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Title---Studies of Factors Affecting Sticky and Crumbly Body of Oregon Butter

Abstract Approved:

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An investigation of butter manufacturing methods was made at the Oregon Agricultural Experiment Station with view of finding a method which would overcome or minimize the crumbly and sticky defects of butter made in Eastern, Central, and Southern Oregon during the fall and winter seasons. The investigation extended from July 1937 to March 1941. A total of 223 experimental churnings was made.

It was found that the rate of cooling the cream after pasteurization, the temperature to which the cream was cooled, the time the cream was held after cooling prior to churning, the churning temperature, the temperature of the water used to wash the butter granules, the temperature of the butter during the working, and the temperature at which the butter was stored affected the body and texture of the butter.

The sticky defect in butter made from cream produced during the alfalfa hay feeding period in Eastern, Central and Southern Oregon could be minimized by using the
following methods of manufacture. (1) Churned the cream as soon as it cooled from the pasteurizing temperature to the churning temperature. Wash the butter granules with water not more than 40°F colder than the buttermilk. Salt and work the butter to completion without delay.

(2) Previously pasteurized and cooled cream that is warmed to 110°F and held for 15 minutes, then cooled to churning temperature and churned results in butter without sticky defects. The butter made by these methods is generally crumbly or brittle.

The crumbly defect in butter could be minimized by the following method. Cool the pasteurized cream to from 50°F to 55°F and hold it for 12 hours before churning. Churn the cream till the butter granules are the size of small peas. Chill the butter granules in the wash water below 40°F. Work the butter to completion without delay. Butter made by this method may show stickiness to some extent, but will possess a fairly soft body and a fair spreading quality.

No method of churning was found that would entirely avoid both the sticky and crumbly defects.
STUDIES OF FACTORS AFFECTING
STICKY AND CRUMBLY BODY
OF OREGON BUTTER

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STUDIES OF FACTORS AFFECTING STICKY AND CRUMBLY BODY OF OREGON BUTTER

INTRODUCTION

A great deal of improvement in the quality of butter produced in Oregon has been made during the last twelve years. This improvement was the result of an intensive educational campaign with the creameries. Conferences with the buttermakers, short courses, and group butter scorings were used to further the butter improvement program.

Perhaps one of the greatest aids in this program was the monthly butter scoring and analysis service conducted by the Dairy Department of Oregon State College. This service was started in 1929. All buttermakers in the State have been asked to take part in this program. The plan calls for two pounds of butter from a regular churning to be sent each month to the Dairy Department at Oregon State College. This butter is scored by a committee of butter graders and analyzed by technicians of the Dairy Department. A confidential report of the scoring and analysis is returned to the buttermaker, along with suggestions as to how they can improve the quality of the butter manufactured.
More uniform methods of butter making throughout the State were one of the results of this butter improvement program (30). This in turn resulted in more uniform body and texture as well as composition of the butter made in Oregon. Cream grading, at first optional with the creameries and later (in 1937) compulsory, had an effect on improving the quality of the butter made.

It was observed at the monthly butter scoring that the percentage of butter samples criticized for crumbly and sticky defect generally was increased during the fall and winter seasons. The majority of the samples so criticized came from the Eastern, Central, and Southern parts of the State.

Buyers of butter both in local and out of State markets also complained of the sticky and crumbly butter manufactured during the fall and winter seasons. The defect was reported not only in Oregon butter but in butter manufactured throughout the Western United States. The defect was principally in the butter made from cream produced by cows that were being fed on a restricted diet of alfalfa hay.

Nearly 11,750,000 tons of alfalfa hay were produced in the eleven western states in 1940. Of this, Oregon produced 686,000 tons or 5.84 per cent (29).
The annual consumption of hay per cow in Eastern, Central, and Southern Oregon in 1933 was 7000 pounds (27). The annual consumption of hay per cow in the Willamette Valley in 1933 was only 5000 pounds. The annual consumption of hay per cow on the Coast area in 1933 was 3,531 pounds. These figures indicate the importance of hay feeding in Eastern, Central and Southern Oregon.

A total of 8,662,087 pounds of butter was manufactured in Eastern, Central, and Southern Oregon in 1939 (32). This was an increase of 3,049,626 pounds over the production in the same section in 1929 (31). A total of 223,799,000 pounds of butter was manufactured in the eleven Western States during 1938 (33).

The butter production in the alfalfa growing regions of Eastern, Central, and Southern Oregon is increasing. The principal hay in these areas will probably continue to be alfalfa hay. Therefore it was deemed necessary to investigate the possibility of changing the method of manufacturing butter in these sections to avoid or minimize the crumbly and sticky defects in butter.
I: PHYSICAL CONDITION OF MILK FAT

A: Physical Condition of Milk Fat in Milk and Cream

Milk when obtained from the cow is an emulsion in which the skim milk is the continuous phase and the milk fat in the form of microscopic globules is the dispersed phase. An emulsion is a mixture of two insoluble liquids, such as oil and water, in which one liquid is distributed as small droplets in the other liquid. The liquid that is distributed as small droplets is called the dispersed phase. The liquid that contains the dispersed phase is called the continuous phase. The milk fat globules range in size from less than one micron (1/25,000 inch) to about twenty microns (1/1200 inch) in diameter (32). The majority of the globules are from three to five microns in diameter. The breed of the cow and period of lactation affect the size of the milk fat globules (29). The milk fat globules in milk from Jersey and Guernsey cows average larger than milk fat globules from Holstein and Ayrshire cows. Milk fat globules in the milk from cows late in lactation average smaller than globules in milk from cows early in lactation. This is true of all breeds.
Each globule is covered by a thin membrane of phospholipin-protein material which is held by chemical attraction between the milk fat and the membrane material to the surface of the globule (4,19). It can be removed only by severe chemical or mechanical treatment. To this globule membrane are adsorbed (held by surface attraction) milk proteins which can be removed by washing of the fat globules. The bulk of the adsorbed milk protein passes into the buttermilk during churning. The adsorbed outer layer of milk protein and the inner layer of globule membrane material help stabilize the milk fat globules in the emulsion by holding the milk fat in small droplets and preventing it from running together or "oiling off" while it is in the liquid state.

