BUTTER MAKING

During Hay Feeding Season

"50-45-40" Method
FOREWORD

Another marketing problem of importance to Oregon dairymen—crumbly, sticky, hard butter—has been solved. These defects are characteristic of butter produced in the regions of Oregon largely dependent upon hay as the main ration during the fall and winter months. The defects appear in butter early in October and disappear with the coming of grass, and may result in a discount of as much as 1 cent a pound. The consumer objects to such butter because it is hard and crumbles and rolls under the knife.

Because of its importance to the butter industry, the Oregon Dairymen’s Association and the Oregon Dairy Manufacturers’ Association both presented to the Oregon Legislature 6 years ago the need for research to develop remedial measures. Funds were appropriated, and this bulletin contains the final results of this particular phase of the butter manufacturing studies by the Oregon Agricultural Experiment Station.

The investigation included a study of the chemical and physical properties of the milk fat produced in typical irrigated alfalfa producing areas of eastern and southern Oregon and in other parts of the state. A report of this particular phase of the study has already been made.

On the basis of the experimental results obtained, a satisfactory method of butter manufacture has been developed. For convenience this has been designated the “50-45-40” method. If the recommended procedure is carefully followed, this method, which has been tested under large-scale commercial conditions in eastern Oregon and southwestern Idaho creameries, will enable buttermakers to produce butter that has a waxy body and a satisfactory spreading quality.

The solution of this baffling problem illustrates in a forceful way the close relationship of the farm and factory to manufacturing and marketing problems. Complete application of the method developed should increase the market value of butter produced in southern and eastern Oregon by $40,000 a year.

As the bulletin has been prepared for the benefit of creamery operators and buttermakers, manufacturing procedures rather than theoretical considerations have been emphasized.

Wm. A. Schoenfeld

Dean and Director
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SUMMARY AND CONCLUSIONS

The research by the Oregon Agricultural Experiment Station during 5 years on the problem of crumbliness, stickiness, and excessive hardness causing poor spreading and printing properties of butter made during the fall and winter season, October to March, has involved the manufacture of approximately one-third million pounds of butter. A total of 383 churnings was made. Cream from milk produced in the irrigated hay-producing sections of eastern and southern Oregon and southwestern Idaho was used. On the basis of the findings from this research, from the adaptation of research findings obtained elsewhere, and from general observations made, it is possible to suggest a satisfactory method of butter manufacture. Briefly this is as follows:

(a) The cream used must be in good physical condition (not frozen, curdy, watery, etc.)
(b) The fat content of the cream should be controlled to range from 32 to 38 per cent.
(c) The cream after pasteurization should be cooled slowly to a temperature of 50°F.
(d) The cream should be held overnight at a temperature of from 50°F to 55°F.
(e) Dilution of the cream with water must be reduced to a minimum.
(f) The temperature of the cream at the time of churning should be regulated so that the buttermilk can be drained within 40 to 50 minutes after churning is commenced.
(g) The butter granules should be the size of small peas.
(h) The butter granules should be washed and thoroughly chilled by means of cold water at a temperature not higher than 45°F.
(i) The buttermaker should adjust the amount of water added with the salt so that the butter when not completely worked will contain within 1 per cent of the desired moisture.
(j) The final working after the make-up water is added should be so thorough that leakiness is not observed on the surface of the printed butter.
(k) The churn and butter worker must be in such condition that the butter does not stick to them.
(l) The churning, working, and packing operations must be done with dispatch.
(m) The freshly packed moulds or cubes of butter should be placed in a refrigerator maintained at a temperature of 40°F.
(n) The whole process of buttermaking must be done as directed above with no deviation.

The butter obtained will be quite soft and waxy. It will be easy to print and wrap and will show no excess leakiness during and after printing. Because the butter will not be hard and crumbly, but fairly soft, restaurant operators and housewives will have no difficulty in cutting it into patties or slices. As has been unmistakingly shown, the butter made by this method possesses good spreadability.
As the method is not a radical departure from the conventional method of butter manufacture, it can easily be adopted by any creamery. The method will also be found satisfactory to use during the fall and winter months by creameries not located in the irrigated sections.

It should be pointed out, however, that if the full benefit of the method is to be obtained there must be no short cuts. Expert workmanship on the part of the buttermaker is absolutely necessary.

Since the pasteurized cream is cooled to 50° F., the butter granules are washed and chilled with water at a temperature of not higher than 45° F., and the finished butter is cooled to 40° F. or below, this procedure of butter manufacture is called the "50-45-40" Method for Making Fall and Winter Butter.
Butter Making During Hay Feeding Season
“50-45-40” Method

By G. H. Wrister, R. E. Stout, R. W. Stein, J. R. Haag, and I. R. Jones

In recent years there has been a considerable increase in the amount of butter made annually in the irrigated alfalfa hay-producing sections of eastern and southern Oregon. In 1925 a total of five and one-half million pounds of butter (23.5 per cent of the State's total) was manufactured in this section compared with nine and one-fourth million pounds (29 per cent of the State's total) in 1940. A previous study (1) showed that of the total annual amount of butter produced in this section 44 per cent was made during October to March inclusive. Hay consumption per cow has been found (2) to average 7,015 pounds per year in the irrigated regions compared to 4,947 pounds in the Willamette Valley and 3,531 pounds in the coast section. The consumption of succulents for the three regions was 1,240, 6,719, and 5,051 pounds, respectively; and grain was 630, 2,060, and 811 pounds, respectively. The length of the pasturing season was 164, 106, and 203 days, respectively, for the three areas. Thus, considerably more hay and less succulents and grain were consumed by the cows in the irrigated sections than in the other two sections. Because the eastern and southern Oregon sections are relatively sparsely populated a large percentage of the butter manufactured is shipped to markets in California, western Oregon, and western Washington.

Buyers and distributors of butter have complained that the butter made in the irrigated sections during the fall and winter months was hard and either crumbly or sticky, caused apparently by the feeding of considerable dry feeds to the cows. Complaints of excessive brine leakage from the printed butter

Figure 1. A dairy farm lay-out typical of the alfalfa hay sections of the West, showing stacked hay, outside feeding racks, milking barn at the right, and calf barn at the left.

*Numbers in parenthesis refer to references on pp. 47 and 48.
were also made. The butter on printing cut badly and was difficult to handle. Because of its hard and crumbly condition, it did not enjoy favorable acceptance by butter buyers. As this butter was marketed in competition with butter made in sections where less dry feeds are fed to the cows, the Oregon Agricultural Experiment Station was requested to study the problem with a view of finding a possible solution. The research work was commenced in 1937.

The defects, crumbliness, stickiness, and excessive hardness of butter, are experienced during fall and winter months in butter-producing sections of the United States and foreign countries when cows are largely limited to dry feeds. One noted authority remarked that the problem of overcoming these defects is by far the most stubborn of all butter problems. It has been found that cows fed dry hay rations, typical of winter feeding, produce milk fat having a high melting point and a low percentage of unsaturated and volatile fatty acids, resulting in butter of excessive hardness. This condition may be met by changing feeding practices or by modifying the butter manufacturing methods. This bulletin deals with the latter.

I. RESUMÉ OF RESEARCH FINDINGS IN OTHER STATES AND IN FOREIGN COUNTRIES TO CORRECT A CRUMBLY, STICKY, AND HARD CONDITION OF BUTTER

Recently Hunziker (3) enumerated the known facts and theories that have been advanced relative to the probable causes of poor spreadability of butter and discussed the most promising means of prevention, commenting in part as follows:

"The factors and combinations of factors that determine or influence the body and texture of butter are numerous. On the basis of our present knowledge they have to do with the composition of the butterfat, structure of the fat globules, rate of fat crystallization in cream and butter, amount of liquid fat and size of fat crystals in the butter. Some of these factors are in turn related to certain phases in the process of manufacture, such as intensity of cream cooling, temperature of butter wash water, manner and intensity of working, and temperature at which the butter is held immediately after manufacture.

"The science of the relationship between some of these factors and their effect on body and texture is generally understood, while that of other factors is as yet largely undetermined. The proper adjustment of the multitude of factors that influence the body and texture of butter to the fluctuating character of the raw material is further complicated by the usual endeavor dictated by competitive expediency of incorporating in butter the maximum percentage of moisture permitted by law."

The authors of the present bulletin have reviewed the reports by research workers in the United States and foreign countries dealing with the subject of improving the body and texture of butter. Brief mention of some of these findings is made below.

Holm (4) has given the following description of the physical structure of butter: "Butter consists, therefore, of fat globules, air bubbles, and water droplets each surrounded by protective films and dispersed, as it were, throughout a mass of free fat."
King (5, 6), of Estonia, stated that the fat in butter exists in two forms; namely, in the form of globules and as a dispersion agent for the globules and water droplets. He pointed out that the so-called unprotected part of the fat must be the fat that as a continuous phase fills up the space between the fat globules and water droplets. This is the liquid fat fraction that in his opinion acts as the real dispersion agent for the water droplets, which for the greater part are between the fat globules. He referred to the work of Boysen, which showed that the number of water droplets in 1 gram of butter normally ranges from 6 to 16 billion and that the fat globules range from 9 to 25 billion.

The presence of a liquid fat fraction in butter was demonstrated by means of X-ray photographs by Van Dam and Burgers in Holland (7). Arup in Ireland (8) was able to separate a liquid fat fraction from butterfat. From fat at a temperature of 50° F. he obtained a yield of from 7 to 8 per cent liquid fat. Van Dam (9) has shown by using dilatometers that in order completely to solidify the fat, it is necessary to cool the cream after pasteurization to about 32° F. and hold it at this temperature for about 24 hours.

The liquid fat phase is important from the point of view of the spreadability of the butter. Mulder in Holland (10) stated that the spreadability of butter is apparently due to the sliding over each other of the fat globules and water droplets; this is favored by the liquid fat present. He pointed out that it is well known that fat melted and afterward solidified can be a good deal firmer than the original butter.

Experiments conducted in Sweden by Haglund, Wode and Olsson (11) showed that it was possible permanently to modify the hardness of butter by a modification of the technique of butter manufacture. It was found that long and intense cooling of the cream before churning increased the hardness of the butter. Similar results were obtained by Coulter and Combs in Minnesota (12). They cooled lots of cream produced during December to temperatures of 40°, 50°, and 60° F. and held the cream overnight. The lots of cream were churned at the same temperature. It was found that cooling cream to the lower temperature caused a marked increase in the firmness of the butter. It also caused the butter to be crumbly and brittle. Essentially the same results were obtained by Lyons in Ireland (13).

Attempts by buttermakers to overcome excessive hardness and crumbliness by raising the churning and wash water temperature and by overworking the butter, have led to the manufacture of butter that has been greasy and sticky, with a dull luster. Research workers, therefore, have been trying to develop methods of butter manufacture that will result in improved waxiness and better spreadability of the butter without the sacrifice of other desirable characteristics. With reference to the body of New Zealand butter, Valentine (14) stated, “The margin between butter with a good body and lustre and butter which is greasy and lardy is a narrow one.” He pointed out that while “hard, short body” is objectionable, a soft, weak, greasy body is also objectionable. A firm, plastic body is desired, he stated. Valentine reported that excessively rapid cooling of cream to a low temperature caused the butter to have a hard, flinty body. When examined after storage it had a short, suety body and was pale in color and without luster. The sudden cooling of the cream over a surface cooler from a ripening temperature of 68° F. to a holding temperature of 36° F. caused butter of a harder body than that cooled slowly, according to the experiments in Sweden by Wode (15).

Paradoxically the cooling of the butter granules before working by means of low-temperature wash water and subjecting the butter to thorough working has been found to decrease the hardness of butter and improve the spreading
property. This was shown by Wode in Sweden (15), by Mohr and Oldenburg in Germany (16) (17), by Storgårds in Finland (18) (19), and by Coulter and Combs in Minnesota (12). In the research by Wode reported in 1933 it was found that washing the butter granules containing fat of a low iodine number (hard fat) with water at a temperature of from 34° to 36° F. resulted in producing butter permanently of a considerably softer body compared with that obtained when the granules were washed with water at the same temperature as the granules. The working time when cold wash water was used was 17 minutes, compared to only 10 minutes when the warmer wash water was used. The results from research on winter-made butter by Mohr and Oldenburg reported in 1934 definitely showed that when "warm" (57°-68° F.) water was used the butter was wet and crumbly whereas when "cold" wash water (35°-46° F.) was used the body was satisfactory and considerably softer even after storage at a temperature of 37° to 41° F. The use of the warmer wash water caused the butter to become friable during storage. They were of the opinion that the better body of the cold-wash-water butter was due to the formation of small-sized fat crystals that favored a soft pliable body, whereas in the warm-wash-water butter, large-sized fat crystals were progressively formed even after the butter was placed in the refrigerator, which favored the development of crumbliness and caused the butter to be excessively hard. These findings were further substantiated by Storgårds who in 1935 and again in 1938 reported that he had been able to produce fine-bodied butter from winter cream in Finland when the cream contained fat of a low iodine value by using wash water at a temperature of from 36° to 43° F. for the chilling of the butter granules. When water at a temperature of 44° to 68° F. was used he obtained butter that was crumbly and brittle and sometimes sticky. He explained the improvement on the basis of King's (5) (6) theory. If the butter granules are cooled to and worked at a low temperature, liquid fat is segregated into the continuous phase and the butter will possess a more desirable body and texture.

