned that dairy cooling units commonly use sulfur dioxide, methyl chloride or ammonia as the cooling medium or refrigerant, but ammonia plants are generally the most efficient. Where a moderate and dependable supply of cool water is available, and a fair sized installation is needed, equipment with a water cooled condenser should be purchased as this type is higher in efficiency than the air cooled type.

"For sanitary reasons, stated White (11), all dry storage boxes should be coated inside with at least 1/2 inch of concrete. A heavier coat (2 inches) is more desirable as it is less apt to crack, but in any case it is desirable to use some reinforcement such as coarse chicken netting tacked on to the frame. A proper coating will also protect the insulation from moisture." (Another common method of lining boxes of both dry and wet type is with galvanized iron sheeting.)

4. Methods of cooling milk and cream.

Two general methods of cooling and storing milk and cream were studied by Price, Hurd, and Copson (15): (a) the wet method, where the cans of milk or cream were immersed in refrigerated water, and (b) the dry method, where the cans of milk or cream were placed in a dry refrigerated chest. Under many circumstances they found precooling by immersion of the cans of milk or cream in a tank of flowing water or by running the milk or cream over a surface cooler was an essential preliminary for dry storage, but not necessary with the wet type of refrigeration boxes having proper size and depth and operated at temperatures of 35 deg. Fah. to 40 deg. Fah. Neither was precooling found necessary by Price and Hurd (12) with the dry storage method having forced air circulation when small cans (5 gallon) of milk or cream were used and the average box temperature was kept at 33 deg. Fah. (Due to the greater conductivity of water, it is 21 times as efficient for cooling as air at the same temperature.)

Cream in 5 gallon cans submerged in refrigerated water at a temperature of 35 deg. Fah. could be cooled from 80 deg. to 37 deg. Fah. in 4 hours, according to Price and Hurd (12). Cooling cream in a dry chest held at 34 deg. Fah. by mechanical unit was very slow, they found, taking 9 hours to cool the cream from 80 deg. Fah. to 50 deg. Fah.

Newlander (16) reported that milk in 10 gallon cans immersed in water at 32 deg. Fah., not stirred, required 1 1/4 hours to cool from 90 deg. to 50 deg. Fah. The most rapid fall in temperature occurred during the first 15 minutes. In a dry chest with an air temperature of 3 deg. to 12 deg. Fah., 5 1/2 to 6 hours were needed to lower the temperature

of the milk from 90 deg. Fah. to 50 deg. Fah.

There are a great many different procedures which are followed in cooling and storing milk. "Where dry storage boxes are used for 10 gallon cans or cases of bottled milk, explained White (11), precooling to about 10 degrees below the temperature at which the milk is to reach the distributor or customer is quite important. Cooling to about 40 deg. Fah. was generally found to be satisfactory. The storage temperature should be below that to which the product is cooled, especially with cream where temperatures not above 33 deg. Fah. are essential to best results -- storage for a week or more."

Ordinary baffled boxes are only satisfactory for storage, as found by Price and Hurd (12), but with forced air circulation using small cans (5 gallons), cream and milk could be both cooled and stored with an air temperature of 34 deg. Fah.

Where wet storage is used the refrigerated water temperature should not be above 40 deg. Fah. (35 to 40 deg. Fah.) if the milk is to be sold raw, and not above 50 deg. Fah. if it is to be pasteurized; the actual milk temperature requirements are the same as for dry storage, as reported by Marquardt and Dahlberg (17) and Gamble and Bowen (13). These temperatures refer to the water before the milk is placed in the tank and give ample leeway for irregularities. This assumes a well insulated tank (3 to 4 inches of cork) or such depth (22 inches) that the water reaches the neck of the cans; ample refrigerating water (2 gallons of water to one gallon of milk), and a refrigerating unit of adequate capacity.

Price, Hurd, and Copson (15) found the stirring of milk unnecessary and stated that there was considerable danger of contamination from the

stirring implement used. They found that stirring hastened the rate of cooling very slightly and what little advantage there was may be gained by stirring once at the end of one or two hours of cooling.

5. Power requirements and energy consumption.

"The size of motor and compressor required to handle a particular dairy refrigeration job will depend upon many factors such as the amount of ice required, gallons of milk cooled and method used, type of cooling system, and whether the unit is air or water cooled," explained White (11).

The energy consumption of dairy refrigerating equipment would vary greatly with such factors as amount of ice used for other purposes than the cooling of milk, gallons of milk cooled and methods used, and quality and size of storage box or tank. Moses and Tavernetti (18) reported that the average for wet storage (tanks) was around 1.0 kilowatt hour per 10 gallon can of milk cooled and stored. For dry boxes, according to the investigators, where the brine system was used the average per 10 gallons of milk was around 1.2 kilowatt hours for cooling and storing; 1.7 kilowatt hours where the milk was cooled and then stored in bottles, and 0.9 kilowatt hour where the milk was cooled but not stored. For dry boxes equipped with direct expansion units the average energy consumption was around 0.5 kilowatt hour per 10 gallons of milk, regardless of whether the milk was merely stored or both cooled and stored. Obviously in every case the requirements varied greatly with the outside temperature.

Five household refrigerators and combination household and dairy refrigerators were studied by Ackerman (19) who found that the average

current consumption was 41 kilowatt hours per month.

6. Cost of dairy refrigeration.

Ackerman (20) compared the cost of natural ice and mechanical refrigeration and gave the following results of his investigations. As a general thing a good ice house would cost nearly as much as a refrigerating unit with its box or tank, and when the labor and sawdust, required to fill the ice house were considered, the operating costs for electrically cooled dairy refrigerators were considerably below those for ice refrigeration. Some actual farm costs from New Hampshire showed ice refrigeration costing a total of 45 to 156 per cent more than electric refrigeration, even though the average cash cost of electric refrigeration was 137 per cent greater than for ice refrigeration. The average yearly cost per cubic foot of total contents was $1.18 for the ice methods, and $0.62 for the electric. The cost per 100 quarts of milk handled (based on a year's operation) was 30 cents for the ice method and 15 cents for the electric.

Under the favorable conditions for ice storage found in Vermont, as shown by Ellenberger (21), mechanical refrigeration (dry storage type) was generally more economical, there being little difference with ice at $2.00 per ton in the ice house when electricity was 5 cents per kilowatt hour, but with ice at $3.00 per ton in the ice house and electricity at 5 cents per kilowatt hour the latter was materially cheaper.

Moses and Tavernetti (18) estimated electric power at 2 cents per kilowatt hour, depreciation at 10 per cent, interest at 7 per cent, and

upkeep at 3 per cent per annum, and calculated that a milk-cooling plant would cost from 1/2 to 1 cent per gallon cooled, depending on the size and type of plant and the method of handling the milk.

Price, Hurd and Copson (15) found it less expensive to cool milk below 50 deg. Fah. in a tank type cooler with mechanical refrigeration using electricity at 3 cents per kilowatt hour than with ice at 1/2 cent per pound.

B. The Manufacture of Butter

1. History of the manufacture of butter.

References to the early manufacture and use of butter were made by Hannay (22). "Butter has been used by the human race since the earliest days from which records have been left. Ancient Egyptian civilization left many records of dairying. In one of the pictures believed to have been made 4,000 B.C., the first churning scene is found and butter is found in finished rolls very much like those made on farms in America today. The practice of storing butter began at an early day in Ireland where Irish peasants made a practice of burying butter in the peat bogs to hide it from invaders. In 1695, John Houghton, an Englishman, visited Ireland and later wrote a book in which he spoke of the habit formed by the Irish of burying butter in the peat bogs. It was also the habit of the people of Dardistan, Asia, where butter was kept for one hundred years before it was used."

"Science was first applied to butter making in the middle of the 19th century, the barrel churn was invented and experimentation in

churning methods improved the product. Between 1840 and 1850, Denmark became famous for its fine dairies and high grade butter."

"The first creamery in the United States was erected in Orange County, New York, in 1856. Since that date rapid strides have been made in the development of the creamery butter industry in this country."

Mechanical refrigeration found wide usage in the dairy industry and made possible the holding of large quantities of butter for long periods of time.

The shipping of butter from the producing areas to the centers of population and holding the butter for distribution, and the storing of surplus butter until it was needed presented the industry with a difficult problem, namely, to produce butter of high quality and butter which would retain its quality during storage. Investigators carried on experiments to determine methods of treatment which would result in the highest quality butter and the butter with the best keeping quality. The research work of this early period was noted for its lack of uniformity in results. Due to the insufficient number of trials made, the failure of some workers to take all factors into consideration, and the difference in opinion as to what constituted high quality butter, the workers presented diverse and very often conflicting statements of their results.

One of the methods which has been under investigation since the early days of the butter industry in this country, is the use of butter culture, or starter, for developing a desirable flavor and aroma in the cream to be used for butter. Arguments have been presented by research workers both for and against ripening cream through the souring of cream naturally or by the use of a culture, many times in the past 43 years.

The earlier workers in the United States in their reports upon the use of starter emphasized the physical advantages of the use of starter with minor emphasis upon the flavor developed. During the earliest days of the creamery butter industry in the United States, creamerymen and research workers ripened the cream by allowing it to stand at a favorable temperature until the desired acidity had been reached, or more frequently, until the cream was ripened until it was distinctly acid without regard to the degree of acidity.

Ladd in 1889 (23) reported that by churning sweet cream at the same or a higher temperature than is required for ripened cream there was a large loss of butterfat but by lowering the temperature from 68 deg. Fah. for ripened cream to from 50 deg. to 54 deg. Fah. for sweet cream there was no greater loss in the buttermilk. Manns (24), Penney (25), and Curtis (26) in 1890, and Robertson (27) in 1891 found that a greater yield of butter was obtained by ripened cream than from sweet cream. Patrick, Leighton, and Bisbee in 1892 (28) noted that: (a) the yield of butter from sour cream was usually larger than from sweet; (b) Sour cream usually churned quicker than sweet; (c) The butter from sour cream usually contained less fat and more water than did that from sweet cream (d) The butter from sour cream usually contained a trifle more casein than did that from sweet; (3) the losses of fat in churning, washing, and working were less with sour than with sweet cream. Hills in 1893 (29) also found that the most complete churning was attained with thick ripened cream at low temperatures. H. H. Dean in 1895 (30) wrote, "We must churn sweet cream at very low temperatures (45 deg. Fah. or below) in order to obtain all the butter. Churning at ordinary temperatures means

a great loss of fat in the buttermilk."

In later years, however, it was decided that the difficulties encountered in churning sweet cream were of small importance, and the additional loss of fat in the buttermilk through the churning of sweet cream instead of ripened cream was not great enough to be considered. Work was then directed toward the development of butter with the desirable flavor and keeping quality. Some of the early investigators also made comments upon the flavor and keeping quality of butter.

Ladd in 1889 (23) commented upon the flavor of sweet cream and ripened cream butter and stated that "the flavor of the butter from sweet cream is quite different from that of butter made from ripened cream."

Manns in 1890 (24) reported that increase in acidity of cream beyond a certain point brought risk of injury to the quality of the butter due to a different fermentation setting in after a certain stage in ripening had been reached. Penney in 1890 (25) stated that sweet cream butter "lacks the stand up quality of sour cream butter, and it is considered by creamerymen not to stand shipment, handling, or warm weather as well. In a word, sweet cream butter is less profitable to make and harder to sell than the sour cream butter." Curtis in 1890 (26) after seven trials with sweet and ripened cream butter from split churnings found scarcely a noticeable difference between the two types of butter, the difference if any being in favor of the sweet cream butter. Dean in 1891 (31) and again in 1892 (32) found that in his comparison of sweet cream and ripened cream butter, after keeping it for three or four weeks the sweet cream butter was reported off in flavor and of inferior quality to the ripened cream butter. Patrick, Leighton and Bisbee in 1892 (28)

and with repeated trials in 1893 when Bisbee was replaced by Heileman as co-investigator (33) discovered some interesting data. In these trials with butter from sweet and ripened cream, the cream was ripened from 17 to 46 hours before being made into butter. The butter was then stored at 50 deg. Fah. and examined at the end of 3 months, 4 months, 6 months, and 7 months. They concluded that "sweet cream butter suffered less deterioration from keeping than did the ripened cream product, and in some measure acquired the flavor characteristic of the latter." Hills in 1893 (29) stated that the finest butters were attained with thick ripened cream at low temperatures and Dean in 1895 (30) reported as the result of eighteen trials that "sweet cream butter does not possess keeping quality the same as ripened cream butter. We have found that it quickly goes off in flavor and does not improve or take on the flavor of ripened cream butter, as claimed by some."

The use of pasteurization of cream and the use of starter for butter making began in this country about 1900. In 1903, Farrington and Russell (34) mentioned the use of pasteurized cream and "pure culture starter" which began in Denmark in 1890 and stated that "uniformity of product is one great advantage. Where the type of fermentation is the same from day to day instead of subject to natural variations, the quality of the butter must be more uniform." Beach in 1906 (35) made a comparison of naturally soured skimmilk and "pure culture" starters in 14 trials and found the average scores of the resulting butter almost identical. High acidity was suspected by Rogers to cause fishy flavor in butter. The cause of fishy flavor in butter was described by him in 1909 (36). He reported, "In the opinion of the writer, fishy flavor is

caused by a slow spontaneous, chemical change to which acid is essential and which is favored by the presence of small amounts of oxygen. Fishy flavor may be prevented with certainty by making butter from pasteurized sweet cream. Butter made from pasteurized sweet cream with a starter but without ripening seldom if ever becomes fishy." Michels stated in 1909 (37), "Indeed, the highest quality of butter is not possible without the use of pure cultures." Melick in 1909 (38) while trying to aid Maryland creameries, in improving the quality of their butter asserted that "while as a whole grading was beneficial the pasteurization and use of starter was still more beneficial." Rogers and Gray in 1909 (39) stated, "It is generally taught by instructors and writers on dairy subjects that to produce good butter it is necessary to develop a certain amount of acid in the cream. The reason for this is twofold -- first, to develop a desirable flavor; and, second, to improve the keeping quality by suppressing the undesirable bacteria. It is recognized, however, that if the fermentation is carried too far the keeping quality of the butter is injured." The investigators found no undesirable bacteria in the cream or butter and heated the cream to destroy possible unfavorable enzymes. Since they added lactic acid directly to the cream as well as developing a high degree of acidity in the cream by means of microorganisms and found the same injury to the flavor of the butter after holding it at very low temperatures, they concluded that the undesirable flavor was due to the presence of acid whether developed naturally or added directly.

Rogers, Thompson, and Keithley in 1912 (40) obtained interesting data on 259 samples of experimental butter from cream of known acidity

in which comparison 1.5 per cent of 137 samples of butter made from cream with an acidity of below .3 per cent at time of churning were described as fishy, while 49.2 per cent of 122 samples from cream with an acidity of .3 per cent or over were fishy. It is also of interest to note in this experiment that all of the samples of ripened cream had acidities of .5 per cent to .62 per cent. This per cent acidity is excessive.

2. Efficiency of pasteurization and the effect of pasteurization on the keeping quality of the butter.

Mortensen, Gaessler, and Cooper (41) reported the results of holding cream in a vat at 145 deg. Fah. for 20 minutes. They stated, "the pasteurization efficiency varied from 99.864 to 99.994, with about one-third of the samples running 99.990 or over." They also noted that the sample with which the lowest efficiency was obtained was the sample showing the smallest initial count and "accordingly very probably had the smallest percentage of Bacterium lactis acidi forms." Hunziker, Spitzer, Mills and Switzer (42) in a comparison of the flash and holding method of pasteurization found the holding process at 145 deg. Fah. was most efficient, averaging over 99.9 per cent in its germ killing effect on all types of microorganisms. They used holding periods of 10, 15, 20 and 40 minutes and found that from the standpoint of keeping quality of the butter, the 20 minute holding period proved best. The greatest reduction in microorganisms occurred when the cream was held at 145 deg. Fah. for 40 minutes. White and Campbell (43) made a comparison of 116

churnings of sweet cream butter for storage in which the cream was pasteurized at 145 deg. Fah. for 25 minutes, 145 deg. Fah. for 30 minutes, 155 deg. Fah. for 30 minutes, and 145 deg. to 165 deg. Fah. for 30 minutes. Samples of the butter were stored at zero deg. Fah. for 7 1/2 to 9 months. Scores of the butter after storage indicate the keeping quality was not influenced by these temperatures of pasteurization of the cream.

3. Object of the use of starter.

In butter, flavor is the most important point considered in determining the quality of the product. Butter is composed of the triglycerides of a number of fatty acids. These acids are as follows: butyric (5.45%), caproic (2.09%), caprylic (0.49%), capric (0.32%), lauric (2.57%), myristic (9.89%), palmitic (38.61%), stearic (1.83%), oleic (32.50%), dihydrostearic (1.00%) (44). Hunziker (45) stated, however, that "the intensity and character of the flavor and aroma of butter will vary widely, and will depend to a large extent on the character of the cream received. The production of a uniform flavor from day to day and season to season is difficult." It becomes necessary, therefore, in the production of butter with uniformly high quality to add a flavoring material which will impart to the butter that highly desired and characteristic flavor and aroma, described as sweet and "nutty". The substance added is a culture of acid, flavor, and aroma producing organisms known in the butter industry as starter.

Starter as used in the manufacture of butter is defined by

Hunziker (45) as "a mixed culture in milk or skim milk of lactic acid bacteria (S. lactis), and associated species capable of developing in milk, cream and butter the flavor and aroma characteristic of good butter." He stated that a good starter contains predominantly lactic acid bacteria of the type Streptococcus lactis. This fact has lead to the early conception by many that a good starter is a pure culture of lactic acid bacteria. It has since been learned that S. lactis produces lactic acid chiefly which is non aromatic and that the production of flavor and aroma requires the development of volatile acidity produced by bacteria other than S. lactis growing associatively. Hammer (46) (47) (48) isolated bacteria other than S. lactis from good butter cultures and divided these "associated" organisms into two types, Streptococcus citrovorus, and Streptococcus paracitrovorus. He reported that "the fundamental difference between the associated organisms is that S. paracitrovorus produces some lactic acid in milk, while S. citrovorus does not. Both organisms produce volatile acid from lactic acid and, accordingly, in pure culture S. paracitrovorus develops more volatile acid than S. citrovorus because of its lactic acid production. S. Paracitrovorus reddens litmus milk and occasionally even coagulates it, while S. citrovorus produced little change in litmus milk other than a slow reduction. The outstanding character of the associated organisms is their fermentation of citric acid with the formation of volatile acid."

4. Relation of starter to the control of undesirable flavors caused in butter by microorganisms.

In addition to the development of a desirable flavor and aroma,

the use of starter has the further advantage of the checking of the growth of certain undesirable bacteria which produce disagreeable flavors and odors in butter.

a. Surface taint. Derby and Hammer (49) Hammer (51), and Russell and Hastings (50) described surface taint as a defect in which the odor and flavor more or less definitely suggest putrefaction. It is first evident at the surface and then gradually penetrates to the center. The defect occurs in butter made from good as well as from poor raw material. For control of surface taint they suggest: (a) Efficient pasteurization, (b) Creamery sanitation, (c) Clean water in the creamery, (d) Salt content of the butter of 1.5 per cent or over, (e) The use of butter culture, (f) Low storage temperatures. "The value of butter culture," stated Derby and Hammer, "in the control of surface taint should be recognized. When such a culture is employed either with or without actual ripening of the cream, the number of butter culture organisms in the fresh butter is comparatively high. The changes in the number of butter culture organisms in butter are greatly influenced by the salt content but under any condition the organisms would be expected to influence the development of the types found capable of producing surface taint, since these belong to a general group of organisms that is sensitive to acid."

Russell and Hastings (50) further reported that development of lactic acid has a protective action against putrefaction. The restraining action of acid on the putrefactive organisms is well known and illustrated by many types of food products.

Hunziker (52) concluded that low acid cream butter is particularly susceptable to surface taint. He reported, "A condition that appears to favor the development of surface taint in butter is low acidity cream that has never been subjected to acid development. These facts suggest that lactic acid bacteria or lactic acid itself, or in case of sour cream neutralized, the sour cream lactic acid constitutes an unfavorable medium for the activity of the germs that are responsible for the offensive odor or surface taint. Experience in the commercial manufacture and in the marketing of butter shows that the factories that have had the most trouble from surface taint are those that receive a comparatively high grade of cream, the factories whose supply is predominatingly sweet and do not ripen their cream, nor use starter in any form. Plants receiving sweet cream and practice cream ripening and those receiving mostly sour cream, on the other hand, have been relatively free from surface taint in their butter. In the manufacture of unsalted butter, starter and cream are almost indispensable."

Eckles (52) reported an outbreak of putrid butter that occurred in 1900 and lasted about two weeks. The defect was so pronounced tha local sale of butter was stopped and what had been sold was returned. The milk received at this plant was of an unsatisfactory quality. Changes involving the rejection of poor quality milk, better care of utensils, and the use of a butter culture were instituted at the plant and about the same time a long dry period was broken by heavy rains. The butter improved at once and no further trouble was experienced. The putrid butter contained an abnormally high number of gelatin liquefiers which included some forms that had a very injurious effect on butter. Eckles

concluded the putrid condition was brought about by contamination of the milk.

Hood and White (54) made a study of butter that had surface taint, found in the Provinces of Quebec, Ontario, Manitoba, Saskatchewan, and Alberta in Canada. All of the samples were found to be abnormally high in yeast and bacterial content, and of the bacteria there was a considerable number capable of decomposing curd in butter. The water supplies of the various creameries were found to introduce large numbers of undesirable organisms.

b. Miscellaneous objectionable flavors. Hunziker (52) declared that the development in the cream and in the butter of a pronounced culture flavor is a great help in keeping such butter fresh until it is consumed and in retarding if not entirely preventing the successive development of a stale, cheesy, and rancid flavor and the appearance of mold.