A negative electric charge is present on each fat globule in the milk (16). Because of the repellent action of similar charged bodies this electric charge also helps to stabilize the emulsion by keeping the fat globules apart.

The milk fat in the globules is a mixture of many fats, called glycerides (8). While all the glycerides in milk fat have not been identified, it is estimated that there are a possible 550 different glycerides in cow milk fat (22). Each glyceride possess different chemical and physical properties. At the lower temperatures, from 80° F. to 32° F., part of these glycerides are in a
solidified crystal state and part are in a liquid state (1). The percentage of the various glycerides in milk fat is largely affected by the feed of the cow (8). The period of lactation also affects the composition of milk fat (10).

B: **Effect of the Butter Manufacturing Processes Upon the Physical Condition of the Milk Fat.**

1: **Effect of Separation Upon the Physical Condition of Milk Fat.**

Separation of whole milk into cream and skimmed milk results in a concentration of the milk fat globules in the cream. Milk fat is in the liquid state at the temperatures commonly used (95° F. to 110° F.) for separation (2). Globules less than two microns in diameter are largely lost in the skim milk (17).

2: **Effect of Pasteurization Upon the Physical Condition of the Milk Fat.**

At the temperatures of pasteurization by the holding method (150° F. to 165° F.), all of the milk fat is in a liquid state (2). The milk fat is also completely liquified when the cream is pasteurized by the high temperature short holding time method of pasteurization (180° F. to 200° F.). Temperatures of the cream above 140° F. may cause a dispersion of the globules, particularly if the cream is subjected to considerable agitation (3).
Too long exposure of the cream to high temperatures (above 140° F.) combined with severe agitation at these temperatures may disrupt the membrane of part of the milk fat globules and permit the milk fat from these globules to run together or "oil off".

3: Effect of Cooling Upon the Physical Condition of Milk Fat.

As the cream is cooled from pasteurizing temperatures, the glycerides in the globules solidify or crystallize. Since these glycerides have different melting points, there will be a different percentage of crystallized glycerides in the globules at different temperatures (1); the lower the temperature of the cream, the higher will be the percentage of crystallized glycerides. Even at the freezing of the cream, however, there will be some liquid glycerides in the globules.

Only a little is known concerning the crystal structure of the glycerides in milk fat. It is believed, however, that the rate of cooling of the cream will affect the size of fat crystals in the fat globules (33). Cream cooled rapidly will cause the formation of small crystals whereas cream cooled slowly will cause the formation of large crystals (20).

A long period of time is required for complete crystallization of the milk fat at any specified
temperature below 80° F. (23). The rate of greatest crystallization for a given temperature occurs most rapidly during the first four hours after the cream has been cooled from the pasteurizing temperature (20). It has been found that at the end of twenty-four hours there is still some crystallization of the fats taking place in the globules.

4: **Effect of Churning Upon the Physical Condition of Milk Fat.**

When milk or cream is agitated the milk fat globules tend to form clusters (3). This tendency for clustering is increased by lower temperatures, increased acidity, higher fat content, and more severe agitation of the milk or cream.

The churning process takes advantage of the tendency of the milk fat globules to cluster together. The churning temperature is that temperature at which the greatest number of the globules will cluster, during the churning process, consistent with a most desirable body and texture of the butter.

From all of the available data it is not yet possible to explain exactly what takes place during the churning process. It is believed that the membrane material which surrounds the milk fat globule may not completely cover the globule. As the globules are jarred against each
other during the agitation of the cream, part of the liquid fat is pressed to the surface of the globule and acts as an adhesive to hold the globules together (13, 11, 23). During the churning, the cream forms a foam or "whips". The milk fat globules are drawn into the skim-milk film which surrounds the air cells in the foam. In this thin film they are also pressed closely together so that the clustering of the globules is favored. As the clustering together proceeds, a point is reached when the globule cluster, or granule, is too large and heavy to be held in suspension. The emulsion system of milk fat in skim milk is broken and the skim milk drains from the granules. During the formation of the butter granules, water droplets and milk protein are trapped in the globule clusters and a different kind of emulsion in which fat with a low melting point is the continuous phase, and milk fat globules, water droplets, milk proteins, and crystallized fat, form the dispersed phase. There is evidence that some of the globules are disrupted during the churning and the crystallized fat from these globules is distributed in the liquid fat (11).

The churning process can also be considered as an extension of the cooling treatment of the cream. The agitation of the cream during the churning process probably has a stimulating effect on the rate of crystallization of the fats. Further crystallization of
the fats during churning is favored if the churning temperature is nearly the same as the temperature to which the cream was cooled and held following pasteurization (28). Melting of some of the previously crystallized fats would occur if the churning temperature was very much higher than the temperature at which the cream was held following pasteurization. The churning process would have no effect on the size of the fat crystals unless the cream was cooled and churned immediately after pasteurization. In this case the stimulating effect of the agitation on crystallization would favor the formation of small crystals rather than large crystals.


