EFFECT OF CERTAIN MANUFACTURING METHODS ON THE PHYSICAL CHARACTERISTICS OF BUTTER

by

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A THESIS

submitted to

OREGON STATE COLLEGE

in partial fulfillment of
the requirements for the
degree of

MASTER OF SCIENCE

June 1958

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Date thesis is presented May 15, 1958

Typed by Mary Rice

ACKNOWLEDGEMENTS

Sincere appreciation is extended to Dr. G.H. Wilster, Professor of Food and Dairy Technology, for his guidance and assistance in the completion of this experimental work and helpful criticism in the preparation of this manuscript.

Appreciation is also extended to R.W. Stein, Professor of Food and Dairy Technology for his assistance in examining the butter and to H.P.C. Nielsen, Experiment Station Technician, for his help in treatment of the cream and preparation of the churnings of butter.

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INTRODUCTION

In 1956, the 2,200 creameries in the United States manufactured 1.5 billion pounds of butter (27). Undesirable physical characteristics of butter reported by butter graders and distributors include leakiness, crumbliness, stickiness, greasiness, excessive hardness and poor spreadability. Butter manufactured in different sections of the country and during different seasons of the year show these defects in varying degree. Butter manufactured during the summer in the mid-west may be too soft and greasy, while that butter made in the western states during fall and winter is often hard, crumbly, sticky, and frequently leaky. When butter is hard and crumbly it is difficult to spread smoothly on bread unless it is softened by warming.

Investigations (4, 7, 21, 31) have indicated that changes in the composition of the milkfat are responsible for the variation in the physical characteristics of butter. The composition of the milkfat changes with the type of feed the cows are being fed, which varies with the season of the year. In the spring and summer, when the cows are on pasture and succulent feed, a fat high in unsaturated and volatile fatty acids is produced. This fat is relatively soft and usually results in soft butter. On the other hand, during fall and winter months the feeding of dry feed causes the fat to be low in unsaturated and volatile fatty acids. The presence of this fat in the cream is responsible for the undesirable physical characteristics of butter manufactured during this period when the customary cream treatments and churning techniques are used.

Inasmuch as the feeding practices for dairy cows cannot be materially changed because of economic reasons, it appears that the immediate and practical solution to this problem lies in the modification of the buttermaking procedure.

Samples of butter manufactured in the fall and winter months throughout the state of Oregon were examined by personnel of the Oregon Agricultural Experiment Station during the fall and winter of 1956-57. It was found that the majority of the Oregon-made butter was leaky, crumbly, sticky, hard, and spread poorly at 48° F. - 50° F.

Recent investigations in Denmark (3, 18) have indicated that there is a possible solution to this problem. Research workers for a number of years have studied butter manufacturing methods during summer and winter with the purpose of developing butter with uniform physical characteristics throughout the year.

The purpose of this investigation was to try to eliminate these undesirable physical characteristics of Oregon butter by using modified manufacturing techniques.

REVIEW OF LITERATURE

Desirable and Undesirable Physical Characteristics of Butter

According to McDowall (17, p.644) the physical characteristics of a sample of butter, the general appearance, and the spreading property supply first impression of the quality of the butter. The presence of a desirable flavor will not dislodge a bias against butter created by unattractive physical properties.

Wilster (26) states that butter with desirable physical characteristics is waxy and possesses a smooth spreading property. It should be pliable, so it can be spread easily on bread and rolls without crumbling or sticking to the knife. The flavor and body and texture should be as uniform as possible throughout the year. The butter should not be leaky.

Butter with undesirable physical characteristics may have one or any combination of the following defects: Excessive hardness, crumbliness, leakiness, stickiness, poor spreading property, greasiness, salviness, oiliness and mealiness.

Stein (24, p.18) described leakiness as the large brine droplets in the butter which should have been more finely divided during the working process. He also pointed out that stickiness is the undesirable condition encountered when butter sticks to the butter trier or knife being used to examine the butter and that crumbliness refers to the short-grainness of the butter.

Factors Affecting the Physical and Chemical Characteristics of Milkfat

Dolby (7) has estimated that 80 per cent of the variation in the physical characteristics of butter is due to changes in the chemical composition of the milkfat. Hunziker (11) has shown that, aside from the manufacturing method, the firmness of the butter is governed by the chemical composition of the butterfat. Haglund, Wode and Olsson (8) in their investigations of the consistency of Swedish butter have shown that the variations in the hardness of butter are related to variations in the iodine value of the fat and are, therefore, a result of the method of feeding. Richardson and Abbott (21) have shown that a ration in which alfalfa hay forms the sole diet is conducive to the production of a milkfat in which the constituents having the higher solidifying temperatures are increased and those of lower solidifying temperatures are decreased. The small increase in unsaturated fatty acids is more than counteracted by the decrease in lower saturated acids. They reported that the result is a much more strongly crystallizing fat at the temperatures employed in churning.

Previous investigations (24, 30, 31) at the Oregon Agricultural Experiment Station have indicated that the defects, crumbliness, stickiness and excessive hardness, are more common in Oregon butter manufactured in the alfalfa hay-producing areas during the fall and winter months. When alfalfa hay was fed as the sole ration to cows, the fat of the milk was found to have a relatively high melting point and a low content of the unsaturated and volatile fatty acids.

Crumbliness, stickiness, and excessive hardness were common in butter when the unsaturated and the volatile fatty acid content of the fat was low (31). Feed was found to be the most important factor controlling the chemical composition of the milkfat (11).

According to Hunziker (11) the olein content of the milkfat is the most dominant factor in the determination of the firmness of butter. Generally speaking the softness of the butter increases or decreases as the per cent olein increases or decreases. At the beginning of the period of lactation the volatile acids were highest and the olein content lowest. As the period of lactation advanced the volatile acids decreased and the olein increased.

Coulter and Combs (4) manufactured butter from cream obtained from milk produced by cows in advanced lactation. This butter did not exhibit undesirable physical characteristics more frequently than butter made from cream obtained from milk produced by cows in other stages of lactation.

Effect of Pasteurization on the Physical Characteristics of Milkfat

The heat treatment involved in the pasteurization of cream for manufacture into butter melts the milkfat in the clusters of fat globules. This makes it possible to control the crystallization of milkfat by proper cooling. This in turn influences the physical characteristics in the resultant butter (17, p.309).

The method of cream pasteurization has an effect on the size and distribution of fat globules in cream and butter. Dolby (6) has shown that Vacreator treatment of cream caused a considerable increase in the number of fat globules present as globules less than 2 microns and a small increase in the number of fat globules present as globules over 10 microns in diameter. High-temperature short-time pasteurization using a plate pasteurizer, on the other hand, caused a slight decrease in the proportion of fat present as small globules and a considerable increase in that present as large globules. He also reported that butter from high-temperature plate pasteurized cream contained numerous large fat globules and fat aggregates, while butter from Vacreator-treated cream contained few large globules.

Effect of Method of Cooling Cream After Pasteurization on the Physical Characteristics of Milkfat

McDowell (17, p.374) stated that the fat in cream is suspended as very small globules in an aqueous medium which can be cooled below 32° F. without solidifying. The cream has a relatively good heat-conductivity. A very rapid cooling of cream to below the melting point of the milkfat is thus possible without introducing mechanical difficulty due to the solidification of milkfat on the equipment. He stated further that the fat globules are individual particles so small that they cannot be stirred to induce crystallization. A greater amount of supercooling is therefore necessary to induce the desired degree of crystallization. The smallness of the milkfat globules and the good conductivity of the cream serum make it possible to impart this supercooling to the milkfat rapidly and completely.

McDowell also stated the type of crystallization obtained in the fat globules has an important influence on the body of the butter. Rapid cooling of cream results in small fat crystals in the globules and consequently hard butter, while slow cooling results in large fat crystals in the globules and relatively soft butter. Zaikovskii (33) reported that slow cooling of milkfat increased the size of the fat crystal. Rapid and slow cooling had no quantitative effect on the equilibrium between the liquid and solid phases. Rapid cooling of milkfat caused the formation of a colloidial system of liquid and solid glycerides. A second cooling of the fat disturbed its structure and lowered its hardness. This investigator reported that the disturbance in structure by repeated cooling was more noted in a fat which was originally cooled slowly. The physical characteristics of butter depended on the process of cooling.

Richardson and Abbott (21) proposed that to eliminate undesirable physical characteristics in butter the cream should be rapidly cooled from a temperature at which the fat is liquid to proper churning temperature. The cream should be churned immediately after cooling. The fat at time of churning would thus be a more or less solidified homogenous mass with a decreased tendency to separate into liquid and crystalline portions. The resultant butter would thus possess that firmness, elasticity, and plasticity required for good spreading quality.

Various investigations (4, 5, 8, 10) have indicated that butter from cream cooled slowly to the desired storage temperature was invariably softer than that made from cream that was rapidly cooled.

Long and intense cooling before churning also increased the hardness of the butter. Valentine and Sargent (28) reported that the rate of cooling cream had more influence on the spreadability of the resulting butter than the temperature to which the cream is cooled.

The Influence of Degree of Solidification of the Fat in Cream on the Churning Time

Rishoi and Sharp (22) have shown that the adjustment of the physical state of the fat globule at low temperature approaches completion in about four hours. This change, the adjustment of the physical state, is the important one which alters the surface properties and adsorption on the fat globules. The amount of solid and liquid fat present in cream varies according to the temperature of the cream and the length of time the cream is held at that temperature (12). Brunner and Jack (2) reported the more fat that was present in a solid state the greater was the time required for churning. Their investigation also indicated that the churning time was not entirely dependent upon the actual degree of solidification in the fat but to a greater extent upon the distribution of the liquid and solid phases on the globular surfaces.

The Effect of Churning on the Physical Characteristics of Milkfat

King (16) summarized the conversion of cream to butter as follows: The fat in cooled cream at churning temperature is present as clusters of globules, and within each globule it is partly in liquid and partly in solid form. Churning of cream breaks up the clusters and causes foam formation. The globules become concentrated to some extent in the film around the air bubbles in the foam and are thus brought into close contact with one another. The movement of the globules over one another in the foam film and the direct concussion between them causes a gradual wearing away of the emulsion-protecting surface layer of phospholipid-protein complex. The globules adhere to form larger and larger particles. Eventually these particles become visible as butter granules. The granules as they form enclose some of the air from the foam. The fat in the granules is still mainly in the globular form. The working of the butter causes the globules to move over one another. Some of them, under the effect of friction and pressure, yield up a portion of the liquid fat enmeshed in the crystalline fat. Other fat globules are broken up by the shearing and sliding effect of the working process. Finally there is enough free liquid fat present to enclose all the water droplets, the remaining undestroyed fat globules, and the air bubbles. The conversion of cream to butter is complete.