By centrifuging Storgårds (19) obtained the following amounts of liquid fat from the butter granules and the butter:

<table>
<thead>
<tr>
<th></th>
<th>Liquid fat</th>
<th>Iodine number of liquid fat</th>
<th>Iodine number of butterfat</th>
</tr>
</thead>
<tbody>
<tr>
<td>Granules after washing</td>
<td>4.19</td>
<td>35.4</td>
<td>32.9</td>
</tr>
<tr>
<td>Butter, half-worked</td>
<td>6.96</td>
<td>36.7</td>
<td>32.9</td>
</tr>
<tr>
<td>Butter, finished</td>
<td>8.77</td>
<td>34.5</td>
<td>32.9</td>
</tr>
<tr>
<td>Butter, overworked</td>
<td>2.58</td>
<td>34.2</td>
<td>32.9</td>
</tr>
</tbody>
</table>

The samples were kept in a refrigerator for 48 hours, then overnight at room temperature, before centrifuging.

The results obtained by the European investigators to overcome a hard, friable condition of butter was later confirmed by Coulter and Combs (12) in Minnesota. Among their suggestions to overcome a crumbly condition and improve the spreading property of winter-made butter they recommended washing the butter granules with water at a temperature of from 40° to 50° F.

On account of war conditions, a lack in Denmark of oil cake as a feed for dairy cows during the winter of 1940-41 caused considerable difficulty with crumbliness in the butter manufactured. In anticipation of further difficulty with the defect during the winter of 1941-42, the Danish dairy experiment station (20) tested the method developed in Sweden by Samuelsson and Pettersson of cooling the pasteurized cream to a temperature ranging
Butter making during hay feeding season from 43° to 46° F., holding at this temperature for 1 to 2 hours, followed by slowly heating the cream, using circulating water not exceeding 77° F., to 66° F. for ripening. After 3 to 3½ hours at this temperature, the cream was cooled to a temperature of 61° F. and held at this overnight. In his discussion of the Danish experiments, N. Kjaergaard-Jensen (20) reported that when the iodine number of the fat was 23.6, when the wash water used was at a temperature of 32° F. and when the butter was worked so that the moisture was thoroughly distributed, this method was found very beneficial in giving the butter a soft, waxy consistency.

When butter is worked it becomes progressively softer. If the working is interrupted, it will be observed that the butter becomes firmer. Additional working will again cause a softening of the butter. This can be repeated a number of times. The phenomenon is also observed with a number of other materials that possess a thixotropic property, which means that the plasticity of the material may be altered by subjecting it to certain mechanical stress. The subject falls within the division of science known as "rheology." The deformation of such materials by the influence of force, according to Mulder (10) depends chiefly on the concentration, the viscosity of the continuous phase, the consistency of the dispersed parts, the size and shape of the dispersed parts and the surface tension.

Richardson and Abbott in 1935 reported (21) results of their studies to prevent the defect "sticky texture" that was common prior to 1930 in approximately 80 per cent of the butter manufactured in California from the period December 1 to March 1. When scored, the butter possessing the defect failed to give a free-pulling core. The defect, they stated, was confined almost solely to districts where a large proportion of the dairy herds were maintained on a diet restricted to alfalfa hay. To prevent "sticky body under winter-feeding conditions" they recommended a prechurning treatment consisting of heating the pasteurized, cooled cream held from one day to the next to a temperature of 110° F., holding it at this temperature for 15 minutes, then cooling rapidly to a temperature 8° to 10° F. lower than the usual churning temperature before it is churned. The cream should be churned without delay and the churning, washing, and working of the butter done with dispatch. With normally firm butter the wash water should be from 3° to 4° F. below the temperature of the buttermilk. The finished butter should be hardened in a room at 50° F. They also recommended churning immediately after pasteurization and cooling. The cream should be cooled quickly to a temperature that would give a churning time of from 50 to 60 minutes. They reported a noticeable improvement in the body of the butter as a result of the adoption of the recommended procedures. Of 14 churnings made in January 1933 at the University Farm at Davis 71.5 per cent were not criticized for defective body, 21.4 per cent were cut one-half point in body score and 7.1 per cent were cut one point. In feeding trials these investigators found that when the regular ration fed to two Jersey cows was changed to one that consisted only of alfalfa hay a change in the chemical character of the milk fat took place. This was particularly shown by a marked decrease in the Reichert-Meissl value and an increase in the iodine value.

It is well known to buttermakers that butter "sets" after it has been completely worked, even though the temperature of the butter is not reduced. Hunziker and co-workers (3) made tests for hardness on butter kept undisturbed at the temperature at which it had been worked for periods up to 72 hours. The butter became progressively harder. The greatest change occurred in the butter made from cream churned immediately after pasteurization and cooling.
With reference to the influence of the temperature of the storage room, in which butter is placed after churning, on the firmness of the butter, Storgård (19) found that butter washed in cold water and worked at a low temperature remained pliable and comparatively soft even when the temperature of the butter storeroom was low. The work of Mulder (22) showed that when samples of butter were kept at temperatures ranging from 32° F. to 61° F. and the firmness of the butter was measured at 61° F., the butter that had been held for 2 weeks at 32° F. was the softest and that held at 55° F. was the hardest. This is clearly shown by the following data given by Mulder:

<table>
<thead>
<tr>
<th>Storage temperature for 2 weeks</th>
<th>32° F.</th>
<th>40° F.</th>
<th>48° F.</th>
<th>55° F.</th>
<th>61° F.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Degree hardness (measured at 61° F.)</td>
<td>9</td>
<td>11</td>
<td>17</td>
<td>21</td>
<td>19</td>
</tr>
</tbody>
</table>

It was conclusively shown by Coulter and Combs (12) that the temperature of the butter trier and the temperature and age of the butter when examining it for body and texture characteristics are very important. They proved, and illustrated this by means of photographs, that "perfectly normal-bodied butter could be made to show a ragged boring condition if the trier were cold enough, or if the butter was examined at a low temperature. Conversely, a smooth plug could be drawn from butter with a very defective body if the trier or the butter were sufficiently warm." It may be added that the type of trier used is also important.

Space does not permit additional discussion of other findings by research workers on this general subject. The most significant recent research findings concerning studies on the body, texture, and spreadability of butter have been abstracted.

It is recognized that present knowledge regarding the chemical and physical factors that may affect the body and texture of butter is meager. Extensive studies of a fundamental nature must be undertaken by chemists and physicists.
in order to discover how the fat in milk is influenced physically and chemically by the factors in the production of milk and in the various phases during the manufacture and handling of the butter.

II. PLAN OF THE EXPERIMENT

With the results from research to improve the body and texture of fall- and winter-made butter conducted prior to 1937 in other states and in foreign countries as a guide, the Experiment Station outlined a project that had for its purpose: (a) a study of the chemical and physical characteristics of the milk fat produced in Oregon, (b) a study of different methods of butter manufacture and handling, and finally (c) the testing, under commercial conditions, of the most promising method of butter manufacture developed.

The study involved:

1. Observations on the body and texture characteristics of butter made during the fall and winter months in the coast area, Willamette Valley, and eastern and southern Oregon.

2. A determination of some of the physical and chemical properties of the milk fat produced in the three areas.

3. The effect of different feeds and other factors on the physical and chemical properties of the milk fat produced in the different areas.

4. Experimentation to determine the influence of different manufacturing methods on the body, texture, and spreadability of butter made from cream produced during the fall and winter months in the alfalfa-producing sections.

5. Manufacture of butter under commercial conditions in creameries by the methods that experimentation had shown were the best.

6. Examination of the butter made in final tests by competent butter graders:

7. Determination of "printability" and "spreadability" of the butter made in final tests.

8. Determination of moisture losses during and subsequent to printing of the butter made in final tests.

9. Submission to consumers of representative samples of butter made in final tests for their decision as to the butter they prefer.

Active work on the project was begun during 1937. The defects being seasonal, it was only possible to conduct the churning experiments during the fall and winter months. The work was handicapped by several short and mild winter seasons, but it was favored, because of an extended dry-feeding period, by the long and relatively severe winter of 1941-42.

Complete reports of the findings under points 1, 2 and 3 have already been made (23), (24), (25). Reprints are available.

This bulletin reports the findings under points 4 to 9 inclusive.

Specific directions for making butter from cream produced during the fall and winter months in the irrigated sections that will (a) have a relatively soft, waxy body, (b) be free from crumbliness, (c) have a good spreading property, and (d) possess desirable printing characteristics are given on pages 43 to 46 inclusive.
III. PRELIMINARY CHURNING EXPERIMENTS
DURING THE FALL AND WINTER MONTHS,
1937-38 AND 1938-39

A. PLAN AND PROCEDURE

Equipment used. A 900-pound capacity coil pasteurizing vat, a 50-gallon jacketed pasteurizer, and a small flash pasteurizer were used for pasteurizing the experimental batches of cream. A surface cooler, using tap water and refrigerated water (33° F.) was used for the surface cooling studies. The coil vat and the jacketed pasteurizer also served for cooling and storage purposes. A 250-pound butter-capacity “Dual” churn was used for the churning and working of the butter made during the 2 years.*

Cream received. During the season from November 11, 1937 to April 1, 1938, seven creameries located in the irrigated sections of eastern and southern Oregon cooperated by each selling to the Experiment Station 10 gallons of cream weekly. During the season October 26, 1938 to February 10, 1939, eight creameries cooperated by each selling 10 gallons of cream weekly. The cream shipped was regular route cream received at the creameries and care was taken to select cream that was produced by cows that were known to be receiving a ration restricted chiefly to alfalfa hay.

All the cream in each shipment when received at the Experiment Station dairy products laboratory 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 70 churnings was made during the two seasons.

Butter samples kept for study. A 2-pound sample of butter was taken from each churning. The samples were kept at 50° F. for 5 days after churning and were then examined for body and texture and spreading characteristics. The trier, spatulas, and knives used for examining the butter were tempered to 50° F. before they were used.

B. MODIFICATIONS OF THE BUTTER MANUFACTURING METHOD STUDIED

1. Comparison of flash pasteurization of cream with vat pasteurization.
2. Comparison of surface cooling of cream with vat cooling.
3. Comparison of cooling cream after pasteurization to below 48° F. with cooling to 50° F. and above. Holding the cream at temperatures cooled to overnight.
4. Comparison of holding cream a short time after pasteurization and cooling before churning with holding it overnight.
5. Comparison of using water at a temperature of 38° to 44° F. for washing the butter granules with washing at 54° to 56° F.
6. Comparison of working the butter at normal speed of the butter-worker with working at reduced speed.

* The courtesy of the Creamery Package Manufacturing Company, Portland, in loaning some of this equipment to the Experiment Station for this research is acknowledged.
BUTTER MAKING DURING HAY FEEDING SEASON

C. RESULTS OBTAINED

1. Effect of flash pasteurization. The effect of pasteurizing the cream to 180° F. by the flash method was studied. The cream was cooled on a surface cooler and was then held overnight. The check churnings were pasteurized in a coil vat at 150° F. and held at this temperature for 30 minutes. They were then cooled in the vat and held overnight.

There was no detectable difference in the body and texture of the butter pasteurized by the two different methods when all other processes of the churning procedure were kept the same.

2. Effect of surface cooling. Cream that had been pasteurized in a vat was cooled rapidly on the surface cooler to 50° F. and compared with check churnings made from cream that was cooled in a vat.

The butter made from the cream cooled by means of the surface cooler was firmer and was more often crumbly than was the butter made from the cream that was cooled in the vat.

3. Temperature to which cream was cooled and held. In order to determine the effect on the body and texture of the butter of the temperature to which the cream was cooled after vat pasteurization and held at overnight, cream was cooled to below 48° F. and compared with check churnings that were not cooled below 50° F.

When the cream was cooled to a temperature of below 48° F. the butter was usually hard, sticky, and crumbly at the time of scoring 5 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 appeared to be the crumbliness and stickiness. Cooling the cream to an extremely low temperature (40° F.) was found greatly to 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 the butter from cream cooled to the lower temperatures. Churning cream that had been held at temperatures above 50° F. was sometimes found to result in sticky butter.

4. Length of time of holding cream cold after pasteurization. The effect of the length of time of holding the cream on the body and texture of the resulting butter was determined. The elapsed period between the time that the cream was cooled after pasteurization and the time the cream was churned was considered the holding time. The cream for one set of churnings was churned soon after vat pasteurization and cooling, and the cream for the other set of churnings was held for 12 to 20 hours from time of vat pasteurization and cooling to time of churning.

Cream that was churned within 2 hours after it had been pasteurized and cooled usually resulted in butter that was free from stickiness, but it was brittle, crumbly, and short-grained. Cream that was cooled to temperatures below 48° F. following pasteurization and held from 12 to 20 hours at this temperature and then churned, resulted in butter that showed both stickiness and crumbliness. When the pasteurized and cooled cream was held overnight, then heated to 120° F. and held at this temperature for 15 minutes, then cooled rapidly in the vat to a suitable churning temperature and churned immediately, the butter obtained had similar body and texture characteristics to that churned soon after pasteurization and cooling.
5. **Temperature of wash water.** A study was made of the effect on the body and texture of the butter of chilling the butter granules with water at from 38° to 44° F. Approximately 2 pounds of wash water to every pound of fat in the churn was used. The results were compared with those obtained when the butter granules were washed with water at from 54° to 56° F.

The butter that was washed with the cold water required more working than did the butter that was washed with water at from 54° to 56° F. Butter that had been subjected to the cold wash water treatment sometimes showed some degree of stickiness. The use of cold wash water, however, was quite effective in eliminating the crumbly defect of the butter. The butter was softer and had better spreadability than butter made when the warmer wash water was used.

It should be stated that perhaps overworking in the small churn used emphasized the sticky defect, when this was apparent.