The purpose of working butter is twofold, namely to bring the butter granules together in a compact mass with a desirable body and texture, and to incorporate and uniformly distribute in the form of fine droplets of brine the desired amount of moisture and salt. During the working, the liquid fat is pressed from the globules (23). The brine droplets are finely divided and each droplet is surrounded by the liquid fat. Some of the globule membranes are probably broken thus liberating fat crystals of the glycerides with higher melting points.
The finished salted butter may be considered an emulsion of small droplets of brine, fat globules, fat crystals, fragments of globule membrane, and minute air cells distributed in the continuous phase of liquid fat.

II: BODY AND TEXTURE OF BUTTER

A: Definition of the Terms Body and Texture of Butter.

The terms body and texture of butter have reference to its physical characteristics such as spreading properties, waxiness, plasticity, crumbliness, hardness, etc. While the term body refers to the condition of the mass of butter and the term texture refers more specifically to the individual butter particles, both are dependent upon the physical and chemical condition of the butterfat, and upon the manufacturing process of the butter (6). Since the terms are so closely related it is common practice to refer to the physical condition of butter by using both terms.

As has been pointed out, the physical and chemical properties of milk fat are affected by several factors, the most important probably being the feed of the cows. Since these factors are beyond the control of the butter-maker, considerable study has been made to determine the effect of changing the manufacturing methods to produce butter with a uniform and desirable body and texture.
despite the changes in the milk fat.

According to the present theories the continuous phase of butter is made up of the glycerides which are liquid at the time the butter is worked (11,23). The most desirable body and texture in butter is obtained if these glycerides have melting points below the temperature at which the butter is used. It is necessary to have enough liquid glycerides at the time of working to properly emulsify or distribute the dispersed materials (brine droplets, fat globules, fat crystals, and milk protein) in the butter (23). During certain periods of the year under changed feeding conditions there is a small percentage of the glycerides with low melting points in the milk fat. If proper working of the butter is to be accomplished with this type of milk fat it is necessary to keep in the liquid state glycerides with higher melting points.

During the storage of the butter the glycerides with melting points higher than the temperature of the butter crystallize, causing the body and texture of the butter to lose its waxiness and to develop poor spreadability. The adjustment of the butter manufacturing methods to overcome the undesirable body and texture characteristics in butter made from this type of milk fat deal fundamentally with the control of the rate and extent of crystallization of the fats.
B: **Effect of the Treatment of the Cream Prior to Pasteurization On the Body and Texture of Butter.**

There is no indication that the normal treatment of milk and cream prior to pasteurization has any detrimental effect on the body and texture of butter. Freezing of milk or cream will cause the fat to separate from the emulsion or oil off if the frozen milk or cream is melted too rapidly (9). Separation of milk at the usual temperature of separation (90° F. to 110° F.) has no detrimental effect on the body and texture of butter.

C: **Effect of Pasteurization on the Body and Texture of Butter.**

Pasteurization in coil vats at normal temperatures (150° F. to 165° F.) for half an hour or to higher temperatures for shorter periods has no detrimental effect on the body and texture of butter. It has been observed that pasteurization of cream by the regenerative system in which the cream is subjected to considerable agitation at high temperature may cause oiling off of the milk fat (9).

D: **Effect of Cooling and Holding of the Cream After Pasteurization On the Body and Texture of Butter.**

The temperature to which the cream is cooled and the length of time at which the cream is held after pasteurization has been shown to have an important effect
on the body and texture of butter (23,14,31,5). Butter churned from cream which is cooled to low temperatures and held for several hours will possess less desirable body and texture characteristics than butter churned from cream which was not cooled to such low temperatures. Cooling of the cream to low temperatures favors crystallization of a greater percentage of the fats (23). The longer cream is held before churning the greater percentage of the fats that will be crystallized at the temperature held (28). A holding period in excess of four hours, if the cream is not cooled too low after pasteurization, favors a more desirable body and texture of butter than a shorter holding period (5).

**E: Effect of churning On the Body and Texture of Butter.**

The temperatures of churning are limited to a rather narrow range when the time of churning and the fat losses in the buttermilk are considered. Long churning periods are not practical because of increased operating costs. Short churning periods may cause high fat losses in the buttermilk. Unless the churning temperature is abnormally high, the churning operation will have little noticeable effect on the body and texture of the finished butter (23). As has been pointed out, the churning process can be considered as a part of the cooling and holding process with respect to the rate and extent of crystallization of the glycerides.
F: **Effect of the Washing of the Butter Granules on the Body and Texture of the Butter.**

Next to the cooling and holding of the cream prior to churning, the tempering of the butter granules before working has a greater effect on the body and texture of butter than any other manufacturing process (14, 23, 5). It has been recommended that the temperature of the wash water be adjusted according to the condition of the butter granules at the completion of the churning process. The use of wash water colder than the butter granules keeps the butter firm during the working process. The use of wash water of the same temperature as that of the buttermilk or slightly warmer will permit the butter to become soft during the working process. The body and texture of butter after twenty-four hours can not always be correlated with the body and texture of the butter just at the end of the working process. In other words, butter may be quite firm at the end of the working process and after twenty-four hours be softer than butter from cream similarly treated but churned and tempered with wash water so as to be soft at the end of the working process (14).

C: **Effect of the Working On the Body and Texture of Butter.**

It is economically necessary during the working process to incorporate about 16.5 per cent of moisture
and two per cent of salt into the butter (9). This moisture and salt must be distributed uniformly throughout the butter mass in the form of small brine droplets. Large droplets favor leakage and consequent loss in weight of the butter during marketing.