McKay (55) stated that it is fully recognized by the leading authorities who have given the subject of keeping qualities of butter some study that a certain amount of free acid is necessary to assure good keeping quality. "Butter containing no acid," he asserted, "will turn rancid."

Grimes (56) declared that where deterioration of butter occurs in cold storage at -6 deg. Fah. it is not due to the normal flora of pasteurized cream, nor to S. lactis or S. paracitrovorus, nor to the lactic acid formed during the ripening of cream by starter. A proof that S. lactis and S. paracitrovorus are not a direct cause of deterioration is shown by the keeping quality of the butter made from cream to which

starter had been added but not ripened. It was found that the bacterial count of the ripened cream had little or no relation to the acidity of the cream. Grimes concluded that the quality of the cream when delivered at the creamery is probably the main factor that determines the keeping quality of butter in cold storage.

5. Acidity of cream and development of fishy flavor.

Where starter is used in the creamery it is of the utmost importance that only a moderate degree of acidity is developed in the cream. Hunziker (45) emphasized that even in the case of sweet cream, the keeping quality of the butter is less uniform and less dependable when the ripening process has been carried to a point where the acidity of the cream at churning time exceeds .32 per cent, and the higher the acidity above this point the more marked is the tendency of the butter to deteriorate with age and to develop fishy flavor and related flavor defects. This fact is confirmed by many research workers.

Gibson (44) advanced two main theories for the cause of fishiness, namely, that it is brought about through biological agencies, and as the result of a purely chemical reaction. The biological agencies mentioned as being concerned are yeasts, molds, bacteria, and bacterial enzymes. The following three objections seem to discountenance largely the biological theory: (a) Inoculation experiments with the organisms supposed to cause fishiness have in general been unsuccessful, (b) Pasteurization does not absolutely prevent fishiness, (c) Fishiness is favored by a high salt content and develops at low temperatures. Condi-

tions which favor the development of fishiness in butter are, (a) high acidity of the cream, (b) high salt content in butter, (c) over working the butter, (d) the presence of iron and copper salts.

Sommer and Smit (57) and Supplee (58) reported results which show that the presence of a certain amount of lactic acid is required for the development of fishy flavors. Further studies of the biochemical action of Bacterium icthyosmius indicated that it would decompose cholin with the liberation of trimethylamine. Sommer and Smit found that the addition of 100 parts of trimethylamine lactate to 1,000,000 parts of butter caused a fishy flavor, and chemical analysis showed that fishy butter contained trimethylamine, but that it was absent in fresh butter. Other experiments indicated that Bacterium icthyosmius and a fishy cream organism can produce trimethylamine under favorable conditions not only from lecithin but also from proteins. The bacterial action is inhibited, however, in the presence of salt or lactic acid, or at the usual storage temperatures for butter. Larger amounts of hydrolyzed lecithin were decomposed into trimethylamine by both chemical and bacterial action than occurred when unhydrolyzed lecithin was used. The results of the tests with lecithin thus show that it is decomposed into trimethylamine under much the same conditions as fishiness develops in butter. This is probably a chemical action on proteins.

Fryhofer (59) asserted, "One thing commonly agreed upon is that acid in cream is essential to the development of a fishy flavor."

Hammer and Baker (60) made various investigations on the acidity of cream and found that, in general, butter churned from cream with considerable acid has poorer keeping qualities than butter made from low acid

cream. The relationship between acid in the cream and keeping qualities of the butter made from it is not a constant one, since occasional lots of butter made from high acid cream keep very well, but it is definite enough so that it has materially modified the method of using starters. Low acidities developed in cream by good starters are now commonly used, since butter produced from satisfactory raw materials by this method has considerable flavor and aroma and also keeps very well.

Bouska (61) stated, "The acidity of the cream comes to effect as acidity in the butter. It is the acidity in the butter that affects its flavor and keeping quality."

White, Trimble and Wilson (62) studied the effect of the acidity of the cream on the quality of the butter produced from it. Their results show that when butter, made from cream with acidities of .14 to .45 per cent, was stored at from zero to 20 deg. Fah. for 8 and 11 months the deterioration was greater in the butter made from cream of greater acidity than in that made from the less acid cream.

Rogers, Thompson, and Keithley (40) reported that the almost uniform occurrence of storage and fishy flavors in the ripened cream butter and the absence of these flavors in the sweet cream butter should not be overlooked. The acidities of all the ripened cream in their data varied from .5 per cent to .62 per cent, which acidities are excessively high.

Hammer (63) concluded that any disadvantage that starters may have, such as causing a rapid deterioration in butter, seem to be due to high ripening and accordingly can be quite readily overcome. He also states, "It is probable that in spite of the opposition to them on the

part of certain individuals starters are more firmly established in the American butter industry than ever before."

Bouska (64) suggested keeping the acidity of butter at a minimum by controlling churning conditions so that the butter granules formed will be the size of wheat and thoroughly washing the butter granules to remove as much adherent buttermilk as possible.

Hammer and Jensen (65) investigated the influence of butter culture acidity on the quality of the butter. Their results indicate that the acidity of the butter culture has no significant influence on the quality and keeping quality of butter made with the following procedures: (a) 10 per cent butter culture, prepared from milk pasteurized at 185 deg. Fah. for 30 minutes, added to pasteurized sweet cream without ripening, (b) 10 per cent butter culture, prepared from milk pasteurized at 185 deg. Fah. for 30 minutes, added to pasteurized and neutralized sour cream without ripening.

6. Corroborative material on the value of starter in butter making.

Hunziker (45) reported that the fundamental objects of cream ripening are to produce butter with a pleasing, pronounced butter flavor and aroma, and to produce this flavor and aroma uniformly year in and year out. Butter that contains the pronounced "nutty" flavor desired, invariably has a high aroma. Butter devoid of aroma is usually flat in flavor. The appearance of aroma requires changes that lead to the development of volatile acidity.

Bouska (66) stated, "The advantages and disadvantages of using

starters in butter making were under discussion for a long time. Today practically all butter makers appreciate their value and almost all the large creameries use them."

Hammer (67) asserted that while butter secured from cream in which there has been no acid development is pleasing to the taste, it is lacking in the flavor that is regarded as so desirable in a high grade piece of butter. The flavor of the fat gives it a definite butter taste but it is not one than can be considered entirely satisfactory according to our present standards. It seems that some of the products formed in the souring of cream must be present in butter to give it the most desirable flavor and, accordingly, it is evident that the desirable flavors of butter are, in part, the result of the action of microorganisms. It is probable that in high quality butter churned from naturally soured cream, the flavor is due to the action of a considerable number of different bacteria. The method of securing flavor by the natural fermentation, however, can not be depended upon because bacteria producing undesirable flavors are very apt to develop and accordingly at the present time the fermentation of the cream is controlled by the use of starters. While it is entirely possible that organisms other than those found in starters might be advantageous from the standpoint of the flavor developed in butter, it is certain that the bacteria found in good starters are capable of producing a flavor that is very satisfactory when they are grown under suitable conditions. Good starters contain at least two types of organisms and the proper balance between them results in the formation of products that give cream and the butter made from it a pleasing flavor. It is necessary that the proper relationship between

these two organisms be maintained if a satisfactory flavor is to develop and suitable temperatures are very important in accomplishing this. The big factor, however, in developing the desirable flavor in butter is the skill of the buttermaker.

Hammer (68) also reported that the manufacture of butter from sweet cream has taught the people using starters a very valuable lesson, since it has shown that butter made from low acid cream has better keeping qualities than butter made from cream with considerable acid. This information has been profitably used and has changed the method of employing starter. Cream is no longer ripened to high acidities, as it formerly was, but the starter is either added to the cream and the cream held at low temperatures so as to prevent any appreciable increase in acid or a short period of growth for the starter organisms, which permits of a small increase in acid is allowed. These procedures yield products which have more flavor than if no starter had been used and which at the same time, have very good keeping qualities. With this revision in the method of using starter the assumed advantages of sweet cream butter in the matter of keeping qualities has largely disappeared.

In the same reference Hammer describes the use of starter in the manufacture of Danish butter. In England, which is the worlds' most discriminating butter market, Danish butter brings the highest prices. This is made with starter and comes into competition with sweet cream butter from such countries as Ireland, New Zealand, Australia, Canada, and the Argentine. The sweet cream butter is recognized as having excellent keeping qualities but its lack of flavor is objectionable to the critical English consumer. With their generous supply of very fine

cream the Danish butter plants are advantageously situated for the manufacture of sweet cream butter but they have continued to use starter and have retained command of their markets in the face of competition from countries making butter without the use of cultures. Some of the countries shipping butter for long distances experienced serious deterioration when starters were used to develop high acidities in the cream but with the more recent methods of using starter deterioration can be quite successfully controlled.

Hunziker (69) declared, "It is important to bear in mind that developing flavors in the cream means fermentation and fermentation means decomposition. Some of the constitutents are broken down. Developing flavor in the cream, or cream ripening, represents the early stages of decomposition of some of the constitutents. It so happens that during these early stages of decomposition the flavors produced are desirable, but when these changes continue, a point is finally reached beyond which the flavors produced are no longer pleasant, they are objectionable. On the other hand, if butter is made from cream that has not been ripened, but in which the flavor has been incorporated by adding it to the cream in the form of a good starter, instead of developing it in the cream by ripening, then the butter taken from the churn has not reached that critical point of decomposition by a long margin. Changes can go on in it for a considerable period of time without the appearance of off-flavors, in fact, the flavor may improve with those changes, and that kind of butter has keeping quality, while at the same time it has real flavor and aroma."

Olson (70) studied the effect of starter on the quality of fresh and stored butter. Lots of cream were churned without the use of starter, after ripening with starter, and after washing butter with starter. The starter butter was found to have a somewhat higher score when fresh and also after six months' storage.

Walts (72) found that butter made with starter averaged 2.3 points higher in score than that made without starter when sweet cream was used in the experiment. When a lower grade of cream was used; namely, sour cream that had been first neutralized and pasteurized, it was found that starter improved the quality .48 and 1.78 points respectively in two sets of experiments. He also made a comparison of the effect of many different types of starters on the quality of the butter and summarized the results as follows. "In so far as the flavor of the butter was a basis of comparison, any of the particular butter cultures studied should prove equally efficient in the hands of an experienced buttermaker in improving the flavor of butter made from either neutralized or sweet cream."

Reid (73) stated, "Starters are being used today by the manufacturers of Americas' best butter because the properties of a high quality of starter impart the greatly desired aroma and flavor to the finished butter. The introduction of the use of starters in butter manufacture represents one of the distinct advances made in the field of dairy manufactures. It now stands as a proven fact that butter made of equally good cream will possess an improved quality when a good starter is used than if the cream is churned without the use of a starter. Cream ripened to a high degree of acidity is no longer tolerated by the manufacturers

of quality butter. That high acid concentration in cream for butter manufacture is detrimental to the quality of the finished butter is no longer a debated issue."

Wilster (74) reported that the results of his experiments show that if a high quality raw material is used while still in a fresh and sweet condition and this is carefully pasteurized and ripened with a fine flavored culture to a low acidity and then made into butter according to the most modern methods, a high quality product possessing keeping qualities can be obtained.

Mortensen (75) concluded as a result of his trials that the demand, as determined by the scores given by commercial judges, is still for butter made from ripened cream, as it possesses the most characteristic butter flavor. Butter made from cream ripened to an acidity of .44 per cent deteriorated, however, faster than either butter made from sweet cream or from sweet cream and starter, but in these trials where low ripening was employed, the ripened cream butter at the end of a two months cold storage period was about of the same quality as the sweet cream butter and the sweet cream and starter butter.

Johnson (76) explained that "unsalted table butter, to satisfy the consumer, must have a decided high lactic acid aroma of good quality and a pronounced lactic acid flavor, pleasing to the taste. Unsalted butter of this type is much in demand, and past experience proves that such butter is less apt to develop a cheesy or yeasty flavor which is undesirable."

Lucas, Ball, Vincent, and Trout (77) reported as a result of their findings that even under ideal conditions it was unwise to ripen cream

if the butter is to be put into storage for any long period. They stated, "It would further appear that the addition of a moderate amount of starter to cream before churning or to the butter at the time of working caused the butter to score somewhat better after a three months storage period than if none had been used."

The New Zealand Department of Scientific and Industrial Research (78) asserted that there is considerable criticism of New Zealand butter on the English market on the grounds that it has sometimes a flat, insipid occasionally "neutral" flavor and a lack of bloom due to long storage. A lack of keeping quality of unsalted butter was also noticed. The principal difficulties are bad flavors present in manufacturing or arising during storage. The Department report continues, "Pasteurization cannot possibly restore to cream that part of the good flavor lost by previous action of the organisms, nor entirely restore the quality which has been lowered by harmful bacteria arising from insanitary conditions in sheds, milking machines, plant, and utensils. Pasteurization cannot entirely remove food taints or absorbed taints from cream. Cream can be readily recontaminated subsequent to pasteurization, from coolers, pumps, holding vats, and from the atmosphere. Certain trades desire butter "fuller" in flavor than the typical New Zealand product. In the present state of knowledge, the only method of securing this flavor is to develop in the cream a desirable degree of acidity by the use of "starter" or by the lesser reduction of acidity in cream than at present."

Barnard (79) declared, "There is in England a definite demand for a full flavored butter, and in parts of England where Danish butter sells particularly well, complaints are sometimes made that the New

Zealand butter is too flat and insipid."

"When the Dominions' Prime Minister, the Honorable G. W. Forbes, was in England last year, he found that there was a section of the trade there complaining of the flatness of New Zealand butter and consequently arranged with our research department to conduct tests in New Zealand and manufacture butter in which a "starter" culture was used. This test is now under way and several lots of butter made with starter have been sent to England. Certain of the biggest dairy factories are testing the matter out for themselves and making starter butter from specially selected cream. It will be seen, therefore, that a very determined attack on the starter butter question is being made by New Zealand, and that no stone will be left unturned to export at least a portion of our butter in the form of full flavored article."

Thomaen (80) asserted that the general understanding is that cream ripening is a method for producing flavor in butter uniformly from day to day. Incidentally such a practice will also affect the exhaustiveness of churning as well as the keeping quality of the butter.

Haughdahl (81) stated, "During the last 25 years or so in all contests, as far as I know, where thousands upon thousands of samples of butter have been judged by different market judges as well as by buttermakers, scientists, educators, in buttermaking, etc., starter made butter has always won out by several points over no starter butter. It is my belief that the starter made butter will come out winner even in keeping quality from like qualities of cream."

In the 1924 cold storage contest of the National Creamery Buttermakers' Association (82) it was found that the averages of butter made

with starter and without starter were as follows:

	Average Score	
	Into Storage	Out of Storage
68 tubs made with starter	93.44	92.90
48 tubs made without starter	92.51	92.03
Difference in favor of starter butter	.93	.87

In the 1928 National Creamery Buttermakers' Association (83) cold storage contest, the June and October averages of starter and no starter butter were as follows:

	Average Score	
	June	October
165 tubs made with starter	92.95	92.83
50 tubs of no starter butter	92.30	92.21
Differences in favor of starter butter	.65	.61

The ten highest scoring tubs of starter butter averaged 94.63 when fresh and the ten highest scoring tubs of no starter butter averaged 93.83, a difference of 1.25 in favor of the starter butter.

At the Pacific International Dairy Show (84) in 1931, 28 samples of contest butter made with the use of starter averaged 93.54 in score and 20 samples made without starter averaged 92.14 in score, a difference of 1.4 in favor of butter made with starter.

III. STATEMENT OF THE PROBLEM

On account of the low production of cream on many Oregon dairy farms and high transportation cost per pound of fat, the farmers have difficulty in getting their cream to the creameries in such condition that

it will lend itself to the production of the highest quality of butter. They hold their cream on the farm until sufficient quantity has been collected to allow it to be shipped economically. Under average conditions on the farms, the cream is held at favorable temperatures for the development of microorganisms. As a result of these conditions, the cream very often arrives at the creamery sour, yeasty, and with undesirable flavors developed in it. Butter of mediocre quality only can be produced from such cream.

The work herein reported was undertaken for the purpose of studying the effect of holding cream in refrigerators on the producing farms on the quality of the butter made from it, when the cream was held in cans in refrigerated water at a temperature of from 35 deg. to 40 deg. Fah. (to retard the development of microorganisms) for twice weekly shipment.

The following points are considered in this report:

(a) Power requirements for the refrigerators and refrigeration costs.

(b) Temperature at which the cream was received at the creamery.

(c) Yearly average temperature of the cream received from each farm.

(d) Acidity of the cream when received at the creamery.

(e) The manufacture of the butter made from the refrigerated cream.

(1) The germ killing efficiency of pasteurization.

(2) The percentage of bacterial types found before and after pasteurization.

(3) Isolation and identification of bacteria found in the cream.

(4) Yeast and mold counts in cream before and after pasteurization and in fresh butter.

(5) The per cent butterfat lost in the buttermilk.

(6) The quality of the butter manufactured using large equipment.

(7) The comparative quality of the butter made by large equipment when starter was used and when no starter was used.

(8) The comparative quality of butter with four methods of cream treatment before churning, using small equipment.

(9) Butter entered in contests.

(10) Butter made from refrigerated and non-refrigerated cream.

(11) Butter made from cream held in covered and uncovered cans.

(12) Butter made from cream with higher than normal acidity.

IV. EXPERIMENTAL

A. Methods Used

At the beginning of this experiment, in June, 1930, three farms were secured on which to place refrigerators, and on June 24, 1930, the first shipment of cream from these farms was received at the creamery. In choosing these farms, the aim was to select three which would be representative of Oregon dairy farms. From the largest herd, farm No. 1, there was received about 430 pounds of cream weekly; from farm No. 2 there was received about 320 pounds of cream weekly; from farm No. 3 there was received about 140 pounds of cream weekly. This cream was shipped twice a week, arriving at the creamery on Tuesdays and Fridays. The flavor of the cream was excellent at all times, with the exception of a few shipments which showed feed or weed flavor.

A General Electric, model DRD4 refrigerator in which the cans of cream are immersed in water, with a capacity of four 10-gallon cans was placed on farm No. 1. This farm is located two miles east of Rickreall which is twenty-five miles north of Corvallis. (Plate 1)

On farm No. 2, located on Kiger Island about 5 miles southeast of Corvallis, was placed a Victor refrigerator box in which the cans of cream are immersed in water with a capacity of four 10-gallon cans. The compressor unit on this farm was originally an electrically operated Frigidaire, but was converted to be operated by a 1 1/2 horse-power gasoline engine as there was no electric service on the farm. (Plate 2)

Farm No. 3, located at Monmouth, 20 miles north of Corvallis, was provided with a combination dairy and household refrigerator. The section of the box wherethe cream was placed had a capacity of two 10-gallon cans or four five-gallon cans immersed in water. The section of the box for household use was of the dry type. The box was cooled by