King (15), by using the polarizing microscope, has shown that the birefringent* layer of the fat globules in butter is a spherical

* birefringent - Having or characterized by the power of double refraction, which is said to be high or low according as the difference between the refractive indices is large or small.

layer-crystal built up of radially orientated rod-like molecules of the higher melting fat fractions. This "shell-crystal" possesses plastic properties and is possibly related to the mesomorphic substances (liquid crystals). Sometimes this layer-crystal may segregate into small needle crystals orientated tangentially to the globule surface, the fat molecules in these flat needles being orientated perpendicularly to the direction of the needle.

He also showed that in cooled cream only a few fat globules with the birefringent layer were found, even after keeping the cream at the cooling temperature for a long time. If, however, an optimum pressure is exerted on the globules, the optically active peripheral layer is formed, owing to the orientation of the molecules of the higher melting fats. This orientation coincides with the squeezing out of some liquid fat from the globules (formation of free fat) and the clumping of the globules. At higher pressures the fat globules are destroyed.

Effect of Wash Water Temperature on the Physical Characteristics of Butter

The use of cold wash water in the washing of butter granules before working reduces the hardness of winter butter. This has been shown by several investigators (4, 5, 10, 21, 26, 30, 32). According to King's theory (13) of butter structure, the hardness and consistency of butter are, to a large extent, influenced by the amount of and the properties of free fat that is present as cementing medium for the fat globules and the water droplets in the butter. The free fat originates from the destroyed fat globules and is squeezed out of fat globules during the working process.

Danish investigators (3) reported that due to the low working temperature brought about by the chilling of the butter granules, it is chiefly the easy-melting fat fractions that are pressed out of the fat globules and pass over into the free fat phase. There will be little fat crystallization taking place in this phase. Although the butter when removed from the churn is relatively firm, it will not, after it has "set", be as hard as butter that has been worked and removed at higher temperatures. Higher working temperatures cause additional groups of glycerides from fat pressed out of fat globules and from destroyed globules to become part of the "free" fat phase.

Effect of Working on the Physical Characteristics of Butter

Stein (24, p.10) stated that the purpose of working butter is twofold: (1) To bring the butter granules together in a compact mass having a desirable body and characteristic texture, and (2) to incorporate and uniformly distribute the brine in the form of fine droplets.

King (13) has shown that during the working process liquid fat is squeezed out of the fat globules to form the cementing medium necessary to enclose the undestroyed fat globules and the brine droplets.

King (14) also showed that the amount of globular fat decreased to a certain value as the amount of working increased. This decrease was brought about by a lowering in the number of fat globules which were destroyed or squeezed during working to form the liquid portion of the butter.

Storgards (25) reported that the hardness of butter decreased during the working process and rose again on standing due to the release of the liquid phase during working and crystallization during storage. Dolby (5) stated that the hardness of butter, particularly after storage, was little affected by wide differences in the amount of working.

Effect of Storage Time and Temperature on the Physical Characteristics of Butter

The results from earlier investigations at the Oregon Agricultural Experiment Station have suggested that, for the most desirable body and texture, butter should be stored below 40° F. (30). Huebner and Thomsen (10) suggested that to maintain the desirable physical characteristics the butter should be stored promptly after printing at -6° F.

Various investigations in Europe (6, 19, 32) have shown that the hardness of butter increased during storage. King (16) explains the hardening of butter during storage as the result of the manner of cooling the cream after pasteurization and the working temperature. The "setting" or hardening of the finished butter is affected by the temperature of the butter. The hardness generally increases more quickly at higher temperatures and in most cases the hardest butter is obtained at a storage temperature of 55° F.

Effect of Reworking Finished Butter on the Physical Characteristics of Butter

The increase in hardness of finished butter during storage as reported by King (16) is caused by 1) thixotropic phenomena, 2) crystallization of super-cooled fat, and 3) recrystallization of the fat. Therefore, two kinds of framework seem to be established within the butter. Upon reworking these frameworks are broken down. The framework due to thixotropic phenomena is broken down reversibly i.e. it spontaneously forms again and butter regains at least a part of its hardness. The framework built up in the course of crystallization of fat tends to give the butter a brittle, crumbly texture, especially in the case of hard fat. On reworking the framework built up by crystallization is broken down almost irreversibly. The recovery in hardness is much less than in the first case.

Huebner and Thomsen (10) in their investigations of the hardness of butter showed that the reworking of the butter caused by the use of a mechanical screw-type printer reduced the hardness of wintermade butter. They felt that this reworking action to a large extent broke the reticular structures that may have been formed and prevented the formation of crystalline structures as unyielding as the previous ones.

Manufacturing Methods Suggested by Previous Investigators for Overcoming Undesirable Physical Characteristics of Winter-made Butter

To prevent body and texture defects of butter caused by the feeding of alfalfa hay, Richardson and Abbott (21) recommended a preheating treatment prior to churning 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 of 8° F. 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° F. 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.

Coulter and Combs (4) found that the body and texture defects of winter-made butter could be overcome by avoiding excessive cooling of the cream. A churning temperature should be chosen that would result in exhaustive churning in 40 to 50 minutes. They further recommended that granules of butter be washed with 40° to 50° F. wash water and the finished butter stored at 40° F. or below.

Earlier investigations at the Oregon Agricultural Experiment Station (30, 31) resulted in the development of the "50-45-40" method for the manufacture of butter during the fall and winter months. The cream to be made into butter should be cooled slowly after pasteurization to 50° F. and held at this temperature overnight. The use of a churning temperature that will give butter granules in 40 to 50 minutes was recommended. The granules of butter should be the size of small peas and should be washed thoroughly and chilled by means of water at a temperature not higher than 45° F. Working of the butter should be commenced immediately after washing. The finished butter should be stored at 40° F. or lower.

The Danish Dairy Experiment Station has, during the past twenty years, studied different methods of butter manufacture to try to find the most suitable method to use for the manufacture of winter butter (3, 18). Several methods have been used in a number of experiments to determine the most satisfactory procedure. The method that resulted in the most satisfactory body and texture and spreading property is: (a) Cool the cream after pasteurization to 46° F. and hold at that temperature for 2 hours, (b) warm the cream slowly with water in the jacket of the vat at 79° F. to 66° F., (c) maintain this temperature for 6 hours, (d) cool the cream to 61° F. and hold until the next morning. The temperature of the finished butter should be relatively low when it is removed from the churn. It was found in the investigations that the higher the temperature of the butter when removed from the churn during the winter, the harder was the butter after short-time storage regardless of the temperature at which the hardness was measured.

EXPERIMENTAL PROCEDURE

A total of 47,000 pounds of butter has been made in 72 churnings during this investigation. The first ten of these churnings were made for preliminary study. These ten churnings were manufactured in August and September, 1956, and the other 62 were manufactured during the period from October, 1956, to February, 1958.

In October, 1956, a project was initiated at the Experiment Station to study the value of a cream-temperature treatment for the manufacture of butter during fall and winter in improving the physical characteristics of butter. Since that period, churnings of butter have been made, alternately using the cream-temperature treatment and the usual method of manufacture.

The churnings that were made using the cream-temperature treatment procedure will hereafter be referred to as the experimental churnings. Churnings that were manufactured using the procedure that had been commonly used at the Experiment Station will be called the control churnings.

CREAM USED

Cream for the experimental and control churnings was obtained from milk produced during the fall, winter and early spring months in the Willamette Valley. Nine of these churnings were made from gathered cream, the remaining 61 were from sweet cream. Two churnings were manufactured from cream obtained from milk produced in the alfalfa hay feeding region of Southern Oregon.

The letter E following the churning number indicates the churning was experimental. The letter A following the churning number refers to control churnings.

Cream was generally received and churned once a week. Usually only one method was used each week. On five occasions split churnings were made; a part of the cream was churned with the control procedure, the remainder was churned, using the experimental procedure.

Equipment Used

Two vat pasteurizers, one 2500-pounds cream capacity and the other 850-pounds, were used to pasteurize and temperature-treat the cream. These pasteurizers were of the spray-jacket type, the cream being heated or cooled by circulating hot or cold water in the jacket. The pasteurizers were equipped with indicating and recording thermometers. They were also equipped with manual temperature controls for the treatment involved in the temperature-treating procedure.

A 1,000-pound butter capacity "Cherry-Burrell" wooden roll-less churn and a 400-pound "Vane" wooden roll-less churn were used to churn the cream. The smaller churn was used only when split churnings were made. The larger churn was equipped with two speeds; high speed, 30 revolutions per minute for churning, and low speed, 16 revolutions per minute for working. The periphery of the barrel of this churn was 15 1/2 feet. The smaller churn had only one speed, 26 revolutions per minute. This speed was used for churning and working. The periphery of the barrel of the smaller churn was 10 2/3 feet.

Cold storage rooms maintained at -10°, 40° and 48° F. were used for storing and tempering the butter.

A "Doering" screw-type butter printer was used to print the finished butter after it had "set" or hardened about 48 hours at 40° F.

CREAM TREATMENT

Cream that was to be churned was pasteurized at 155° F. and held at this temperature for 30 minutes. Cream for the control churnings was cooled immediately to 46° F. , or below, and held at that temperature overnight. If necessary, the cream was warmed to churning temperature the next morning and was churned immediately.

Cream to be used for the experimental churnings was cooled to 46° F. immediately after pasteurization and held at that temperature for two hours. At the end of that time the cream was heated slowly, with water in the jacket of the vat at 79° F., to 66° F. One hour was usually required to warm the cream to 66° F. This temperature was maintained for six hours. The cream was then cooled to 61° F. and held overnight. The next morning the cream was cooled to churning temperature and churned immediately.

A churning temperature was used for both the control and the experimental churnings that would result in the formation of butter granules approximately one-fourth inch in diameter after 40 to 50 minutes of churning. A churning temperature 2° to 4° lower than that used for the control churnings was necessary for the experimental churnings. If the same temperature was used, large granules would form in 10 to 20 minutes.

STANDARD CHURNING PROCEDURE

Churning procedures were the same for both the control and experimental churnings. Immediately after the buttermilk was drained off, the butter granules were rinsed with cold tap water to remove some of the buttermilk from the surface of the granules.

Water for washing the butter granules was cooled in the 2500-pound capacity pasteurizer. When the investigation was first initiated, it was thought that two washes of short duration (one minute each) were necessary to chill the granules thoroughly. When two batches of wash water were used, approximately 150 gallons were used in each, the churn was revolved for one minute at working speed for washing and the water was then drained off.

As the investigation proceeded, it was shown that one wash of long duration (three to four minutes) chilled the granules thoroughly. When one washing was used, approximately 250 gallons of water were used. The churned was revolved three to four minutes at churning speed.