The amount of working necessary to properly incorporate the brine in butter depends on the condition of the butter granules, and the type of workers used. When the butter granules are firm, more working is required than when the granules are soft. Overworking causes the butter to have a salvy texture with a dull lifeless color. The butter may also become sticky. There is a relationship between the amount of liquid fat in the milk fat and the amount of working butter may stand before becoming over worked. Butter may be over worked with respect to the amount of liquid fat and be sticky, yet be under worked with respect to the brine droplets and be leaky (23). Ideal working depends upon the adjustment of the crystallization of the fats in the globules during cooling, holding, and churning of the cream, and the tempering of the butter granules.

In the United States little adjustment of the working process can be made because of the type of butter workers now used. The use of a variable speed butter worker has been reported by European investigators to benefit the
body and texture of butter (23). A very slow working speed is used for the final working of butter.

H: Effect of Storage Temperature On the Body and Texture of Butter.

There is evidence that the storage temperature may be adjusted to benefit the body and texture of butter (23). This is particularly true if the butter has a tendency to be hard and crumbly (31). Storing the butter at about 50°F for one week before chilling to lower temperatures has been reported to minimize the crumbliness of the butter (15).

III: PREVIOUS ATTEMPTS TO OVERCOME STICKY AND CRUMBLY BUTTER

A: Definition of the Terms Sticky and Crumbly.

The sticky and crumbly defect in butter are two distinct faults, though they may be a result of the same primary cause. During the fall and winter, cows in many sections are fed largely upon dry feeds. Alfalfa hay forms the principal roughage for most dairy cows in several of the western states particularly in those regions with the more severe winters as in Eastern Oregon (21). On this type of feed the cows produce milk fat that is low in the percentage of the glycerides which have low melting points or which are in the liquid state at
temperatures below 50°F. (24, 7, 18). The absence of these glycerides with low melting point seems to be the cause of sticky and crumbly butter when normal methods of manufacture are followed.

Butter may be sticky or it may be crumbly, and it may possess both defects. Severe stickiness is often confused with crumbliness though careful examination of butter will show the difference. Stickiness is a self describing term. The butter clings to the knife or spatula and to the back of a trier. The butter has poor spreadability, tending to curl up behind the knife. Crumbliness also is self descriptive. The butter does not form desirable pats for hotel and restaurant use but tends to break into small pieces. This crumbly character also causes poor spreading properties.

During recent years, two systems of treating the cream prior to churning and tempering of the butter granules prior to working have been developed in an attempt to overcome the sticky and crumbly defects in butter.

B: Churning Immediately After Pasteurization of the Cream.

One system prescribes that the cream be cooled rapidly after pasteurization to such a temperature as will permit a churning time of about fifty to sixty minutes and the cream churned immediately after cooling (18). The
butter granules are washed with water about four degrees fahrenheit lower than that of the buttermilk, depending on the firmness of the granules. The butter is worked and packed as rapidly as possible and stored at temperatures that are not below 50° F. If on the other hand the cream is cooled and held for some time, it is necessary to heat the cream to 110° F. and hold at this temperature for fifteen minutes. The process is then completed as above.

It is reasoned that by churning immediately after pasteurization and cooling, glycerides do not become completely crystallized. As has been pointed out, glycerides require a period of time to become completely crystallized at any temperature. Completion of the churning and working in a short period of time then leaves fats with melting points higher than the temperature of working in the liquid form.

These liquid glycerides will be expressed from the globules, partly during churning, and more completely during working of the butter. Thus adequate liquid fat will be provided for properly emulsifying the dispersed material in the butter, if the process is completed quickly. Storing the butter at approximately 50° F. permits the final crystallization of the fats to be completed at a temperature near that at which the butter
will be used. A larger percentage of glycerides are left in the liquid state than if the butter were cooled to lower temperatures. By this method of churning and working the butter the glycerides with melting points higher than the working temperature are incorporated into the continuous phase of the butter as liquid glycerides. When these glycerides crystallize they lose their capacity to lubricate the dispersed phase and the butter becomes friable or crumbly.

C: The Use of Cold Wash Water.

The second systemprescribes that the cream be cooled after pasteurization to such a temperature that after twelve hours the cream will be at the right temperature to permit churning in from fifty to sixty minutes (5). The cream is churned until the granules are about the size of small peas. The butter granules are washed with water at a temperature below 42°F. A volume of water equal to the volume of buttermilk is used and the granules are kept agitated in the water for five minutes or longer to insure complete chilling. The wash water is drained, the granules salted and worked. A longer time is needed for working the butter because the chilled granules do not mat readily. Butter made by this method usually is not crumbly but may show stickiness.
It is reasoned by the research workers who recommend this method that if a smaller percentage of the glycerides with higher melting points are incorporated in the continuous phase of the butter, the butter texture will be less crumbly. When the cream is held at churning temperatures for twelve hours, a large percentage of the glycerides which will crystallize at that temperature are crystallized in the fat globules. During churning part of the liquid fats are pressed from the globules. The butter granules are chilled to low temperature during the washing, to prevent or minimize the melting of any of the glycerides with high melting points as a result of the heat developed in the butter during the churning and working. As the butter is worked at the lower temperatures, only the fat in the globules that is liquid at the low temperature is expressed. A smaller amount of liquid fat is thus available for emulsifying the dispersed material. If the available liquid fat is not sufficient for the proper working, the butter becomes sticky.
EXPERIMENTAL PROCEDURE AND RESULTS

I: COOPERATING AGENCIES

The literature reviewed indicated that the body and texture of butter can be materially affected by modifying the manufacturing methods. A study of some modifications of the manufacturing methods was made at the Oregon Agricultural Experiment Station. It was desired to find some method, or combination of methods, of manufacturing butter which would overcome or minimize the crumbly and sticky defects.

Crumbliness and stickiness was found to occur most commonly in butter made from cream obtained from milk produced by cows fed a restricted diet of alfalfa hay.