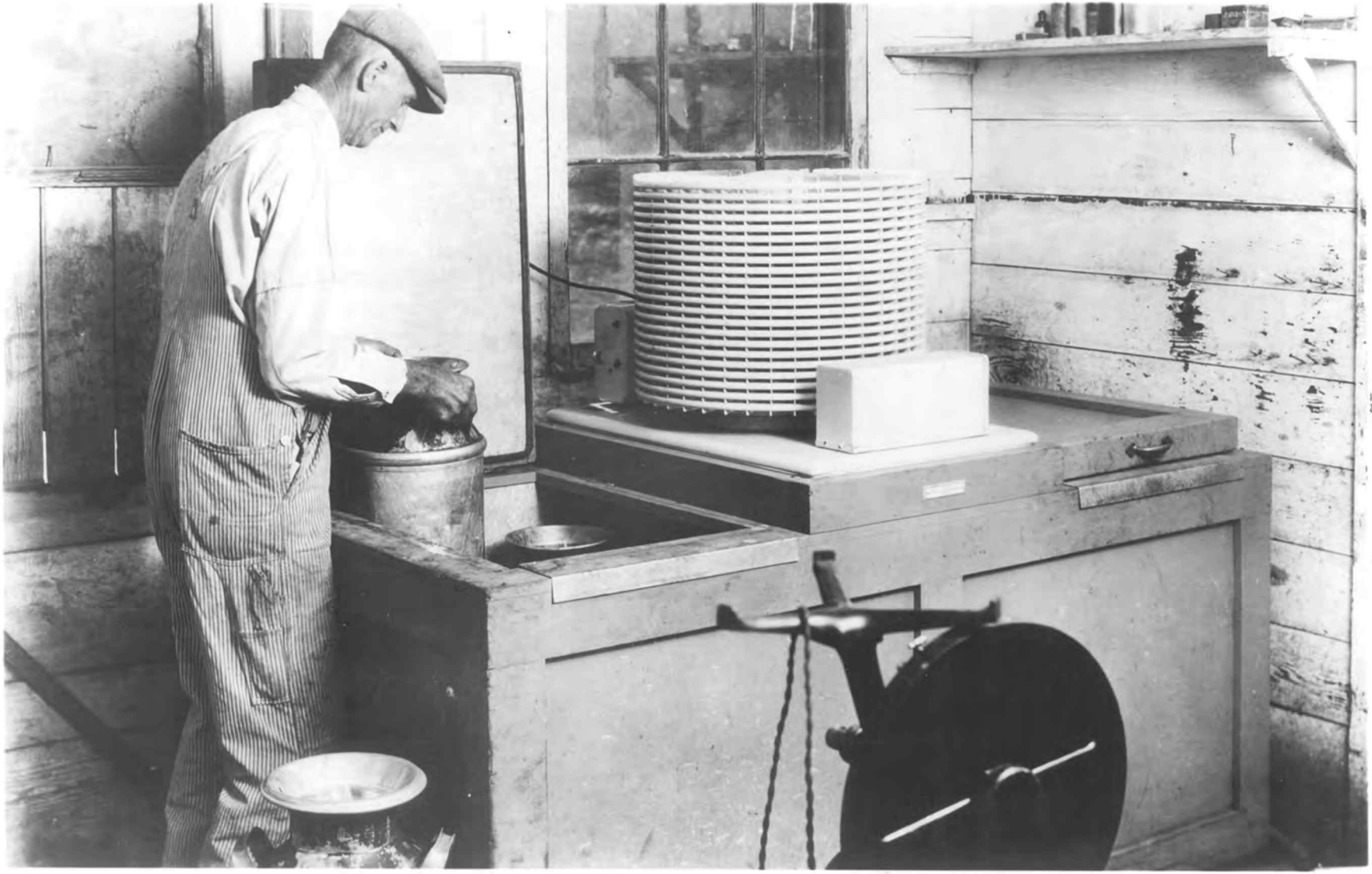

Plate 1. Refrigerator on Farm No. 1

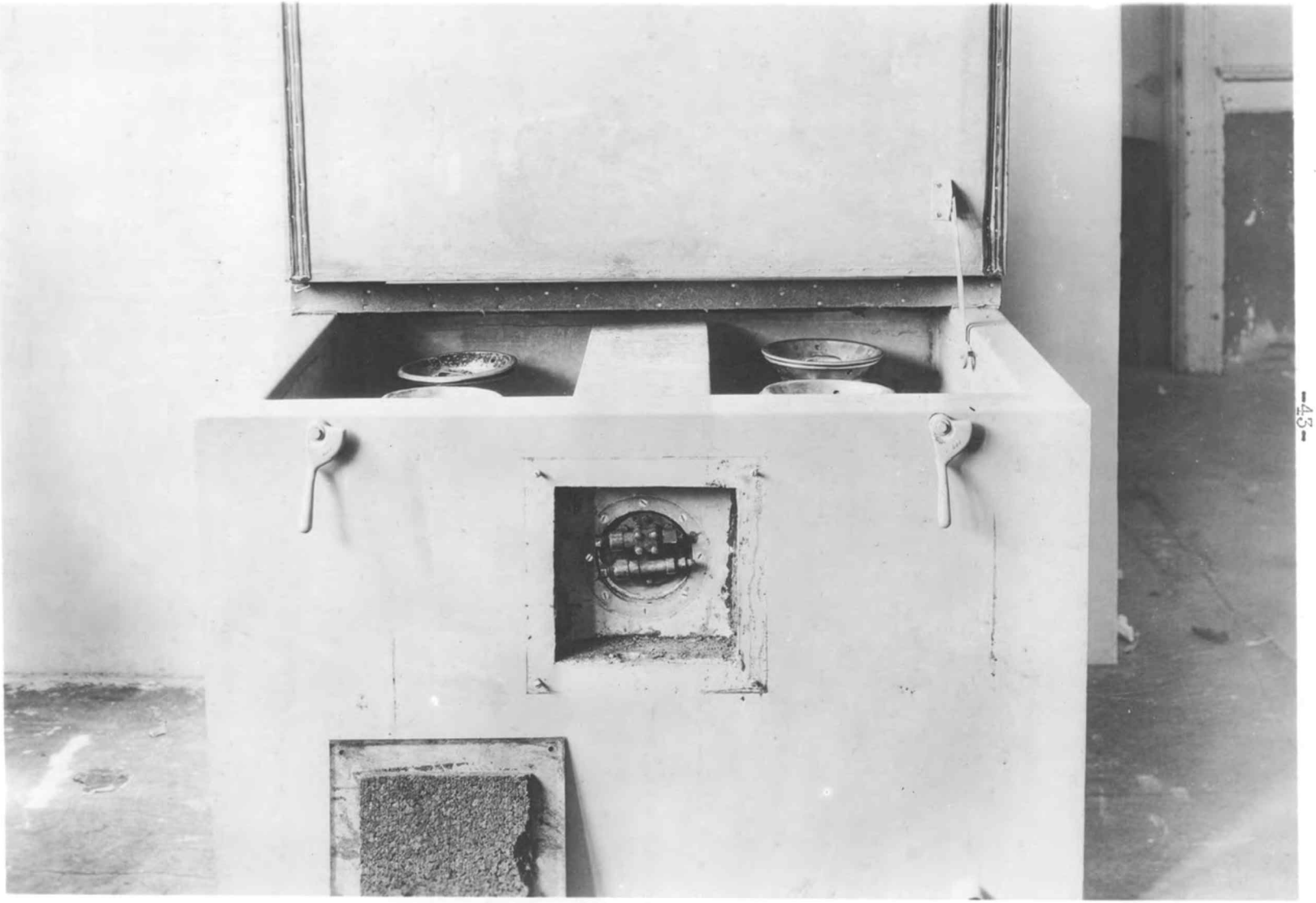

Plate 2. Refrigerator on Farm No. 2

a Frigidaire compressor with a 1/3 horse-power electric motor. (Plate 3)

After separation of the cream on the farms the warm cream was placed in the refrigerator and cooled to below 40 deg. Fah. The cream from each succeeding separation was also cooled to below 40 deg. Fah. before adding it to the previously cooled cream. This was done to prevent an increase in temperature of the cream previously cooled. All the cream was held in the refrigerators with the covers on the cans. On all the farms the cream was held at 36 deg. to 40 deg. Fah., with the exception of the cream from the milking of the morning on which the cream was shipped from farms No. 1 and No. 3. Since it requires four hours for cream to cool from 80 deg. Fah. to 37 deg. Fah. (12), there was not sufficient time in which to cool the cream on farms No. 1 and No. 3 between separation of the cream and the time for it to be taken to the station.

The cream from farms No. 2 and No. 3 was delivered by the farmers to the station 15 to 20 minutes before train time. It was necessary for the farmers to transport the cream a distance of approximately 2 miles from each farm to the station.

The cream was collected by a Southern Pacific train from farm No. 1 at Derry at 10:13 A.M. and the cream from farm No. 3 at Independence at 10:30 A.M. every Tuesday and Friday. The cream was unloaded at the station in Corvallis and delivered at 1:00 P.M. to the creamery. The cream from farm No. 2 was transported by truck directly to the creamery, also arriving there at 1:00 P.M.

On receipt at the creamery, the temperature of each can of cream was recorded; the cream was weighed; samples were taken for the butterfat

Plate 3. Refrigerator on Farm No. 3

and acidity tests; and the cream was emptied into a 200 gallon capacity vat pasteurizer. It was pasteurized and cooled to from 35 deg. to 40 deg. Fah. The cream was always held over night to be churned the following morning.

In pasteurizing the cream, a temperature of 145 deg. Fah. for 30 minutes was used. While bringing the temperature up to that point, care was taken to keep the temperature of the hot water circulating through the coils from exceeding the temperature of the cream by more than 20 degrees in order to prevent the cream from getting a scorched flavor. After pasteurization, the cream which was to be ripened, was cooled to 70 deg. Fah. The starter was then added, and the cream was held at 70 deg. Fah., until the desired acidity was developed. The cream was then cooled to from 35 deg. to 40 deg. Fah. to prevent further increase in acidity.

When starter was added to the cream without ripening and when no starter was added to the cream, the cream was cooled promptly to from 35 deg. to 40 deg. Fah. All cream was held over night to be churned the following morning.

With each batch of cream in 65 churnings, the germ killing efficiency of pasteurization was studied. The germ killing efficiency was calculated on the difference between the number of bacteria found per cubic centimeter before and the number found after pasteurization, for example--in one case 530,000 bacteria were found before pasteurization and only 300 per cubic centimeter were found after pasteurization. The number destroyed is the difference between 530,000 and 300, or 529,700. This number divided by the number before pasteurization or 530,000 and

the result multiplied by 100 gives 99.943 per cent efficiency.

Example of Calculation

$$\frac{530{,}000 - 300}{530{,}000} = 100 = 99.943\%$$

Before plating out the cream for bacterial count, dilutions of 1-1000, and 1-10,000 were made on the cream taken before pasteurization. No dilution and a dilution of 1-100 were made on the cream taken after pasteurization. The dilutions were plated on standard beef extract agar (agar - 1.5%, beef extract .3%, peptone .5% and water 97.7%), (85) with a pH value of 6.6, and after incubation for 48 hours at 99 deg. Fah. the macroscopic colony count was made with the aid of a Buck colony counter. Selection of colonies for classification was made from these plates by picking contiguous colonies on a fractional area of the plate and inoculating them into milk with litmus added.

The types of bacteria before and after pasteurization were studied. Samples of the cream were taken from the vat before and after pasteurization in sterile test tubes and the cream was diluted before plating. The plates were then placed in the incubator at 99 deg. Fah. for 48 hours, after which time the colonies were counted. The colonies were picked into tubes of sterile milk to which litmus had been added and allowed to grow at room temperature for 10 days to two weeks when they were classified according to the action of the bacteria on the milk. Seven classifications were made, acid coagulators, acid non-coagulators, alkali formers, inert, acid peptonizers, alkali peptonizers, and neutral peptonizers. The percentages of these types found before and after pasteurization were calculated. 855 litmus cultures were classified before

pasteurization and 682 litmus cultures were classified after pasteurization.

Eleven different organisms were isolated from the refrigerated sweet cream and identified.

In 31 churnings, yeast and mold counts were made before and after pasteurization and on the fresh butter.

Platings for yeasts and molds were made on malt agar (Bacto Dehydrated Malt Agar added to water, 45 grams per liter) with a pH value of 3.5. The agar was made acid in reaction to restrict the growth of microorganisms to yeasts and molds only. Since the number of yeasts and molds appearing on the plates was small no dilution was used. These plates were held for 48 hours in an incubator at 99 deg. Fah. and for 48 hours at room temperature (about 72 deg. Fah.) before being counted with the aid of a Buck colony counter.

The per cent butterfat lost in the buttermilk was determined and a comparison made between the average per cent butterfat lost when starter was added to the cream and the average per cent butterfat lost when no starter was added to the cream. The Babcock method of testing for butterfat in buttermilk was employed, using a 17.5 cc. portion of buttermilk and an equal quantity of acid.

During the first year of this experiment the equipment used for pasteurizing and churning was the type which is used in the average size creameries. A Wizard coil pasteurizer of 200 gallon capacity, stainless steel lined, manufactured by The Creamery Package Manufacturing Co., was used. The churn used was a No. 6 Victor with a capacity of 600 pounds of butter, manufactured by The Creamery Package Manufacturing Co.

(Plate 4).

At the beginning of the experiment several methods of making butter with starter were used, namely, (a) two churnings with 10 per cent starter added and the cream ripened,* (b) two churnings with 5 to 7 per cent starter added and the cream ripened, (c) two churnings with 10 per cent starter added to the cream just before churning, and (d) two churnings of sweet cream without starter. It was concluded that this program covered too large a field for one experiment, so it was reduced to two types of churnings, (a) with starter added and the cream ripened and (b) sweet cream with no starter added.

The last two methods were adopted to give more complete information and to enable more accurate conclusions to be drawn on the relative merits of the two methods of making butter. The two methods were alternated, making two churnings of butter with starter one week and two churnings without starter the next week.

The use of the large equipment continued until May, 1931, when it was desired to vary the method of butter manufacture. Operation of the large churn and pasteurizer had several disadvantages; first, a comparison of only two methods of cream treatment was feasible in the time available; second, a different batch of cream was used each time, allowing for a variation in flavor, acidity, types and number of bacteria; therefore, the results were not exactly comparable.

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* The process of ripening as referred to in this paper means the holding of cream, after the addition of starter, until the desirable flavor, aroma, and acidity are developed in the cream before making it into butter.

Large Equipment Used in the Experiment
Plate 4.

Small Churns Used in the Experiment
Plate 5.

In order to make a fair comparison, split churnings would have to be made, using the same cream for each method. This could not be done with the large churn because of the lack of sufficient sweet cream.

It was for the above reason that two small No. 2 Minnetonna churns, manufactured by The Creamery Package Manufacturing Co., were installed. (Plate 5). These each had a capacity of 25 to 40 pounds of butter, were equipped with a roll or worker, and were mechanically operated so that in all respects they were similar to the larger creamery churns. The small churns made it possible to use four methods of of treating the cream and to make four separate churnings from each lot of cream. The methods used were--(a) sweet cream with 8 per cent starter added and ripened at 70 deg. Fah. to an acidity of .27 per cent or .28 per cent, then cooled and held over night at 40 deg. Fah. or lower to prevent further development of acidity; (b) sweet cream with 8 per cent starter added and the cream cooled immediately to below 40 deg. Fah.; (c) sweet cream with 8 per cent starter added before churning; (d) sweet cream with no starter added. 16 comparisons were made with 4 churnings in each comparison, or a total of 64 churnings. The same physical conditions have been maintained throughout for all the churnings in each group. The churning temperature, temperature of wash water, per cent salt, and revolutions of working have been as uniform as possible for each comparison.

From each of the churnings, both large and small, three samples of butter were taken, one sample to be scored when fresh, one to be scored after holding for one month at from 35 deg. to 45 deg. Fah., and the other to be scored after holding for six months at from zero deg.

to 10 deg. Fah. All samples were held at from zero deg. to 10 deg. Fah. until the first subsequent monthly scoring. Thus, all samples less than one month old were scored as fresh. A number was used to designate each sample, so the identity and method of manufacture of the butter was unknown to the judges. The judges usually numbered three from the following selection and are qualified critics: Mr. H. C. Raven of the Raven Dairy Co., Portland; Mr. R. E. Cavett of the Ideal Dairy Co., Portland; Mr. J. E. Draper of the Unisted States Department of Agriculture, Portland; Mr. R. S. Smith of the United States Department of Agriculture, Portland; Mr. L. B. Ziemer, formerly of the State Department of Agriculture; and Mr. George Jacobsen, of the Jacobsen Dairy, Portland.

It has been observed that from month to month the standards for judging have fluctuated, the subsequent scoring occasionally being consistently higher or consistently lower than the preceding month. For example, one month the scores may range from 91.00 to a maximum of 93.00 and the next month the scores may range from 92.00 to a maximum of 94.50. The scores of each time are consistent with the comparative quality of the butter which would indicate that the fluctuations are due to different standards for judging of flavor and aroma employed at each scoring. This fact may explain the increases in score of several of the samples after holding for one month.

Some of the butter manufactured from the refrigerated cream was entered in the 1930 Pacific International Dairy Products Show; the 1931 National Creamery Buttermakers' cold storage contest at St. Paul, Minnesota; the 1931 National Creamery Buttermakers' fresh butter contest at Madison, Wisconsin; the 1931 Pacific International Dairy Products

Show; and the 1931 Oregon State Fair.

Additional trials were conducted to make a comparison of the quality of butter made from refrigerated and non-refrigerated cream. For one week the farmers were instructed to place half of the cream separated from each milking in a can standing outside the refrigerator and to place the other half in a can inside the refrigerator. These cans were marked accordingly and on receipt at the creamery the two classes of cream were churned separately in the Minnetonna churns and the quality of the butter made therefrom determined by the butter judges when the butter was fresh and after it had been held for one month at from 35 deg. to 45 deg. Fah.

An additional study was made to determine the quality of the butter made from cream held in the refrigerator with the cover on the can and with the cover removed. The cream, when received in the creamery, was mixed, divided into two portions, and the lid of one can was removed. The two cans were then placed in a large refrigerator located in the creamery and held for an additional three days. A variety of products was also kept in the refrigerator, including cheese, and there was a noticeable odor from the other products present. This cream, at the end of three days, was churned into butter and the resulting butter was scored and examined for evidence of flavor absorbed from the foreign odors present in the box. This butter was also scored by the commercial butter judges from Portland.

Three trials were made to determine the effect of acidity in the cream on the keeping quality of the butter. For three churnings the acidity of the cream in ripening was allowed to increase to a higher degree

than is normally practical in making butter. The resulting butter was examined and scored when fresh, after one month at 35 deg. to 45 deg. Fah., and after six months at from zero deg. to 10 deg. Fah.

B. Results Obtained

1. Power requirements and cost of refrigeration.

Table 1 shows the butterfat and power records for the three farms on which refrigerators were used. From June 14, 1930 to August 10, 1931, the period during which power records were kept, farm No. 1 produced 8,740 pounds of butterfat. The power used during this period by the refrigerator was 859 kilowatt hours, or an average of 2 kilowatt hours per day. On farm No. 2, 3,981.9 pounds of butterfat were produced from September 4, 1930 to September 5, 1931. The engine attached to the refrigerator on this farm consumed 86 gallons of gasoline during the period in which power records were kept or an average of 1/4 gallon of gasoline per day. On farm No. 3, 2,363.3 pounds of butterfat were produced from August 13, 1930 to August 10, 1931. The power used during the year in which records were kept was 999 kilowatt hours, or an average of 2.8 kilowatt hours per day.

Table 1.

BUTTERFAT AND POWER RECORDS FOR THE THREE FARMS ON

WHICH REFRIGERATORS WERE USED

Shipper	Refrigerator	Time	Butterfat (pounds)	Power used by Refrigerator
Farm No. 1	General Electric 4 can immersion type, Model DRD 4	June 14, 1930 to August 10, 1931 (14 months)	8740	859 K.W.H. 2.0 K.W.H. per day
Farm No. 2	Victor 4 can immersion type 1 1/2 H.P. gasoline engine. Type O Frigidaire compressor	September 5, 1930 to September 5, 1931 (One year)	3981.9	86 gallons gasoline,* 1/4 gallon gasoline per day
Farm No. 3	Combination dairy and household refrigerator. A.W. Frigidaire compressor. 1/3 H.P. electric motor	August 13, 1930 to August 10, 1931 (One year)	2363.3	999 K.W.H., 2.8 K.W.H. per day

* Quantity of gasoline estimated from 3 months test.

Courtesy of F. E. Price

The electric dairy refrigerator on farm No. 1 used 2 k.w.h. per day which at 3 cents per k.w.h. amounted to 6 cents a day, as shown in Table 2. Estimated interest and depreciation of 20 cents per day brought the total daily cost to 26 cents. With a daily butterfat production of 20 pounds, the daily cost per pound of butterfat was 1.3 cents. The daily premium amounted to 60 cents for the sweet cream with the premium at 3 cents per pound of butterfat.

The average fuel consumption for the refrigerator operated by gasoline engine on farm No. 2, as shown in Table 2, was 1/4 gallon per day or about 4 cents per day for fuel. Interest and depreciation of 20 cents per day brought the total cost to 24 cents. With a daily butterfat production of 11 pounds, the daily cost per pound of butterfat was 2.2 cents. The daily premium amounted to 33 cents for the sweet cream with the premium at 3 cents per pound of butterfat. About 3 to 5 cents per day should be added to the cost of operation for engine repair and replacement.

The combination dairy and household refrigerator on farm No. 3 used an average of 2.8 k.w.h. per day which at 3 cents per k.w.h. would amount to 8.4 cents per day. Interest and depreciation of 20 cents per day increased the total cost per day to 28.4 cents. With a daily butterfat production of 6.5 pounds, the daily cost per pound of butterfat was 4.4 cents. The daily premium amounted to 19.5 cents for the sweet cream with the premium at 3 cents per pound of butterfat. The total cost included the household refrigerator service which was not available with the other two refrigerators. This would probably cost 8 to 10 cents a day for power, interest, and depreciation for an electric household

Table 2

COST SUMMARY FOR THE THREE FARMS ON WHICH

REFRIGERATORS WERE USED

	Average butterfat per day (lbs.)	Fuel or power used per day	Operating cost per day	Interest and depreciation per day	Total cost per day	Daily premium at 3¢ per lb. butterfat	Total cost per pound butterfat	Net Profit per day
Farm No. 1	20.0	2.0 K.W.H.	6.0¢	20¢	26.0¢	60.0¢	1.3¢	34.0¢
Farm No. 2	11.0	1/4 gallon gasoline	4.0¢	20¢	24.0¢	33.0¢	2.2¢	9.0¢
Farm No. 3	6.5	2.8 K.W.H.	8.4¢	20¢	28.4¢	19.5¢	4.4¢	-8.9¢

Courtesy of F. E. Price

refrigerator.

In the cost summary it is noted that the total cost per day for the three farms was very nearly the same, but the cost per pound of butterfat varied almost directly with the production.

A premium of 3 to 5 cents is commonly paid for No. 1 sweet cream which grade was given all of this cream. Dairies No. 1 and No. 2 would pay a profit on the refrigeration installation at a 3 cent premium, but dairy No. 3 would not, particularly with the household refrigerator service charged to the dairy refrigerator. The small daily production is the chief reason for high cost of refrigeration per pound of butterfat.

2. Temperatures at which the cream was received at the creamery.

The temperatures at which the cream was received, shown in Table 3, ranged from 37 deg. to 66 deg. Fah. and averaged 50.61 deg. Fah. for the whole year and all farms. The average monthly temperature of the cream when it was received at the creamery was found to follow a reasonably uniform curve. Starting with January at 45.75 deg. Fah., the temperature increased to a high point of 57 deg. Fah. in July, from which point the temperature consistently decreased to another low point of 44.16 deg. Fah. in December. The months in which an average temperature of over 50 deg. Fah. occurred were May, June, July, August and September. The mean monthly atmospheric temperatures at Corvallis for the same year shown in Table 3, were obtained from the United States Weather Bureau. These temperatures were plotted on a graph with the average monthly temperatures of the cream when received. (Chart 1) In an analysis of the

two curves it is seen that the curves bear a fairly definite relationship to each other. Since the mean temperature is merely a mid-point between the maximum and minimum temperatures for each month the seeming inconsistencies between the two curves is easily explained. A temperature curve giving the average monthly temperatures during the hours of the day when the cream was in transit would be much more accurate, but these were not obtained.

Table 3.