Butter that had been treated by the cold-wash-water method was harder in the churn than butter washed with water at a higher temperature; after storage, however, the butter made by the cold-wash-water method possessed a definitely softer body than did the butter made by the other method.

6. **Speed of working the 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.

It was found that the method of slow working required a longer time for complete working of the butter, and the texture of the butter that was worked by this method was not uniformly better than that worked at normal speed.

### IV. STUDIES MADE DURING THE FALL AND WINTER MONTHS 1939-40 AND 1940-41

The experimental churnings made during the previous 2 years were preliminary in nature and the chief purpose was to study the different methods of pasteurization, churning, and working in order that some information would be gained that would show the influence of certain methods on the body and texture. They also afforded an opportunity of determining what factors caused crumbliness and what factors caused stickiness or aggravated these defects. The results obtained from the two seasons of investigation were not considered conclusive in determining the best methods to use in order to overcome the two defects. It was observed that certain manufacturing methods tended to minimize the defects. Further to study these methods with larger churnings in the Experiment Station laboratory and in commercial creameries, the investigation was continued during the fall and winter months of 1939-40 and 1940-41. A total of 130 commercial-size churnings was made in the dairy products laboratory and in the creameries cooperating in the study. The cream used was typical fall-and-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° to 50° F. for scoring and for further laboratory study. Several methods of procedure in manufacturing the butter were outlined for study. These methods were closely adhered to throughout both seasons so that the results would be comparable. All samples were examined when at a temperature from 48° to 55° F. The triers when not in use were kept in cold running tap water that had a temperature of approximately 50° F.
Results obtained by churning procedure number 1. This consisted of churning the cream immediately after vat pasteurization, and cooling. A total of 29 churnings was made. The cream was neutralized and pasteurized in a coil vat at from 155° to 160° F., and was cooled as rapidly as possible by means of brine or refrigerated water to the churning temperature, and then churned. A temperature that would cause granules the size of small peas to form in from 45 to 60 minutes of churning was selected. The washing of the butter granules was completed as rapidly as possible by one batch of wash water, using approximately as much water as there was buttermilk, at a temperature of about 4° below that of the buttermilk. Speed was stressed in this procedure.

Butter from all 29 churnings was sufficiently crumbly to be criticized, and 22 samples (76 per cent) were sticky enough to be criticized. All the samples were firm.

Results obtained by churning procedure number 2. After pasteurization the cream was cooled in a coil vat to from 40° to 50° F. and was then held overnight. 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 as used under number 1 was followed from then on. A total of 22 churnings was made.

Of the churnings sixteen (73 per cent) were sticky or slightly sticky, seventeen (77 per cent) were brittle or crumbly, and seven (32 per cent) had poor spreadability.

Results obtained by churning procedure number 3. The pasteurized cream was held overnight at a comparatively high temperature. The vat-pasteurized cream was cooled to a temperature that ranged from 50° to 60° F. and was held within this range overnight. A total of nineteen churnings was made by this method. The temperature of the cream before churning was adjusted so that granules the size of small peas could be obtained in from 45 to 60 minutes. Usually only one wash water was used, and the temperature of the water ranged from 54° to 56° F.

The butter from all nineteen churnings was criticized for some degree of stickiness, while only four (21 per cent) were criticized for crumbliness. Two samples had a brittle body. Of the nineteen samples, ten (52 per cent) had a soft and pliable body, and eleven (58 per cent) showed satisfactory spreadability. One of the samples was gummy and only one had a poor spreading property.

Results obtained by churning procedure number 4. Cold wash water 38° to 40° F. was used. The cream was churned immediately after vat pasteurization and cooling as in procedure number 1. The buttermilk was drained and water at a temperature of from 38° to 40° F. was added. About 1 gallon of water to every 10 pounds of butter was used in each of two washes. The churn was revolved ten times in high gear for the first wash; the water was then drained quickly and the second wash water was added. The churn was revolved for 5 minutes in low gear. The granules were not worked in the water. Dry salt was added after the second wash water had been removed. Three churnings were made by this method.

The butter from all churnings was sticky, crumbly, and possessed a poor spreading property.

Results obtained by churning procedure number 5. Cold wash water and a low temperature for holding the cream were employed. The cream was
held after vat pasteurization overnight at a temperature of 40° F. The cream was churned at a temperature of 60° F., and the butter granules were washed with wash water of a temperature of 38° to 40° F. The granules were washed as under number 4. Two churnings were made by this method.

The butter from both churnings was sticky, and from one it was also short-grained.

Results obtained by churning procedure number 6. Cold wash water was used with twenty-four churnings. The cream was neutralized and vat pasteurized in the usual manner. Following pasteurization the cream was cooled to from 50° to 55° F. The cream was held overnight at this temperature and was churned the following day at a temperature that would allow a churning time of from 45 to 60 minutes. The butter was churned until the granules were the size of small peas. The granules were washed as under 4.

The butter from all of these churnings was criticized for being slightly sticky. Only one sample was slightly crumbly. The butter from twenty-three churnings was quite soft and pliable; twenty-one (91 per cent) had satisfactory spreadability.

Results obtained by churning procedure number 7. The procedure used was the same as used under number 3, except that the cream was cooled to below 50° F. (ranging from 35° to 46° F.) and the cream held overnight. The butter from all thirteen churnings made by this method showed stickiness. From eight churnings (61.5 per cent) it was crumbly and from four (30.8 per cent) it was brittle. The butter from four churnings (30.8 per cent) was soft and pliable and from eight (61.5 per cent) had a firm body.

Results obtained by churning procedure number 8. Hot water (170° to 180° F.) was added to the cream in the churn at the time of "breaking." The method was used for eight churnings. The cream was churned immediately after vat pasteurization and cooling. Approximately 10 gallons of hot water per 1,000 pounds of butter was used. For washing the granules two batches of wash water were used, the first at a temperature of from 55° to 60° F. and at a ratio of 1 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 45° to 50° F.; the butter was worked in this water for five to ten revolutions.

The butter from all eight churnings was sticky and crumbly. The butter from six churnings (75 per cent) had very poor spreadability.

Results obtained by churning procedure number 9. The vat pasteurized cream was held overnight at a temperature below 50° F. Hot water was added at the time of breaking with five churnings. Other conditions were the same as under number 8.

The butter from all five churnings was sticky and from three churnings it was crumbly. The butter from two churnings had a poor spreadability and that from one had a satisfactory spreadability.

Results obtained by churning procedure number 10. Rapid cooling of vat-pasteurized cream was studied. The pasteurized cream was cooled by means of a surface cooler to approximately 42° F. The cream was held overnight before churning. One batch of wash water at 47° F. was used for washing the butter granules.
The butter from four churnings was hard and crumbly. From two of these it was also sticky. The butter was firmer than that made from vat-cooled cream from the same lot.

Results obtained by churning procedure number 11. An extended working time was used. In three churnings the working time was extended by working intermittently over a 90-minute period after the first moisture test had been made. The butter was worked for a few revolutions and then allowed to remain in a closed churn for from 10 to 15 minutes. This was repeated until the butter had been completely worked.

Two lots of cream were held overnight and made in accordance with procedure number 3 except that it was worked by the intermittent method. One lot of cream was handled in accordance with procedure number 1 except that the working was intermittent.

The butter from the first two lots of cream was sticky. The butter from the single churning was slightly sticky and definitely crumbly.

Summary. Summarizing the results obtained in this series of experiments involving 130 commercial size churnings, it can be concluded that:

1) Churning cream immediately after vat pasteurization and cooling; or holding the pasteurized, cooled cream overnight, then reheating to 110° F., cooling quickly to a suitable churning temperature and churning at once, reduced the sticky condition, but emphasized the crumbly and hard condition.

2) Holding the vat-pasteurized, cooled cream at a temperature of from 50° to 60° F. overnight before churning largely overcame the hard, crumbly condition, but stickiness was quite common.

3) When low-temperature wash water was used for washing the butter granules with the hold-over, not-preheat method the sticky condition was not quite overcome, but the butter when examined was considerably softer and possessed a good spreading property.

4) Cooling the pasteurized cream to a low temperature either in a vat or on a surface cooler and holding the cream at a low temperature overnight appeared detrimental to the body and texture of the butter.

5) The addition of hot water to the cream in the churn at the time of “breaking” had no merit.

6) Extending the working time proved of no benefit under the conditions employed.

V. FINAL STUDIES IN CREAMERIES DURING DECEMBER 1941 AND JANUARY 1942

The results obtained from experimentation during four fall and winter seasons to solve the problem of a hard body and a crumbly and sticky condition of the butter made in the irrigated areas of eastern and southern Oregon had indicated that one general method of manufacture gave promise of avoiding or greatly minimizing crumbliness, stickiness, and excessive hardness of butter. After discussions with several creamery managers, buttermakers, and butter distributors in leading markets it was decided that a thorough, final test of this method of butter manufacture be made in creameries that were located in the irrigated sections. The test would include two methods that were in use in some of the creameries. A study of the printing properties of the butter manufactured would also be included.
An opportunity to make such a final study presented itself during December 1941 and January 1942 when “a colder than usual” winter was experienced. There was an absence of green feed of any kind in the fields and the cows’ ration consisted of dry feeds, principally alfalfa hay and limited grain. A total of six creameries cooperated in this particular study. Observations were made on a large number of commercial-size churnings representing somewhat more than one-quarter million pounds butter. By special arrangement with Dr. D. R. Theophilus, Head, Department of Dairy Husbandry, University of Idaho, Moscow, Idaho, and with the managers of two Idaho creameries, some of the experiments were made in two creameries located in southwestern Idaho. These creameries obtain milk and cream from certain eastern Oregon irrigated districts as well as from the irrigated districts in the Idaho territory. Samples of the butter made in the six creameries were examined by Dr. Theophilus.

A. OUTLINE FOR RESEARCH DURING DECEMBER 1941 AND JANUARY 1942

The outline made for the study during this period was:

1. Make visits to the creameries and arrange to make full-size churnings by the following three methods:
   
   **Method A.** Churn cream immediately after pasteurization and cooling.
   1. Use cold wash water.
   2. Use wash water of slightly lower temperature than butter-milk.

   **Method B.** Cool cream after pasteurization to about 50° F. Hold overnight. Next morning heat the cream to about 110° F. and hold for 15 minutes, or to 130° F. without holding. Cool to a satisfactory temperature for churning.
   1. Use cold wash water.
   2. Use wash water of slightly lower temperature than butter-milk.

   **Method C.** Cool cream after pasteurization to about 50° F. Hold overnight. Churn next morning without preheating.
   1. Use cold wash water.
   2. Use wash water of slightly lower temperature than butter-milk.

Method A (2) and Method B (2) were used regularly for a part of the butter made by three of the creameries.

2. Obtain a sample of butter from each churning for examination in the laboratories at Moscow and Corvallis.

3. Ship 68-pound cubes of butter from a number of the experimental churnings to butter distributors.

4. Arrange to have the federal butter grader at Portland examine the butter for body and texture characteristics.

5. Study each method from the point of view of convenience, practicability, and economics.

6. Determine the amount of fat lost in the buttermilk.

7. Study the effect of the chilling and storage temperature of the finished butter on the firmness and spreadability.
8. Determine the loss of brine during printing with a mechanical power printer and determine the subsequent loss of brine from the printed butter.

9. Examine butter from additional churnings made in the cooperating creameries during the months of December and January. Study the butter manufacturing reports made for each churning.

10. Obtain consumer comments with reference to body and texture characteristics and spreadability.

This outline was followed in making the study.

Complete records of the methods used in the handling and churning of the cream were made. The size of the churnings was of 1,000 pounds and 2,000 pounds butter each, depending on the capacity of the churns.

The samples used for examination at Moscow and Corvallis were obtained direct from the churn and were then placed in a refrigerator maintained at from 35° to 40° F. When transported they were kept at approximately 40° F. in an insulated container.

The temperature of the butter when examined in the laboratories at Corvallis and Moscow was regulated to from 40° to 45° F. The trier was cooled and wiped with a paper napkin before the plug of butter was obtained. When determining the spreadability of the butter a portion of the plug of butter was spread on cold, hard-toasted bread by means of a sharp, thin-bladed, stainless steel knife. It is acknowledged that the butter would show a much better spreading property at a temperature of from 50° to 60° F. It was desired, however, to make the test when the butter was of as near household-refrigerator temperature as possible. Differences in spreadability were more easily determined at the lower temperature.

The fat content of the cream used in churning was generally between 32 and 38 per cent. No observations were made on butter from churnings of low-fat or high-fat cream.

B. RESULTS OBTAINED—FIELD STUDIES BY SENIOR AUTHOR

Three methods of butter manufacture used. The comments by the federal grader at Portland on the butter from thirty-nine churnings made in the six creameries and also the comments from the examinations of samples from these churnings made at Moscow, Idaho, and at Corvallis are given in Table 1.

Butter made by Method A. Cream churned immediately after pasteurization and cooling. Churned at approximately 44° F.

(1) When cold wash water was used (40° F.)

Only 1 churning was made by this method. The butter obtained was hard, crumbly, somewhat sticky, but had fair spreadability.

(2) When regular temperature wash water was used (51°-55° F.)

A total of seventeen churnings was made by this method. The general comment was that the butter was hard, crumbly, slightly sticky and had poor spreadability.

Butter made by Method B. The cream was cooled after pasteurization to 47° to 50° F. and held overnight.

Before churning the cream was heated to either 110° F. and held for 10 to 15 minutes at this temperature or to 130° F. and not held at this temperature.
Method A— Cream churned immediately after pasteurization and cooling. 1. Cold wash water (40°-45° F.)