To remove excess water after the wash water was drained off, the churn was revolved at working speed with the door ajar for five minutes. 2.2 per cent salt, that had been tempered to the temperature of the butter granules with cold water was added and the butter was worked until very little free moisture was apparent on the surface of the butter. A determination for moisture was made in order to determine if any make-up water was necessary. The make-up water was tempered to the temperature of the butter before it was added to the butter. The butter was then worked until there was no apparent moisture on the surface of the butter and the characteristic sheen of finished butter was observed.

The butter was removed from the churn and placed in parchment-lined wire baskets. These were then placed in a 40° F. refrigerator for the butter to harden.

VARIATIONS

It was desired to study the affect of different wash water temperatures in both the experimental and control churnings. Thirty-seven churnings were made using two washings, one at 52° F., and the other at 46° F. Ten churnings were made using 52° F. wash water and nine churnings were made using 45° F. to 52° F. water. In addition, 26 churnings were made using wash water below 45° F.

Since the churns used had only one working speed, modifications in the working technique were limited. Storgards (25) suggested that intermittent working with intervals during which crystallization could proceed would improve the physical characteristics of butter. Three churnings were made with 5-minute intervals between 10-minute working periods. No improvement was noted when the butter was examined at 48° F. in the spreading property and hardness. This modification was therefore not further investigated.

A second modification that was investigated was allowing the unwashed butter granules to remain in the churn with the door closed three hours before the working process was started. Three churnings were made using this modification. No benefit was observed from this modification and it was therefore not further investigated.

SAMPLING PROCEDURE

Two pounds of butter were removed from the churn upon completion of the working procedure. These were molded into one-pound prints in a wooden mold and wrapped in parchment paper. They were placed immediately in refrigerated rooms maintained at - 10° and 40° F. where they were stored for two weeks. A six-ounce sample was also removed at this time for melting point and iodine number determinations. This sample was stored at 40° F.

Two one-pound prints of butter were obtained after printing and wrapped in parchment paper. They were stored at - 10° and 40° F. for two weeks. The samples were tempered to 48° F. for 72 hours before being examined for physical characteristics.

METHODS OF EXAMINING PHYSICAL CHARACTERISTICS

Hardness

A hardness tester similar to the one used by the Danish investigators (18) was designed and constructed by National Appliance Company, Portland, Oregon (See Figure 1) for hardness determinations. The tester consisted of a constant speed motor which forced a plunger 4 cm^2 down into the butter at a rate of 20 mm. per minute. A scale placed below the plunger measured the hardness in kilograms. Hardness was determined in an insulated room maintained at 48° F. The butter was tempered for 72 hours in this room before hardness determinations were run. The force exerted by the plunger was measured at the end of 30 seconds. The plunger during this time traveled a distance of 10 mm. Duplicate determinations were run and the hardness was considered to be the average of the two. The majority of the duplicate determinations were identical. Hardness determinations were run on the one-pound prints removed from the churn and stored at -10° and 40° F. and on the one-pound prints obtained after being printed and stored at -10° and 40° F.

Body, Texture, Spreading Property and Leakiness

All of the samples procured at the churn and after printing were examined for body and texture and spreading property by G.H. Wilster, H. P. C. Nielsen and R. W. Stein of the Department of Food and Dairy Technology of the Oregon Agricultural Experimental Station three weeks after the butter had been manufactured. The one-pound prints of butter were tempered to 48° F. for 72 hours before being examined. Each print was removed from the refrigerator and examined immediately for spreading property. The time the butter was out of the 48° F. refrigerator was 3 to 5 minutes. A

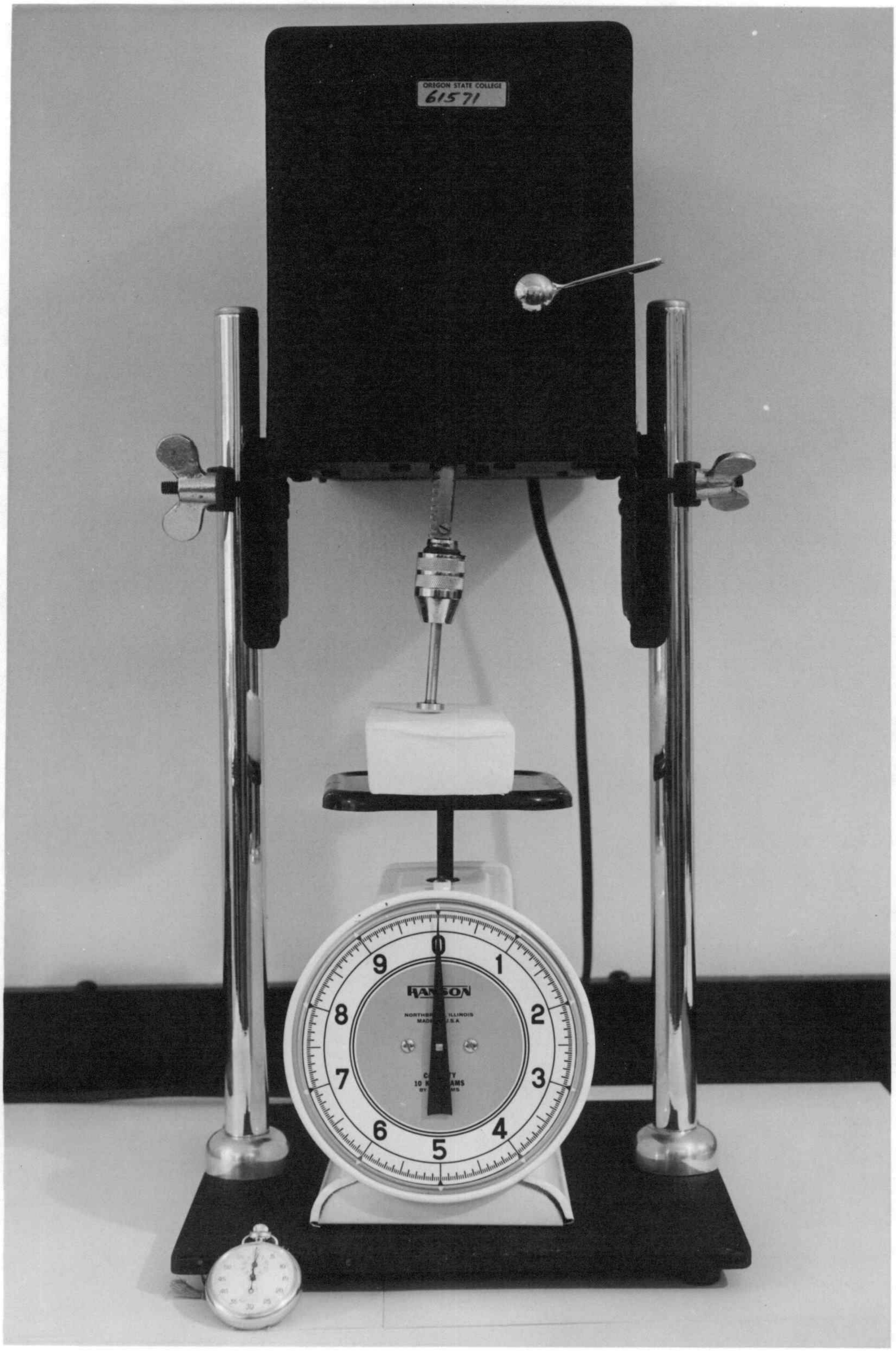


FIGURE 1 - Hardness Tester

Plunger not engaged

stainless steel table knife was used to obtain a sample from each print of butter. The sample was placed on a wooden board and spread with the knife. The spreading property of the butter was noted and rated poor, fair, good or excellent. Any body and texture defects such as crumbliness and stickiness were also noted at this time.

Indicator paper developed by the Danish investigators (3, 18) and brought from Denmark by G. H. Wilster was used for the detection of leakiness. The yellow indicator paper was impregnated with bromphenol-blue and hydrochloric acid. A slice of butter was cut from a pound of butter and the paper placed upon the cut side. The appearance on the paper of dark blue spots after one minute indicated the presence of free moisture. Using this method it was possible to estimate the per cent leakiness of the butter by the number of spots on the paper. Testing for leakiness was done at the same time the butter was examined for body and texture and spreading property. In addition, all the butter samples were examined visually for free moisture.

Melting Point and Iodine Absorption Number of the Milkfat

Dry milkfat for the melting point and iodine number determinations was obtained by filtering the sample of butter obtained at the churn when at a temperature of 110° F. To prevent oxidation of the fat at this temperature, the fat was filtered as rapidly as possible and cooled immediately after filtration to 40° F.

The melting point of the milkfat was determined on the fat from the butter in 51 of the churnings manufactured from October, 1956 to September, 1957. Melting point determinations were made using the Wiley Method (1, p. 429).

Iodine absorption numbers were run on the fat from the butter produced in 40 of the churnings made during the fall, winter and early spring. These values were obtained by using the Hanus Method (1, p. 432).

Keeping Quality

To determine the effect of different storage temperatures on the physical characteristics and to determine if the temperature treatment involved in the experimental procedure increased bacterial activity a keeping quality test was run. One pound samples of butter from control and experimental churnings were stored at 40°, 48°, 60° and 70° F. After seven and fourteen days of storage at the different temperatures, the samples were tempered to 48° F. for 48 hours and examined for flavor, body and texture and spreading property.

The samples were examined by G.H. Wilster, H.P.C. Nielsen and R.W. Stein.

Bacteria Counts on the Pasteurized Cream

Because of the higher storage temperatures for the pasteurized cream involved in the temperature-treatment procedure, standard plate counts (17, p. 617) were run on the cream to detect any increase in bacterial population. Samples were taken for plating after the cream had been pasteurized, cooled and held at 46° F. for two hours, after holding at 66° F. for six hours, and after holding at 61° F. for 12 hours. Plates were poured and incubated for 48 hours at 90° F. Counts were made at the end of this time. Standard plate counts were run on nine of the experimental churnings.

RESULTS AND DISCUSSION

Preliminary Study

A total of 66 one-pound prints of commercially-made butter purchased in grocery stores in Oregon was examined at 48° F. for physical characteristics during the fall and winter of 1956-1957. Results of the examination are given in Table I. The majority of these samples were found to be hard, crumbly, leaky, sticky and to spread poorly.

To determine the influence of the standard churning procedure on the physical characteristics of the resultant butter, ten churnings were manufactured in the dairy products laboratory during the late summer and early fall of 1956 using the standard procedure. Samples of butter were obtained from the ten churnings and examined at 48° F. for physical characteristics. Results of the examination of butter samples from the ten churnings are given in Table II.

The butter from 8 of the 10 churnings possessed poor spreading property. It was hard, leaky, crumbly, and sticky. The butter from churnings 1 and 7 had fair spreading property, but they were hard, leaky, and sticky.