AVERAGE MONTHLY TEMPERATURES AT WHICH CREAM WAS RECEIVED FROM ALL FARMS AND RANGE IN TEMPERATURES DURING EACH MONTH AND MONTHLY MEAN ATMOSPHERIC TEMPERATURES

Month	Average Temperature of cream (deg. Fah.)	Range in Temperature (deg. Fah.)	Mean Atmospheric Temperature (deg. Fah.)
January	45.75	43.00 - 48.00	43.60
February	46.25	43.00 - 49.00	43.70
March	47.57	45.00 - 53.00	48.60
April	49.75	44.30 - 56.00	55.30
May	55.33	49.60 - 61.70	61.30
June	55.92	52.50 - 63.30	62.00
July	57.00	51.00 - 66.00	66.20
August	56.00	54.00 - 58.00	68.40
September	51.72	50.20 - 55.00	62.50
October	47.50	43.00 - 53.00	53.00
November	46.33	39.00 - 55.00	44.60
December	44.16	37.00 - 51.00	40.00

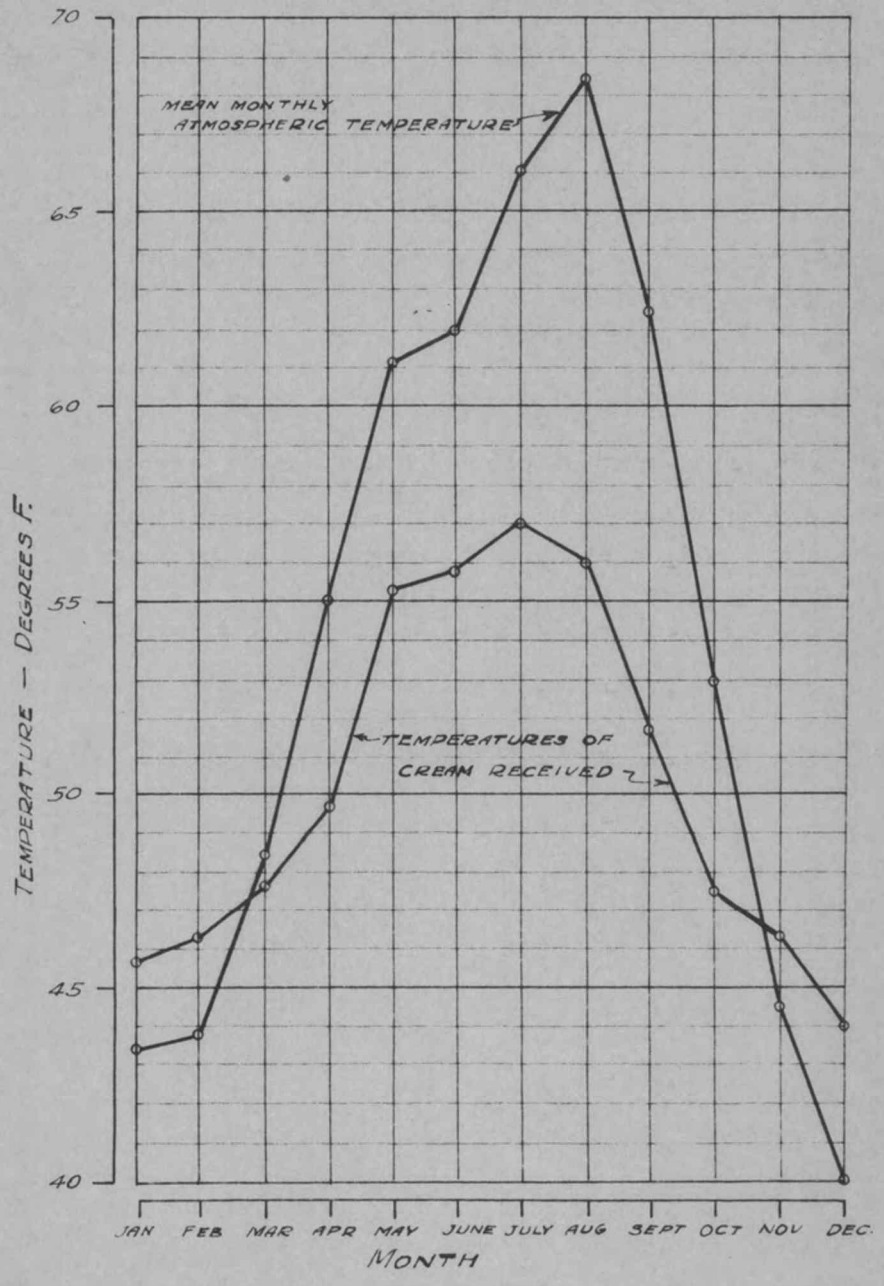
Chart 1.

AVERAGE MONTHLY TEMPERATURE OF CREAM WHEN RECEIVED AT CREAMERY

AND

MEAN MONTHLY ATMOSPHERIC TEMPERATURES AT CORVALLIS

JAN. 1931 — JAN. 1932.



3. Yearly average temperatures of the cream from each farm.

The yearly average temperatures at which the cream was received from each farm were calculated. According to Table 4, cream from farm No. 1, shipped a distance of 25 miles, ranged in temperature from 38.50 deg. to 66.00 deg. Fah. and was received at an average temperature of 51.20 deg. Fah.; that from farm No. 2, shipped 5 miles in a non-covered truck, ranged in temperature from 37.00 deg. to 68.00 deg. Fah., and was received at an average temperature of 48.24 deg. Fah.; and that from farm No. 3, shipped a distance of 20 miles, ranged in temperature from 36.00 deg. to 65.00 deg. Fah. and was received at an average temperature of 50.09 deg. Fah. The time in transit for the cream from farm No. 1 was approximately 3 1/4 hours; that from farm No. 2 was approximately 3/4 of an hour; and that from farm No. 3 was approximately 2 and 3/4 hrs. There seems to be a slight relationship, though not proportional, between the temperature at which the cream was received, (or the rise in temperature between shipping and receiving), and the distance the cream was shipped. Other factors may have influenced the temperature rise, such as, time left out of the refrigerator before shipping, amount of warm cream poured into cold cream before shipping, and type of conveyance by which the cream was transported.

Table 4.

YEARLY AVERAGE TEMPERATURES AT WHICH CREAM WAS RECEIVED FROM EACH FARM AND RANGE OF TEMPERATURES

	Farm No. 1	Farm No. 2	Farm No. 3
Range in Temperatures (deg. Fah.)	38.50 - 66.00	37.00 - 68.00	36.00 - 65.00
Average Temperature at Which Received (deg. Fah.)	51.20	48.24	50.09
Distance Shipped	25 miles	5 miles	20 miles
Approximate Time in Transit	3 1/4 hours	3/4 hours	2 3/4 hours

4. Acidity of the cream when received at the creamery.

Table 5 shows that the acidity of the cream when received at the plant ranged during the year from .11 per cent to .23 per cent with an average of .135 per cent. On curves in Charts 2 and 3, showing the average monthly acidities of the cream when received, when compared to the average monthly temperatures of the cream when received, it was found that there was a correlation between the temperature of the cream when received and the acidity of the cream when received at the creamery. In general, high average monthly temperatures were accompanied by relatively high average monthly acidities and low average monthly temperatures were accompanied by low average monthly acidities, though the lowest average acidity was not found in the month with the lowest average temperature and the highest average acidity was not found in the month with the highest average temperature. The months in which average acidities of over .14 per cent occurred were March, April, May, June,

Chart 2.

AVERAGE MONTHLY TEMPERATURE OF CREAM WHEN RECEIVED

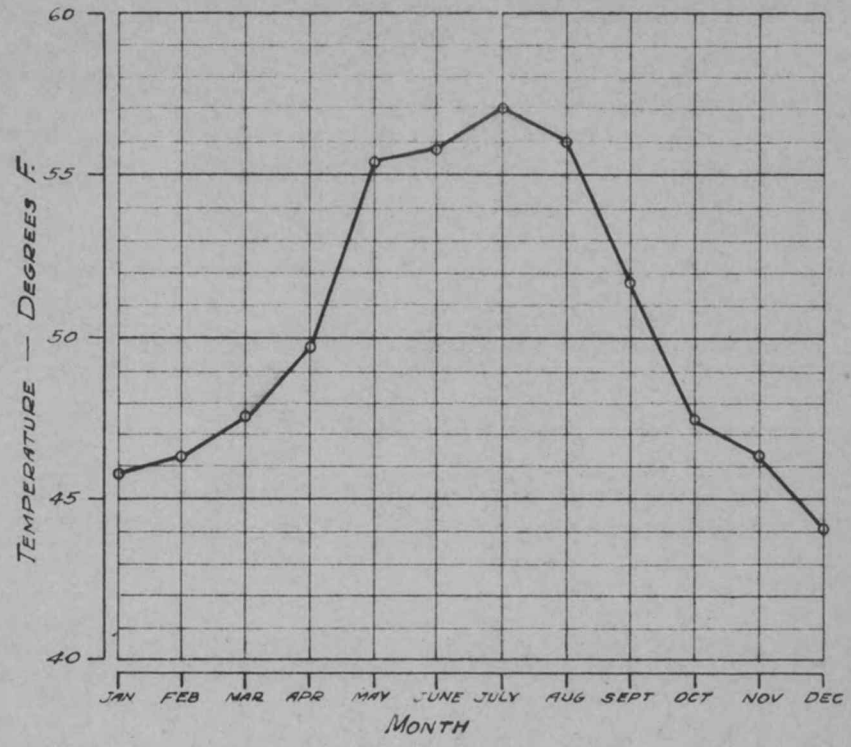
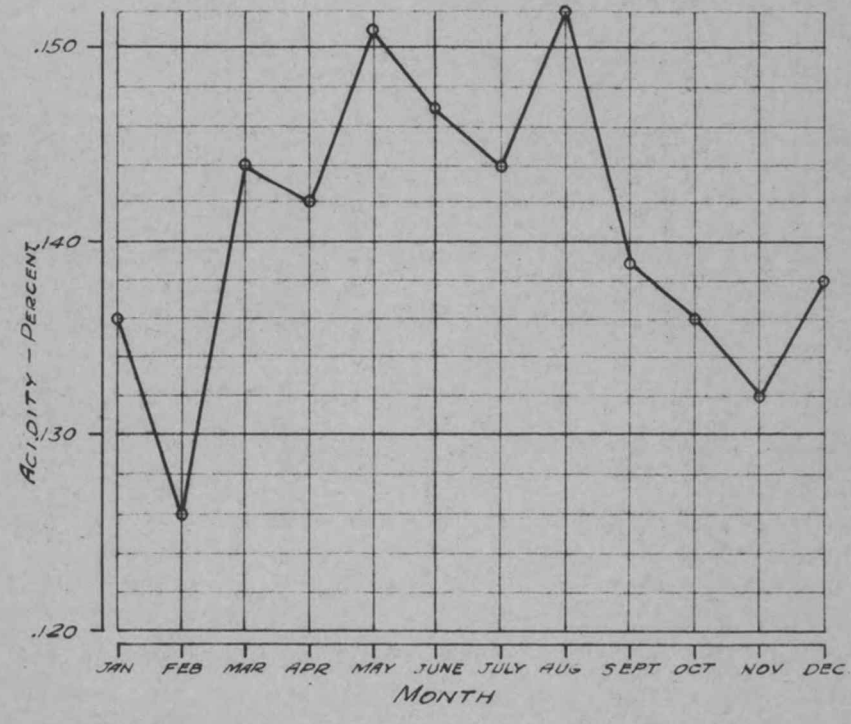


Chart 3.

AVERAGE MONTHLY ACIDITIES OF CREAM WHEN RECEIVED



July and August.

Table 5

MONTHLY AVERAGE ACIDITIES WHEN CREAM WAS RECEIVED AND RANGE OF ACIDITIES

	Average Acidities	Range in Acidities
January	.136	.110 - .160
February	.126	.110 - .140
March	.144	.140 - .150
April	.142	.130 - .150
May	.151	.120 - .200
June	.147	.130 - .230
July	.144	.120 - .180
August	.152	.120 - .210
September	.139	.110 - .170
October	.136	.110 - .170
November	.132	.120 - .140
December	.138	.130 - .150

5. The quality of the butter made from the refrigerated cream.

a. The germ killing efficiency of pasteurization. The numbers of bacteria found before and after pasteurization, and the pasteurization efficiencies are listed in Table 6. The number of bacteria found before pasteurization ranged from 46,500 per cubic centimeter to 14,700,000 per cubic centimeter and averaged 1,781,584. The number found after pasteurization ranged from 100 to 54,000 per cubic centimeter and averaged

5,700. For the series of 65 pasteurizations, the efficiency averaged 98.299 per cent. (Plate 6.).

It was noticed that, in general, a low bacterial count before pasteurization was accompanied by a low efficiency of pasteurization and a high bacterial count before pasteurization was accompanied by a high efficiency of pasteurization. There were exceptions to this rule in the case of low bacterial counts before pasteurization, but high bacterial counts before pasteurization were accompanied by high pasteurization efficiencies in every example; this is due to the fact that high counts on raw cream usually include many S. Lactis organisms which are rather easily killed by heat.

Table 6.

EFFICIENCY OF PASTEURIZATION
At 145°F. for 30 Minutes
65 Pasteurizations

No. of Sample	Before Past. No. of Bact. per cc.	After Past. No. of Bact. per cc.	Germ Killing Efficiency of Pasteurization
1	6,700,000	54,000	99.194%
2	6,100,000	1,200	99.980
3	2,860,000	36,300	98.730
4	2,650,000	2,000	99.924
5	5,540,000	300	99.994
6	14,700,000	300	99.997
7	4,500,000	12,500	98.722
8	3,300,000	800	99.975
9	9,600,000	1,300	99.986
10	630,000	1,200	99.809
11	8,300,000	5,000	99.939
12	850,000	800	99.905
13	630,000	900	99.857
14	1,890,000	1,100	99.941
15	1,100,000	600	99.945

No. of Sample	Before Past. No. of Bact. per cc.	After Past. No. of Bact. per cc.	Germ Killing Efficiency of Pasteurization
16	1,940,000	4,100	99.788
17	380,000	400	99.894
18	780,000	100	99.987
19	1,800,000	4,600	99.744
20	630,000	5,800	99.079
21	530,000	300	99.943
22	50,000	9,200	81.600
23	1,490,000	1,800	99.879
24	180,000	13,700	92.388
25	4,000,000	18,000	99.550
26	120,000	10,000	91.666
27	50,000	600	98.800
28	110,000	1,300	98.818
29	120,000	2,600	97.833
30	80,000	14,800	81.500
31	190,000	15,000	92.105
32	930,000	2,500	97.731
33	250,000	21,000	91.600
34	210,000	3,000	98.571
35	140,000	4,500	96.785
36	2,000,000	6,800	99.660
37	80,000	3,900	95.125
38	80,000	600	99.250
39	1,500,000	2,000	99.866
40	485,000	530	99.890
41	142,000	245	99.827
42	740,000	385	99.947
43	810,000	882	99.891
44	550,000	235	99.957
45	900,000	385	99.957
46	705,000	125	99.982
47	265,000	295	99.888
48	2,400,000	350	99.985
49	1,160,000	265	99.977
50	285,000	410	99.856
51	380,000	235	99.938
52	355,000	1,850	99.478
53	600,000	1,010	99.831
54	46,500	425	99.086
55	59,500	2,235	96.243
56	745,000	4,900	99.342
57	245,000	7,300	97,020
58	380,000	18,200	95.210
59	1,145,000	5,750	99.497
60	550,000	19,100	96.527
61	1,875,000	14,650	99.218
62	435,000	2,800	99.356
63	3,950,000	9,400	99.762

No. of Sample	Before Past. No. of Bact. per cc.	After Past. No. of Bact. per cc.	Germ Killing Efficiency of Pasteurization
64	5,350,000	1,800	99.966
65	4,750,000	11,900	99.749
			98.299

b. Percentage of bacterial types found in cream before and after pasteurization (Classified by action on litmus milk). Table 7 shows that of 855 litmus milk cultures obtained from colonies picked before pasteurization, 19.5 per cent were acid coagulators, 23.5 per cent acid non-coagulators, 19.4 per cent alkali formers, 7.4 per cent inert, 20.4 per cent acid peptonizers, 0.9 per cent alkali peptonizers, and 8.5 per cent were neutral peptonizers. (Plate 7).

Of 682 litmus cultures picked from colonies obtained after pasteurization, 14.3 per cent were acid coagulators, 68.6 per cent acid non-coagulators, 4.1 per cent alkali formers, 5.3 per cent inert, 4.1 per cent acid peptonizers, 0.14 per cent alkali peptonizers, and 3.6 per cent were neutral peptonizers.

The results show that both before and after pasteurization the acid non-coagulators were in the majority. A greater percentage of the acid non-coagulators survived pasteurization than all the other types combined. All other types showed decreases as a result of pasteurization.

Table 7.

PERCENTAGE OF BACTERIAL TYPES OCCURRING IN REFRIGERATED CREAM BEFORE AND AFTER PASTEURIZATION

	Acid		Alkali		Peptonizers	
	Coagulators	Non-coagulators	Formers	Inert	Alkali	Neutral
Before Past.	19.5%.	23.5%	19.4%	7.4%	.9%	8.5%
After Past.	14.3%	68.6%	4.1%	5.3%	.14%	3.6%

Number of litmus cultures before pasteurization -- 855

Number of litmus cultures after pasteurization -- 682

c. Isolation and identification of bacteria found in refrigerated cream. During the course of the experiment, several kinds of bacteria were isolated from the cream and identified. The bacteria were maintained on whey peptone agar slopes and later identified. The methods given in the Manual of methods for Pure Culture Study of Bacteria (87) were used in studying the characteristics of the organisms. The organisms were identified by reference to Bergey's Manual of Determinative Bacteriology. (88).

The following organisms were obtained from the cream before it had been pasteurized:

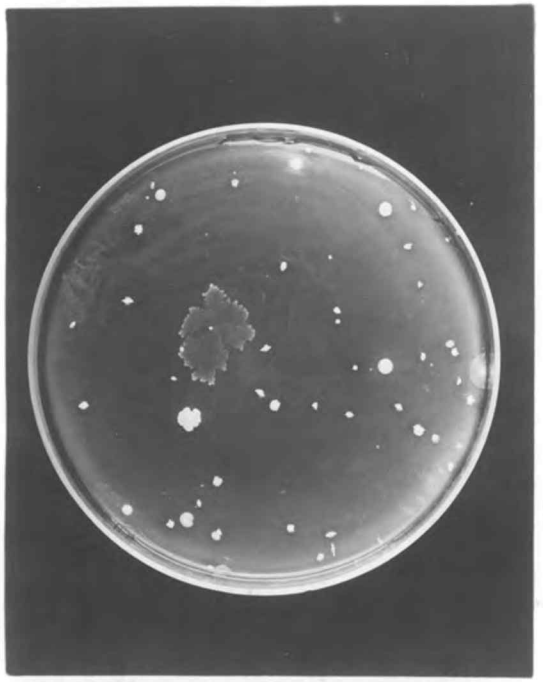
1. Micrococcus candicans Flügge.
2. Streptococcus citrovorus Hammer.
3. Escherichia communior (Durham) Bergey et al.
4. Bacillus subtilis (Ehrenberg) Cohn.
5. Escherichia coli (Escherich) Castellani and Chambers.
6. Achromobacter tiogense (Wright) Bergey et al.
7. Achromobacter fermentationis (Chester) Bergey et al.
8. Streptococcus glycerinaceous Orla-Jensen.
9. Streptococcus lactis (Lister) Löhnis.
10. Bacillus tumescens Zopf.
11. Achromobacter lipolyticum (Huss) Bergey et al.

It was observed that in addition to the bacteria usually found in

Efficiency of Pasteurization of Cream

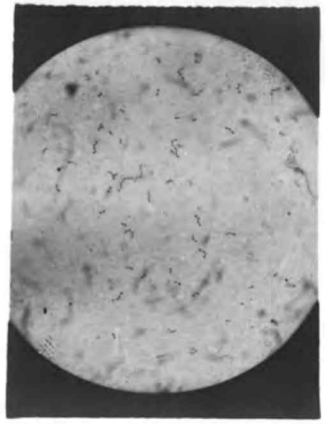
Bacteria before Pasteurization
Colonies from 1/1000 cc. of
cream before pasteurization

Plate 6.