<table>
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<th>Date</th>
<th>Characteristics of butter</th>
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<th>Characteristics of butter</th>
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<tbody>
<tr>
<td></td>
<td>Crumbliness</td>
<td>Stickiness</td>
<td>Spread-ability</td>
</tr>
<tr>
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<td>Definite</td>
<td>Slight</td>
<td>Poor</td>
</tr>
<tr>
<td>12/14-3</td>
<td>Definite</td>
<td>Slight</td>
<td>Poor</td>
</tr>
<tr>
<td>12/14-4</td>
<td>Definite</td>
<td>Slight</td>
<td>Very poor</td>
</tr>
<tr>
<td>12/14-5</td>
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<td>Slight</td>
<td>Very poor</td>
</tr>
<tr>
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<td>Poor</td>
</tr>
<tr>
<td>12/15-3</td>
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<td>Slight</td>
<td>Fair</td>
</tr>
<tr>
<td>12/15-4</td>
<td>Slight</td>
<td>Slight</td>
<td>Poor</td>
</tr>
<tr>
<td>12/15-5</td>
<td>Slight</td>
<td>Slight</td>
<td>Poor</td>
</tr>
<tr>
<td>12/16-2</td>
<td>Definite</td>
<td>Slight</td>
<td>Poor</td>
</tr>
<tr>
<td>12/16-3</td>
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<td>Poor</td>
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<td>12/16-4</td>
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<td>12/16-6</td>
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<tr>
<td>12/22</td>
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<td>No comment</td>
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Identification

Sprad-Relative

Crumbliness Stickiness Spread-ability Relative hardness

Trier sample. Cold trier used
### Table 1. Experimental Churnings in Six Creameries, December 1941—Continued

<table>
<thead>
<tr>
<th>Identification</th>
<th>Examined at Corvallis</th>
<th>Examined at Moscow</th>
<th>Examined at Portland</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Samples obtained direct from churn, kept refrigerated until examined, butter 42°-45° F. when examined</td>
<td>Samples obtained direct from churn, butter 40° F. when examined, trier 50° F.</td>
<td>68 lb. cube examined by federal grader, butter 50° F. when examined</td>
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<tr>
<td><strong>Characteristics of butter</strong></td>
<td><strong>Characteristics of butter</strong></td>
<td><strong>Characteristics of butter</strong></td>
<td></td>
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<tr>
<td>Crumbliness</td>
<td>Stickiness</td>
<td>Spreadability</td>
<td>Relative hardness</td>
</tr>
<tr>
<td>Method B— Cream cooled after pasteurization to 47°-50° F., held overnight, then heated to 110° F., held 10-15 minutes or to 130° F. and not held, cooled and churned immediately. 1. Cold wash water (40°-45° F.)</td>
<td>Definite</td>
<td>Slight</td>
<td>Poor</td>
</tr>
<tr>
<td>12/16.5 (130° F.)</td>
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<td>Slight</td>
<td>Poor</td>
</tr>
<tr>
<td>351 C, 110° F.</td>
<td>Definite</td>
<td>Slight</td>
<td>Very poor</td>
</tr>
<tr>
<td>Method B— Cream cooled after pasteurization to 47°-50° F., held overnight, then heated to 110° F., held 10-15 minutes or to 130° F. and not held, cooled and churned immediately. 2. Regular temperature wash water (50°-55° F.)</td>
<td>Definite</td>
<td>Slight</td>
<td>Poor</td>
</tr>
<tr>
<td>12/17-3</td>
<td>Slight</td>
<td>Slight</td>
<td>Poor</td>
</tr>
<tr>
<td>352B</td>
<td>Definite</td>
<td>Slight</td>
<td>Poor</td>
</tr>
<tr>
<td>352C</td>
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<td>Poor</td>
</tr>
<tr>
<td>353C</td>
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<td>Poor</td>
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<tr>
<td>353D</td>
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<td>Slight</td>
<td>Hard</td>
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Table 1. Experimental Churnings in Six Creameries, December 1941—Continued

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<td>Crumbliness</td>
<td>Stickiness</td>
<td>Spreadability</td>
</tr>
<tr>
<td><strong>Examined at Corvallis</strong></td>
<td>Samples obtained direct from churn, kept refrigerated until examined, butter 42°-45° F. when examined</td>
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<td></td>
</tr>
<tr>
<td>Method C—</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cream cooled after pasteurization to 42°-50° F., held overnight, then not preheated. 1. Cold wash water (40°-45° F.)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>12/15-2</td>
<td>Slight</td>
<td>Slight</td>
<td>Fine</td>
</tr>
<tr>
<td>351D</td>
<td>Not crumbly</td>
<td>Slight</td>
<td>Fine</td>
</tr>
<tr>
<td>352F</td>
<td>Not crumbly</td>
<td>Definitely</td>
<td>Good</td>
</tr>
<tr>
<td>352A</td>
<td>Not crumbly</td>
<td>Definitely</td>
<td>Good</td>
</tr>
<tr>
<td>352B</td>
<td>Not crumbly</td>
<td>Very</td>
<td>Fine</td>
</tr>
<tr>
<td>354-212</td>
<td>Not crumbly</td>
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<td>Fine</td>
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<tr>
<td>360-109</td>
<td>Not crumbly</td>
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<td>Fine</td>
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<tr>
<td><strong>Examined at Moscow</strong></td>
<td>Samples obtained direct from churn, butter 40° F. when examined, trier 50° F.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Method C—</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Cream cooled after pasteurization to 42°-50° F., held overnight, then not preheated. 2. Regular temperature wash water (50°-55° F.)</td>
<td></td>
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<tr>
<td>12/14-1</td>
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<tr>
<td>12/18R2</td>
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<td>Not sticky</td>
<td>Fair</td>
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</table>
The cream after having been heated was cooled as quickly as possible to a temperature of from 44° to 47° F. and churned at once.

(1) When cold wash water was used (40°-45° F.).  
The butter obtained in two churnings was hard, crumbly, sticky, and did not spread well on toast. The butter from one churning showed lumpiness and the color was mottled.

(2) When regular temperature wash water was used (50°-55° F.).  
The butter in five churnings had a definitely hard body, it was definitely crumbly and sticky and it did not have a good spreading property.

Butter made by Method C. The cream was cooled after pasteurization to a temperature of from 47° to 50° F. It was then held overnight and not preheated before churning. The churning temperature ranged from 55° to 62° F. depending on the conditions.

(1) When cold wash water was used (40°-45° F.).  
Crumbliness was practically absent in the butter from seven churnings. The spreadability was good and the butter had a fairly soft and waxy consistency. A slight stickiness was the chief criticism.

(2) When regular temperature wash water was used (50°-55° F.).  
Slight crumbliness and slight or definite stickiness were the general criticisms of the butter from seven churnings. The spreading property was quite good and the butter had a fairly soft consistency.

Conclusions. From the results obtained in this series of experiments, it can be concluded that:

1) Churning the cream immediately after pasteurization and cooling or holding the pasteurized cream cold overnight and preheating and cooling it before churning resulted in butter that was comparatively hard and showed definite crumbliness but only slight stickiness. The spreadability was generally poor. The use of cold wash water was of no particular benefit; in fact, it had the disadvantage in that it caused lumpiness and a mottled color of the butter.

2) When the cream was cooled after pasteurization to a temperature of 50° F. or slightly below and held overnight at from 50° to 55° F. for churning the following morning without further treatment, it generally resulted in butter that was free from crumbliness, but the butter showed some degree of stickiness. The body was quite soft and the spreading property, considering of course that the butter was made during the winter and contained high-melting-point fat, was good. The use of this method, churning to granules the size of small peas, then chilling and washing the granules with a large batch of cold water at a temperature of from 40° to 45° F. followed by a thorough working, unmistakably resulted in butter that had the best body and texture characteristics in the series. Stickiness could be practically eliminated by expert workmanship. The spreading property was excellent. It should be emphasized, however, that careful attention to temperatures and the exercise of expert workmanship on the part of the buttermaker are necessary if butter with a desirable spreading property is to be obtained.
C. CONVENIENCE, PRACTICABILITY, AND ECONOMIC CONSIDERATION OF EACH OF THE THREE METHODS OF BUTTER MANUFACTURE STUDIED

The results from the experiments conducted to improve the body, texture, and spreading property of fall- and winter-made butter manufactured in the irrigated sections indicate that Method C, when cold wash water was used and the butter was worked thoroughly but not overworked to the extent of producing stickiness, was the superior method. Before the industry will accept a specific method it is necessary to show that this method is practical and economical. A discussion of the convenience, practicability, and economics of Methods A, B and C is therefore in order.

Method A—Cream churned immediately after pasteurization and cooling. The cream must be cooled to a lower temperature for churning than is necessary when the cream is held overnight and is not preheated. The additional lowering in the temperature ranges from 10° to 14° F. This additional cooling requires not only more refrigeration but also more electricity for operation of the cooling equipment. The method has the disadvantage that the distribution and utilization of labor in the creamery, with the majority of plants, are not as good as when the churning operation is commenced during the morning. With Method A churning is commenced during the afternoon and evening. Additional use of electric lights is also necessary. A serious disadvantage is that the cream must be pumped into the churn as soon as the cream has cooled to the churning temperature, and the churning must be started as soon as the batch of cream has been placed in the churn. If the cream remains in the vat at the low temperature of about 44° F. for some time, prolonged churning is experienced. It is necessary with this method to complete the churning and working within a reasonable time. If the working operation is delayed or interrupted, the butter may “set up” and moisture incorporation becomes exceedingly difficult. Ordinarily the butter as it is removed from the churn when this method is used, is at a temperature of about 58° to 62° F.; it is therefore relatively soft, and is easy to handle. But if the removal of the butter from the churn is delayed the butter becomes firm and is difficult to tamp into boxes so that there are no holes. The last butter removed from the churn is usually much firmer than that removed at first. If the butter has been allowed to become firm, tamping the butter into the boxes causes unnecessary expulsion of moisture from the butter, the butter will show leakiness, and, furthermore, there is some difficulty in preventing the boxes from breaking open unless a special box clamping device is used. It is common in the plants that have used this method to commence putting it into effect during the beginning of October and continue until some time in April, when a change-over to the usual hold-over method is made. Churning during late afternoon and evening is generally necessary when Method A is used.

Method B—Cooled pasteurized cream held overnight, then reheated and cooled. With this method a second heating and cooling of the cream is used. This means additional cost and a longer total time to complete a churning. Steam in sufficient quantity must be available in the morning before the heating of the cream is commenced. The method has the advantage over Method A that the churning operation is commenced in the morning instead of during the afternoon. There is better distribution of labor and the steam supply is used over a shorter period during the working hours. Otherwise, the method has the same faults from the point of view of convenience and practicability as Method A.
Costs of heating and cooling cream in creameries are often not known by creamery managers. They may be termed "hidden costs." An analysis of the additional costs of preheating and cooling cream before churning is presented herewith.*

**CALCULATION OF COST OF HEATING AND COOLING CREAM**

Estimated Cost of Steam, Water, Refrigeration, Power, Labor, and Depreciation and Maintenance for Heating 300 Gallons (2,500 lbs.) of Cream in a Coil Machine from 50° to 110° F., Holding for 15 Minutes, Then Cooling with Water and Brine to 45° F.

### Steam
Temperature range in heating from 50° to 110° F. = 60°
Average specific heat of cream assumed to be .85
Heat loss through radiation 10 per cent—Steam cost $0.40 per 1,000 lbs. Total heat in 1 lb. of steam 1,000 Btu.

$$\text{Steam Cost} = \frac{2,500 \times .85 \times 60 \times 1.10 \times .40}{1.000 \times 1.000} = \$0.056$$

### Water
Cooling from 110° to 90° F. with 56° F. water.
Water cost—$0.09 per 1,000 gallons.
Flow of water through 300-gallon coil machine = 50 gallons per minute.
Cooling rate assumed to be 1.5° per minute.
$$\text{Water Cost} = \frac{60 \times 15}{60} = .059$$

### Refrigeration
Cooling with brine from 90° to 45° F. = 45 Btu to be removed from each pound of cream.
Refrigeration cost assumed to be $1.00 per 24-ton hours—Estimated loss in efficiency of cooling apparatus and radiation 10 per cent.
One ton refrigeration = 288,000 Btu.

$$\text{Refrigeration Cost} = \frac{2,500 \times .85 \times 45 \times 1.10 \times 1.00}{288,000} = .365$$

### Power
Estimated time required for heating, holding and cooling to be 1.25 hours.
1 hp motor on 300-gallon coil machine.
1 hp requires .746 kw per hour.
Estimate motor efficiency at 86 per cent.
Energy cost at $0.03 per kw.

$$\text{Power Cost} = \frac{1 \times 1.25 \times .746 \times .03}{.86} = .032$$

### Labor
Estimate labor at $.60 per hour and 15 minutes time required for the intermittent taking of temperatures and operating coil machine.

$$\text{Labor Cost} = \frac{60 \times 15}{60} = .150$$

### Depreciation and Maintenance
Depreciation and maintenance estimated at 10 per cent of original cost per year.
Estimated cost of 300-gallon motor-drive coil machine = $1,300.00.
Eight machines at $1,300 = $10,400.00 investment.
10 per cent of $10,400.00 = $1,040.00 depreciation cost per year.
2,000,000 pounds butter manufactured.

$$\text{Depreciation Cost} = \frac{1,040.00 \times 2,000,000}{1,000 \times 0.00052} = .52$$

Estimated butter from 2,500 lbs. cream = 1,000 lbs.
$$\text{Depreciation Cost per pound butter} = \frac{.52 \times 6}{1.00}$$

$$\text{TOTAL COST} = \$0.693$$

*Acknowledgment is made of the assistance of the engineering staff of the Cherry-Burrell Corporation of Chicago in assembling the cost data.
In making the estimates of the cost of heating and cooling cream average values have been used. It is recognized that the efficiency with which steam, water, etc., is used when heating and cooling cream by means of coil pasteurizers varies greatly in different creameries. The cost of producing steam and other items also varies. Some plants produce steam for 15 cents per 1,000 pounds, whereas in others the cost is as high as 85 cents per 1,000 pounds. Likewise some plants figure the refrigeration costs at 60 cents per 24 ton hours, whereas in others the cost is as much as $1.50 and higher. By using the method of calculating given below any creamery manager may calculate the cost of doing this work in his creamery if he knows what the cost items are.