The results of this preliminary study prompted the initiation of further study to determine the effect of a cream-temperature treatment on the physical characteristics of the butter.

TABLE I

PHYSICAL CHARACTERISTICS OF COMMERCIAL BUTTER PURCHASED AND EXAMINED FALL AND WINTER 1956-57

SAMPLE NO.	DATE EXAMINED	PHYSICAL CHARACTERISTICS AT 48° F.
1	7-26-56	Firm, crumbly, tough, sticky
2	7-26-56	Sticky, leaky, hard
3	7-26-56	Greasy, sticky, leaky
4	7-26-56	Hard, crumbly, leaky
5	7-26-56	Short grained, crumbly, leaky
6	7-26-56	Sticky, hard, leaky
7	7-26-56	Hard, sticky, crumbly
8	7-26-56	Sticky, hard, crumbly
9	7-26-56	Sticky, leaky
10	8-2-56	Sticky, greasy, soft
11	8-2-56	Hard, crumbly
12	8-2-56	Hard, leaky, sticky
13	8-2-56	Hard, crumbly
14	8-2-56	Firm, crumbly, sticky
15	8-2-56	Very hard, crumbly
16	8-2-56	Greasy, leaky, good spread.
17	8-2-56	Hard, very crumbly
18	8-2-56	Hard, leaky, sticky
19	8-2-56	Greasy, good spread.
20	8-2-56	Crumbly, hard, leaky
21	8-2-56	Very hard, brittle
22	8-21-56	Very hard, crumbly
23	8-21-56	Very crumbly, hard
24	8-21-56	Sticky
25	8-21-56	Soft, good spread.
26	8-21-56	Crumbly, sticky
27	8-21-56	Excellent spreadability
28	8-21-56	Hard, waxy
29	8-21-56	Very hard, crumbly
30	8-21-56	Very hard, crumbly
31	8-21-56	Hard, crumbly
32	8-21-56	Soft, excellent spread.
33	8-21-56	Leaky, good spread.
34	8-21-56	Leaky, hard
35	8-21-56	Leaky, hard
36	8-21-56	Hard, crumbly, leaky

SAMPLE NO.	DATE EXAMINED	PHYSICAL CHARACTERISTICS AT 48° F.
41	9-6-56	Very hard, sticky
42	9-6-56	Very hard, very crumbly
43	9-6-56	Hard, crumbly
44	9-6-56	Waxy
45	9-6-56	Hard
46	9-6-56	Soft, sticky
47	9-6-56	Very hard
48	9-6-56	Soft, excellent spread.
49	9-6-56	Hard, waxy
55	10-4-56	Soft- greasy
56	10-4-56	Leaky, sticky
57	10-4-56	Brittle, sticky
58	10-4-56	Leaky, hard, crumbly
59	10-4-56	Hard, crumbly
60	10-4-56	Hard, sticky
61	10-4-56	Hard, brittle, flaky
62	10-4-56	Very hard, crumbly
87	12-4-56	Leaky, sticky, hard, crumbly
88	12-4-56	Hard, crumbly, sticky
89	12-4-56	Hard, sticky, crumbly
90	12-4-56	Hard, sticky
91	12-4-56	Very sticky, soft
92	12-4-56	Leaky, hard, crumbly
93	12-4-56	Hard, very crumbly
94	12-4-56	Hard, sticky
115	1-21-57	Hard, crumbly, sticky
116	1-21-57	Hard, crumbly, sticky
117	1-21-57	Hard, crumbly, sticky
144	3-1-57	Hard, crumbly, sticky
145	3-1-57	Hard, crumbly, sticky

TABLE II

CHARACTERISTICS OF BUTTER MADE IN PRELIMINARY STUDY WITH STANDARD CHURNING PROCEDURE

CHURNING NO.	DATE MFG.	WASH WATER TEMPERATURE OF	HARDNESS IN Kg/4cm^2 AT 48°F.	SPREADING PROPERTY AT 48°F.	BODY AND TEXTURE AT 48°F.
1	8-15-56	52 & 46	2.9	Fair	Hard, leaky, sticky
2	8-17-56	52 & 46	2.8	Poor	Hard, crumbly
3	8-22-56	52 & 46	2.8	Poor	Hard, sticky
4	8-24-56	52 & 46	2.9	Poor	Hard, crumbly
5	8-29-56	52 & 46	2.8	Poor	Hard, crumbly
6	8-31-56	52 & 46	2.9	Poor	Hard, crumbly
7	9-5-56	52 & 46	2.6	Fair	Leaky, sticky
8	9-12-56	52 & 46	2.8	Poor	Brittle, sticky
9	9-19-56	52 & 46	2.8	Poor	Hard, crumbly, leaky
10	9-19-56	52 & 46	2.8	Poor	Hard, crumbly, leaky

Control Churnings

During the course of this investigation, 30 churnings of butter were manufactured using the procedure that was commonly used in the dairy products laboratory. Hardness values and comments on the body and texture and spreading property for the butter in these 30 churnings are given in Table III.

Butter from the 30 churnings, with one exception, possessed undesirable physical characteristics. Churning 43A, manufactured in the late spring, was the only one with a good spreading property. The use of wash water below 45° F. in 10 churnings did not appear to improve the physical characteristics of the butter.

Experimental Churnings

A total of 32 churnings of butter was made during this series of churnings using the cream-temperature treatment. Results from the examination of the butter made in these churnings are given in Table IV.

In general, the butter manufactured when the cream-temperature treatment was used possessed superior physical characteristics to that made with the control procedure. Not a single experimental churning received a poor rating on spreading property. Of the 32 churnings, 14 resulted in butter with a good spreading property and 12 resulted in butter with an excellent spreading property. Manufacturing reports for the 12 churnings of butter possessing excellent

TABLE III

CONTROL CHURNINGS, WASH WATER TEMPERATURE, HARDNESS AND PHYSICAL CHARACTERISTICS

CHURNING NO.	DATE MFG.	WASH WATER TEMPERATURE °F	HARDNESS IN $Kg/4cm^2$ AT 48°F	SPREADING PROPERTY AT 48°F	BODY AND TEXTURE AT 48°F
12A	10-18-56	52 & 46	2.8	Poor	Sticky
14A	11-1-56	52 & 46	2.7	Poor	Sticky, crumbly
16A	11-15-56	52 & 46	2.6	Poor	Hard, crumbly, sticky
18A	12-6-56	52 & 46	2.9	Poor	Hard, crumbly, sticky
20A	12-12-56	52 & 46	2.8	Poor	Hard, crumbly, sticky
22A	1-10-56	52 & 46	2.7	Fair	Sticky
24A	2-1-57	52 & 46	2.7	Fair	Sticky, leaky
26A	2-21-57	47	2.7	Poor	Hard, crumbly, sticky
29A	3-7-57	52	2.9	Poor	Hard, crumbly, sticky
32A	3-28-57	52	2.8	Poor	Hard, crumbly, sticky
34A	4-11-57	52	2.9	Poor	Leaky, sticky
36A	4-25-57	52	2.7	Poor	Hard, crumbly, sticky, leaky
39A	5-9-57	52	2.9	Poor	Hard, crumbly, brittle, sticky
40A	5-10-57	40	2.8	Fair	Sticky, leaky
41A	5-16-57	42	2.8	Poor	Hard, crumbly, brittle, sticky
42A	5-23-57	39	2.8	Fair	Sticky, leaky
43A	5-24-57	40	2.7	Good	-
44A	5-31-57	39	2.8	Fair	Firm, leaky
45A	6-6-57	39	2.8	Poor	Brittle, hard, sticky
46A	6-7-57	39	3.0	Poor	Hard, crumbly, sticky
47A	6-13-57	38	3.0	Poor	Hard, brittle, sticky
48A	6-27-57	38	2.9	Poor	Hard, brittle, sticky

CHURNING NO.	DATE MFG.	WASH WATER TEMPERATURE °F	HARDNESS IN Kg/4cm^2 AT 48° F	SPREADING PROPERTY AT 48°F	BODY AND TEXTURE AT 48° F
50A	8-22-57	46	2.9	Poor	Hard, crumbly, sticky
53A	9-19-57	47	3.0	Poor	Hard, crumbly, sticky
54A	9-26-57	48	2.9	Poor	Hard, crumbly, sticky
56A	10-18-57	46	2.8	Poor	Hard, crumbly, sticky
57A	10-21-57	48	2.7	Poor	Hard, crumbly, sticky
61A	11- 4-57	46	2.9	Poor	Hard, crumbly, sticky, leaky
65A	11-18-57	46	2.9	Poor	Crumbly, hard, leaky
70A	12-16-57	45	2.9	Poor	Hard, crumbly, leaky

TABLE IV

EXPERIMENTAL CHURNINGS CREAM TEMPERATURE-TREATED
WASH WATER TEMPERATURES, HARDNESS, AND PHYSICAL CHARACTERISTICS

CHURNING NO.	DATE MFG.	WASH WATER TEMPERATURE °F	HARDNESS IN Kg/4cm^2 AT 48°F	SPREADING PROPERTY AT 48°F	BODY AND TEXTURE AT 48°F
11E	10-11-56	52 & 46	2.6	Good	Waxy, soft
13E	10-25-56	52 & 46	2.6	Good	Soft, sticky
15E	11- 8-56	52 & 46	2.6	Good	Sticky, leaky
17E	11-29-56	52 & 46	2.8	Fair	Firm, sticky
19E	12-13-56	52 & 46	2.6	Excellent	-
21E	1-10-57	52 & 46	2.7	Fair	Sticky
23E	2- 2-57	52 & 46	2.6	Fair	Sticky
25E	1-31-57	52 & 46	2.6	Good	-
27E	2-21-57	52 & 46	2.7	Good	Leaky, sticky
28E	2-28-57	52 & 46	2.7	Fair	Soft, sticky
30E	3-14-57	52	2.6	Excellent	Soft, sticky
31E	3-21-57	52	2.8	Good	Soft, sticky
33E	4- 4-57	52	2.7	Fair	Leaky, sticky
35E	4-18-57	52	2.8	Good	-
37E	4-25-57	47	2.7	Excellent	-
38E	5- 2-57	45 & 40	2.7	Excellent	-
49E	8-15-57	38	2.8	Excellent	Soft, waxy
51E	8-29-57	36	2.8	Good	-
52E	9-12-57	40	2.7	Excellent	-
55E	10-11-57	40	2.8	Excellent	Waxy
58E	10-25-57	42	2.6	Good	Waxy
59E	10-28-57	36	2.7	Good	Waxy, sl. leaky
60E	11- 1-57	44	2.6	Fair	Waxy, leaky

CHURNING NO.	DATE MFG.	WASH WATER TEMPERATURE °F	HARDNESS IN Kg/4cm^2 AT 48°F	SPREADING PROPERTY AT 48°F	BODY AND TEXTURE AT 48°F
62E	11- 8-57	40	2.8	Good	Leaky
63E	11-11-57	42	2.9	Good	Hard
64E	11-15-57	40	2.8	Good	Waxy, leaky
66E	11-22-57	40	2.7	Excellent	-
67E	12- 6-57	40	2.7	Good	Leaky
68E	12- 9-57	40	2.7	Excellent	-
69E	12-13-57	43	2.8	Excellent	-
71E	2-10-58	41	2.7	Excellent	-
72E	2-11-58	44	2.7	Excellent	-

spreading property are given in Table V.