Creameries located in the regions of the State in which a great deal of alfalfa hay is fed to dairy cows were asked to cooperate in the study. It was in the sections represented by these creameries that sticky and crumbly defects in butter were most noticeable during the fall and winter season.

II: STUDIES MADE DURING 1937-1938, 1938-1939

A: Equipment Used.

A nine hundred pound capacity coil pasteurizing vat, a fifty gallon jacketed starter tank, and a small
flash pasteurizer were used for pasteurizing the cream. The coil vat and the starter tank were used for holding the cream after pasteurization. A surface cooler using tap water and refrigerated water (33° F.) was used in the surface cooling studies. A two hundred fifty pound capacity Dual churn was used for the churning and working of the butter made during the first two years of the study.

B: Cream Received.

During the season from November 11, 1937 to April 1, 1938, seven creameries each sent ten gallons of cream weekly to the Experiment Station laboratory in Corvallis. Eight creameries each shipped ten gallons of cream weekly during the season from October 26, 1938 to February 10, 1939. The cream that was shipped was regular route cream received at the creameries except that care was taken to select cream that was produced by cows which were known to be receiving a restricted alfalfa hay diet.

The cream when received at the Experiment Station, was thoroughly mixed and divided into two equal batches for churning. The two batches of cream provided an experimental churning and a control churning. A total of seventy churnings were made during the two seasons.

C: Butter Samples Kept For Study.

Two-pound samples of butter from each churning were kept at 50° F. for five days after churning and judged
for body and texture and spreading characteristics. The
trier, spatulas, and knives used for examining the butter
were tempered in the 50° F. box with the butter.

D: **Effect of Flash Pasteurization on the Body and Texture of Butter.**

The effect of pasteurizing the cream to 180° F. by
the flash method of cream pasteurization was studied in
nine comparative churnings. The cream was cooled on a
surface cooler. The check churnings were pasteurized in
a coil vat at 150° F. and held at this temperature for
thirty minutes. There was no detectable difference in
the body and texture of butter pasteurized by the two
different methods when all other processess of the
churning procedure were kept the same.

E: **Effect of Surface Cooling the Cream On Body and Texture of Butter.**

Twenty four churnings were made from cream cooled
rapidly on the surface cooler to 50° F. and compared with
check churnings in which the cream was cooled in a vat.
The butter made from the cream cooled on the surface
cooler was harder, and more often crumbly than butter
made from cream cooled in the vat. The effect of the
fast cooling was overcome by the effect of the tempera-
ture and time of holding the cream after cooling from
pasteurization temperature and prior to churning and the
temperature of the water used for washing the butter granules.

F: **Effect of Cooling the Cream After Pasteurization on the Body and Texture of Butter.**

In order to determine the effect of the temperature to which the cream was cooled after pasteurization on the body and texture of the butter nine churnings of cream were cooled to below 48° F. and compared with nine check churnings which were not cooled below 50° F. When cream was cooled to a temperature below 48° F. the butter was usually hard, sticky and crumbly at the time of scoring five days later, even though the churning temperature was raised to 60° F. The lower the temperature to which the cream was cooled after pasteurization, the more pronounced was the crumbliness and stickiness in the butter. Cooling the cream to an extremely low temperature (40° F.) was found to greatly increase the crumbliness and stickiness of the butter. It was found that cream cooled to a temperature of 50° F. or slightly above after pasteurization, and held at this temperature until the time of churning resulted in butter that was less crumbly than was that from cream cooled to lower temperatures. Churning cream which had been held at temperatures above 50° F. was found to sometimes result in sticky butter.
G: **Effect of Holding Time of Cream on the Body and Texture of Butter.**

The effect of the time of holding the cream on the body and texture was determined with nine comparative sets of churnings. The elapsed period between the time that the cream is cooled after pasteurization to the time that the cream is churned is considered the holding time. The cream for one set of churnings was churned immediately after pasteurization and the cream for the other churnings was held from 12 to 20 hours between pasteurization and churning. Cream which was churned within two hours after it had been pasteurized and cooled usually resulted in butter that was free from stickiness, although it was brittle, crumbly, and short grained. Cream which was cooled to temperatures (below 48° F.) following pasteurization, and held for several hours at this temperature and then churned, resulted in butter that was both sticky and crumbly. When pasteurized and cooled cream was held overnight then heated to 120° F. and held for fifteen minutes, cooled rapidly in the vat to a suitable churning temperature and churned immediately, the results were similar to those obtained when the cream was churned immediately following pasteurization.
H: Effect of Cold Wash Water on the Body and Texture of Butter.

Thirty five churnings were made in which wash water (38° F. to 44° F. or lower) was used. The effect on the body and texture of butter was compared with 35 churnings in which wash water of from 54° F. to 56° F. was used. The butter which was washed with cold wash water required more working than the butter which was washed with water at 54° F. to 56° F. Butter that has been subjected to the cold wash water treatment usually showed a pronounced sticky defect. It was believed that the extra working of the harder granules caused this defect to be more evident. The use of cold wash water, however, was quite effective in reducing the crumbly defect of the butter. The butter was softer and displayed better spreadability than butter washed with water at 54° F. to 56° F.

The following factors are important if best results are to be obtained by using cold wash water:

1: The cream should be churned till the granules are the size of small peas and no larger. This is necessary to insure complete chilling of the granules during the washing.

2: The wash water temperature should be lower than 38° F.
3: The volume of water used should be equal to the volume of the buttermilk.

4: The butter granules should be allowed to temper in the wash water for at least five minutes.

5: The butter granules should be agitated in the wash water. This can be done by revolving the churn in low gear without the rollers.