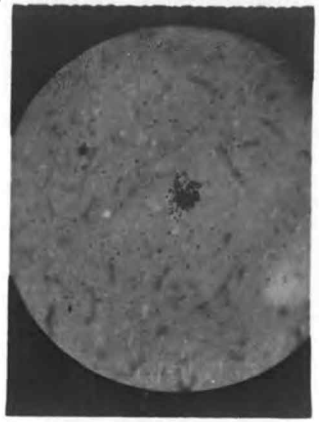


Bacteria after Pasteurization
Colonies from 1/1000 cc. of
cream before pasteurization

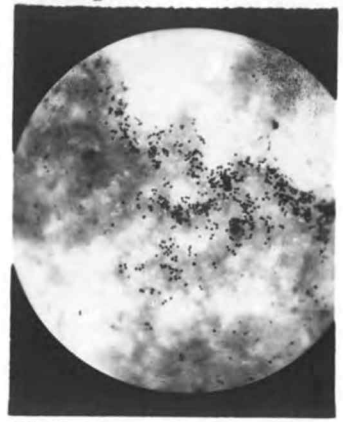
Types of Bacteria Isolated from Cream Before and After Pasteurization (Classified by action in litmus milk). Also Streptococci from Starter



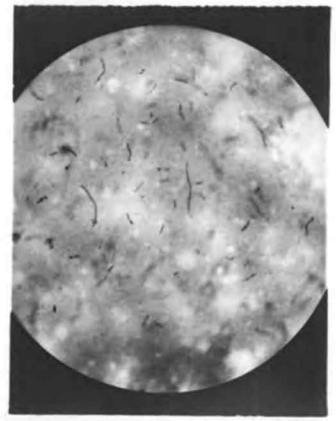
Before Pasteurization
Acid peptonizer



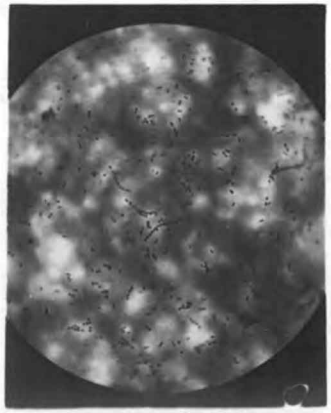
Before Pasteurization
Acid peptonizer



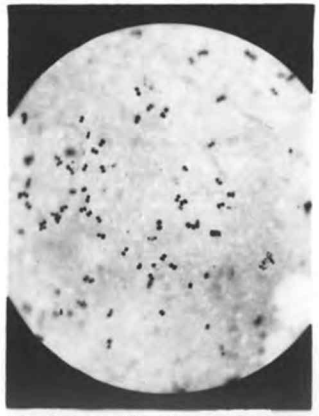
After Pasteurization
Acid peptonizer



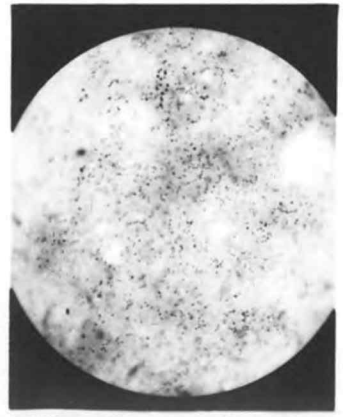
After Pasteurization
Acid peptonizer



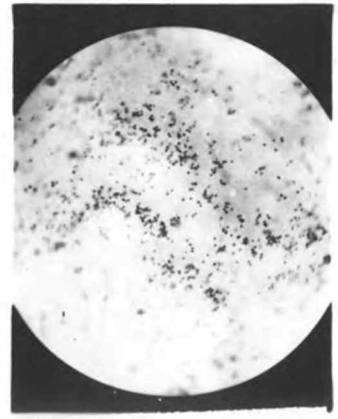
Streptococci from
starter



Before Pasteurization
Acid coagulator



After Pasteurization
Acid non-coagulator



After Pasteurization
Alkali peptonizer

Plate 7.

milk and cream there were several additional species of bacteria present. No. 1, Micrococcus candicans, named above, has its natural habitat in air, water, and milk; No. 2 is associated with S. lactis in starter; No. 4, No. 7, and No. 10 have their habitat in soil; No. 6 has its habitat in water. Those nearly always found in milk include No. 3, No. 5, No. 8, No. 9, and No. 11.

d. Yeast and mold counts of cream before and after pasteurization and of fresh butter.

The yeast and mold counts of 31 samples of cream before and after pasteurization and in the fresh butter are shown in Table 8. The yeast counts of the cream before pasteurization ranged from zero to 6.00 and averaged 1.16 per cubic centimeter, and the mold counts ranged from zero to 18.00 and averaged 2.00 per cubic centimeter. In the cream after pasteurization, 30 samples were free from yeasts and one sample contained 1 yeast per cubic centimeter, an average of .032 per cubic centimeter for all samples. One mold per cubic centimeter was found in each of four samples, and 27 samples were free from molds, which was an average of .225 per cubic centimeter for all samples. In the fresh butter the yeast counts ranged from zero to 18.00 and averaged 5.29 per cubic centimeter, and the mold counts ranged from zero to 45 and averaged 2.52 per cubic centimeter.

The data show that the yeasts and molds were generally decreased during pasteurization. The yeast and mold counts were larger in the fresh butter than were those of the pasteurized cream in the vat, in nearly every churning. Since the cover of the vat was closed until churning time, subsequent contamination must have occurred during the

Table 8.

YEAST AND MOLD COUNTS OF CREAM BEFORE AND AFTER PASTEURIZATION AND OF FRESH BUTTER

No.	Before Pasteurization		After Pasteurization		Fresh Butter	
	Y	M	Y	M	Y	M
1.	1	1	0	0	0	3
2.	0	1	0	0	0	0
3.	1	4	0	0	16	6
4.	0	2	0	0	5	3
5.	3	5	0	0	2	1
6.	5	18	0	1	1	4
7.	1	2	0	0	0	2
8.	1	0	0	0	10	0
9.	1	0	0	0	1	0
10.	6	0	0	0	8	0
11.	4	3	0	0	1	0
12.	3	5	0	0	0	3
13.	0	1	0	0	2	4
14.	1	0	0	1	0	0
15.	1	0	1	1	2	0
16.	0	1	0	2	0	0
17.	0	1	0	0	5	0
18.	1	7	0	0	0	0
19.	0	4	0	0	13	0
20.	1	4	0	1	17	1
21.	0	0	0	1	6	0
22.	0	1	0	0	6	0
23.	0	0	0	0	9	0
24.	0	0	0	0	12	1
25.	0	0	0	0	4	0
26.	0	0	0	0	9	45
27.	3	0	0	0	18	0
28.	3	0	0	0	1	5
29.	0	1	0	0	12	0
30.	0	1	0	0	1	0
31.	0	0	0	0	3	0
Average	1.16	2.00	.032	.225	5.29	2.52

transfer of the cream from the pasteurizing vat to the churn and during the churning process. The organisms must have been added to the cream in the pipe line, pump, strainer, and the churn.

e. Per cent butterfat lost in buttermilk. From Table 9 it is seen that in 53 churnings, the per cent butterfat in the buttermilk ranged from .06 to .50 and averaged .205 per cent. In 31 churnings of butter with which starter was used the per cent butterfat in the buttermilk ranged from .06 to .50 and averaged .214 per cent. In 22 churnings of butter with which no starter was used the per cent butterfat in the buttermilk ranged from .07 to .50 and averaged .193 per cent.

The results show that there was very little difference between the butterfat lost when starter was used and when no starter was used. The difference of .021 per cent in favor of the butter with which no starter was used was insignificant as a basis for favoring one method of butter manufacture against the other.

Table 9.

PER CENT BUTTERFAT IN BUTTERMILK

Butter with which starter was used		Butter with which no starter was used	
Number of Churning	Percent Butterfat Lost	Number of Churning	Percent Butterfat Lost
1	.10	32	.10
2	.10	33	.10
3	.10	34	.10
4	.10	35	.40
5	.10	36	.10
6	.45	37	.10
7	.10	38	.50
8	.20	39	.45
9	.10	40	.20
10	.10	41	.20
11	.20	42	.10
12	.10	43	.07
13	.45	44	.08
14	.30	45	.11
15	.20	46	.17
16	.40	47	.14
17	.20	48	.15
18	.06	49	.09
19	.30	50	.25
20	.23	51	.24
21	.24	52	.19
22	.26	53	.40
23	.25		
24	.15	Average per cent butterfat lost	.193
25	.09		
26	.15		
27	.07		
28	.42		
29	.22		
30	.40		
31	.50		
Average per cent butterfat lost	.214		

Average per cent butterfat in buttermilk for all churnings = .205

f. The quality of the butter made by the large churn. There were 47,634 pounds of cream received during the period in which the large churn was used. From this cream 17,684 pounds of butter were manufactured in 93 churnings.

Table 10 shows the average scores and range of scores of all butter made with this churn. It was found that the scores of the fresh butter ranged from 90.50 to 95.00 and averaged 92.62. After holding the butter for one month at from 35 deg. to 45 deg. Fah. the scores ranged from 89.00 to 94.00 and averaged 91.90. The average decrease after one month of holding was .72 of a point. After holding it for six months at from zero deg. to 10 deg. Fah. the scores ranged from 89.66 to 94.00 with an average score after six months of 92.11. The average decrease in score after holding for six months was .51 of a point.

From the frequency distribution in Table 11 it is seen that the majority, or 68.81 per cent, of the scores of the fresh butter were in the range between 92.00 and 94.00; 13.98 per cent of the scores were above 94.00; and 17.21 per cent of the scores were below 92.00.

After holding the butter at from 35 deg. to 45 deg. Fah. for one month a slight majority, or 50.54 per cent, of the scores were also found to be in the range between 92.00 and 94.00, but only 6.45 per cent of the scores were above 94.00, and 43.01 per cent of the scores were below 92.00.

After holding the butter for six months at from zero deg. to 10 deg. Fah. the majority, or 64.52 per cent, of the scores were found to be in the range between 92.00 and 94.00; 1.08 per cent of the scores

were above 94.00; and 34.40 per cent of the scores were below 92.00.

The above data show that the quality of this butter was uniformly high, since over 82 per cent of the scores of the fresh butter were 92.00 or higher. The keeping quality of the butter was quite good, since nearly 57 per cent of the samples of the one month old butter scored 92.00 or higher, and over 65 per cent of the samples of the six months old butter scored 92.00 or higher. The decreases in score during the holding periods were, in general, very slight. When the butter was held at from zero deg. to 10 deg. Fah. for six months it kept better than it did when it was held at from 35 deg. to 45 deg. Fah. for one month.

Table 10.

AVERAGE SCORES AND RANGE OF SCORES WHEN FRESH, AFTER ONE MONTH, AND AFTER SIX MONTHS MADE IN THE LARGE CHURN. 93 CHURNINGS

Range in Scores of Fresh Butter	Av. Score of Fresh Butter	Range in Scores After 1 month at 35 to 45 deg. Fah.	Av. Score After 1 Month at 35 to 45 deg. Fah.	Av. Decrease in Score After 1 month	Range in Scores After 6 Months at 0 to 10 deg. Fah.	Av. Score After 6 Months at 0 to 10 deg. Fah.	Av. decrease in Score After 6 Months
90.50 - 95.00	92.62	89.00 - 94.00	91.90	.72	89.66-94.00	92.11	.51

Table 11.

FREQUENCY DISTRIBUTION. 93 CHURNINGS

Scores	Fresh Butter	Percent of all Scores	Butter Held for 1 Month at 35 to 45 deg. Fah.	Percent of all Scores	Butter Held for 6 Months at 0 to 10 deg. Fah.	Percent of all Scores
94.5 - 95.0	5	5.38	0	0.00	0	0.00
94.0 - 94.5	8	8.60	6	6.45	1	1.08
93.5 - 94.0	12	12.90	10	10.75	5	5.38
93.0 - 93.5	18	19.35	5	5.38	22	23.66
92.5 - 93.0	15	16.13	10	10.75	13	13.98
92.0 - 92.5	19	20.43	22	23.66	20	21.50
91.5 - 92.0	6	6.45	13	13.98	11	11.83
91.0 - 91.5	9	9.68	13	13.98	14	15.05
Below 91.0	1	1.08	14	15.05	7	7.52

In Table 12 are shown the average monthly scores of all butter made in the large churn, when fresh, after holding for one month at from 35 deg. to 45 deg. Fah., and after holding for six months at from zero deg. to 10 deg. Fah. It is seen from Chart 4 that the average monthly scores of the fresh butter were uniformly above 92.00 with one exception which occurred in January. It is noted that the scores of the fresh butter, for the summer months, May, June, July, and August, were 92.70 or higher. Since the cows were on grass pasture during these months the kind of feed may have influenced the quality of the butter favorably. The average monthly score of the fresh butter which was made in September was lower than were those of the previous four months and was followed by a high average score in October. This fluctuation corresponds closely with the drying up of the pasture at the end of the summer in the Willamette Valley, followed by the feeding of kale and silage on the producing farms in the early fall. The seasonal change in feeding may have influenced the quality of the butter made during September and October. After the holding period of one month it was found that the scores were not as uniform as the scores of the butter when fresh. The average scores of the one month old butter made in January, March, July, August, and December were found to be below 92.00 and the average scores of the other months were above 92.00. After the holding period of six months the average monthly scores of the butter were found to be more uniform than after the one month holding period. The average monthly scores of the butter made in January, February, May, August, and December were found to be below 92.00, after the six months holding period and the average scores of the other months

Table 12.

AVERAGE MONTHLY SCORES OF BUTTER WHEN FRESH,
AFTER ONE MONTH, AND AFTER SIX MONTHS

93 Large Churnings

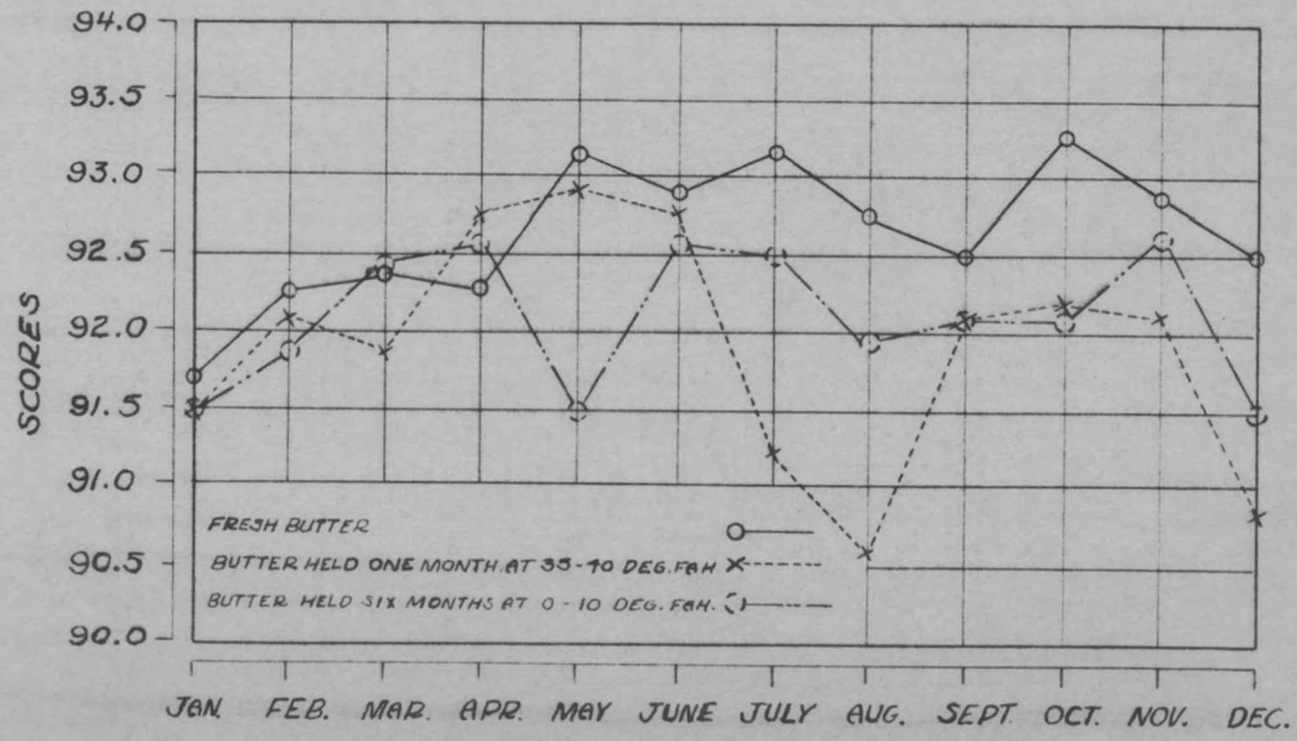
Month in Which Butter was Manufactured	Average Score When Fresh	Average Score After Holding for 1 Month at 35 deg. to 45 deg. Fah.	Per cent Decrease	Per cent Increase	Average Score After Holding for 6 Months at 0 deg. to 10 deg. Fah.	Per cent Decrease	Per cent Increase
January	91.66	91.50	.18		91.50	.18	
February	92.27	92.06	.23		91.93	.37	
March	92.39	91.90	.54		92.41		.03
April	92.31	92.79		.52	92.65		.37
May	93.18	92.92	.28		91.54	1.77	
June	92.85	92.70	.17		92.60	.27	
July	93.14	91.21	2.08		92.50	.69	
August	92.70	90.60	2.27		91.96	.80	
September	92.44	92.11	.36		92.10	.37	
October	93.25	92.20	1.13		92.10	1.24	
November	92.87	92.12	.81		92.67	.22	
December	92.45	90.72	1.88		91.50	1.03	

Chart 4.

AVERAGE MONTHLY SCORES OF BUTTER

FRESH ~ ONE MONTH ~ SIX MONTHS

93 LARGE CHURNINGS



were above 92.00.

There seems to be a similarity between the average monthly scores of the fresh butter and the average monthly scores after the one month and six months holding periods, since the curves showing the scores after the one month and six months holding periods, shown in Chart 4, correspond, in general, with the curve showing the scores of the fresh butter. After the one month holding period, however, the months with marked decreases in average monthly score were July, August, October, and December which had percentage decreases of 2.08, 2.27, 1.13, and 1.88 respectively. The other months had smaller percentage decreases in average monthly score, after the one month holding period. After the six months holding period the months with marked decreases in average monthly score were May, October, and December which had percentage decreases of 1.77, 1.24, and 1.03 respectively. The other months had smaller percentage decreases in average monthly score after the six months holding period. It is noted that April had an increase in average monthly score of .52 per cent after one month and an increase in average monthly score of .37 after six months, and that March had an increase in average monthly score of .03 after six months. This increase in score may be attributed to the differences in standards of judging employed by the judges at the separate scorings, since butter is not apt to increase in score during the holding periods.

g. The comparative quality of the butter made in the large churn when starter was used and when no starter was used. (93 churnings*).

In comparing the scores of 59 large churnings with which starter was used and 34 with which no starter was used, it is found that when starter was used the scores of the fresh butter ranged from 90.50 to 95.00 and averaged 93.03 while the scores of the fresh butter made without starter ranged from 90.50 to 93.50 and averaged 91.96. The data are shown in Table 13. After holding for one month at from 35 deg. to 45 deg. Fah. the scores of the butter made with starter ranged from 89.00 to 94.00 and averaged 92.07 while the scores of the butter made without the use of starter ranged from 89.00 to 94.00 and averaged 91.60. After six months at from zero deg. to 10 deg. Fah. the scores of the butter made with the use of starter ranged from 90.00 to 94.00 and averaged 92.40 while the scores of the butter made without the use of starter ranged from 89.66 to 93.50 and averaged 91.63. This shows that butter made with starter scored 1.07 points higher when fresh, .47 of a point higher after one month at from 35 deg. to 45 deg. Fah., and .77 of a point higher after six months at from zero deg. to 10 deg. Fah. than did the butter made without starter.

The differences in average score after the holding periods of one month and six months are also shown in Table 13. The average score of the butter made with starter was .96 of a point lower after holding for one month at from 35 deg. to 45 deg. Fah. and .63 of a point lower after holding for six months at from zero deg. to 10 deg. Fah. as compared to the average score of the butter made without starter

* Mentioned previously in the report.

Table 13.

AVERAGE SCORES AND RANGE OF SCORES WHEN FRESH, AFTER ONE MONTH, AND AFTER SIX MONTHS OF BUTTER WITH WHICH STARTER WAS USED AND OF BUTTER WITH WHICH NO STARTER WAS USED

59 Large churnings of butter with which starter was used.
34 Large churnings of butter with shich no starter was used.

	Range in Scores of fresh butter	Av. Score of fresh butter	Range in Scores after 1 month at 35-46 deg. Fah.	Av. Score after 1 month at 35 - 45 deg. Fah.	Av. decrease in score after 1 month	Range in scores after 6 months at 0 to 10 deg. Fah.	Av. Score after 6 months at 0 to 10 deg. Fah.	Av. decrease in score after 6 months
Butter made with the use of starter	90.50 - 95.00	93.03	89.00 - 94.00	92.07	.96	90.00 - 94.00	92.40	.63
Butter made without the use of starter	90.50 - 93.50	91.96	89.00 - 94.00	91.60	.36	89.66 - 93.50	91.63	.33
Difference in favor of butter made with the use of starter		1.07		.47			.77	

which was .36 of a point and .33 of a point lower after the respective holding periods. It was observed that the decreases in score were greater each time in butter with starter used than in butter with no starter used. The division between "Extra" and "Standard" grade butter in Oregon is 92.00. Butter made with starter had an average score that was higher than 92.00 when the butter was fresh, and also after it had been held for one month and for six months. The butter with which no starter was used, on the other hand, had an average score which was slightly less than 92.00 when the butter was fresh, and less than 92.00 both after holding it for one month and after holding it for six months.

From the frequency distribution in Table 14, showing the grouping of the scores of the butter made with starter and the grouping of the scores of the butter made without starter, and in Chart 5, it is seen that 93.23 per cent of the scores of the fresh butter made with starter were above 92.00 as compared to 61.77 per cent of the scores above 92.00 for the fresh butter made without starter. Only 6.77 per cent of the scores of the fresh butter made with starter were below 92.00 while 38.23 per cent of the scores of the fresh butter made without starter were below 92.00. These data show that the fresh butter made with starter was uniformly higher in quality than the butter made without starter, since a much larger percentage of the scores of the butter made with starter was above 92.00 than was that of the butter made without starter.

After the butter had been held for one month at from 35 deg. to

Table 14.