It is postulated that storage of the cream at the temperatures and periods of time used in the experimental procedure had an influence on the proportion of liquid fat present in the fat crystals. King (13) has stated that the hardness and consistency of butter is influenced by the amount of liquid fat present. Brunner and Jack (2) have shown that the more fat there is in a solid state in the cream at the time of churning, the greater is the time required for churning and, conversely, the more fat there is present in the liquid state the shorter is the time required for churning. Their study further indicated that the churning time is not entirely dependent upon the actual degree of solidification in the fat, but to a greater extent upon the distribution of the liquid and solid phases on the globular fat surfaces.

It was stated in the experimental procedure that a churning temperature 3° to 4° F. lower than that used for the control churnings was necessary for the experimental churnings to prevent too rapid churning. It can be assumed from the churning temperatures that were used with the experimental churnings that a larger proportion of liquid fat was present in the cream at churning that was temperature-treated. This may be partly illustrated by the split churnings that were made. Cream from the same source was used, a portion was used with the control procedure and the remainder was temperature-treated. In each case the temperature-treated cream

TABLE V

SELECTED MANUFACTURING REPORTS OF BUTTER
WITH EXCELLENT PHYSICAL CHARACTERISTICS
CREAM TEMPERATURE-TREATED

Churning Number	19E	30E	37E	38E	49E	52E
Pasteurization Temp. Held 30 Minutes °F.	155	155	155	155	155	155
Length of time to cool in hrs.	2¼	2	1½	1½	2¼	2½
Temp. After Cooling °F.	46	46	46	46	46	46
Temp. in Morning °F.	61	61	61	61	61	61
Temp. when Churned °F.	48	47	47	46	47	47
Time Held Before Churning Hrs.	16	18	19	18	20	17
Minutes of Churning	25	30	30	40	25	20
Size of Granules Inch	¼-½	¼-½	¼-½	¼	1	½
Wash Water Temp. °F.	52-46	52	45	45-40	38	40
Temp. Butter After Washing °F.	51	53	50	44	42	42
Mins. Working Before First Moisture	40	25	23	15	30	70
First Moisture	15.8	14.3	16	11.5	13.7	16.9
Pounds Water Added	7.5	20	4.8	55	25	
Mins. Working After Water Added	15	15	7	35	12	-
Total Time of Working After Wash Water Drained	55	40	30	50	42	70
Temp. Butter at end of Working °F.	59	60	56	52	53	48
Temp. Butter When Removed From Churn	59	60	56	52	53	48
Pounds Butter	573	681	649	911	714	733
Per Cent Overrun	25.1	23.7	25.3	24.3	26.4	24.0
Per Cent Fat in Buttermilk	.48	.53	.45	.42	.38	.40

TABLE V (CONTINUED)

Churning Number	55E	66E	68E	69E	71E	72E
Pasteurization Temp. Held 30 Minutes °F.	155	155	157	157	155	156
Length of time to cool in hrs.	2	$2\frac{1}{4}$	$2\frac{1}{2}$	$2\frac{1}{2}$	$1\frac{1}{2}$	2
Temp. After Cooling °F.	46	46	46	42	46	46
Temp. in Morning °F.	61	61	60	61	61	60
Temp. When Churned °F.	46	44	45	45	48	48
Time Held Before Churning Hrs.	20	18	18	16	18	18
Minutes of Churnings	30	45	35	43	80	35
Size of Granules Inch	$\frac{1}{4}$	$\frac{1}{2}$	$\frac{1}{4}-\frac{1}{2}$	$\frac{1}{4}-\frac{1}{2}$	$\frac{1}{4}-\frac{1}{2}$	$\frac{1}{2}$
Wash Water Temp. °F.	40	40	40	40	41	44
Temp. Butter After Washing °F.	42	44	44	43	42	45
Mins. Working Before First Moisture	35	43	45	42	50	35
First Moisture	13.7	15.5	14.9	15.2	14.2	13.7
Pounds Water Added	28.5	11.5	17.5	14.5	23	30
Mins. Working After Water Added	10	7	15	12	10	15
Total Time of Working After Wash Water Drained	45	50	60	54	60	50
Temp. Butter at End of Working °F.	52	53	52	54	50	52
Temp. Butter When Removed From Churn	52	53	52	54	50	52
Pounds Butter	784	700	759	778	921	818
Per Cent Overrun	24.0	24.7	24.8	26.2	24	24.2
Per Cent Fat in Buttermilk	.36	.46	.45	.34	.34	.28

churned in almost the same time but at a temperature 3° to 4° F. lower. This is shown in Table VI. The need for the lower churning temperature could be caused by the increased proportion of liquid fat present in the fat globules.

TABLE VI

SPLIT CHURNINGS, CHURNING TEMPERATURE AND TIME

CHURNING NO.	DATE MFG.	CHURNING TEMP °F	CHURNING TIME (MIN)
19E	12-12-56	48	25
20A	12-12-56	52	35
21E	1-10-57	48	35
22A	1-10-57	52	35
26A	2-21-57	50	70
27E	2-21-57	47	55
36A	4-25-57	50	35
37E	4-25-57	47	30

At the start of this investigation, butter from a number of experimental churnings was criticized for stickiness. It was found that the use of wash water at a temperature below 45° F. not only aided in the prevention of this defect but also helped produce desirable physical characteristics in the butter. It is possible that the use of a churn with more than one working speed would aid in the prevention of stickiness. As the churns that were used in this investigation had only one working speed, it was impossible to investigate this possibility.

Low-temperature water (below 45° F.) for washing the butter granules has been shown by several investigators (4,5,10,21,26,30,32) to have a beneficial effect on the body and texture of the butter. Of the butter in the 12 churnings that possessed an excellent physical property previously referred to, only two were made using wash water above 45° F. Wash water temperatures in the other 10 ranged from 38° to 45° F.

According to King's theory (13) of butter structure, the hardness of butter is influenced by the amount and properties of the free fat that is present as a cementing medium for fat globules and the water droplets of butter. This free fat originates from the destroyed fat globules and is squeezed out of the fat globules during the working process.

It can be assumed, therefore, that by chilling the butter granules with the cold wash water the amount of free fat is at a minimum before working is commenced. It will therefore take longer to work out enough free fat to act as the cementing medium. The free fat released during this low-temperature working process is pressed out, not by a higher temperature, but by the squeezing and breaking up of the fat globules during the working process. Since the free, or liquid, fat is released by the working action and not by heat, the fat should remain free, or liquid, at the lower temperature (below 50° F.). This could account partly for the greater softness and smoother spreading property of winter-made butter that had been washed with chilled water.

Thus the assumption may be made that both the cream-temperature treatment and the use of low-temperature wash water increased the amount of liquid or free fat present in the butter and materially affected the physical characteristics of the butter. Of the two, the cream-temperature treatment was found to more effective while both together were the most effective.

Hardness

Hardness values were obtained from the one-pound samples of butter taken from each churning. Measurements were made at 48° F. Eighteen control and 18 experimental churnings were randomly selected and a statistical analysis was made on the hardness values. These values appear in Table VII. Statistical comparison was made on the effects of: (A) control and experimental methods of manufacture and (B) printing the butter immediately after churning and printing with a screw-type printer after the butter had become firm. Results of the analysis are presented in Table VIII.

The analysis of variance indicated that the cream-temperature treatment resulted in a softer bodied butter than the control procedure. It also showed that printing with a screw-type printer after the butter had become firm lessened the hardness values of the butter. Since the interaction between treatments and sampling time was not significant, this indicated that the difference between experimental and control churning methods is the same at both sampling times.

TABLE VII

HARDNESS VALUES OF BUTTER FROM CONTROL AND EXPERIMENTAL CHURNINGS SAMPLED AT VARIOUS TIMES

HARDNESS IN $Kg/4cm^2$ AT 48° F.

EXPERIMENTAL CHURNINGS			CONTROL CHURNINGS		
	SAMPLING TIMES			SAMPLING TIMES	
CHURNING NO.	OUT CHURN	AFTER PRINTING	CHURNING NO.	OUT CHURN	AFTER PRINTING
13E	2.3	2.6	14A	2.7	2.8
17E	2.6	2.8	16A	2.7	2.6
19E	2.8	2.6	18A	2.9	2.9
23E	2.7	2.6	20A	2.8	2.8
25E	2.9	2.6	22A	2.8	2.7
27E	2.7	2.7	24A	3.0	2.7
28E	2.7	2.7	26A	2.8	2.7
30E	2.7	2.6	29A	2.9	2.9
31E	2.8	2.7	32A	2.9	2.8
35E	2.8	2.8	34A	2.9	2.9
37E	2.8	2.7	36A	2.9	2.7
51E	2.8	2.7	50A	2.9	2.9
52E	2.7	2.7	53A	3.0	3.0
55E	2.8	2.6	54A	3.0	2.9
59E	2.7	2.7	56A	2.8	2.9
62E	2.8	2.8	57A	2.9	2.7
63E	2.9	2.7	61A	2.9	2.8
64E	2.8	2.8	65A	2.9	2.8

TABLE VIII

ANALYSIS OF VARIANCE OF HARDNESS VALUES FROM TABLE VII

SOURCE VARIATION	d.f.	SUM OF SQUARES	MEAN SQUARE	F
Between treatments	1	.2813	.2813**	20.68
Between sampling times	1	.0613	.0613**	7.96
Interaction between treatments and sampling times	1	.0012	.0012	.16
Among churnings within treatments	34	.4636	.0136	
Interaction between sampling times and churnings within treatments	34	.2625	.0077	

** Significant at probability level .01

Treatment means
- Experimental = 2.71 ± .019
- Control = 2.83 ± .019

Sampling time means
- Out churn 40° = 2.81 ± .015
- After cut 40° = 2.75 ± .015

In addition, throughout the period of this study, it was noticed by the persons who examined the butter for physical characteristics, that the butter obtained after printing was consistently softer and spread easier than the butter that was sampled immediately after churning. This was also shown by the hardness values given in Table VII. The sampling time means illustrate this very well. Samples removed from the churn had an average hardness value of 2.81 while the samples obtained after printing had an average hardness value of 2.75. This is in agreement with recent studies by Huebner and Thomsen (9, 10).