6: The butter must be worked to completion without delay.

In connection with the last factor it was found necessary to be able to obtain the correct moisture in the butter without adding additional water when the working was nearly completed. The working necessary to incorporate the additional water would cause the butter to become definitely over worked.

Butter that had been treated by the cold wash water method was harder in the churn than butter washed with normal temperature wash water. However, after storage the butter which had been made by using cold wash water possessed a softer body than the butter which had been made by using wash water at normal temperatures.

I: Effect of Slow Working of the Butter on the Body and Texture of Butter.

The effect of slow working of the butter was studied by reducing the working speed of the churn to one half
the normal speed. Seventeen churnings of butter were worked by the reduced speed method and compared with churnings which were worked at the normal speed. It was found that the method of slow working required a longer time for complete working of the butter than the regular working speed. The texture of the butter that was worked by the slow method was not uniformly better than the texture of the butter that had been worked at the normal speed. However, slow working and the use of cold wash water appeared to be beneficial in reducing the degree of crumbliness in the butter. It was difficult to detect when the butter had been worked sufficiently because the change in the appearance of the butter in the churn was so slow. There was danger of overworking butter when using the slow working speed on the churn.

J: Effect of Temperature of Storing Butter.

Samples of sticky butter were held for one week at temperatures of 40°F, and 70°F respectively. At the end of the week the butter was tempered for two days to 50°F and examined. The butter that had been held at 40°F and 50°F showed stickiness but little crumbliness. The butter that had been held at 70°F was reasonably free from stickiness but showed pronounced crumbliness.
III: STUDIES MADE DURING 1939-1940 AND 1940-1941

The results of the first two years of this study were not considered conclusive in determining a specific method to be used in overcoming the sticky and crumbly texture of butter. It was observed that certain manufacturing methods tended to minimize the defects. To further study these methods with larger churnings in the laboratory and in commercial creameries, the sticky and crumbly butter investigation was continued during the winters of 1939-1940 and 1940-1941. A total of 153 commercial size churnings were made in the dairy products laboratory at Oregon State College and in the churn rooms of creameries cooperating in the study. The cream used was typical winter cream produced in sections of the State where the cows were fed a ration that consisted principally of alfalfa hay.

Samples of butter from the experimental churnings were taken directly from the churn and held at 40°F to 50°F for scoring and further laboratory study. Several methods of procedure in manufacturing the butter were outlined for study. These methods were closely adhered to through both seasons so that results might be comparable. All samples were scored at 48°F to 55°F. The triers when not in use, were kept in cold running tap water to maintain a constant temperature.
during the scoring.

A: **Churning Procedure Number 1.**

Churning procedure number 1 was a study of the effect of churning the cream immediately after pasteurization and cooling on the body and texture of butter. The cream was neutralized and pasteurized in coil vats and cooled as rapidly as possible to churning temperature and churned. A temperature which would cause granules the size of small peas in from 45 to 60 minutes of churning was selected. The washing of the butter granules was completed as rapidly as possible by using only one batch of wash water at a temperature about 4° F. below that of the buttermilk. Speed was stressed in this procedure as the sooner the butter could be packed from the start of the churning, the greater were the benefits to be derived.

A total of 29 churnings was made by this method. Butter from all the churnings was sufficiently crumbly to be criticized. Only 22 samples (76 per cent) were sticky enough to be criticized. All the samples were firm; 14 (48 per cent) had poor spreadability; 16 (55 per cent) were criticized as short grained; 20 (69 per cent) were brittle.

B: **Churning Procedure Number 2.**

Churning procedure number 2 differed from procedure number 1 in that the cream was cooled to between 40° F.
and 50° F. after pasteurization and held at that temperature over-night. The following day the cream was heated to 110° F. and held at this temperature for 15 minutes, then cooled as rapidly as possible and the same procedure was followed as in procedure number 1.

A total of 22 churnings was made by procedure number 2. The butter from all 22 churnings was crumbly, however, the tendency toward extreme crumbliness did not seem as pronounced as in the butter made by procedure number 1. Of the churnings 16 (73 per cent) were sticky or slightly sticky; 7 samples (77 per cent) had poor spreadability; 13 samples (59 per cent) were short grained; and 17 samples (77 per cent) were brittle.

C: Churning Procedure Number 3A.

Procedure Number 3A involved a study of the effect of using cold wash water to wash the butter granules. The cream was neutralized and pasteurized in the usual manner. Following pasteurization it was cooled to from 50° F. to 55° F. The cream was held over-night at this temperature and churned the following day at a temperature that would allow a churning time of from 45 to 60 minutes. The butter was churned till the granules were the size of small peas. The buttermilk was drained and water, 38° F. to 40° F., was added. About one gallon of water to every ten pounds of butter was used in each of the two washes. The churn was revolved ten times in high gear for the
first wash; the water was drained immediately and the second wash water added. The churn was revolved for five minutes in low gear. The butter was not worked in the water. Dry salt was added after the second wash water was drained.

Twenty four churnings were made by procedure number 3A. Butter from all these churnings was criticized as being sticky; 14 samples (58 per cent) were definitely sticky. Only one sample was slightly crumbly. The butter from 23 churnings was quite soft and pliable; 21 (88 per cent) of these had satisfactory spreadability.

Two churnings were made using procedure number 3A except that the cream was held over Sunday instead of over-night at from 50° F. to 55° F. The butter from both churnings was definitely sticky, but it was quite soft and pliable and possessed satisfactory spreadability.