FREQUENCY DISTRIBUTION

Butter with which Starter was Used — 59 Large churnings

Scores	Fresh Butter: No. of samples	Fresh Butter: Per cent of all scores		Butter held for 1 month at 35 deg. to 45 deg. Fah.: No. of samples	Butter held for 1 month at 35 deg. to 45 deg. Fah.: Per cent of all scores		Butter held for 6 months at 0 to 10 deg. Fah.: No. of samples	Butter held for 6 months at 0 to 10 deg. Fah.: Per cent of all scores	
94.5 - 95.0	5	8.47		0	0.00		0	0.00	
94.0 - 94.5	8	13.56	93.23	5	8.47	61.02	2	3.39	77.97 Per cent
93.5 - 94.0	10	16.95	Per cent	8	13.56	Per cent	6	10.17	above 92.00
93.0 - 93.5	14	23.73	above	5	8.47	above	19	32.20	
92.5 - 93.0	10	16.95	92.00	3	5.09	92.00	8	13.56	
92.0 - 92.5	8	13.57	6.77	15	25.43		11	18.65	
91.5 - 92.0	1	1.69	Per cent	8	13.56	38.98	4	6.78	22.03 Per cent
91.0 - 91.5	2	3.39	below	9	15.25	Per cent	8	13.56	below 92.00
Below 91.0	1	1.69	92.00	6	10.17	below 92.00	1	1.69	

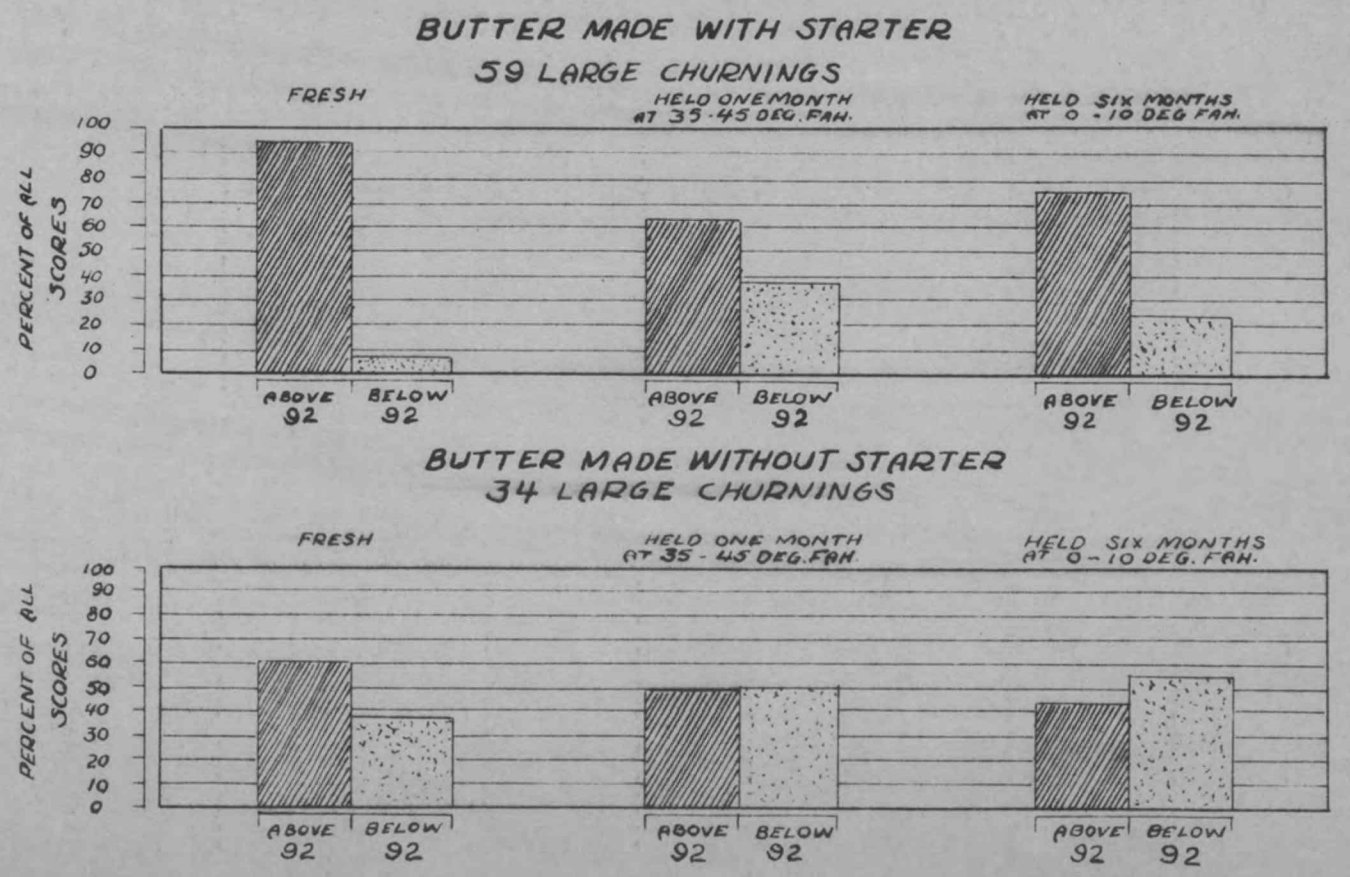
Butter with which no Starter was Used — 34 Large churnings

94.5 - 95.0	0	0.00		0	0.00		0		
94.0 - 94.5	0	0.00	61.77	1	2.94	49.98	0		
93.5 - 94.0	2	5.88	Per cent	2	5.88	Per cent	1	2.94	44.12 Per cent
93.0 - 93.5	3	8.82	above	0	0.00	above	1	2.94	above 92.00
92.5 - 93.0	5	14.71	92.00	7	20.58	92.00	5	14.71	
92.0 - 92.5	11	32.36		7	20.58		8	23.53	
91.5 - 92.0	5	14.71	38.23	5	14.71	50.02	7	20.58	55.88 Per cent
91.0 - 91.5	7	20.58	Per cent	4	11.77	Per cent	6	17.65	below 92.00
Below 91.0	1	2.94	below 92.00	8	23.54	below 92.00	6	17.65	

Chart 5.

PERCENTAGES OF SCORES OF BUTTER ABOVE AND BELOW 92

BUTTER MADE WITH AND WITHOUT STARTER
SCORED WHEN FRESH ~ ONE MONTH ~ SIX MONTHS
93 LARGE CHURNINGS



45 deg. Fah., 61.02 per cent of the scores of the butter made with starter were above 92.00 and 38.98 per cent were below. 48.98 per cent of the scores of the butter made without starter were above 92.00 and 50.02 per cent were below. It was noted that one score of the butter made without starter was above 94.00 after the one month holding period and that there were no scores above 94.00 when the butter was fresh. This apparent increase in score was probably due to a difference in the standards of judging used by the judges.

After the butter had been held for six months at from zero deg. to 10 deg. Fah., 77.97 per cent of the scores of the butter made with starter were above 92.00, and 44.12 per cent of the scores of the butter made without starter were above 92.00. 22.03 per cent of the scores of the six months old butter made with starter were below 92.00 while 55.88 per cent of the scores of the six months old butter made without starter were below 92.00.

It is seen from these data that the butter made with starter and the butter made without starter were both of high quality, since a large percentage of the scores of the butter made with the two methods was above 92.00. It is shown, however, that a better quality butter can be made with starter than without it, since a greater percentage of the scores of the butter made with starter were above 92.00 than were those of the butter made without the use of starter.

It appears that there was very little difference between the keeping quality of the butter made with starter and that of the butter made without starter. The scores of the butter made with starter decreased the most after the one month holding period, and the scores

of the butter made without starter decreased the most after the six months holding period. At the end of the holding periods of one month and of six months, however, the butter made with starter had a larger percentage of scores above 92.00 than did the butter made without starter.

The comments of the judges on the butter with which starter was used were characterized by "fine starter flavor", "creamy flavor", "sweet and clean", "fine aroma", "fine flavor". The comments of the judges on the butter with which no starter was used were characterized by "flat", "lacking in character", "insipid", "starter would improve", "tallowy".

h. Comparative quality of butter with four methods of cream treatment before churning. (64 churnings from 16 lots of cream).

There were 4,426 pounds of cream received during the period in which the small churns were used. From this cream 1,678 pounds of butter were manufactured in 64 small churnings.

The scores of the butter when fresh made from ripened cream, shown in Table 15 and Chart 6, ranged from 92.00 to 94.00 and averaged 93.29; those of the butter made from cream to which starter had been added and the cream immediately cooled ranged from 92.00 to 94.50 and averaged 93.24; those of the butter made from cream to which starter was added just before churning ranged from 92.00 to 93.75 and averaged 92.73; and those of the butter made from cream to which no starter was added ranged from 91.70 to 93.50 and averaged 92.41. Thus, when fresh, the butter made from ripened cream scored an average of .88 of a point higher than butter with which no starter was used; the butter made from

Table

INFLUENCE OF STARTER
BUTTER MADE FROM
64 churnings from 16

No. of churning	Ripened Cream			Starter added afternoon before and cooled		
	Fresh	After 1 mo. at 45° F.	After 6 mo. at 10° F.	Fresh	After 1 mo. at 45° F.	After 6 mo. at 0 to 10° F.
1	93.50	94.00	93.25	94.00	94.50	93.00
2	93.50	93.50	92.00	94.00	94.00	92.00
3	94.00	94.00	92.75	93.50	94.00	93.25
4	93.50	91.50	93.00	92.70	93.00	93.50
5	93.20	93.30	92.00	93.20	92.70	93.00
6	93.00	93.20	92.50	92.50	92.70	93.50
7	93.50	93.50	93.00	92.50	92.70	93.50
8	93.50	93.20	93.00	92.70	92.80	93.50
9	94.00	92.00	93.00	94.50	93.00	93.50
10	93.50	92.66	93.50	93.00	92.50	93.00
11	94.00	93.00	94.00	94.50	94.00	93.50
12	92.80	92.00	90.50	93.20	92.00	90.16
13	92.50	93.00	88.16	93.00	93.50	91.00
14	93.00	92.00	90.66	93.50	92.50	92.00
15	93.20	92.50	90.66	92.00	93.00	90.00
16	92.00	94.50	92.33	93.00	94.00	91.66
Average Score	93.29	92.99	92.14	93.24	93.18	92.50
Average decrease after storage for 1 mo. at 45° F.		.30			.06	
Average increase after storage for 1 month at 45° F.						
Average decrease after storage for 6 months at 0 - 10° F.			1.15			.74

15

ON THE SCORE OF
SWEET CREAM
lots of sweet cream

Starter added to cream before churning			No starter added to cream		
Fresh	After 1 mo. at 45° F.	After 6 mo. at 10° - 10° F.	Fresh	After 1 mo. at 45° F.	After 6 mo. at 0 - 10° F.
93.00	93.00	92.00	93.00	93.00	92.75
93.75	93.00	91.00	93.00	92.50	92.75
93.50	92.50	92.00	93.00	92.00	92.25
92.50	93.50	93.00	91.70	93.50	92.50
92.20	92.50	91.50	91.80	91.80	92.00
92.50	92.00	92.50	92.00	91.80	93.00
92.80	92.50	92.00	91.80	92.00	92.00
92.30	92.20	93.00	92.00	92.70	92.00
93.00	91.50	92.00	92.50	92.50	92.50
92.00	92.20	92.50	93.00	91.30	92.00
93.50	93.00	92.50	92.50	92.50	92.00
92.80	91.50	89.83	91.80	92.00	89.33
92.50	93.50	89.50	93.00	94.00	90.50
92.50	92.00	92.00	92.00	92.50	89.66
92.30	93.00	90.50	92.00	93.50	91.83
92.50	93.00	92.66	93.50	93.00	92.50
92.73	92.55	91.78	92.41	92.53	91.84

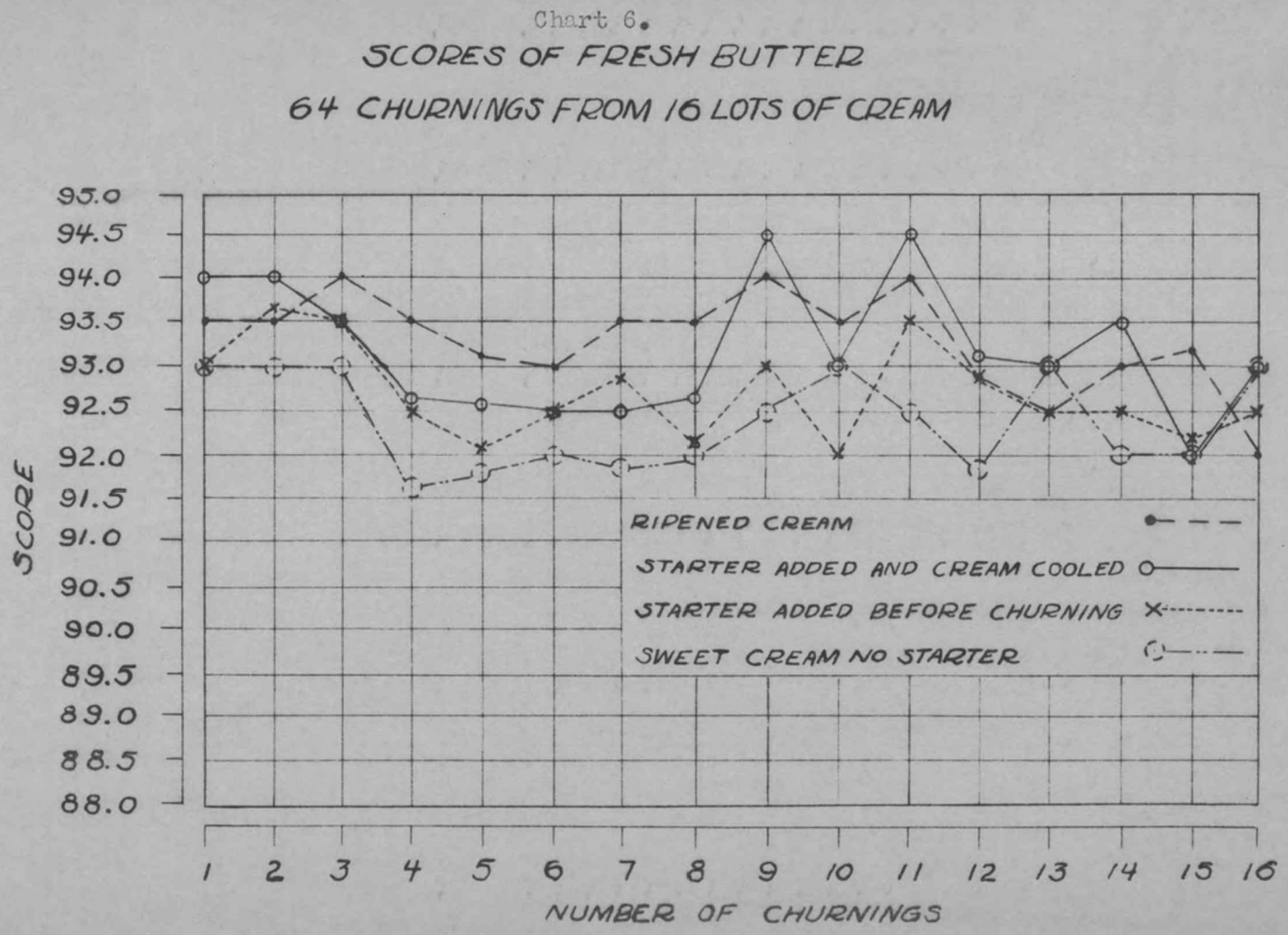
.18

.12

.95

.57

Chart 6.

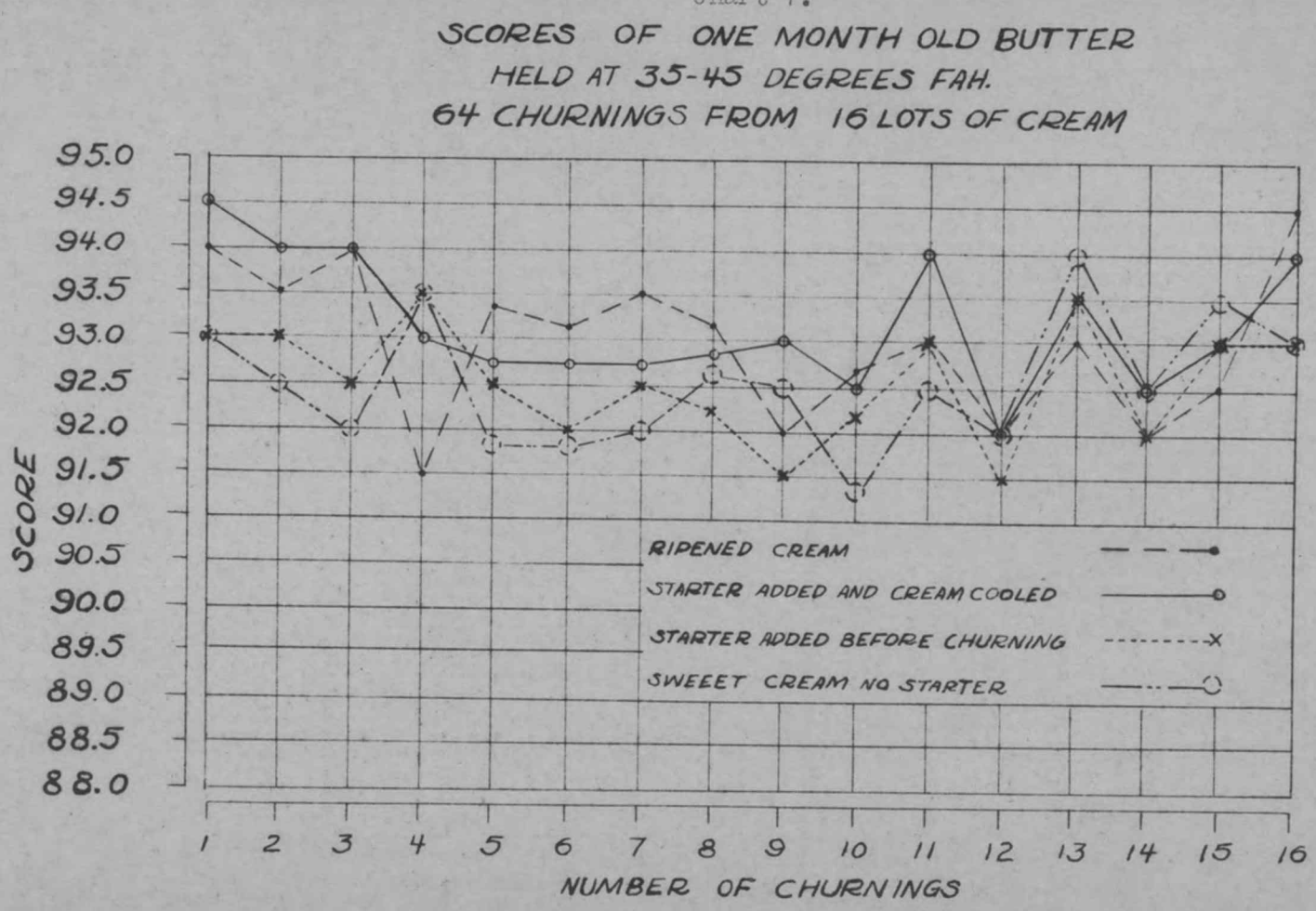

SCORES OF FRESH BUTTER
64 CHURNINGS FROM 16 LOTS OF CREAM
SCORE
95.0
94.5
94.0
93.5
93.0
92.5
92.0
91.5
91.0
90.5
90.0
89.5
89.0
88.5
88.0
RIPENED CREAM
STARTER ADDED AND CREAM COOLED
STARTER ADDED BEFORE CHURNING
SWEET CREAM NO STARTER
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16
NUMBER OF CHURNINGS

cream to which starter had been added and the cream cooled scored an average of .83 of a point higher than the butter with which no starter was used; and the butter made from cream to which starter was added just before churning scored an average of .32 of a point higher than the butter with which no starter was used.

Table 15 and Chart 7 show that after holding for one month at from 35 deg. to 45 deg. Fah. the scores of the butter made from ripened cream ranged from 91.50 to 94.50 and averaged 92.99; those of the butter made from cream to which starter had been added and the cream immediately cooled ranged from 92.00 to 94.50 and averaged 93.18; those of the butter made from cream to which starter was added just before churning ranged from 91.50 to 93.50 and averaged 92.55; and those of the butter made from cream to which no starter was added ranged from 91.30 to 94.00 and averaged 92.53. Thus, after one month at from 35 deg. to 45 deg. Fah., the butter made from ripened cream scored an average of .46 of a point higher than the butter with which no starter was used; the butter made from cream to which starter had been added and the cream cooled scored an average of .65 of a point higher than the butter with which no starter was used; and the butter made from cream to which starter was added just before churning scored an average of but .02 of a point higher than the butter with which no starter was used. The difference of .02 of a point in the last case is insignificant.

The average decreases in score after the one month holding period were .30 of a point for the butter made from ripened cream, .06 of a point for butter made from cream to which starter had been added and the cream cooled, and .18 of a point for butter made from cream to

Chart 7.