Printing the butter with a screw-type printer tends to rework the butter. This reworking of the butter breaks up crystalline structures and prevents the formation of new structures as unyielding as the original ones.

Melting Point and Iodine Values

Melting point values obtained from dry milkfat from 41 churnings of butter manufactured during the period from October 1956 to September 1957 are shown in Table IX.

The values ranged from a low of 89.9° F. in April to a high of 95° F. in January. (See Figure 2).

Iodine values of the milkfat from 38 churnings of butter appear in Table X. The iodine values varied from a high of 41.40 in April to a low of 29.65 in March. (See Figure 3).

TABLE IX

MELTING POINT OF MILKFAT FROM BUTTER IN 41 CHURNINGS
OCTOBER, 1956 TO SEPTEMBER, 1957

CHURNING NO.	DATE MFG.	MELTING POINT °F
11E	10-11-56	91.04
12A	10-18-56	93.74
13E	10-25-56	93.92
14A	1- 1-56	93.74
15E	11- 8-56	94.28
16A	11-15-56	93.92
17E	11-29-56	94.28
18A	12- 6-56	94.10
19E	12-12-56	94.28
20A	12-12-56	94.82
21E	1-10-57	95.0
22A	1-10-57	94.92
23A	2- 2-57	94.1
24A	2- 2-57	94.1
25E	1-31-57	93.92
26A	2-21-57	93.74
27E	2-23-57	94.64
28E	2-28-57	94.46
29A	3- 7-57	93.74
30E	3-14-57	93.74
31E	3-21-57	93.92
32A	3-28-57	92.2
33E	4- 4-57	89.96
34A	4-11-57	92.66
35E	4-18-57	92.12
36A	4-25-57	90.68
37E	4-25-57	91.22
38E	5- 2-57	92.12
39A	5- 9-57	92.12
40A	5-10-57	91.94
41A	5-16-57	92.48
42A	5-23-57	90.86
43A	5-24-57	91.58
44A	5-31-57	91.58
45A	6- 6-57	92.12
46A	6- 7-57	92.84
47A	6-13-57	92.84
48A	6-27-57	91.94
49E	8-15-57	92.12
50A	8-22-57	92.48

CHURNING NO.	DATE MFG.	MELTING POINT °F
51E	8-29-57	92.30

FIGURE 2 MELTING POINT OF MILKFAT FROM 41 CHURNINGS

OCTOBER 1956 TO SEPTEMBER 1957

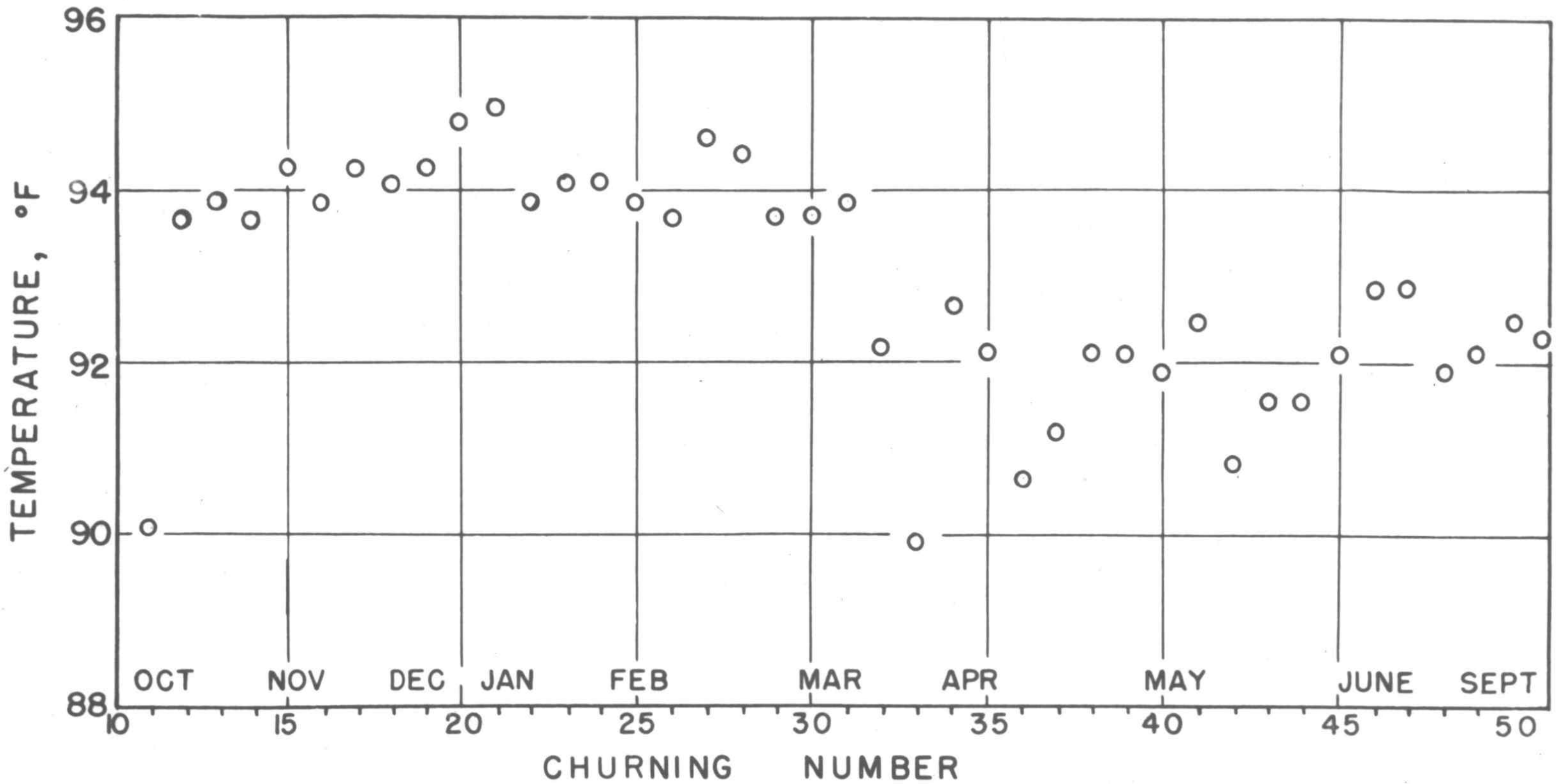


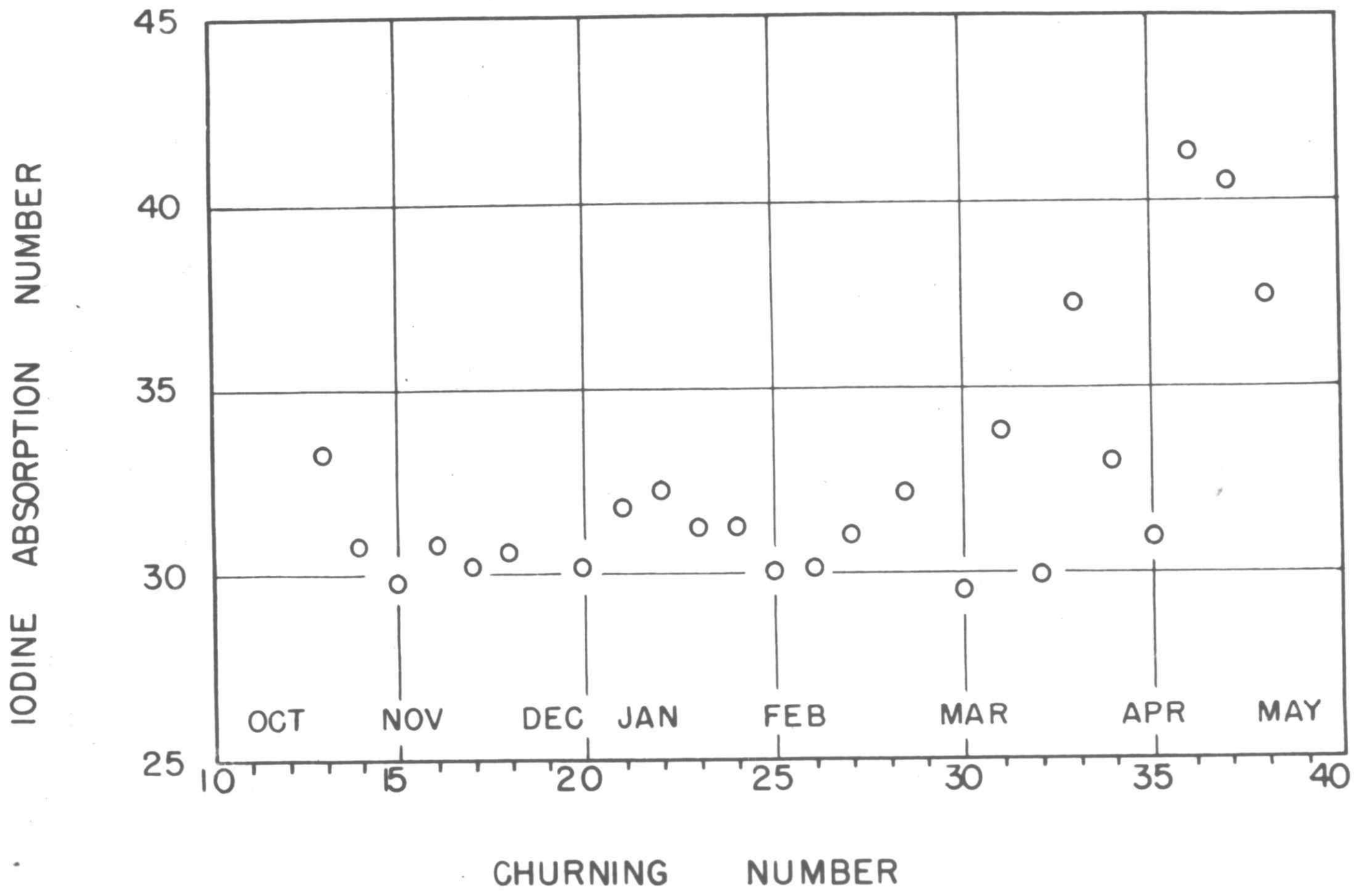
TABLE X

IODINE ABSORPTION NUMBER OF MILKFAT FROM BUTTER IN 38 CHURNINGS

CHURNING NO.	DATE MFG.	IODINE ABSORPTION NUMBER
13E	10-25-56	33.3
14A	11- 1-56	30.7
15E	11- 8-56	29.95
16A	11-15-56	30.93
17E	11-29-56	30.30
18A	12- 6-56	30.75
20A	12-12-56	30.30
21E	1-10-57	31.70
22A	1-10-57	32.35
23E	2- 2-57	31.4
24A	2- 1-57	31.4
25E	1-31-57	30.1
26A	2-21-57	30.2
28E	2-28-57	31.18
29A	3- 7-57	32.20
30E	3-14-57	29.65
31E	3-21-57	33.9
32A	3-28-57	29.98
33E	4- 4-57	37.34
34A	4-11-57	33.05
35E	4-18-57	31.05
36A	4-25-57	41.40
37E	4-25-57	40.60
38E	5- 2-57	37.50
52E	9-12-57	35.75
55E	10-11-57	32.50
56A	10-18-57	29.50
57A	10-21-57	27.30
58E	10-25-57	29.58
59E	10-28-57	29.65
61A	11-4-57	29.93
62E	11- 8-57	30.6
64E	11-15-57	29.98
66E	11-22-57	30.63
67E	12-9- 57	30.80
68E	12- 9-57	30.50
69E	12-13-57	27.80
70A	12- 6-57	27.95