The cost of additional heating and cooling for different amounts of butter would therefore be:

<table>
<thead>
<tr>
<th>Amount of Butter</th>
<th>Cost of Heating and Cooling</th>
</tr>
</thead>
<tbody>
<tr>
<td>1,000 pounds</td>
<td>$0.69</td>
</tr>
<tr>
<td>10,000 pounds</td>
<td>$6.93</td>
</tr>
<tr>
<td>100,000 pounds</td>
<td>$69.30</td>
</tr>
<tr>
<td>1,000,000 pounds</td>
<td>$693.00</td>
</tr>
<tr>
<td>2,000,000 pounds</td>
<td>$1,386.00</td>
</tr>
<tr>
<td>3,000,000 pounds</td>
<td>$2,079.00</td>
</tr>
<tr>
<td>4,000,000 pounds</td>
<td>$2,772.00</td>
</tr>
<tr>
<td>5,000,000 pounds</td>
<td>$3,465.00</td>
</tr>
</tbody>
</table>

These costs were compiled for a large creamery and the costs for steam, refrigeration, etc., were average and conservative. In a small or less efficiently operated creamery the costs may easily be twice as high.

Method C—Pasteurized, cooled cream held overnight, not re-heated. This is the general method that is most commonly used in creameries in the United States. The pasteurized cream is kept cold overnight. Adjustment of the temperature of the cream before churning is necessary. The method is commonly used in the thirty-one creameries located in the irrigated sections of eastern and southern Oregon, but some modifications must be made in the usual method of butter manufacture during fall and winter if butter of good body and texture that can be handled and spread easily is to be manufactured. These modifications are such that they do not materially affect the present operating methods. Any creamery can easily adopt them.

D. AMOUNT OF FAT LOST IN THE BUTTERMILK WHEN THE THREE METHODS WERE USED.

The fat in the buttermilk from twenty-two of the thirty-nine churnings in the six creameries was determined. The Babcock-butyl-alcohol method was used in making this test. The percentage of the total fat churned that was lost in the buttermilk ranged from 0.6 to 1.36. With the churnings from batches of cream of similar fat content, there was no significant difference in the amount of fat lost in the buttermilk with the three methods of butter manufacture. It was observed that the amount of fat lost in the buttermilk was consistently lower in some creameries than it was in others, even when the same general method of manufacture was used. This should be investigated further.
E. EFFECT OF THE STORAGE TEMPERATURE ON THE FIRMNESS OF THE BUTTER

Butter made during the fall, winter, and early spring seasons in the irrigated sections when held at household- or restaurant-refrigerator temperature of about 40° to 45° F. may be somewhat firm for satisfactory cutting and spreading because of the physical and chemical properties of the fat. Any modification of the method of manufacture and subsequent storage of the butter that will result in a softer, waxier, and more spreadable body would be desirable.

Some butter distributors have advised creameries to store the fall- and winter-made butter after manufacture at a somewhat higher temperature than is common during the summer months. They believed that not chilling the butter to a low temperature would aid in producing a softer body. Furthermore, the butter, if not stored in the creamery at too low a temperature, was thought to be easier to sample and print when it was received by the distributors.

When, however, duplicate or triplicate small samples, or 68-pound cubes of butter, were taken directly from the churns in each creamery and placed at different temperatures for periods of 24 hours and sometimes for several weeks, and then kept at a temperature of about 45° F. until the temperature of the samples became uniform, it was definitely shown that the butter stored at the lower temperature always had the softest consistency. For instance, freshly packed butter was kept at churn-room temperature (60°-65° F.) and at refrigerator-room temperature (35°-40° F.) for 1 day. Both samples were then placed in the refrigerator at about 35° to 40° F. Examination of the butter several days afterward showed that the butter held at the lower temperature since it was removed from the churn was definitely the softest, and the difference persisted over extended periods when the butter was held at refrigerator temperature. Numerous samples from different creameries were used for this test. It was quite easy for the many persons who were asked to examine the butter for firmness to note this difference. Butter placed at a temperature of 0° F. and then tempered, after the tempering period was always softer than butter that had initially been stored at churn-room temperature.

When 68-pound cubes or small samples of butter made by the three methods were placed directly in a refrigerator maintained at a temperature of from 35° to 40° F., it was observed that the butter made by Method C (cream held over and not preheated) was always softer than the butter made by the other two methods. It was easy to pick out from the mixed lots of butter made by the three methods the butter that was made by Method C. It was reported from one of the markets that butter made by Method C when cold wash water was used was too soft to print with a power printer when printed at the same temperature as butter made by the other two methods. Distributors prefer all the butter handled be made by similar methods in order that print-room methods may be standardized.

F. LOSS OF BRINE DURING AND SUBSEQUENT TO PRINTING

A high percentage of the butter handled by the butter distributors in the Pacific Coast markets is printed by means of power machines. Butter is received by the distributors from widely separated sections. It is of importance that the butter from the irrigated sections of Oregon during the period October
to March-April be manufactured to possess as good printability as that from other sections. The butter should have a waxy body. It should not be too hard. It should possess a well-knit texture. This can be accomplished by churning the cream at the correct temperature, by not overchurning the granules, by using cold wash water, and by working the butter thoroughly. Crumbliness and pronounced stickiness must be controlled. Considerable attention should be given to the proper incorporation of the brine with the butter. If the butter is soft and greasy, the incorporation of the brine in the form of minute droplets is impossible unless the butter is worked to such an extent that it becomes pronouncedly sticky or salvy. If too firm when being worked, the butter will not “take up” the moisture.

Expert buttermakers follow the system of regulating the moisture content of the butter so that when the butter is almost worked to completion and the first moisture test is made the moisture content will fall between 15 and 16 per cent. Trying to obtain the exact amount of moisture (usually 16.5 per cent), without having to adjust the percentage by adding water, often results in a higher moisture content than desired. The attempt to expel the excess moisture by pounding may result in butter that is leaky. If an attempt is made to overcome this leakiness by additional working, stickiness may result. If on the other hand, a buttermaker follows the system of draining the wash water until practically no water is draining from the churn, adding no water with the salt, and working the butter until it is quite “dry,” the moisture content will usually be quite low, probably only about 13 to 14 per cent. The water added to increase the moisture content to 16.5 per cent may not be thoroughly incorporated with the butter in the form of minute droplets, unless the butter is greatly overworked. It has been observed that pronounced stickiness of the butter is produced if, after the “make-up” water is added, the butter is worked until it is again “dry.” The butter is overworked to the extent that the “grain” is injured. This method therefore should not be used.

From observations in creameries it is concluded that expert buttermakers can make butter that does not show leakiness when printed or subsequent to printing. The printed butter will be quite dry on the surface, and stickiness will not be a serious fault.

A number of cubes of butter from the experimental churnings in the six creameries were printed in the plant of the Interstate Associated Creameries at Portland by means of an automatic “Kustner” butter printer and wrapper. The butter was molded by the machine into 1-pound prints. As was customary, the butter during the fall and winter months was tempered in a room for several days before it was printed. The temperature of the butter at the time of printing was 56° F. Dry parchment wraps were used. The butter made in accordance with Method C, especially when cold wash water was used and the butter was worked thoroughly, showed little or no loss of brine when it passed between the worm gears in the bottom of the hopper of the printer, whereas considerable brine loss generally took place when the butter made in accordance with Methods A and B passed through the printer.

On account of using only one cube of butter from each churning for printing it was not possible accurately to determine the loss of brine from each cube. The machine was emptied as much as possible after each 68-pound lot of butter had passed through. When about one-half of the 68-pound lot had passed through the machine, ten 1-pound prints of the wrapped butter were collected for a brine-loss study. The results of this study are given in Table 2. The procedure followed was to determine the weight of each print immediately after printing, using a highly sensitive “Torsion” balance. The weight of each
print, determined to the nearest 1/32 ounce, was recorded. Each 10 pounds of butter were then placed in a 30-pound capacity fiberboard butter box and stored in a refrigerator maintained at a temperature of approximately 40° F. After storage periods of 24 and 72 hours each print was weighed and the loss of moisture from the 10 pounds of butter was determined.

Table 2. Loss of Brine from Printed Butter
Ten 1-pound prints used for each test. Butter wrapped in dry parchment. Temperature of refrigerator where wrapped butter was kept: 40° F.

<table>
<thead>
<tr>
<th>Test</th>
<th>Total brine loss after 24 hours in refrigerator</th>
<th>Total brine loss after 72 hours in refrigerator</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Per cent</td>
<td>Per cent</td>
<td></td>
</tr>
<tr>
<td>Method A After pasteurization (Average of 6 churnings)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>0.481</td>
<td>0.673</td>
<td>Parchment generally wet and wrinkled. Bottom of box wet.</td>
</tr>
<tr>
<td></td>
<td>Range: 0 to 0.916</td>
<td>Range: 0.039 to 1.306</td>
<td></td>
</tr>
<tr>
<td>Method B Held over and preheated (Average of 5 churnings)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>0.783</td>
<td>1.041</td>
<td>Parchment wet and wrinkled. Bottom of box quite wet.</td>
</tr>
<tr>
<td></td>
<td>Range: 0.351 to 1.189</td>
<td>Range: 0.644 to 1.599</td>
<td></td>
</tr>
<tr>
<td>Method C Held over, not preheated (Average of 8 churnings)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>0.141</td>
<td>0.146</td>
<td>Parchment dry or slightly moist and wrinkled. Bottom of box generally dry.</td>
</tr>
<tr>
<td></td>
<td>Range: 0 to 0.294</td>
<td>Range: 0 to 0.390</td>
<td></td>
</tr>
</tbody>
</table>

Reasons for controlling leakiness. There are several reasons why butter should be made in such a way that it does not show leakiness either before, during, or subsequent to printing.

1. If brine leaks from a cube of butter, there is an economic loss either to the creamery or to the buyer on account of short weight.
2. If brine leaks during printing, an economic loss is sustained by the distributor.
3. If leaky butter is printed or if the type of butter that usually leaks after printing is printed, it is necessary to compensate for the subsequent loss in weight of the printed butter while it is kept in the refrigerator by printing overweight units.
4. When dry wraps are used, as is common with many automatic power printers, leaky butter causes an unsightly wrinkled appearance of the parchment.
5. Leakiness favors the growth of mold and bacteria.
6. Restaurant operators and housewives object to leaky butter because they think the butter contains an excessive amount of moisture.
7. When leaky butter is exposed to the air evaporation of moisture takes place, leaving white salt crystals. These are objected to by customers.
8. The butter has a briny, harsh taste.
9. When leaky butter is spread on bread or toast, brine may spurt out to the surprise and irritation of the customer.

In Table 3 is shown the economic loss sustained when the loss due to leakage during and subsequent to printing ranges from 0.1 to 2.0 per cent and the price of butter is 30 cents and 40 cents a pound.
It follows from the foregoing discussion and the data presented that the buttermakers' job not only is to make butter that has a good body and texture so that it can readily be cut and spread on bread but it also must include making butter that does not leak brine. The Oregon state law specifically prohibits the sale of short-weight butter:

"It shall be unlawful for any person to sell, offer or expose for sale any short-weight butter within the state of Oregon. All butter sold or exposed or offered for sale in rolls, prints or squares within the state of Oregon shall be plainly marked with the net weight thereof, and every roll, print or square sold or offered or exposed for sale shall contain the weight marked thereon."

As the laws in other states in which considerable amounts of Oregon butter are sold also have similar strict regulations, it is necessary for Oregon creameries to make butter that does not show leakiness resulting in short weight after it has been printed and before it is offered for sale to the consumers. Short-weight butter may be seized or confiscated by state regulatory officials.

This particular phase of the study was extended to include observations on churnings of butter using different methods of manufacture made subsequent to the visits to the creameries in eastern Oregon and Idaho. A summary of the data obtained is given in Table 4.