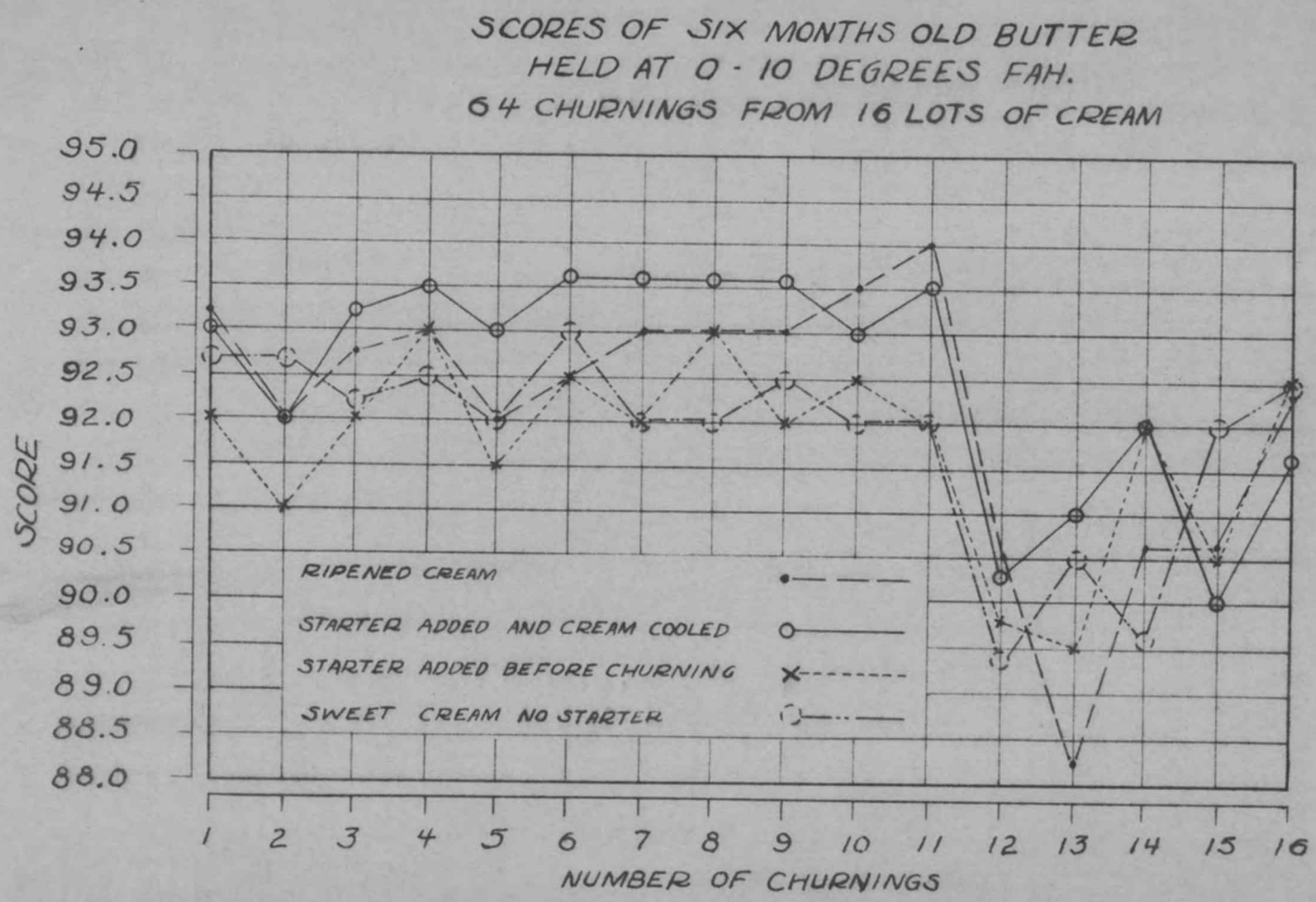

SCORES OF ONE MONTH OLD BUTTER
HELD AT 35-45 DEGREES FAH.
64 CHURNINGS FROM 16 LOTS OF CREAM
SCORE
95.0
94.5
94.0
93.5
93.0
92.5
92.0
91.5
91.0
90.5
90.0
89.5
89.0
88.5
88.0
RIPENED CREAM
STARTER ADDED AND CREAM COOLED
STARTER ADDED BEFORE CHURNING
SWEEET CREAM NO STARTER
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16
NUMBER OF CHURNINGS

which starter had been added just before churning. In the case of butter made from cream to which no starter was added there was an average increase in score of .12 of a point. This increase is not large enough to be significant and may be explained by the difference in scoring standards of the judges which caused some of the samples to apparently increase in score.

After holding for six months at from zero deg. to 10 deg. Fah., according to Table 15 and Chart 8, scores of butter made from ripened cream ranged from 88.16 to 94.00 and averaged 92.14; those of the butter made from cream to which starter had been added and the cream cooled ranged from 90.00 to 93.50 and averaged 92.50; those of the butter made from cream to which starter was added just before churning ranged from 89.50 to 93.00 and averaged 91.78; and those of the butter made from cream to which no starter was added ranged from 89.33 to 93.00 and averaged 91.84. Thus, after six months at from zero deg. to 10 deg. Fah., the butter made from ripened cream scored an average of .30 of a point higher than the butter with which no starter was used; the butter made from cream to which starter was added and the cream cooled, scored an average of .66 of a point higher than the butter with which no starter was used; and the butter made from cream to which starter was added just before churning scored an average of .06 lower than the butter with which no starter was used. The difference noted in the last example of .06 of a point is insignificant in value for determining the relative merits of the two last mentioned methods of treating the cream.

It would seem that the two methods, making butter from ripened

Chart 8.


SCORES OF SIX MONTHS OLD BUTTER
HELD AT 0 - 10 DEGREES FAH.
64 CHURNINGS FROM 16 LOTS OF CREAM
SCORE
95.0
94.5
94.0
93.5
93.0
92.5
92.0
91.5
91.0
90.5
90.0
89.5
89.0
88.5
88.0
RIPENED CREAM
STARTER ADDED AND CREAM COOLED
STARTER ADDED BEFORE CHURNING
SWEET CREAM NO STARTER
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16
NUMBER OF CHURNINGS

cream and making butter from cream to which starter had been added and the cream cooled, were of nearly equal value when the average scores of the fresh samples are observed. However, it would appear that the butter made by the second method, with starter added to the cream and cream cooled and held overnight before churning, had the best keeping quality, scoring higher both after the one month and after the six months holding periods.

Of the last two methods, making butter from cream to which starter was added just before churning and making butter from cream to which no starter was added, it would seem that there was little difference between them. The average socre when fresh was higher for the butter made from cream to which starter was added just before churning, but the scores after one month and six months were approximately the same for both samples. The only two average scores below 92.00 were found in these two methods of cream treatment after holding for six months at from zero deg. to 10 deg. Fah. Apparently when the starter was added to the cream just before churning it was not allowed to be in contact with the cream for sufficient time to impart the full starter flavor to the cream.

In Chart 8, showing the trend of scores after the butter had been held for six months, it is noticed that the scores from numbers 12 to 15 inclusive were considerably lower than the scores of the other butter held for the same length of time. This butter was all manufactured during the month of July and a seasonal influence may have affected the keeping quality of the butter when it was held for six months.

The frequency distribution in Table 16 shows the grouping of the scores of the butter made with four methods of cream treatment before churning when the butter was fresh, after it had been held for one month at from 35 deg. to 45 deg. Fah., and after it had been held for six months at from zero deg. to 10 deg. Fah. Chart 9 illustrates the grouping of the scores of the fresh butter; Chart 10 illustrates the grouping of the scores of the butter after it had been held for one month at from 35 deg. to 45 deg. Fah.; and Chart 11 illustrates the grouping of the scoresoof the butter after it had been held for six months at from zero deg. to 10 deg. Fah.

In Table 16 and Chart 9, it is shown that no scores of the fresh butter were below 92.00 when the cream was treated in the following ways: starter added to the cream and the cream ripened, starter added to the cream and the cream immediately cooled, and starter added to the cream before churning. When no starter was added to the cream, however, four scores of the butter made from it were below 92.00.

Table 16 and Chart 10 show that after one month at from 35 deg. to 45 deg. Fah., one score of the butter made from ripened cream was below 92.00; two scores of the butter made from cream with starter added before churning were below 92.00; and three scores of the butter made from cream with no starter added were below 92.00.

From Table 16 and Chart 11, it is seen that after six months at from zero deg. to 10 deg. Fah. four scores were below 92.00 when each of the three methods, adding starter and ripening the cream, adding starter and cooling the cream, and adding no starter, were used. Five scores of the butter were below 92.00 when starter was added to the cream before churning.

Table 16.

FREQUENCY DISTRIBUTION
64 Churnings from 16 Lots of Sweet Cream

Scores	Ripened Cream	Starter Cooled	Starter before Churning	Sweet Cream
Fresh Butter				
94.5 - 95.0	0	2	0	0
94.0 - 94.5	3	2	0	0
93.5 - 94.0	6	2	3	1
93.0 - 93.5	4	5	2	5
92.5 -93.0	2	4	7	2
92.0 - 92.5	1	1	4	4
91.5 - 92.0	0	0	0	4
91.0 - 91.5	0	0	0	0
1 Month Old Butter				
94.5 - 95.0	1	1	0	0
94.0 - 94.5	2	4	0	1
93.5 - 94.0	2	1	2	2
93.0 - 93.5	5	3	5	2
92.5 - 93.0	2	6	3	5
92.0 - 92.5	3	1	4	3
91.5 - 92.0	1	0	2	2
91.0 - 91.5	0	0	0	1
6 Months Old Butter				
94.5 - 95.0	0	0	0	0
94.0 - 94.5	1	0	0	0
93.5 - 94.0	1	6	0	0
93.0 - 93.5	5	4	2	1
92.5 - 93.0	2	0	4	5
92.0 - 92.5	3	2	5	6
91.5 - 92.0	0	1	1	1
91.0 - 91.5	0	1	1	0
Below 91.0	4	2	3	3

Chart 9.

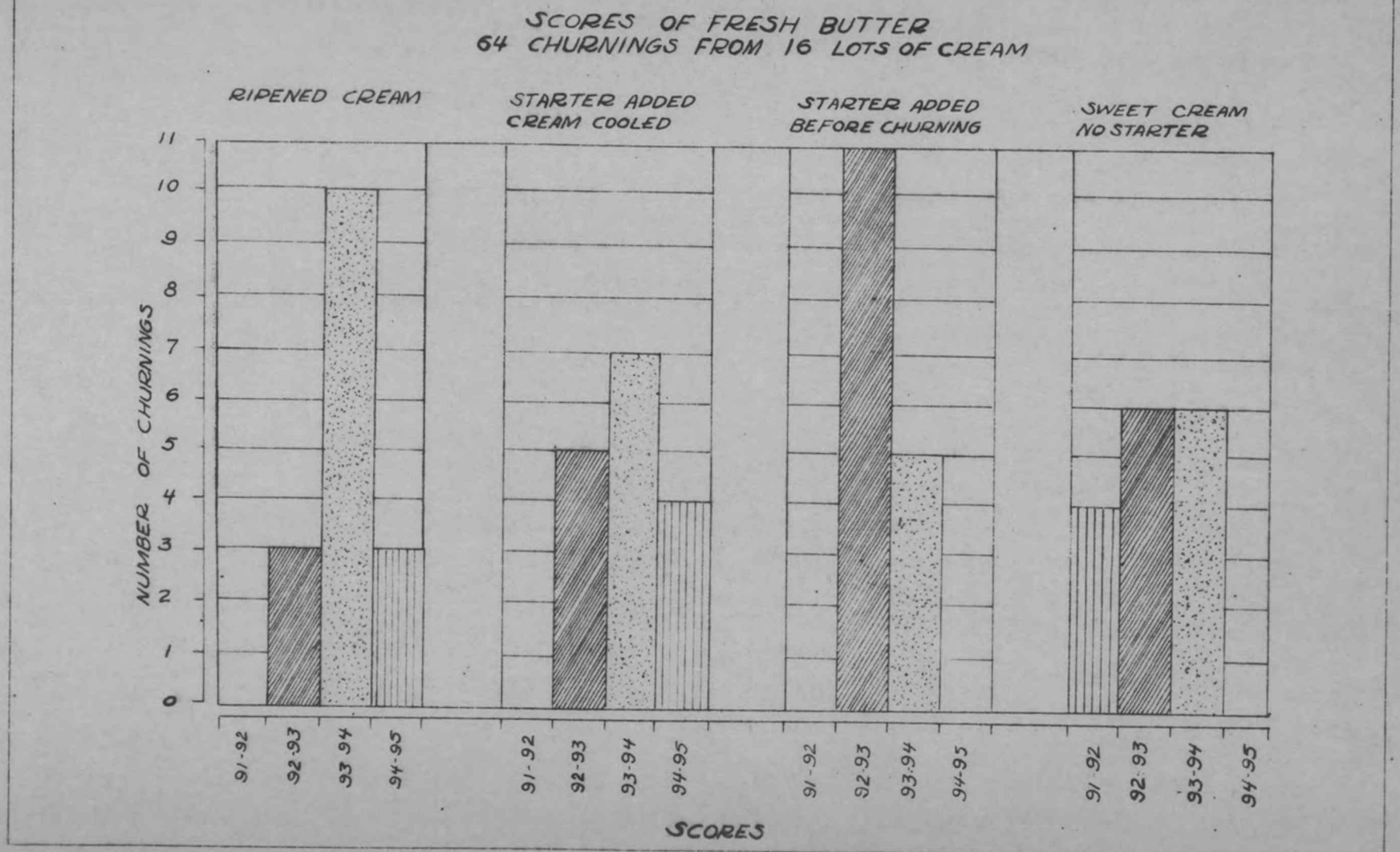

SCORES OF FRESH BUTTER
64 CHURNINGS FROM 16 LOTS OF CREAM
RIPENED CREAM
STARTER ADDED CREAM COOLED
STARTER ADDED BEFORE CHURNING
SWEET CREAM NO STARTER
NUMBER OF CHURNINGS
0
1
2
3
4
5
6
7
8
9
10
11
91-92
92-93
93 94
94-95
91-92
92-93
93-94
94-95
91-92
92 93
93.94
94-95
91 92
92 93
93-94
94 95
SCORES

Chart 10.

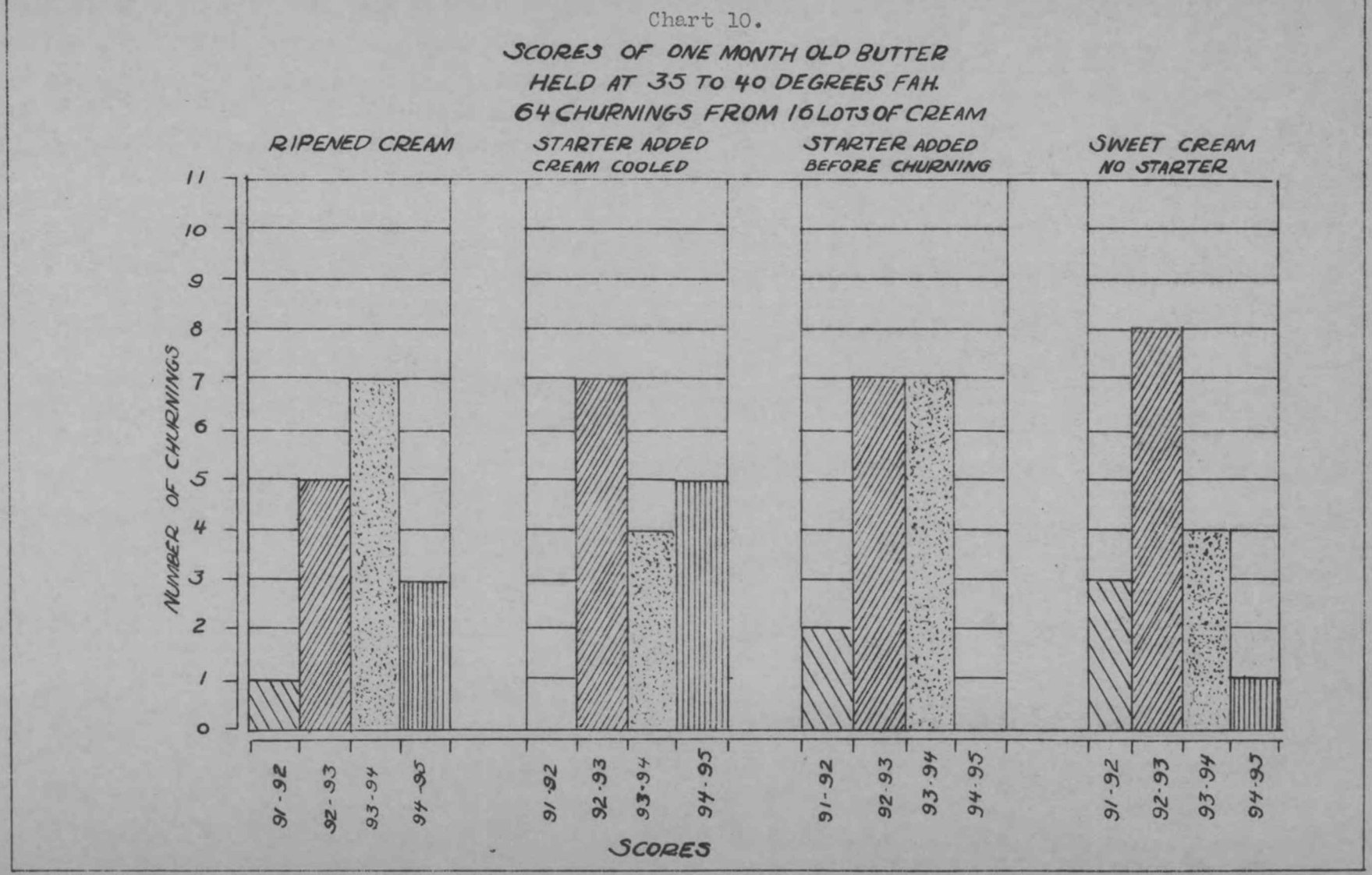
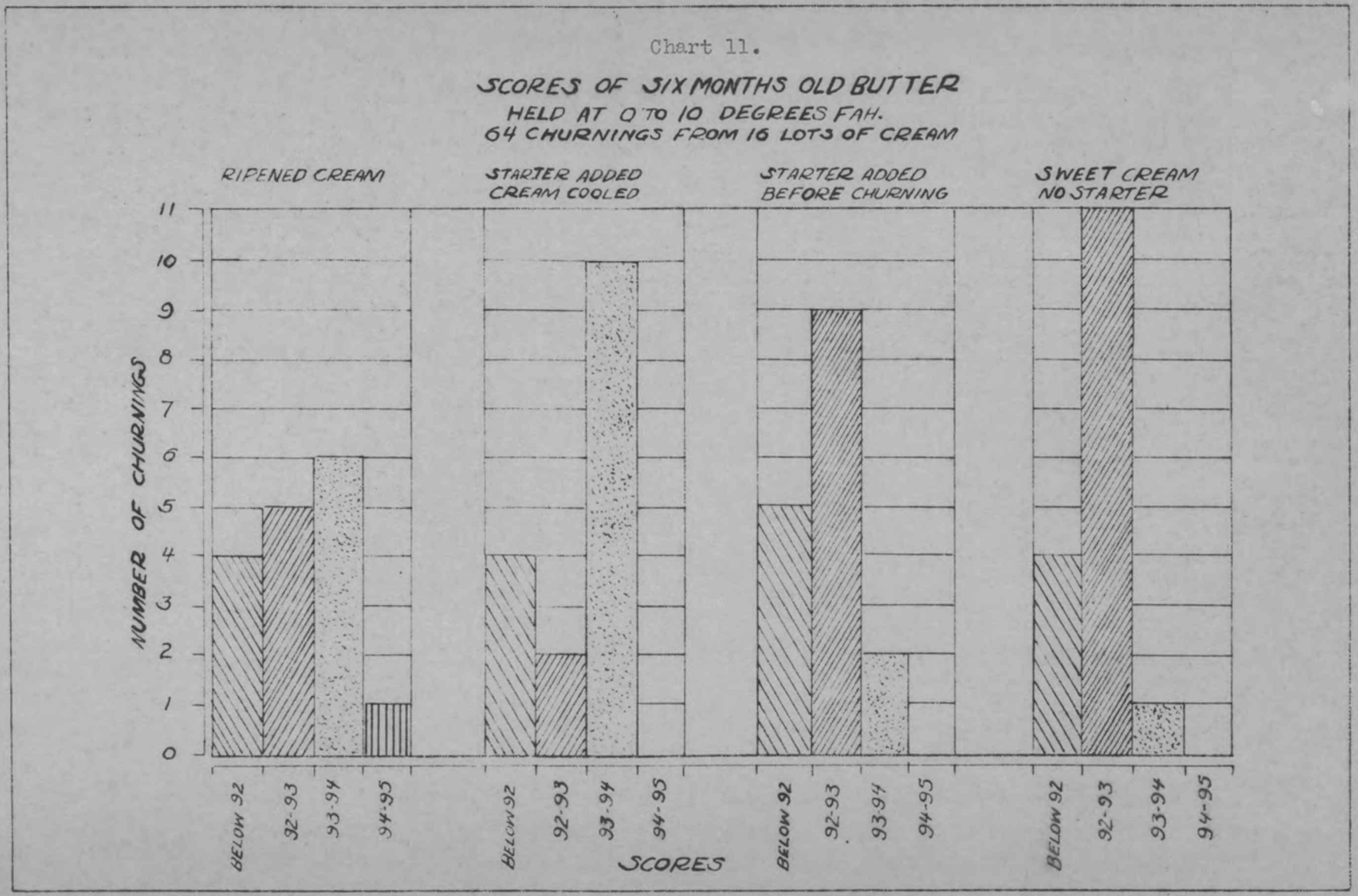

SCORES OF ONE MONTH OLD BUTTER
HELD AT 35 TO 40 DEGREES FAH.
64 CHURNINGS FROM 16 LOTS OF CREAM
RIPENED CREAM
STARTER ADDED CREAM COOLED
STARTER ADDED BEFORE CHURNING
SWEET CREAM NO STARTER
NUMBER OF CHURNINGS
0
1
2
3
4
5
6
7
8
9
10
11
91-92
92-93
93-94
94-95
SCORES

Chart 11.


SCORES OF SIX MONTHS OLD BUTTER
HELD AT 0 TO 10 DEGREES FAH.
64 CHURNINGS FROM 16 LOTS OF CREAM
RIPENED CREAM
STARTER ADDED CREAM COOLED
STARTER ADDED BEFORE CHURNING
SWEET CREAM NO STARTER
NUMBER OF CHURNINGS
0
1
2
3
4
5
6
7
8
9
10
11
BELOW 92
92-93
93-94
94-95
SCORES

With each method of treating the cream and with each holding period the great majority of the scores were above 92.00.