Two churnings were also made from cream held over Sunday at 50° F. to 55° F. but wash water of about 48° F. was used instead of the cold wash water. Only one washing was used. The butter from these two churnings was definitely sticky. One of the churnings was criticized for being slightly crumbly and slightly brittle. Butter from both churnings possessed fair spreadability.
D: Churning Procedure Number 3B.

Churning procedure number 3B was used to study the effect of extremely cold wash water (38° F. to 40° F.) on butter churned from cream immediately after pasteurization and cooling as in method number 1.

Only three churnings were made by this method. The butter from all churnings was definitely sticky, crumbly, and possessed poor spreading properties.

E: Churning Procedure Number 3C.

Churning procedure number 3C was used to study the effect of cold wash water (40° F.) on butter granules obtained from churning cream that had been held over-night at a low temperature (40° F.). The cream was churned at 60° F. and the butter granules were washed and worked the same as in procedures number 3A and 3B.

Two churnings were made by this procedure. Butter from both churnings was definitely sticky and from one was also short grained.

F: Churning Procedure Number 4A.

Churning procedure number 4A was used to study the effect of holding the pasteurized cream over-night at a comparatively high temperature (50° F. to 60° F.) before churning. The cream was churned at temperatures that would result in granules the size of peas to be churned
in about 45 to 60 minutes. Usually only one wash water was used, the temperature of the water (54° F. to 56° F.) was adjusted according to the degree of firmness or softness of the butter granules.

A total of 19 churnings was made by this method. Butter samples from all 19 churnings were criticized for stickiness while only four (20 per cent) were criticized for crumbliness. Two samples had a brittle body. Of the 19 samples 10 (52 per cent) had a soft and pliable body and 11 samples (58 per cent) showed satisfactory spreadability. One of the samples was also gummy and only one had poor spreading properties.

Ten churnings were made in which the cream was not cooled below 60° F. after pasteurization. All ten samples of butter from these churnings were sticky. Of the 10 samples (70 per cent) were crumbly; two (20 per cent) were short grained; four (40 per cent) were brittle; two were soft and pliable; two (20 per cent) had poor spreadability; and three (30 per cent) possessed satisfactory spreadability.

G: Churning Procedure Number 4B.

Churning procedure number 4B was the same as number 4A except that the cream was cooled to below 50° F. (ranging from 35° F. to 46° F.) and held over-night.

The 13 churnings made by this method all resulted
in sticky butter. Eight of them (61 per cent) were crumbly. Four (30 per cent) were brittle and three (23 per cent) were short grained. Four samples (30 per cent) were soft and pliable and eight samples (61 per cent) were firm bodied.

H: **Churning Procedure Number 5A.**

Churning procedure number 5A was used to study the effect of adding hot water (170° F. to 180° F.) directly to the cream in the churn at the time of breaking. The cream was churned immediately after pasteurization and cooling to the churning temperature. Approximately ten gallons of water per 1000 pounds of butter were used. Two batches of wash water were used, the first at a temperature of from 55° F. to 60° F. and at a ratio of one gallon of water to 60 pounds of butter. The churn was revolved in low gear for ten revolutions with the first wash water. The second batch of wash water was at a temperature of from 45° F. to 50° F.; the butter was worked in this water for five to ten revolutions.

Eight churnings were made using churning procedure number 5A. The butter from all eight churnings was sticky and crumbly. Six of the samples (75 per cent) had very poor spreadability.
I: Churning Procedure Number 5B.

Churning procedure number 5B was the same as number 5A except that the cream was held over-night at temperatures below 50° F.

Five churnings were made using this procedure. Butter from all five churnings was sticky and from three churnings crumbly. Two churnings had poor spreadability and one was satisfactory.

J: Methods Using Rapid and Low Cooling Over Surface Cooler.

Four churnings were made from cream that had been cooled to approximately 42° F. over a surface cooler after pasteurization. Each lot was held over-night before churning. One lot of wash water at 47° F. to 48° F. was used. Butter from the four churnings was sticky but none was crumbly. Three samples had fair spreadability and only one possessed a very firm body, the others being medium soft.

K: Method using Intermittent Working.

Three churnings were made by extending the working time intermittently over a 90 minute period after the first moisture test had been made. This was done by allowing the butter to "set" for from 10 to 15 minutes and then working it for a sufficient time to make the butter soft again.
Two lots of cream were held over-night and the churning made as in procedure 4A with intermittent working; one churning was made as in procedure number 1 with intermittent working. Butter from the two lots of cream held over-night were both definitely sticky. The butter from the third churning was slightly sticky and crumbly. Only one sample showed fair spreadability and it was from cream held over-night. The butter from cream churned immediately after cooling from pasteurization temperature was very brittle.


The effect of vacuum pasteurization of cream on the texture of butter was also tried with five lots of cream obtained from Eastern Oregon. Four churnings were held over-night at about 50°F and the same churning method used as in procedure 4A. The fifth lot of cream was churned immediately after pasteurization as in procedure number 1.

All samples of butter from the cream that was held over-night were crumbly, brittle, and short grained and possessed a body which had poor spreadability. One of these samples was slightly sticky. Butter from cream that was churned immediately following pasteurization was definitely sticky and slightly crumbly.
DISCUSSION OF RESULTS FROM THE
CHURNING EXPERIMENTS

Crumbly butter was generally obtained when the milk fat was not given sufficient time to crystallize after pasteurization, when the crystallization was completed at temperatures above 60°F, when the temperature of the wash water was above 54°F, when part of the milk fat was melted by the addition of hot water in the churn at the time of breaking, and when the cream was cooled over a surface cooler to 50°F. Two of these conditions on the same churning, such as churning immediately after cooling from the pasteurizing temperature and using wash water at about 54°F, increased the crumbly defect in the butter.