### Table 3: Economic Loss on Account of Brine Leakage from Butter

<table>
<thead>
<tr>
<th>Per cent loss</th>
<th>Price of butter 30 cents</th>
<th>Price of butter 40 cents</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>On 1,000 pounds</td>
<td>On 10,000 pounds</td>
</tr>
<tr>
<td>0.1</td>
<td>$0.30</td>
<td>$6</td>
</tr>
<tr>
<td>0.2</td>
<td>$0.60</td>
<td>$12</td>
</tr>
<tr>
<td>0.3</td>
<td>$0.90</td>
<td>$18</td>
</tr>
<tr>
<td>0.4</td>
<td>$1.20</td>
<td>$24</td>
</tr>
<tr>
<td>0.5</td>
<td>$1.50</td>
<td>$30</td>
</tr>
<tr>
<td>0.6</td>
<td>$1.80</td>
<td>$36</td>
</tr>
<tr>
<td>0.7</td>
<td>$2.10</td>
<td>$42</td>
</tr>
<tr>
<td>0.8</td>
<td>$2.40</td>
<td>$48</td>
</tr>
<tr>
<td>0.9</td>
<td>$2.70</td>
<td>$54</td>
</tr>
<tr>
<td>1.0</td>
<td>$3.00</td>
<td>$60</td>
</tr>
<tr>
<td>1.1</td>
<td>$3.30</td>
<td>$66</td>
</tr>
<tr>
<td>1.2</td>
<td>$3.60</td>
<td>$72</td>
</tr>
<tr>
<td>1.3</td>
<td>$3.90</td>
<td>$78</td>
</tr>
<tr>
<td>1.4</td>
<td>$4.20</td>
<td>$84</td>
</tr>
<tr>
<td>1.5</td>
<td>$4.50</td>
<td>$90</td>
</tr>
<tr>
<td>1.6</td>
<td>$4.80</td>
<td>$96</td>
</tr>
<tr>
<td>1.7</td>
<td>$5.10</td>
<td>$102</td>
</tr>
<tr>
<td>1.8</td>
<td>$5.40</td>
<td>$108</td>
</tr>
<tr>
<td>1.9</td>
<td>$5.70</td>
<td>$114</td>
</tr>
<tr>
<td>2.0</td>
<td>$6.00</td>
<td>$120</td>
</tr>
</tbody>
</table>

It is estimated from the foregoing discussion and the data presented that the buttermakers' job not only is to make butter that has a good body and texture so that it can readily be cut and spread on bread but it also must include making butter that does not leak brine. The Oregon state law specifically prohibits the sale of short-weight butter: "It shall be unlawful for any person to sell, offer or expose for sale any short-weight butter within the state of Oregon. All butter sold or exposed or offered for sale in rolls, prints or squares within the state of Oregon shall be plainly marked with the net weight thereof, and every roll, print or square sold or offered or exposed for sale shall contain the weight marked thereon." As the laws in other states in which considerable amounts of Oregon butter are sold also have similar strict regulations, it is necessary for Oregon creameries to make butter that does not show leakiness resulting in short weight after it has been printed and before it is offered for sale to the consumers. Short-weight butter may be seized or confiscated by state regulatory officials.

This particular phase of the study was extended to include observations on churnings of butter using different methods of manufacture made subsequent to the visits to the creameries in eastern Oregon and Idaho. A summary of the data obtained is given in Table 4.

### Table 4: Loss of Brine from Printed Butter

<table>
<thead>
<tr>
<th>Creamery</th>
<th>Average leakage</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. (Eastern Oregon)</td>
<td>0.361</td>
</tr>
<tr>
<td>February 1942</td>
<td>0.035</td>
</tr>
<tr>
<td>1.5</td>
<td>March 1942</td>
</tr>
<tr>
<td>Churnings</td>
<td>0.107</td>
</tr>
<tr>
<td>Cream churned immediately after pasteurization and cooling</td>
<td>0.107</td>
</tr>
<tr>
<td>Cream held over, not preheated</td>
<td>0.107</td>
</tr>
<tr>
<td>Cold wash water used (40°-42° F.)</td>
<td>0.107</td>
</tr>
<tr>
<td>Creamery 2. (Eastern Oregon)</td>
<td>0.107</td>
</tr>
<tr>
<td>March 1942</td>
<td>0.107</td>
</tr>
<tr>
<td>6 churnings</td>
<td>0.107</td>
</tr>
<tr>
<td>Cream held over, not preheated</td>
<td>0.107</td>
</tr>
<tr>
<td>Cold wash water used (45° F.)</td>
<td>0.107</td>
</tr>
</tbody>
</table>

* Data through the courtesy of A. W. Hare, Superintendent, Interstate Associated Creameries, Portland.
Other data assembled in California from brine leakage studies on Oregon and Idaho made butter are on file. The greatest loss occurred when "pre-heated"-cream butter was printed with a power printer and the smallest loss occurred when butter made from "held-over," not preheated cream, was printed with a power printer.

G. PRACTICAL APPLICATION OF THE DIFFERENT CHURNING METHODS

Examination of butter from churnings in six creameries during December 1941 and January 1942 (142 churnings)

The buttermakers in the six creameries that cooperated in the work were asked to remove representative samples from a number of churnings during December and January and place these without delay in the regular butter refrigerator. Most of these samples were examined during visits to the creameries. The buttermakers participated in this. Some samples were shipped by truck or express to Corvallis. Two triers were used. One was constructed from polished stainless steel. The other was constructed from ordinary steel. Before obtaining a plug of butter the trier was cooled by means of cold water and was then thoroughly dried by means of a paper napkin. The stainless steel trier was used as much as possible. Occasionally it was not possible to obtain a plug of butter made in accordance with Methods A and B by means of the stainless steel trier. The plug would not adhere to the trier. In such cases the rough-surfaced trier constructed from ordinary steel was used. As the conditions for obtaining a satisfactory plug of butter by means of a trier depend upon the temperature of the butter and the trier, the type of trier used, the condition of the surface of the trier and other factors, as have already been pointed out (12), this method of judging the body and texture of butter is inadequate. In order to examine the butter thoroughly with the view of determining its waxiness and spreading property a portion of the butter from each trier was removed, and was spread by means of a sharp-bladed stainless steel knife on cold, hard toasted bread.

Method A—Churned immediately after pasteurization. (Regular wash water 51°-55° F.) A total of seventy-one churnings was made by this method. The comments on the body and texture characteristics are given in Table 5.
Table 5. BODY AND TEXTURE CHARACTERISTICS OF COMMERCIAL CHURNINGS OF BUTTER MADE IN THE SIX CREAMERIES DURING DECEMBER 1941 AND JANUARY 1942

Method A. Cream churned immediately after pasteurization and cooling.
Regular temperature wash water 51° to 55° F.

<table>
<thead>
<tr>
<th>Churning number</th>
<th>Crumbliness</th>
<th>Stickiness</th>
<th>Spreadability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temperature of butter when examined 43° F.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Definite</td>
<td>Slight</td>
<td>Poor</td>
</tr>
<tr>
<td>2</td>
<td>Definite</td>
<td>Slight</td>
<td>Poor</td>
</tr>
<tr>
<td>3</td>
<td>Definite</td>
<td>Definite</td>
<td>Poor</td>
</tr>
<tr>
<td>4</td>
<td>Definite</td>
<td>Slight</td>
<td>Poor</td>
</tr>
<tr>
<td>5</td>
<td>Pronounced</td>
<td>Slight</td>
<td>Very poor</td>
</tr>
<tr>
<td>6</td>
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<td>Definite</td>
<td>Poor</td>
</tr>
<tr>
<td>7</td>
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</tr>
<tr>
<td>8</td>
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<td>Poor</td>
</tr>
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<td>9</td>
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<td>Slight</td>
<td>Poor</td>
</tr>
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<td>10</td>
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<td>Slight</td>
<td>Very poor</td>
</tr>
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<td>11</td>
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<td>Slight</td>
<td>Poor</td>
</tr>
<tr>
<td>12</td>
<td>Pronounced</td>
<td>Slight</td>
<td>Poor</td>
</tr>
<tr>
<td>13</td>
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<td>Poor</td>
</tr>
<tr>
<td>14</td>
<td>Pronounced</td>
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</tr>
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<td>15</td>
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<td>Poor</td>
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<td>16</td>
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</tr>
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<td>Poor</td>
</tr>
<tr>
<td>18</td>
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<td>Poor</td>
</tr>
<tr>
<td>19</td>
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<td>Poor</td>
</tr>
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<td>Slight</td>
<td>Poor</td>
</tr>
<tr>
<td>21</td>
<td>Definite</td>
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<td>Very poor</td>
</tr>
<tr>
<td>22</td>
<td>Definite</td>
<td>Slight</td>
<td>Poor</td>
</tr>
<tr>
<td>23</td>
<td>Slight</td>
<td>Slight</td>
<td>Poor</td>
</tr>
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<td>24</td>
<td>Slight</td>
<td>Slight</td>
<td>Fair</td>
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<td>25</td>
<td>Slight</td>
<td>Slight</td>
<td>Fair</td>
</tr>
<tr>
<td>26</td>
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<td>Poor</td>
</tr>
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<td>27</td>
<td>Slight</td>
<td>Slight</td>
<td>Poor</td>
</tr>
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<td>28</td>
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<td>Slight</td>
<td>Poor</td>
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<td>Slight</td>
<td>Poor</td>
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<td>30</td>
<td>Definite</td>
<td>Slight</td>
<td>Poor</td>
</tr>
<tr>
<td>31</td>
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<td>Slight</td>
<td>Poor</td>
</tr>
<tr>
<td>32</td>
<td>Pronounced</td>
<td>Slight</td>
<td>Poor</td>
</tr>
<tr>
<td>33</td>
<td>Definite</td>
<td>Slight</td>
<td>Poor</td>
</tr>
<tr>
<td>34</td>
<td>Definite</td>
<td>Slight</td>
<td>Poor</td>
</tr>
<tr>
<td>35</td>
<td>Definite</td>
<td>Definite</td>
<td>Poor</td>
</tr>
<tr>
<td>36</td>
<td>Definite</td>
<td>Slight</td>
<td>Poor</td>
</tr>
<tr>
<td>37</td>
<td>Definite</td>
<td>Slight</td>
<td>Poor</td>
</tr>
<tr>
<td>Temperature of butter 44° F.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>38</td>
<td>Definite</td>
<td>Slight</td>
<td>Poor</td>
</tr>
<tr>
<td>39</td>
<td>Definite</td>
<td>Slight</td>
<td>Poor</td>
</tr>
<tr>
<td>40</td>
<td>Definite</td>
<td>Slight</td>
<td>Poor</td>
</tr>
<tr>
<td>41</td>
<td>Definite</td>
<td>Slight</td>
<td>Poor</td>
</tr>
<tr>
<td>42</td>
<td>Definite</td>
<td>Slight</td>
<td>Poor</td>
</tr>
<tr>
<td>43</td>
<td>Definite</td>
<td>Slight</td>
<td>Poor</td>
</tr>
<tr>
<td>Temperature of butter 46° F.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>44</td>
<td>Definite</td>
<td>Slight</td>
<td>Poor</td>
</tr>
<tr>
<td>45</td>
<td>Definite</td>
<td>Slight</td>
<td>Poor</td>
</tr>
<tr>
<td>46</td>
<td>Definite</td>
<td>Slight</td>
<td>Poor</td>
</tr>
<tr>
<td>47</td>
<td>Definite</td>
<td>Slight</td>
<td>Poor</td>
</tr>
<tr>
<td>48</td>
<td>Definite</td>
<td>Slight</td>
<td>Poor</td>
</tr>
<tr>
<td>49</td>
<td>Pronounced</td>
<td>Slight</td>
<td>Poor</td>
</tr>
<tr>
<td>50</td>
<td>Pronounced</td>
<td>Slight</td>
<td>Poor</td>
</tr>
<tr>
<td>51</td>
<td>Definite</td>
<td>Slight</td>
<td>Poor</td>
</tr>
<tr>
<td>52</td>
<td>Definite</td>
<td>Slight</td>
<td>Poor</td>
</tr>
<tr>
<td>53</td>
<td>Definite</td>
<td>Slight</td>
<td>Poor</td>
</tr>
<tr>
<td>54</td>
<td>Definite</td>
<td>Slight</td>
<td>Poor</td>
</tr>
<tr>
<td>Temperature of butter 48° F.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>55</td>
<td>Definite</td>
<td>Slight</td>
<td>Poor</td>
</tr>
<tr>
<td>56</td>
<td>Definite</td>
<td>Slight</td>
<td>Poor</td>
</tr>
<tr>
<td>57</td>
<td>Definite</td>
<td>Slight</td>
<td>Poor</td>
</tr>
<tr>
<td>58</td>
<td>Definite</td>
<td>Slight</td>
<td>Poor</td>
</tr>
</tbody>
</table>
Table 5. Body and Texture Characteristics of Commercial Churnings of Butter Made in the Six Creameries During December 1941 and January 1942—Continued

Method A. Cream churned immediately after pasteurization and cooling.
Regular temperature wash water 51° to 55° F.

<table>
<thead>
<tr>
<th>Churning number</th>
<th>Crumbliness</th>
<th>Stickiness</th>
<th>Spreadability</th>
</tr>
</thead>
<tbody>
<tr>
<td>52° F.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>59</td>
<td>Definite</td>
<td>Slight</td>
<td>Poor</td>
</tr>
<tr>
<td>60</td>
<td>Definite</td>
<td>Slight</td>
<td>Poor</td>
</tr>
<tr>
<td>61</td>
<td>Definite</td>
<td>Slight</td>
<td>Poor</td>
</tr>
<tr>
<td>62</td>
<td>Definite</td>
<td>Slight</td>
<td>Poor</td>
</tr>
<tr>
<td>63</td>
<td>Definite</td>
<td>Slight</td>
<td>Poor</td>
</tr>
<tr>
<td>64</td>
<td>Definite</td>
<td>Slight</td>
<td>Poor</td>
</tr>
<tr>
<td>65</td>
<td>Definite</td>
<td>Slight</td>
<td>Poor</td>
</tr>
<tr>
<td>66</td>
<td>Definite</td>
<td>Slight</td>
<td>Poor</td>
</tr>
<tr>
<td>67</td>
<td>Definite</td>
<td>Slight</td>
<td>Poor</td>
</tr>
<tr>
<td>68</td>
<td>Definite</td>
<td>Slight</td>
<td>Poor</td>
</tr>
<tr>
<td>69</td>
<td>Definite</td>
<td>Slight</td>
<td>Poor</td>
</tr>
<tr>
<td>70</td>
<td>Pronounced</td>
<td>Slight</td>
<td>Very poor</td>
</tr>
<tr>
<td>71</td>
<td>Pronounced</td>
<td>Slight</td>
<td>Very poor</td>
</tr>
</tbody>
</table>

It will be noted that the butter generally:

a) Was definitely or pronouncedly crumbly.
b) Was slightly or definitely sticky.
c) Had a poor spreading property.