It is shown by these data that an excellent quality of butter was made by the four methods of cream treatment used, since in all trials the majority of the samples of butter scored 92.00 or higher. However, it is evident that when starter was used, a higher quality butter was made than when no starter was used, since a larger number of the scores of the butter made with the three methods of using starter were in the higher scoring groups than when no starter was used.

The keeping quality of the butter made with the four methods of cream treatment was excellent, since very few scores were below 92.00 after each of the two holding periods. The butter made from cream with starter added and the cream cooled seemed to have the best keeping quality for there were no scores below 92.00 after the one month holding period, and after the six months holding period this butter had the same number of scores below 92.00 as the butter made from ripened cream and the butter made from cream with no starter added, and one less score below 92.00 than the butter made from cream to which starter was added before churning.

i. Butter entered in contests. Butter from the refrigerated cream to which starter was added was exhibited at five contests during the period of the experiment, shown in Table 17. At the Pacific International Dairy Products show in 1930 it was entered for complimentary score and placed sixth high in a field of approximately 50 entries with a score of 94.50.

In 1931 an entry was sent to the National Creamery Buttermakers'

Cold Storage Contest where it obtained fourth place among 70 entries in the Junior Contest, scoring 93.50 in June on entering cold storage and scoring 94.25 in October when taken out of cold storage. The scores indicate that the butter increased..75 of a point during storage, but this is not reasonable to believe. Since the butter was scored competitively the apparent increase in score might have been due to the fact that the score of the other entries decreased more than did that of this sample.

Another entry was sent to the National Creamery Buttermakers' Fresh Butter Contest in 1931 at Madison, Wisconsin where it again secured fourth place among 73 contestants in the Junior Contest with a score of 94.25.

At the Pacific International Dairy Products show in 1931 two samples of butter were entered for complimentary score. Both samples were made from the same lot of refrigerated cream. Starter was added to the cream from which one sample was made while no starter was used with the second entry. The butter with which starter was used obtained a score of 94.00 and a Silver Medal Diploma. The butter with which no starter was used obtained a score of 92.50.

Butter was also exhibited for complimentary score at the Oregon State Fair in 1931 where it placed sixth high with a score of 94.00.

Table 17.

SCORES AND PLACINGS OF BUTTER EXHIBITED AT CONTESTS

Name of Contest		Score	Placing
Pacific International Dairy Products Show, 1930		94.50	6th place (comp.)
National Creamery Buttermakers' Cold Storage Contest, 1931, St. Paul, Minnesota	June 93.50	Oct. 94.25	Junior Class 4th Place
National Creamery Buttermakers' Fresh Butter Contest, 1931, Madison, Wisconsin.		94.25	Junior Class 4th Place
Pacific International Dairy Products Show, 1931	Starter used	94.00	----
	No starter used	92.50	----
Oregon State Fair, 1931		94.00	Sixth high score

j. Butter made from refrigerated and non-refrigerated cream. In comparison No. 1, presented in Table 18, of the cream held in the refrigerator and the cream held outside the refrigerator the fresh butter made from refrigerated cream to which starter was added scored 93.70 and the fresh butter made from non-refrigerated cream to which starter was added scored 93.40 or a difference of .30 of a point in favor of the refrigerated cream. The fresh butter made from refrigerated cream to which no starter was added scored 92.25 and the butter made from non-refrigerated cream scored 92.87 or a difference of .62 of a point in favor of the butter from non-refrigerated cream.

After one month at from 35 deg. to 45 deg. Fah. the butter made from refrigerated cream to which starter was added scored 93.00 and the butter made from non-refrigerated cream to which starter was added scored 92.25 or a difference of .75 in favor of the butter from

refrigerated cream. The butter made from refrigerated cream to which no starter was added scored 92.00 after one month and the butter made from non-refrigerated cream to which no starter was added scored 92.00, there being no difference in score.

In comparison No. 2 the fresh butter made from refrigerated cream to which starter was added scored 94.25 and the butter made from non-refrigerated cream to which starter was added scored 93.75 or a difference of .50 of a point in favor of refrigerated cream. The fresh butter made from refrigerated cream to which no starter was added scored 92.00 and the butter made from non-refrigerated cream to which no starter was added scored 93.00 or a difference of 1 point in favor of non-refrigerated cream.

After one month at from 35 deg. to 45 deg. Fah. the butter made from refrigerated cream to which starter was added scored 92.00 and the butter made from non-refrigerated cream to which starter was added scored 93.00 or a difference of 1 point in favor of non-refrigerated cream. The butter made from refrigerated cream to which no starter was added scored 92.00 after one month and the butter made from non-refrigerated cream to which no starter was added scored 92.00, there being no difference in score.

On observing the average scores of all butter it was found that the average score of all fresh butter made from refrigerated cream was 93.05 and the average score of all fresh butter made from non-refrigerated cream was 93.25 or a very slight difference of .20 of a point in favor of the butter from non-refrigerated cream. After one month at from 35 deg. to 45 deg. Fah. the average score of all butter

made from refrigerated cream was 92.25 and the average score of all butter made from non-refrigerated cream was 92.31 or a difference of .06 of a point in favor of the butter from the non-refrigerated cream.

There seemed to be an inconsistency in the scores of the refrigerated and non-refrigerated cream, and there seemed to be no advantage in refrigerating the cream. This may be explained by the fact that during the latter part of November and the first of December when these trials were made there was a period of cold weather at which time the average mean atmospheric temperature for the week of the experiment was 35.31 deg. Fah. This temperature was lower than that maintained inside the refrigerator box. There was also an insufficient number of trials made to draw conclusions from the results, and the trials were not made over representative periods of the year.

Table 18.

BUTTER MADE FROM REFRIGERATED AND NON-REFRIGERATED CREAM

Average Mean Atmospheric Temperature for the week of the Trial -- 36.31

Temperature Maintained Inside the Refrigerator -- 35 deg. to 40 deg. Fah.

Refrigerated Cream

	No. of Comparison	Score when Fresh	Score after 1 month at 35 deg. to 45 deg. Fah.
Starter Used	1	93.70	93.00
	2	94.25	92.00
No Starter Used	1	92.25	92.00
	2	92.00	92.00
Average		93.05	92.25

Non-Refrigerated Cream

Starter Used	1	93.40	92.25
	2	93.75	93.00
No Starter Used	1	92.87	92.00
	2	93.00	92.00
Average		93.25	92.31

k. Butter made from cream held in covered and uncovered cans.

Table 19 shows that in one trial the butter made from cream which had been held in the refrigerator uncovered scored 89.66 both when fresh and after one month at from 35 deg. to 45 deg. Fah. The butter made from cream which had been held in the refrigerator with the cover on scored 88.00 when fresh and 89.66 after one month at from 35 deg. to 45 deg. Fah. or an increase of 1.66 points.

The one trial was very inaccurate in the results. Since the cream was held for 7 days altogether in the refrigerator and since there was no difference of value between the two classes of butter it would seem that the age of the cream influenced the quality of the butter more than did the fact that one can of cream was covered and the other uncovered.

Table 19.

BUTTER MADE FROM CREAM HELD IN COVERED AND UNCOVERED CANS

	Score when fresh	Score after 1 month at 35 deg. to 45 deg. Fah.
Lid off	89.66	89.66
Lid on	88.00	89.66

1. Butter made from high acid cream. When cream that had been ripened to acidities higher than are normally practical was made into butter it was seen, in Table 20, that butter made from cream with an acidity of .36 per cent scored 93.00 when fresh, 87.00 after one month at from 35 deg. to 45 deg. Fah. or a decrease of 6 points, and 88.00 after six months at from zero deg. to 10 deg. Fah. or a decrease of 5 points in score. Butter made from cream with an acidity of .48 per cent scored 93.00 when fresh, 90.00 after one month at from 35 deg. to 45 deg. Fah. or a decrease of 3 points, and 92.00 after six months at from zero deg. to 10 deg. Fah. or a decrease in score of 1 point. Butter that was made from cream with an acidity of .57 per cent scored 90.00 when fresh, 88.00 after one month at from 35 deg. to 45 deg. Fah. or a decrease of 2 points, and 87 after six months at from zero deg. to

10 deg. Fah. or a decrease of 3 points.

From the averages it was observed that the average acidity of the cream was .47 per cent, the average score of the butter when fresh was 92.00, the average score after holding for one month was 88.33 or an average decrease of 3.66 points, the average score after holding for six months was 89.00 or an average decrease of 3.00 points.

It would seem from these results that it was undesirable to ripen cream to a high acidity for the making of butter since the butter made from highly ripened cream had very poor keeping quality.

Table 20.

CHURNINGS FROM HIGH ACID CREAM

3 Churnings

Acidity of cream at Churning	Score of Butter when Fresh	Score of Butter after 1 month at 35 to 45 deg. Fah.	Decrease in Score	Score of Butter after 6 months at 35 to 45 deg. Fah.	Decrease in Score
			Points		Points
.36	93.00	87.00	6.00	88.00	5.00
.48	93.00	90.00	3.00	92.00	1.00
.57	90.00	88.00	2.00	87.00	3.00
Av. .47	92.00	88.33	3.66	89.00	3.00

Comments by the judges after both holding periods on the three churnings of butter were "fishy" and "high acid".

V. DISCUSSION OF RESULTS

The study of the cost of cream refrigeration showed that the total cost per day for the three farms was very nearly the same, but the cost per pound of butterfat varied almost directly with the pounds of butterfat produced. A premium of three cents above the sour cream price per pound of fat was received. Under this condition, farms No. 1 and No. 2 showed a profit, after the refrigeration cost had been deducted. No profit was shown by farm No. 3, however, since the daily butterfat production was low and the household refrigerator service was charged to the dairy refrigerator. Refrigeration permitted twice a week delivery of sweet cream, whereas more frequent delivery would have been required without refrigeration in order to obtain the same premiums. This resulted in a saving in cost of transportation. The saving varied according to the distance of each farm from the creamery or from the local cream route.

The average monthly temperatures of the cream when it was received at the creamery followed a reasonably uniform curve for the year of the experiment and corresponded quite closely to the curve representing the mean monthly atmospheric temperatures at Corvallis. The temperatures of the cream when received were quite low. They ranged from 37 deg. Fah. to 66 deg. Fah. and averaged 50.61 deg. Fah. The months in which an average temperature of over 50 deg. Fah. occurred were May, June, July, August, and September.

In comparing the yearly average temperatures of the cream from each farm, a relationship, though not proportional, was shown between

the temperature of the cream when received and the distance the cream was shipped. Other factors may have influenced the temperature rise, such as, time left out of the refrigerator before shipping, amount of fresh cream of a higher temperature mixed with the refrigerated cream on the day of shipping, and method of transportation.

When the average monthly acidities of the cream and the average monthly temperatures of the cream when received were compared, it was noted that there was a correlation between them. In general, high average monthly temperatures were accompanied by relatively high average monthly acidities and low average monthly temperatures were accompanied by low average monthly acidities, though the lowest average acidity was not in the month with the lowest average temperature and the highest average acidity was not in the month with the highest average temperature. The acidities of the cream in all shipments were low. In only two shipments, the acidities of the cream were above the Oregon state standard for "First" grade cream. The acidities of these two cream shipments were .21 per cent and .23 per cent. For all shipments, the acidities of the cream ranged from .11 per cent to .23 per cent and averaged .135 per cent.

The numbers of bacteria were high in many lots of cream received, but there was no noticeable evidence of off-flavors in the cream as a result of bacterial fermentation.

With the pasteurization of 65 lots of cream, it was noted that, in general, a low bacterial count before pasteurization was accompanied by a low efficiency of pasteurization and high bacterial count before pasteurization was accompanied by a high efficiency of pasteurization.

The high bacteria killing efficiencies with cream that contained a large number of bacteria may be accounted for by the presence of many S. lactis organisms which are relatively easily killed by heat.

When the bacterial types found in cream before and after pasteurization were isolated and classified according to their action in litmus milk, it was observed that both before and after pasteurization the acid non-coagulators were in the majority. These organisms were more resistant to the heating process than were the other types present, since there was a greater percentage of them in the pasteurized cream than there was in the raw cream. The percentage of the other types showed decreases as a result of the pasteurization process.

The cream before pasteurization contained some yeasts and molds. The counts made on the cream after pasteurization showed that these organisms were, in most cases, destroyed during the heating process. The yeast and mold counts were higher in the butter taken directly from the churn, in nearly every instance, than were those of the pasteurized cream. Since the cover of the vat was closed until churning time, the subsequent contamination must have occurred during the transfer of the cream from the pasteurizing vat to the churn and during the churning process. The yeasts and molds must have been added to the cream by the pipe line, pump, strainer, churn, and the air.

The results of testing the buttermilk for butterfat showed that there was very little difference between the butterfat lost in the churnings when starter was used and in the churnings when no starter was used. The small difference in favor of the butter with which no starter was used was insignificant as a basis for favoring one method

of butter manufacture over the other.

It was found that the quality of the butter made by the large churn was excellent. It scored "Extra" grade, on an average, or higher, when fresh. Of the 93 churnings, only 17 scored below 92.00. The keeping quality of the butter was very good, since the scores after the holding periods of one month and six months were only slightly less than when the butter was fresh.

With the 93 large churnings, 59 were made with starter, and 34 were made without starter. When the quality of the butter made with starter and that of the butter made without starter were compared, the results showed that a better quality of butter was made with than without starter, since there was a greater percentage of the scores of the butter made with starter above 92.00 than there was of the butter made without the use of starter. There was very little difference in the keeping quality of the butter made with starter and that of the butter made without starter. The butter made with starter decreased more in score after the one month holding period than did the butter made without starter. The butter made without starter showed the greatest decrease in score, however, for the six months holding period. At the end of the holding periods of one month and of six months, the butter made with starter had a larger percentage of scores above 92.00 than did the butter made without starter.

A comparison was made of the quality of the butter with four methods of making butter -- with starter added to the cream and the cream ripened, with starter added to the cream and the cream immediatley cooled, with starter added to the cream before churning, and with

sweet cream, no starter added. The same lot of cream was used for each comparison. Of the four methods of making butter, the data obtained show that the two methods -- making butter from ripened cream and making butter from cream to which starter had been added and the cream cooled -- were of nearly equal value when the average scores of the fresh samples were observed. It appeared, however, that the butter made by the second method, where starter was added to the cream and the cream cooled and held overnight before churning, had the best keeping quality, since it scored higher both after the one month and after the six months holding periods. Of the other two methods -- making butter from cream to which starter was added just before churning and making butter from cream to which no starter was added -- it would seem that there was little difference in favor of one over the other. The average score of the butter when fresh, was slightly higher for the butter made from cream to which starter was added just before churning, but the average scores of the butter after one month and six months were approximately the same with both methods. Apparently when the starter was added to the cream just before churning it was not allowed to be in contact with the cream for sufficient time to impart the full starter flavor to the cream.

At the various contests in which the butter was entered, high scores and high placings were obtained. All butter entered in the contests was made by the large churn from the pasteurized refrigerated cream with starter added. One tub of this butter was entered in the 1931 National Creamery Butter Makers Association's Cold Storage Contest at St. Paul, Minnesota, where it was exhibited in competition

with 70 other tubs of butter from all parts of the United States. This entry was given a score of 93.50 when entering cold storage and a score of 94.25 when taken from storage, after four months.

In a comparison of the quality of the butter made from two lots of refrigerated and non-refrigerated cream, it would be expected that the quality of the butter made from the refrigerated cream was superior to that of the butter made from the non-refrigerated cream. The scores of the fresh butter made without starter from the non-refrigerated cream were higher than the scores of the fresh butter made from the refrigerated cream. The probable reason for this is that during the latter part of November and the first of December when these trials were made the average mean atmospheric temperature for the week of the experiment was lower than the temperature maintained inside the refrigerator box. There was an insufficient number of trials made to draw conclusions from, and the trials were not made over representative periods of the year.

The scores of the butter made from high acid cream indicate that it is undesirable to ripen cream to a high acidity, since the quality of the butter is not uniform and does not keep well in storage.

VI. SUMMARY AND CONCLUSIONS

(1) Refrigerators were placed on three farms at distances of 5, 20, and 25 miles from Corvallis. Cream was shipped to the College Creamery from each farm twice weekly for 15 months.

(2) Power records were kept on the refrigerators and power requirements and refrigeration costs were studied. The total cost per day was very nearly the same for each of the three farms. The cost per pound of butterfat was 1.3 cents, 2.2 cents, and 4.4 cents respectively for the three farms. The cost was greatest for the farm producing the least butterfat and lowest for the farm producing the most butterfat.

(3) The temperatures of the cream when received at the creamery were recorded for each shipment. They ranged from 37 deg. Fah. to 66 deg. Fah. and averaged 50.61 deg. Fah. for the year of the experiment.

(4) The acidities of the cream when received at the creamery were recorded for each shipment. They ranged from .11 per cent to .23 per cent and averaged .135 per cent.

(5) The germ killing efficiency of pasteurization was studied in 65 trials. The efficiencies averaged 98.299 per cent.

(6) The effect of pasteurization on the types of bacteria was studied. 855 cultures of bacteria were isolated from the cream before pasteurization and 682 cultures of bacteria were isolated from the cream after pasteurization. They were classified by their action in litmus milk. Both before and after pasteurization the acid non-coagulators were in the majority. They were present in larger percentages after than before pasteurization. The other types showed decreases in the percentages present as a result of pasteurization.

(7) The following species of organisms were obtained from the cream before it had been pasteurized: Micrococcus candicans Flügge, Streptococcus citrovorus Hammer, Escherichia communior (Durham) Bergey et al, Bacillus subtilis (Ehrenberg) Cohn, Escherichia coli (Escherich) Castellani and Chambers, Achromobacter tiogense (Wright) Bergey et al, Achromobacter fermentationis (Chester) Bergey et al, Streptococcus glycerinaceous Orla-Jensen, Streptococcus lactis (Lister) Löhnis, Bacillus tumescens Zopf, Achromobacter lipolyticum (Huss) Bergey et al.

(8) In 31 tests, yeast and mold counts were made on the cream before and after pasteurization and on the fresh butter. The yeasts and molds present in the raw cream were, in most cases, destroyed during the heating process, but the yeast and mold counts were higher in the butter taken directly from the churn than were those of the cream. In the 31 tests, the counts on the cream before

pasteurization averaged 1.16 yeasts and 2 molds; on the cream after pasteurization they averaged .032 yeast and .225 mold; and on the fresh butter they averaged 5.29 yeasts and 2.52 molds. Considerable care was taken at all times to clean the equipment but it was apparently not completely sterilized since it caused a slight contamination in the fresh butter with yeasts and molds.

(9) Tests were made to compare the per cent butterfat contained in the buttermilk when starter was used and when no starter was used. The per cent butterfat in the buttermilk in the 31 churnings where starter was used ranged from .06 to .50 and averaged .214, and the percentages in the churnings where no starter was used ranged from .07 to .50 and averaged .193. There was no significant difference in the butterfat content of the buttermilk with the two methods used.

(10) The quality of the butter made from 93 lots of refrigerated cream when large equipment was used was determined by qualified commercial butter judges. The scores were uniformly high. 82 per cent of the scores of the fresh butter were 92.00 or higher and 18 per cent ranged from 90.50 to 92.00. The butter kept well in storage. 57 per cent of the samples of the butter after being held at from 35 deg. to 45 deg. Fah. for one month scored 92.00 or higher and the balance scored from 89.00 to 92.00, with an average decrease of .72. 65 per cent of the samples of the butter after being held for six months at from zero to 10

deg. Fah. scored 92.00 or higher and the balance scored 89.66 to 92.00, with an average decrease of .51. The decreases in score during the holding periods were, in general, very slight.

(11) In the 93 churnings, mentioned above, the quality of the butter made with starter and that of the butter made without starter were compared. The butter was made with starter in 59 churnings, and in 34 churnings it was made without starter. Higher scoring butter was made with than without starter. The butter made with starter scored 1.07 points higher when fresh, .47 of a point higher after one month, and .77 of a point higher after six months than did the butter made without starter. There was very little difference between the keeping quality of the butter made with starter and that of the butter made without starter. The scores of the butter made with starter decreased the most after the one month holding period, and the scores of the butter made without starter decreased the most after the six months holding period. The data showed, however, that at the end of both holding periods the butter made with starter had a larger percentage of scores above 92.00 than did the butter made without starter.

(12) In a separate study of the influence of starter on the quality of the butter made from refrigerated cream, 16 lots of cream were used. Each lot was divided into four parts which were churned separately. A total of 64 churnings was made.

When fresh, the scores of the butter made from ripened cream averaged .88 higher; those of the butter made from cream with starter added and the cream cooled averaged .83 higher; and those of the butter made from cream with starter added before churning averaged .32 higher than those of the butter made from sweet cream with no starter added.

After one month, the scores of the butter made from ripened cream averaged .46 higher; those of the butter made from cream with starter added and the cream cooled averaged .65 higher; and those of the butter made from cream with starter added before churning averaged .02 higher than those of the butter made from sweet cream with no starter added.

After six months, the scores of the butter made from ripened cream averaged .30 higher; those of the butter made from cream with starter added and the cream cooled averaged .66 higher; and those of the butter made from cream with starter added before churning averaged .06 lower than those of the butter made from sweet cream with no starter added.

These data show conclusively that the use of starter resulted in the higher quality of the butter.

(13) Butter made from the pasteurized refrigerated cream was exhibited at five contests in various parts of the United States during the experiment. The butter was entered in competition with approximately 280 other entries and obtained sixth place, fourth place, fourth place, sixth place, and sixth place respectively in

in each of the contests.

(14) The work on the manufacture of butter from refrigerated cream has shown that it was possible to make butter, scoring from 90.50 to 95.00 with 93 per cent of the churnings scoring 92.00 or higher when the cream was held in refrigerators on the farms for twice weekly shipment, and the butter was made by the best manufacturing methods.

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