Under these conditions, the development of the crumbly defect can probably be explained by Storgards (23) reasoning. The glycerides with melting points above the temperature at which the butter is examined (50°F) are either still in the liquid state at the time of working, or brought into the liquid state due to the high temperature of the butter at the time of working. The liquid fats are incorporated in the continuous phase of the butter during the working. As the butter is chilled after completion of the working, these glycerides
crystallize. The crystals in the continuous fat causes the continuous fat to lose its ability to hold the butter together as a waxy mass and the butter becomes friable or crumbly.

Sticky butter was generally obtained when the cream was cooled below 50° F. after pasteurization and held for about twelve hours, when the cream was held for 36 hours at 50° F. to 55° F., when cream was held at above 50° F. for 12 hours and wash water of from 54° F. to 56° F. was used, when wash water 40° F. and below was used to chill the butter granules, when hot water was added to the cream in the churn at the time of breaking, and when the cream was cooled to 42° F. or below on the surface cooler and held over-night.

The development of sticky butter by practically all methods of manufacture except that as used in method number 1 and method number 2 indicates that it is necessary to have more glycerides in the liquid state for adequate working of the butter than are present in the milk fat when it is held for 12 hours at or below the churning temperature. Milk fat produced by cows on a restricted diet of alfalfa hay is known to have a low percentage of the low melting points glycerides (7, 18, 24). The liquid glycerides are pressed from the fat
globules during the working of the butter and surround the brine droplets, the fat globules, and protein material in the butter. If the milk fat is not permitted to crystallize completely before working the uncrystallized liquid glycerides allow for a more adequate working of the butter.

The European investigators who developed and used the method of cold wash water successfully (21,23,14) were attempting to avoid a hard, or friable, condition in winter butter. The results of the Oregon experiments confirm those obtained in Europe and at Minnesota (5). The use of wash water below 40°F. on the butter granules churned from cream which had been held at the churning temperature for 12 hours resulted in butter that usually was not crumbly, and which was quite soft and pliable and possessed satisfactory spreadability although it generally showed stickiness in varying degree.

Although only four churnings were studied in which the cream was cooled rapidly on a surface cooler to 42°F., the results indicated that this procedure gave butter similar in body and texture to that obtained when the cream was held at the churning temperature for 12 hours and when the granules were washed with wash water 38°F. to 42°F. In both methods the butter
granules were in a firm condition for working. A larger percentage of the glycerides which are liquid below 50°F were likely forced from the milk fat globules during working than would be the case if the butter were softer and was less severely worked. More severe working of the butter at temperatures below 55°F seemed to give softer butter with better spreadability than less severe working at temperatures above 55°F. although the more severe working also accentuates stickiness.

The addition of hot water to the cream at the time of breaking increased the sticky and crumbly defects in the butter. Using wash water below 40°F on butter granules churned from cream treated as in method number 1 and 2 caused the butter to be both sticky and crumbly.
CONCLUSION

1: The churning of 223 lots of cream obtained during the fall and winter months from the alfalfa growing sections of Oregon showed that the defects crumbliness and stickiness of the body and texture of the butter made were quite common.

2: No method of manufacturing the butter was found which would completely eliminate both defects. Methods used to avoid sticky butter generally resulted in butter that was hard and crumbly, and that lacked good spreading properties although it was possible to draw a clean trier plug. This butter possessed a bright luster. Methods used to avoid crumbly butter generally resulted in butter that was sticky. A poor trier plug was obtained and the butter had a dull, lifeless appearance. However, this butter was generally softer than the crumbly butter, and usually possessed fair spreading properties.

3: In order to reduce stickiness of butter during the fall and winter months when the milk fat contains less of the glycerides with low melting points it is necessary to (1) hold the pasteurized cream at a higher temperature, (2) churn at a higher temperature, and
(3) use wash water at a higher temperature than during the spring and summer months. If the cream is churned the same day that it is pasteurized, the extent of cooling before churning will have to be adjusted to obtain a churning time of from 45 to 60 minutes. The temperature of the wash water is adjusted to about four degrees below the temperature of the buttermilk.

4: If it is desired to reduce crumbliness of butter, the cream can be cooled rapidly, as on a surface cooler, to about 42° F., and held at 42° F. to 48° F., or cooled in a vat from 50° F. to 58° F. After being held for about 12 hours the temperature of the cream should be adjusted so granules the size of small peas will be obtained in from 45 to 60 minutes of churning. The temperature of the wash water should be below 42° F. in the case of vat cooled cream and the butter granules should be thoroughly chilled in the wash water. One batch of wash water at 47° F. is used for the surface cooled cream. It is not so important that the granules be thoroughly chilled.

5: The rate of cooling the cream, the time of holding the pasteurized cream before churning, the temperature at which the cream was held, the churning temperature, the temperature of the wash water, and the
method of washing were all important factors in controlling the body and texture of the butter. Since the composition of milk fat does not change markedly from one day to the next, but changes slowly with the seasons, it becomes necessary for the buttermaker to carefully watch for any indications of change in the milk fat and to make the proper adjustments in the manufacturing methods in accordance with the degree of change in the milk fat.

6: It will be necessary to establish which of the defects of butter, crumbliness or stickiness, is less desirable on the butter market before the results of this investigation can be fully applied. From the results of this investigation buttermakers can be advised how the defects of crumbliness and stickiness in butter can be reduced. It is not possible to recommend a method of butter manufacture that will completely eliminate both defects. It is believed that butter that shows a slight degree of stickiness, but has a fairly soft body and good spreading properties when used at a temperature of about 58° F. to 60° F. will be preferred by the majority of the consumers over butter which is hard and crumbly.
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