Method B—Cream cooled after pasteurization to 47° to 50° F., held overnight; before churning, cream heated to 110° F., held for 10 to 15 minutes, cooled to churning temperature, and churned immediately. (Regular temperature wash water 50°-55° F.) A total of thirty-one churnings was made. The comments on the body and texture characteristics are given in Table 6.


Method B. Cream cooled after pasteurization to 47° to 50° F. Held overnight. Cream heated to 110° F.; held for 10 to 15 minutes. Cooled and churned immediately. Regular temperature wash water (50° to 55° F.)

<table>
<thead>
<tr>
<th>Churning number</th>
<th>Crumbliness</th>
<th>Stickiness</th>
<th>Spreadability</th>
</tr>
</thead>
<tbody>
<tr>
<td>47° F.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Definite</td>
<td>Slight</td>
<td>Poor</td>
</tr>
<tr>
<td>2</td>
<td>Definite</td>
<td>Slight</td>
<td>Poor</td>
</tr>
<tr>
<td>3</td>
<td>Definite</td>
<td>Slight</td>
<td>Poor</td>
</tr>
<tr>
<td>4</td>
<td>Definite</td>
<td>Slight</td>
<td>Poor</td>
</tr>
<tr>
<td>5</td>
<td>Definite</td>
<td>Slight</td>
<td>Poor</td>
</tr>
<tr>
<td>6</td>
<td>Definite</td>
<td>Slight</td>
<td>Poor</td>
</tr>
<tr>
<td>7</td>
<td>Definite</td>
<td>Slight</td>
<td>Poor</td>
</tr>
<tr>
<td>8</td>
<td>Definite</td>
<td>Slight</td>
<td>Poor</td>
</tr>
<tr>
<td>9</td>
<td>Definite</td>
<td>Slight</td>
<td>Poor</td>
</tr>
<tr>
<td>10</td>
<td>Definite</td>
<td>Not sticky</td>
<td>Poor</td>
</tr>
<tr>
<td>11</td>
<td>Definite</td>
<td>Not sticky</td>
<td>Poor</td>
</tr>
<tr>
<td>12</td>
<td>Pronounced</td>
<td>Not sticky</td>
<td>Very poor</td>
</tr>
<tr>
<td>13</td>
<td>Pronounced</td>
<td>Not sticky</td>
<td>Very poor</td>
</tr>
<tr>
<td>14</td>
<td>Pronounced</td>
<td>Not sticky</td>
<td>Very poor</td>
</tr>
<tr>
<td>15</td>
<td>Pronounced</td>
<td>Not sticky</td>
<td>Very poor</td>
</tr>
<tr>
<td>16</td>
<td>Pronounced</td>
<td>Not sticky</td>
<td>Very poor</td>
</tr>
<tr>
<td>17</td>
<td>Definite</td>
<td>Not sticky</td>
<td>Poor</td>
</tr>
<tr>
<td>18</td>
<td>Definite</td>
<td>Not sticky</td>
<td>Poor</td>
</tr>
<tr>
<td>19</td>
<td>Definite</td>
<td>Not sticky</td>
<td>Poor</td>
</tr>
<tr>
<td>20</td>
<td>Definite</td>
<td>Not sticky</td>
<td>Poor</td>
</tr>
<tr>
<td>21</td>
<td>Definite</td>
<td>Slight</td>
<td>Poor</td>
</tr>
</tbody>
</table>
36  


Method B. Preheating temperature used for samples below was 140° F.  Cream not held but cooled and churned at once.  Churning temperature 49° to 52° F.

<table>
<thead>
<tr>
<th>Churning number</th>
<th>Crumbliness</th>
<th>Stickiness</th>
<th>Spreadability</th>
</tr>
</thead>
<tbody>
<tr>
<td>22</td>
<td>Definite</td>
<td>Not sticky</td>
<td>Poor</td>
</tr>
<tr>
<td>23</td>
<td>Definite</td>
<td>Not sticky</td>
<td>Poor</td>
</tr>
<tr>
<td>24</td>
<td>Definite</td>
<td>Slight</td>
<td>Very poor, butter crumbled</td>
</tr>
<tr>
<td>25</td>
<td>Pronounced</td>
<td>Not sticky</td>
<td>Very poor, butter crumbled</td>
</tr>
<tr>
<td>26</td>
<td>Definite</td>
<td>Slight</td>
<td>Poor</td>
</tr>
<tr>
<td>27</td>
<td>Definite</td>
<td>Not sticky</td>
<td>Very poor, butter crumbled</td>
</tr>
<tr>
<td>28</td>
<td>Definite</td>
<td>Slightly sticky</td>
<td>Poor</td>
</tr>
<tr>
<td>29</td>
<td>Pronounced</td>
<td>Not sticky</td>
<td>Very poor</td>
</tr>
<tr>
<td>30</td>
<td>Definite</td>
<td>Not sticky</td>
<td>Poor</td>
</tr>
<tr>
<td>31</td>
<td>Not crumbly</td>
<td>Slight</td>
<td>Fine</td>
</tr>
</tbody>
</table>

The butter made in accordance with Method B generally:

a) Had a definitely or pronouncedly crumbly texture.

b) Was free from stickiness or this defect was only slight.

c) Possessed a poor spreading property, being hard and crumbly.

Method C. Cream cooled after pasteurization to 47° to 50° F. Held overnight. Cream not preheated. The body and texture characteristics are listed in Table 7.


Method C. Cream cooled after pasteurization to 47° to 50° F. Held overnight. Cream not preheated. Cold wash water (45° F.).

<table>
<thead>
<tr>
<th>Churning number</th>
<th>Crumbliness</th>
<th>Stickiness</th>
<th>Spreadability</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Not crumbly</td>
<td>Slight</td>
<td>Fine, soft</td>
</tr>
<tr>
<td>2</td>
<td>Not crumbly</td>
<td>Slight</td>
<td>Fine, soft</td>
</tr>
<tr>
<td>3</td>
<td>Not crumbly</td>
<td>Slight</td>
<td>Fair, good</td>
</tr>
<tr>
<td>4</td>
<td>Slight</td>
<td>Slight</td>
<td>Fine, soft</td>
</tr>
<tr>
<td>5</td>
<td>Not crumbly</td>
<td>Very slight</td>
<td>Fine, soft</td>
</tr>
<tr>
<td>6</td>
<td>Not crumbly</td>
<td>Very slight</td>
<td>Fine, soft</td>
</tr>
<tr>
<td>7</td>
<td>Not crumbly</td>
<td>Very slight</td>
<td>Fine, soft</td>
</tr>
<tr>
<td>8</td>
<td>Not crumbly</td>
<td>Very slight</td>
<td>Fine, soft</td>
</tr>
<tr>
<td>9</td>
<td>Not crumbly</td>
<td>Slight</td>
<td>Fine, soft</td>
</tr>
<tr>
<td>10</td>
<td>Slightly crumbly</td>
<td>Slight</td>
<td>Fair, soft</td>
</tr>
<tr>
<td>11</td>
<td>Not crumbly</td>
<td>Slight</td>
<td>Fine, soft</td>
</tr>
<tr>
<td>12</td>
<td>Not crumbly</td>
<td>Slight</td>
<td>Fine, soft</td>
</tr>
<tr>
<td>13</td>
<td>Not crumbly</td>
<td>Slight</td>
<td>Fine, soft</td>
</tr>
</tbody>
</table>
Method C. Cream cooled after pasteurization to 47° to 50° F. Held overnight. Cream not preheated. Regular temperature wash water (50°-55° F.)

To summarize the comments on the butter made in accordance with Method C:

1) When cold wash water was used (45° F.). The butter from thirteen churnings:
   a) Was generally free from crumbliness.
   b) Showed very slight or slight stickiness.
   c) Had a good spreading property.

2) When regular temperature wash water was used (50°-55° F.). The butter from twenty-seven churnings:
   a) Was not or only slightly crumbly.
   b) Showed slight or definite stickiness.
   c) Possessed a good spreading property.

The results obtained in these 142 churnings agree with those obtained when the experimental churnings were under the direct observation of the member of the experiment station.
Summarizing the results from the 142 churnings, it was found that:

1) When the cream was churned immediately after pasteurization and cooling, butter with a crumbly texture, some degree of stickiness, a hard body, and poor spreadability was obtained. Cold wash water was not used as it had been found to cause lumpiness in the butter as well as a mottled color.

2) When the cream was held overnight after pasteurization and cooling, then heated to 110° F. and held for 10 to 15 minutes and cooled rapidly to a low temperature and then churned, the butter obtained was crumbly but as a rule not sticky. The butter possessed a poor spreading property, being hard and crumbly. Cold wash water was not used as the butter became lumpy and moisture control was difficult.

3) When the cream was cooled to from 47° to 50° F. after pasteurization and held overnight and churned without preheating, when regular temperature wash water was used, butter that was not crumbly but that showed some degree of stickiness was obtained. The butter was relatively soft and could be spread easily. When cold wash was used with this method butter with an excellent body and texture was obtained. The spreading property was very good. Lumpiness of the butter, or difficulty with moisture control or with the color of the butter was not experienced. Buttermakers reported that the butter had a soft, waxy body and did not “set up” when it was being removed from the churn. It took longer to work the butter when this method was used.

H. OPINIONS BY BUTTER DEALERS, PRINT-ROOM OPERATORS, RESTAURANT PROPRIETORS, AND OTHERS REGARDING THE HANDLING AND SPREADING PROPERTIES OF BUTTER MADE BY SEVERAL METHODS

It was the chief purpose of the experiments to develop a method of manufacture and handling that would result in butter that would find favorable market and consumer acceptance. Therefore it was decided to obtain the opinions of butter dealers, butter print-room operators, restaurant operators, and consumers on typical examples of the butter made by several methods.

A butter dealer in Seattle gave his opinion on the type of butter that was required. He stated in a letter to the Experiment Station:

“We find that the consumer prefers butter that is spreadable and does not show leakiness. Also from the distributors’ point of view, they are now preferring a type-bodied butter that is waxy and doesn’t have free moisture. The reason for this is the fact that many distributors have power cutters and if the body is leaky the loss in brine while cutting will be tremendous.

“From our point of view, as marketing agents, we would much prefer the above-mentioned type, as it will work in Simpson cutters or power cutters as well.”

In some of the creameries visited during the study two methods of butter manufacture were regularly used: one method for butter intended for local
BUTTER MAKING DURING HAY FEEDING SEASON

sale and another for butter to be sold in out-of-state markets. The "preheat" or the "churned-at-once" method was generally used when the butter was to be shipped to California. The conventional method of holding the pasteurized cooled cream in the vat overnight and churning without preheating was followed when the butter was to be sold locally. Print room operators in the creameries remarked that the butter made by the two methods: ("preheat," or "churned-at-once" after pasteurization and cooling) was too hard and crumbly. It cut badly by means of a wire butter cutter, they reported. The butter would "roll up" or crumble on the surface when the 96-pound block of butter was cut. The wires broke frequently. Difficulty with wrapping by means of an automatic wrapping machine was also experienced. The girls in one print room remarked that they were "very unhappy" when occasionally butter by the "preheat" method was to be printed. It was difficult to patch the prints. Much neater looking prints could be obtained when the butter had been made in accordance with the "hold-over" not preheated method, and the work of printing and wrapping the "hold-over"-cream butter could be done much faster than when the butter was made by the "preheat" method. In another print room it was reported that when butter that had been churned immediately after pasteurization and cooling was printed it "was crumbly and hard and would not stick together." The girls had no complaints regarding the butter as ordinarily printed when this was made by the "hold-over" method.

When butter made by the "preheat" or "churned-at-once" method was sold to restaurants in several of the towns visited complaints on account of the butter being hard and crumbly were made by the restaurant owners. They demanded butter with better handling and spreading properties. This was the chief reason for the creamery managers adopting the "hold-over" not preheated method of butter manufacture for the butter to be sold locally. One restaurant operator reported that he had not seen crumbly butter for a long time. He was well satisfied with the cutting and spreading properties of the butter. Uniform patties could easily be cut from the pound prints. This he demonstrated by displaying a neat stack of patties that had been cut prior to the visit. He was emphatic in stating that he did not want hard, crumbly butter.

Several wholesale dealers in Portland that operate print rooms have refused to buy butter that is hard, crumbly, or sticky.

Samples of butter made in accordance with the three different methods studied in the six creameries were submitted to a number of State College faculty members for a critical examination in their homes. The samples were known by number only. Without exception the comment was that one sample had a good spreading property (made by Method C) while the others were hard and difficult to spread. "The butter crumbled," was the common criticism of the butter that had been made by the "preheat" and "churned-at-once" methods.

VI. FINAL TEST OF CHURNING METHOD C
("50-45-40" METHOD)

The experiments have definitely shown that butter of the best body and texture can be made by Method C. The butter will possess printing and spreading properties superior to that made by any other method studied.

The method principally involves:
1) Cooling the pasteurized cream to not less than 50° F.
2) Holding the cream overnight at a temperature of from 50° to 55° F.
3) Churning to obtain granules the size of small peas.
4) Chilling and washing the granules with water at a temperature not above 45° F.
5) Incorporating the salt and water by efficient working of the butter.
6) Reducing the temperature of the finished butter quickly to a temperature of 40° F. or below.

This method will be referred to hereafter as the "50-45-40" method for making fall and winter butter.