FIGURE 3 IODINE ABSORPTION NUMBER OF MILKFAT FROM 24 CHURNINGS

NOVEMBER, 1956 TO MAY, 1957



It was possible to manufacture butter with desirable physical characteristics when the melting point of the fat was high and the iodine value was low using the cream-temperature treatment. For example, butter from Churning 30E, the milkfat of which had an iodine value of 29.65 and a melting point value of 93.7° F., indicating a relatively hard fat, was not criticized for any body and texture defects and had a smooth spreading property. Conversely, it was possible to manufacture butter with undesirable physical characteristics using the control procedure when the iodine value and melting point value indicated relatively soft fat. The milkfat in control Churning 36A had an iodine value of 41.40 and a melting point of 90.6° F. which indicated relatively soft fat. Butter made from this milkfat was criticized for being hard, crumbly, sticky and exhibiting poor spreadability.

Detection of Free Moisture

Use of the yellow indicator paper for the detection of free moisture in butter was shown to be more accurate than visual observation. Ten samples of butter from control and experimental churnings were randomly selected and examined visually and with the indicator paper for free moisture. Results of the detection of free moisture with the indicator paper are shown in Figure 4. No free moisture was detected in samples 2, 7 and 8. A small amount was detected in samples 1, 3, 4, 5 and 10. Samples 6 and 9 were

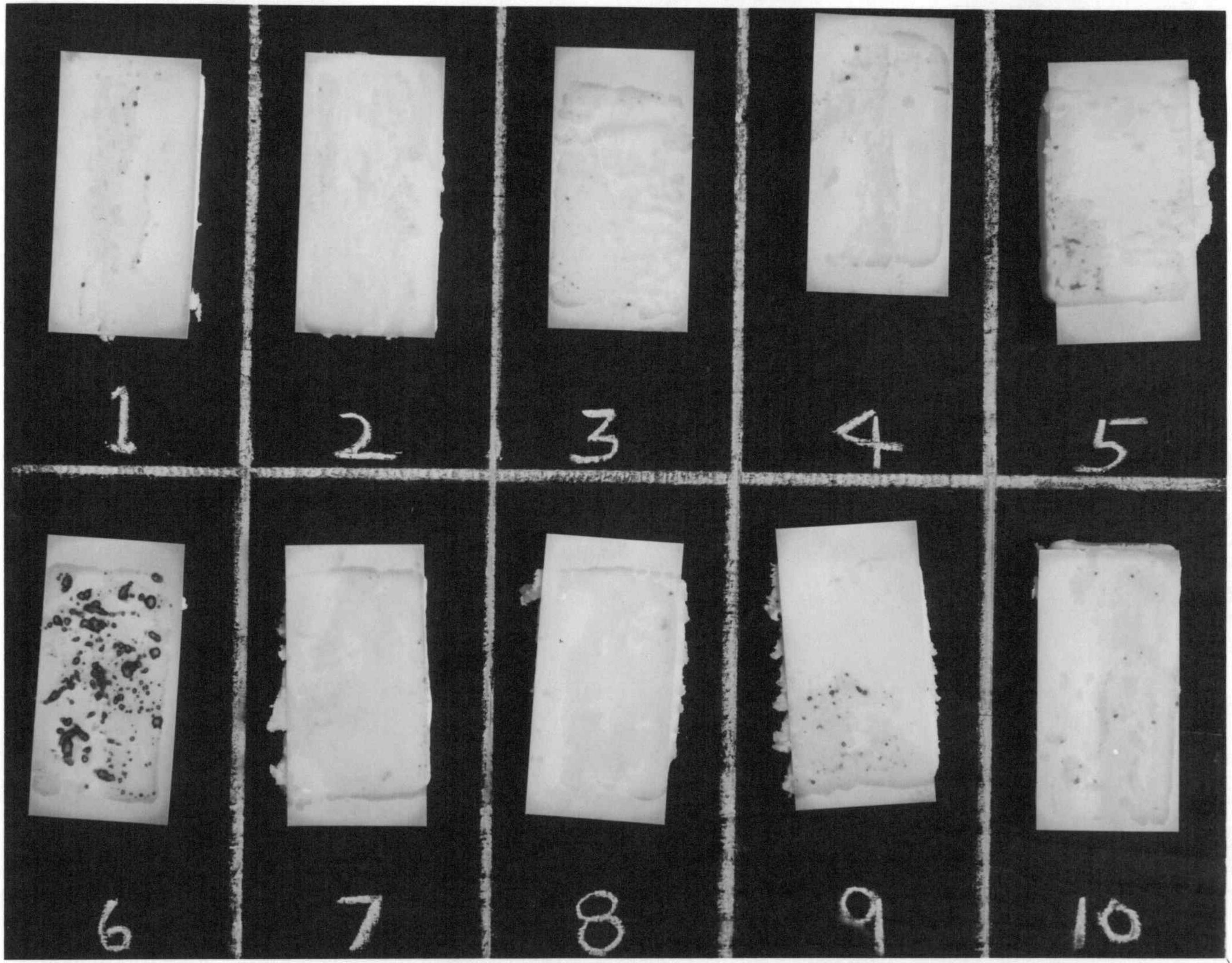


Figure 4. Detection of free moisture in butter with yellow indicator paper. Dark spots on paper indicate free moisture. (See also, Table IX)

definitely leaky. A comparison of the two methods is given in Table XI.

Storage Time and Temperature

Butter was examined for physical characteristics throughout this investigation when at a temperature of 48° F. Previous investigators (9, 20, 23) used higher temperatures in their studies of the hardness and spreadability of butter. It was felt in the present study that 48° F. was much nearer the temperature of butter when it is removed from a household refrigerator and used by consumers. It was further thought that if butter possessed desirable characteristics at this temperature it would be more readily accepted by consumers.

It was stated in the Review of Literature that a storage temperature below 40° F. for the butter aided in the production of a softer-bodied butter and that higher storage temperatures tended to cause the butter to be firmer. This was shown by the data obtained in the keeping quality test which was made to determine the effects of storage temperatures on the physical characteristics and flavor of the control and experimental butter. The data are given in Table XII.

No change was noticed during the 14-day storage period in the physical characteristics and flavor of the experimental butter at 40° F. During the first 7 days of storage at 48° F. no apparent change in the body and texture took place in the butter, but after 14

TABLE XI

COMPARISON VISUAL DETECTION OF FREE MOISTURE AND INDICATOR PAPER (SEE ALSO FIGURE 4)

SAMPLE NO. FROM FIG. 4	FREE MOISTURE	
	VISUAL DETECTION	INDICATOR PAPER
1	None	Slight
2	None	None
3	None	Slight
4	Slight	Slight
5	None	Slight
6	Definite	Definite
7	None	None
8	None	None
9	None	Moderate
10	Slight	Slight

TABLE XII

KEEPING QUALITY TEST

EXPERIMENTAL BUTTER

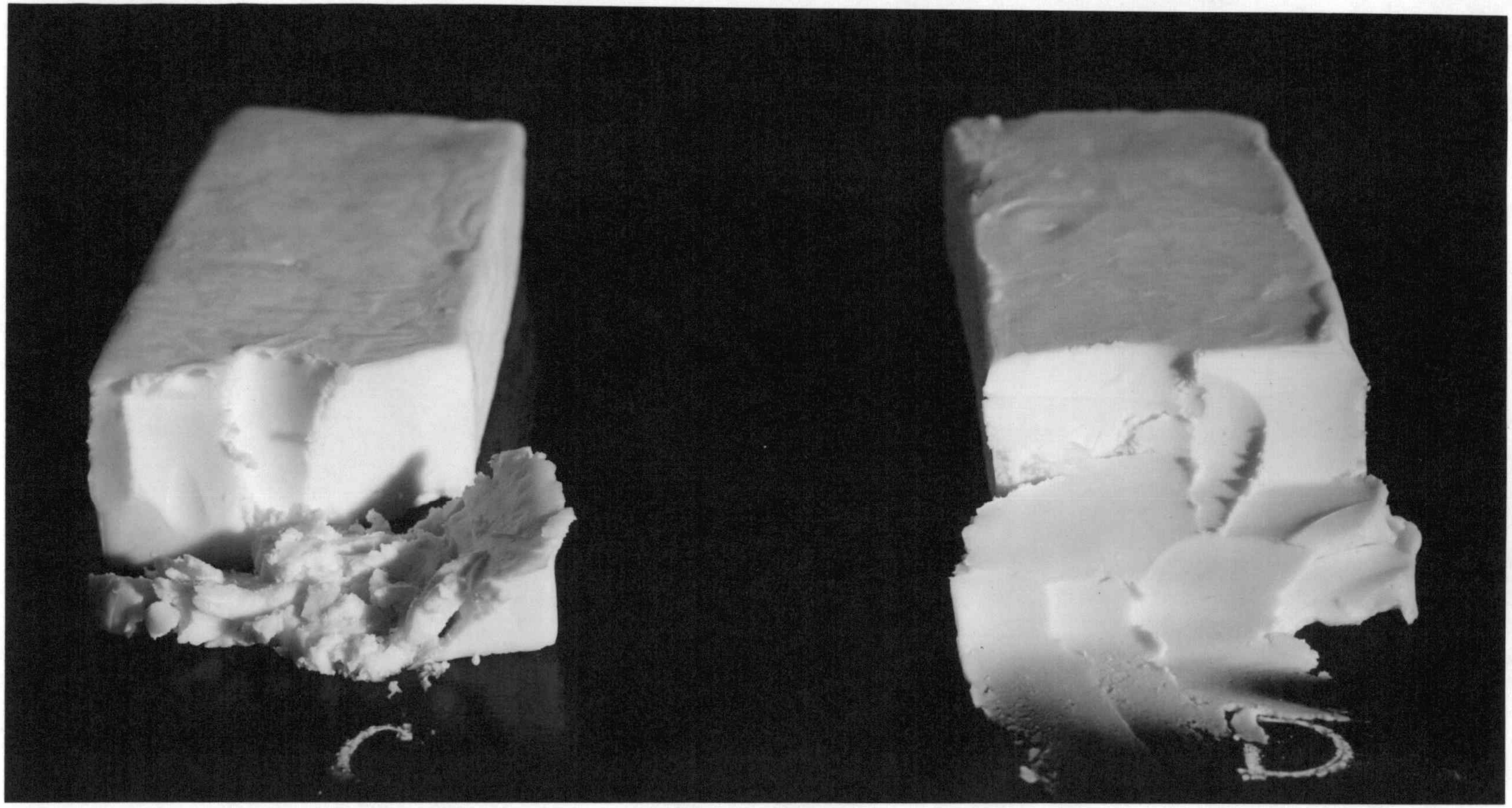
	INTO STORAGE		7 DAYS		14 DAYS	
STORAGE TEMP.	FLAVOR SCOPE	PHYSICAL CHARACTERISTICS	FLAVOR SCOPE	PHYSICAL CHARACTERISTICS	FLAVOR SCOPE	PHYSICAL CHARACTERISTICS
42° F	93	Excellent	93	Excellent	92	Excellent
48° F	93	Excellent	93	Excellent	92	Good
60° F	93	Excellent	91	Sticky	91	Hard, brittle
70° F	93	Excellent	89	Hard, brittle, crumbly	88	Very hard, crumbly, brittle