It was decided to make a commercial churning of butter by the "50-45-40" method and also a churning in accordance with Method A (churning at once) for a final test in which a large number of persons would give their opinion regarding the body and texture of the butter. One of the six creameries that had previously cooperated offered to make the two churnings. Whole milk produced in a typical alfalfa hay section and separated in the creamery was used. The conditions of manufacture are indicated in Table 8.

Table 8. Manufacturing Data for Two Churnings of Butter

<table>
<thead>
<tr>
<th>Method A</th>
<th>&quot;50-45-40&quot; Method</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cream churned at once after pasteurization and cooling</td>
<td>Pasteurized cream cooled to 50° F., held overnight, cold wash water used</td>
</tr>
<tr>
<td>Date churned</td>
<td>February 7, 1942</td>
</tr>
<tr>
<td>Pounds of cream</td>
<td>4,500</td>
</tr>
<tr>
<td>Test of cream</td>
<td>37%</td>
</tr>
<tr>
<td>Pounds of fat</td>
<td>1,665</td>
</tr>
<tr>
<td>Initial acidity</td>
<td>0.12%</td>
</tr>
<tr>
<td>Starter added</td>
<td>None</td>
</tr>
<tr>
<td>Temperature of pasteurization</td>
<td>160° F.</td>
</tr>
<tr>
<td>Time held at pasteurization temperature</td>
<td>30 min.</td>
</tr>
<tr>
<td>Temperature to which cooled</td>
<td>44°F.</td>
</tr>
<tr>
<td>Time held before churning</td>
<td>Not held</td>
</tr>
<tr>
<td>Churning temperature</td>
<td>44°F.</td>
</tr>
<tr>
<td>Churning time</td>
<td>45 min.</td>
</tr>
<tr>
<td>Temperature of buttermilk</td>
<td>55°F.</td>
</tr>
<tr>
<td>Temperature of wash water</td>
<td>55°F.</td>
</tr>
<tr>
<td>Fat content of buttermilk</td>
<td>0.50%</td>
</tr>
<tr>
<td>Fat content of butter</td>
<td>80.3%</td>
</tr>
</tbody>
</table>

A 68-pound cube from each of these churnings was shipped to the Experiment Station after the butter had been chilled in the regular refrigerator (40°F.). The butter arrived in excellent condition. After being stored for 2 days in a refrigerator it was cut into 1-pound prints by means of a "Simpson" wire butter printer. When at the refrigerator temperature it was quite noticeable that the butter made by the "50-45-40" method was considerably softer than the butter made by Method A. The girl who cut and wrapped the butter had no knowledge regarding the methods used in manufacturing the butter. After she had printed and wrapped the butter from the two cubes, she was asked which of the two lots of butter had the best body and texture. The butter from one cube ("50-45-40" method) was quite soft and easy to handle, she reported, while the butter from the other (Method A) was hard and crumbly, and it was difficult to make nice looking prints.

The pound prints from each cube were marked with identification numbers and the butter was kept at approximately 40°F. in the butter refrigerator.

One-pound prints of the butter made by the two methods are shown in Figures 3 and 4. It will be noted that the butter made by Method A (churned
at once) was definitely crumbly. The print broke when a plug of butter was obtained by a trier. The spreading property was poor. The butter made by the "50-45-40" method (cream held over, cold wash water, etc.) was not crumbly. The spreading property was good. A good trier plug was obtained.

When prints of butter were cut into patties by means of a restaurant type

Figure 3. Butter made by Method A. (Cream churned at once after pasteurization and cooling in a coil vat.) Temperature of butter when examined 45° F.

Figure 4. Butter made by the "50-45-40" method (Cream pasteurized, cooled in a coil vat to 50° F., held overnight, cold wash water used.) Temperature of butter when examined 48° F.
wire printer the butter made by Method A was difficult to cut as it was quite hard, whereas the butter by the "50-45-40" method because of its softer consistency was quite easy to cut. The temperature of the butter at time of cutting was 48°F. The two prints as they appeared after cutting are shown in Figures 5 and 6.

Figure 5. Butter made by Method A. (Cream churned at once after pasteurization and cooling in a coil vat.) Temperature of butter when printed 48°F.

Figure 6. Butter churned by the "50-45-50" method. (Cream pasteurized, cooled in a coil vat to 50°F., held overnight, cold wash water used.) Temperature of butter when printed 48°F.
A number of faculty members and others not associated with the State College were asked to give their opinion regarding the butter made by the two different methods. In all instances it was stated that one sample was softer and had a much better spreading property ("50-45-40" method) than the other, which was criticized for being crumbly and difficult to spread (Method A). These opinions included also those of the federal butter grader stationed at Portland and a number of creamery operators who examined the butter at Corvallis.

Prints of the butter were examined by buttermakers, creamery operators, and out-of-state visitors who attended the annual convention and short course held at Corvallis during the third week in February 1942. It was the consensus of those present that the body and texture and spreading property of the butter made by the "50-45-40" method were far superior to those of the butter made by Method A.

The difference in the spreadability of the butter made by the two methods was also visually demonstrated during the annual banquet held during the convention. The banquet was attended by 300 persons, including the buttermaker who had made the butter. Two 1-pound prints from each churning, properly labeled and the method of manufacture briefly given on each label, were placed on each table. The superior spreading property of the butter made by the "50-45-40" method was easily noted by those present.

Samples of butter from these churnings were also sent to a wholesale butter dealer in Seattle. The butter arrived there in good condition, it was reported. The prints were marked: No. 1 and No. 2. Number 1 was made by the "50-45-40" method and number 2 was made by Method A. After the samples had been held in a refrigerator until the following day, they were examined by four competent men, two being butter buyers and two federal butter graders. The comments were: "Sample No. 1 is the desirable piece of butter. We noted that Sample No. 1 had much better grain and spreadability and was the softer of the two. Sample No. 2 was short-grained, very brittle, and broke when the trier was inserted."

The "50-45-40" method was used successfully by several eastern Oregon creameries during the 1941-42 winter season. It has also been adopted as standard during the fall and winter months in the Dairy Products Laboratory at Oregon State College. Definitely softer, waxier, and more spreadable butter is obtained.

VII. RECOMMENDED METHOD OF BUTTER MANUFACTURE—"50-45-40" METHOD

On the basis of the experience gained from research on the problem of crumbliness, stickiness, and poor spreadability of butter made during the fall and winter months in eastern and southern Oregon when dry feeds are fed to cows, it is possible to outline a method of butter manufacture that, if followed, will result in butter that has a desirable waxy body so the butter can readily be spread on bread. The butter will not be hard and crumbly, but it may show a slight degree of stickiness particularly if a sample is taken from a cube of butter when at a temperature below 50° F. by means of a cold butter trier. If the butter is worked thoroughly, leakage of brine from the butter during and subsequent to printing will be practically avoided. This means better looking prints, less loss in weight, less grief with state and federal regulatory authorities, and better consumer acceptance.
Capable buttermakers, if they exercise their skill, will be able to make butter of desirable body and texture characteristics by this method. If, on the other hand, a buttermaker overlooks certain important points and drifts into a state of automatism or indifference, the butter will either be sticky or crumbly and will probably leak during and after printing. Constant alertness and attention to details are necessary in order to make butter of desirable body and texture. The buttermaker must be an artist and not an automaton if fall and winter butter that has good printability and spreadability is to be manufactured.

Outline of the "50-45-40" method

1) Cool the cream after pasteurization to 50° F. and maintain a temperature of the cream from 50° to 55° F. overnight. Cooling in a coil vat as ordinarily practiced is satisfactory.
   - Don't cool below 50° F.
   - Don't add an excessive amount of trimmings to the cream.
   - Don't use more rinse water than absolutely necessary.
   - Don't agitate the cream in the vat too vigorously during cooling.
     It may cause partial churning, resulting in short-grained butter.
   - Don't cool cream quickly to a temperature below 50° F. on a surface cooler.

2) Inasmuch as the churning temperature varies with the amount, test, acidity of the cream, the size and type of churn, and other factors, it is important that the churning temperature be adjusted so that granules the size of small peas are formed in from 40 to 50 minutes of churning. Cream testing from 32 to 38 per cent fat is satisfactory. If the churn is filled to 40 per cent of the total capacity, a temperature of the cream from 55° to 60° F. is usually satisfactory.
   - Don't overchurn. Large granules cannot be thoroughly washed or chilled.
   - Don't overload the churn. Slightly underloading is preferable.

3) Spray the granules with a small amount of chilled water and allow the rinsings to drain from the churn.
   - Don't add the rinse water from the regular supply line; place it in a tank or in a clean cream vat and correctly adjust the temperature.

4) For washing and chilling, with a normal-sized churning, add enough filtered water at a temperature of not more than 45° F. so that the water and granules occupy two-thirds of the space of the churn, or add at least as much water as there was cream.
   - Don't allow the temperature of the wash water to exceed that recommended. It may be less than 45° F., but not above this temperature.

5) Revolve the churn in high gear 12 to 15 revolutions. Then, if a roll churn, revolve in low gear with worker connected 10 to 15 revolutions. With a roll-less churn revolve in high gear a little longer. As the granules will be firm they will break up to a uniform size resulting in a uniform chilling of the butter during washing.

6) Drain the wash water.

7) With the churn door ajar work the granules until they have formed into a mass. Considerable water will escape.
8) Drain the water from the churn. Then add the salt. The temperature of the salt should be adjusted to 45° to 50° F. Add some chilled water in order that the moisture content of the butter at the time of making the first moisture test is 15.6 to 16.0 per cent. The amount of water to add will depend on the churning conditions as they may prevail in the different creameries. This water should be poured over the salt to aid in its solution.

9) Work the butter until it is fairly dry. Avoid overworking at this point. Then test for moisture. Working low-moisture butter almost dry, then adding the necessary water to increase the moisture to the proportion desired, and again working the butter until it is dry causes an increase in the working time resulting in stickiness, and as the added water may not be finely divided in the butter, leakiness generally results.

10) Add the required amount of water in order to increase the moisture to that desired. The temperature of the water should be the same as the temperature of the butter. Be sure to calculate correctly and weigh this water. Complete the working of the butter. Work the butter thoroughly. There should be no free moisture visible. Because the butter will be firm, the working time will be longer than under summer conditions, and also when wash water warmer than recommended is used under winter conditions.

Stickiness may result from excessive working.

11) Store the butter in a refrigerator maintained at a temperature of from 35° to 40° F.

After 12 hours or longer, if the butter is examined when it has been brought to a temperature of 50° F., it will not be brittle or crumbly. It may be slightly sticky, especially if it is worked quite dry, but it will have a fairly soft consistency and a good spreading property. It will find satisfactory consumer acceptance.

Important points

1) Use accurate thermometers. Recording thermometers on the cream vats are desirable.

2) Accurately determine the amount of fat in each lot of cream.

3) Add the correct amount of salt.

4) Churn the cream in each lot so that the granules are of the correct size.

5) Drain the wash water until the water only drips from the churn before the salt is added.

6) Adjust the amount of water to add with the salt in accordance with the size of the churning so the butter at the time of making the first moisture test will always contain less than the final desired moisture. The amount of water to add is determined by experience.

7) Avoid making “high moisture” churnings. Moisture removal results in leaky and sticky butter.

8) Pack the butter as soon as it has been worked to completion. (Allowing the butter to remain in the churn for some time, then working it again, may result in leakiness and stickiness.)

9) Place the cubes or moulds of butter in a refrigerator. Holding the butter at churn room temperature for an extended time results in a firmer body.
10) Wash the churn properly so that difficulty with butter sticking to it during working is not experienced.

11) Examine the butter at time of printing or shipping to a distant market in order to determine if the butter has a desirable waxy body and is free from leakiness.

12) Before fall- and winter-made butter is printed or cut into patties or slices it should be kept at such a temperature and length of time that it will be of the right consistency for easy handling.

Even though the body of fall- and winter-made butter manufactured in accordance with the "50-45-40" method is relatively soft, it is usually not as soft as spring- and summer-made butter. Whereas spring- and summer-made butter may be of the right consistency for restaurant patty production by means of a hand wire printer when at a temperature of about 40° F., fall- and winter-made butter would be of the most desirable firmness at 50° F. or slightly above.

Restaurant operators and consumers do not understand why fall- and winter-made butter, produced under dry-feeding conditions, is not as soft at 40° F. as spring- and summer-made butter, produced when cows receive green feed, if also kept at 40° F. Creamery operators and butter distributors should advise the restaurant operators and consumers regarding the best methods of handling butter made during the different seasons.

**Improvement effected**

The improvement in the body and texture of fall- and winter-made butter resulting in better printability and spreadability is effected by:

1) Adjustment of the temperature of the cooled, pasteurized cream so that crystallization of the fat in the cream is controlled.

2) Regulation of the size of the butter granules during churning, and chilling the granules by means of cold water, followed by a thorough working. This controls liquid fat crystallization and favors the segregation of liquid fat from the fat globules.

In the opinion of research workers the cold water causes rapid crystallization of liquid fat present and the formation of many minute crystals resulting in a smoother, more pliable butter. An analogy to this is in the freezing and hardening of ice cream. It is well known that rapid freezing of ice cream mix followed by rapid reduction in the temperature of the frozen ice cream in the hardening room causes the formation of many minute ice crystals, rather than a smaller number of coarse crystals, resulting in a smooth-textured ice cream.

3) Working the butter thoroughly so that the brine droplets are finely divided.

4) Attention to details and the application of expert workmanship on the part of the buttermaker.

5) Storing the butter at a regulated temperature to favor the formation of a fairly soft, waxy body.
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† On leave for duration for military service.