CONTROL BUTTER

	INTO STORAGE		7 DAYS		14 DAYS	
STORAGE TEMP.	FLAVOR SCOPE	PHYSICAL CHARACTERISTICS	FLAVOR SCOPE	PHYSICAL CHARACTERISTICS	FLAVOR SCOPE	PHYSICAL CHARACTERISTICS
42° F	93	Hard, crumbly, sticky	92	Hard, crumbly, sticky	92	Hard, crumbly, sticky
48° F	93	Hard, crumbly, sticky	92	Hard, crumbly, sticky	92	Hard, crumbly, sticky
60° F	93	Brittle, sticky	91	Hard, crumbly, sticky	89	Hard, crumbly, sticky
70° F	93	Hard, crumbly, sticky	89	Hard, crumbly, sticky	87	Very hard, brittle, very crumbly

days at this temperature the butter became firmer. Changes in the physical characteristics of the butter stored at 60° and 70° F. were very noticeable after 7 days storage. After 14 days at 60° and 70° F. the butter had lost its smooth spreading property when examined at 48° F. and was very hard, brittle and very crumbly. The change in the body and texture of butter stored at high temperatures was probably caused by the release of the fat fractions that are liquid at that temperature and upon cooling, the crystallization of these liquid fractions gave a structure more unyielding than the previous one.

Storage temperature effects were similar for the butter from the control churnings. At 60° and 70° the poor physical properties became more pronounced when the butter was examined at 48° F. Changes in the flavor score of butter from both methods of manufacture were identical.



Sample C stored at 70°F

Sample D stored at -10°F

Figure 5. Effect of high storage temperatures. Samples examined at 48°F.

The effect of high storage temperatures on physical properties of butter is illustrated in Figure 5. Two pounds of butter from an experimental churning were used. Both samples were stored at -10° F. for 2 months. Sample C was then warmed to 70° F. and held at that temperature for 36 hours. Sample D remained at -10° F. Both samples were then tempered to 48° F. for 48 hours and examined for physical characteristics at that temperature. Sample C was very hard, sliced easily, but was difficult to spread as it was brittle and tended to crumble quite easily. Sample D was soft and waxy and spread smoothly.

To determine the effects of long-time storage at -10° F. on the physical characteristics of the control and experimental butter, seven samples of butter from control churnings and ten samples of butter from experimental churnings were re-examined when at 48° F. after varying storage periods at -10° F. Results of the original examination and the re-examination are given in Table XIII.

Very little change was noted in the physical characteristics of both the experimental butter and the control butter during storage at -10° F. It was significant that the excellent spreading property of the butter from the experimental churnings was not lost during low-temperature storage period.

T.E. Fallihee, Federal Butter Grader and Lyle W. Hammark, creamery operator, examined samples of butter from 20 churnings at 48° F. for physical properties. They commented that the butter made with the experimental method was superior in spreading property to that manufactured by the usual procedure.

TABLE XIII

PHYSICAL CHARACTERISTICS OF CONTROL AND EXPERIMENTAL BUTTER
AFTER STORAGE AT -10° F.

CHURNING NO.	DATE MFG.	PHYSICAL CHARACTERISTICS AT 48° F	TIME STORED -10° F MONTHS	DATE RE-EXAMINED	PHYSICAL CHARACTERISTICS AT 48° F
53A	9-19-57	Hard, crumbly, sticky	7	3-27-58	Hard, crumbly, sticky
54A	9-26-57	Hard, crumbly, sticky	7	3-27-58	Hard, crumbly, sticky
56A	10-18-57	Hard, crumbly, sticky	6	3-27-58	Hard, crumbly, sticky
57A	10-21-57	Hard, crumbly, sticky	6	3-27-58	Hard, crumbly, sticky
61A	11- 4-57	Hard, crumbly, sticky	5	3-27-58	Hard, crumbly, sticky
65A	11- 8-57	Leaky, hard, crumbly	5	3-27-58	Leaky, hard, crumbly
70A	12-16-57	Hard,leaky,crumbly,sticky	4	3-27-58	Hard,leaky,crumbly,sticky
58A	10-25-57	Waxy, good spreadability	6	3-27-58	Sl. leaky, good spread.
59E	10-28-57	Waxy, good spreadability	6	3-27-58	Waxy, good spreadability
60E	11- 1-57	Soft, good spreadability	5	3-27-58	Waxy, good spreadability
62E	11- 8-57	Waxy, soft,excel. spread.	5	3-27-58	Waxy, excel. spread.
66E	11-22-57	Waxy, excel. spread.	5	3-27-58	Pleasantly pliable
67E	12- 7-57	Soft, good spreadability	4	3-27-58	Good spreadability
68E	12- 9-57	Waxy, excel. spread.	4	3-27-58	Soft, smooth, excel.spread.
69E	12-13-57	Waxy, excel. spread.	4	3-27-58	Smooth, excel. spread.
71E	2-10-58	Soft,waxy, excel.spread.	2	3-27-58	Smooth,waxy,soft,excel. spread.
72E	2-11-58	Soft, waxy,excel.spread.	2	3-27-58	Smooth,waxy,soft,excel. spread.

A - Churning 72E
Manufactured 2/11/58

B - Churning 70A
Manufactured 12/16/57

Figure 6. Samples of butter manufactured with experimental and control procedures. Examined at 48°F.

Figure 6 illustrates the difference in physical characteristics obtained when the two manufacturing procedures were used. Sample A was from experimental churning 72E made in February, 1958. The butter was waxy, smooth, and spread easily at 48° F. Sample B was from control Churning 70A, made in December, 1957. This butter was hard, crumbly and spread poorly.

Standard plate counts on the pasteurized cream involved in the cream-temperature treatment are given in Table XIV. The counts on the cream showed a slight increase in bacterial numbers. No effect was noted on the keeping quality of the experimental butter due to this slight increase in the number of bacteria. This was shown in Table XII.

During the entire period of this study fat tests were made on the buttermilk from each churning. The n-butyl alcohol Babcock procedure was used (16, p. 873). No difference in the average fat loss between the experimental and control churnings was noted.

TABLE XIV

TOTAL BACTERIA COUNTS ON PASTEURIZED CREAM
EXPERIMENTAL CHURNINGS

CHURNING NO.	SAMPLING TIMES - NO. COLONIES PER Ml. OF CREAM		
	C-1	C-2	C-3
35E	-30	-3000	3000
38E	-30	-3000	-3000
60E	-30	-3000	-3000
62E	-30	-3000	-3000
63E	-30	-3000	-3000
64E	-30	-3000	-3000
67E	-30	-3000	3000
68E	-30	-3000	3000
69E	-30	-3000	3000

Sampling times:

C-1 - Cream after pasteurization cooled to 46° F. and hold for 2 hours.
C-2 - Cream after holding at 66° F. for 6 hours.
C-3 - Cream after holding at 61° F. for 12 hours.

SUMMARY

Commercial samples of butter obtained from grocery stores in Oregon, and samples of butter from ten churnings of butter manufactured in the dairy products laboratory using the usual manufacturing procedure were examined for physical characteristics during the fall and winter of 1956-1957. The majority of these samples when examined at 48° F. were found to be hard, crumbly, sticky, leaky and generally spread poorly.

Results of a preliminary investigation prompted the initiation of a study to investigate the effects of manufacturing methods on the physical characteristics of butter. Two methods were investigated, one, the control procedure, was essentially the method commonly used to manufacture butter in Oregon. The other method was a cream-temperature treatment which consisted of: (1) cooling the cream after pasteurization to 46° F. and holding at that temperature for two hours, (2) warming the cream slowly with water in the jacket of the vat at 79° F. to 66° F. and holding at that temperature for 6 hours, and (3) cooling the cream to 61° F. and holding without further treatment overnight.

Samples of butter were obtained from each of 72 churnings made and critically examined when at a temperature of 48° F. for physical characteristics. Hardness values were determined by means of a specially constructed hardness tester. Effects of chilled wash water,

storage temperature of the finished butter and printing with a screw-type printer on the physical characteristics of the butter were studied.

These examinations showed that the cream-temperature treatment resulted in butter that was relatively soft, waxy and spread smoothly when examined at 48° F. The butter made in accordance with the control procedure was generally hard, crumbly, sticky, and spread poorly.

The use of cold wash water for the chilling of the butter granules before working had a desirable effect on the body and texture of the butter manufactured. Printing of the butter after it had become firm with a screw-type printer lessened the hardness and slightly improved the spreading property.

Storage of the finished butter at -10° F. retained the excellent physical characteristics of the butter made in accordance with the experimental procedure. Storage temperatures above 40° F. caused an increase in the hardness of the butter; the greatest increase occurred when the butter was stored at 70° F. for several days and subsequently cooled to a lower temperature.

CONCLUSIONS

1. Physical characteristics of butter made during fall and winter in Western Oregon were improved materially by using a modified manufacturing technique.

2. The cream-temperature treatment used in the experimental churnings resulted in butter that was relatively soft, waxy and smooth spreading. Butter manufactured with the control procedure was generally hard, crumbly, sticky and spread poorly.

3. It was possible to manufacture butter with the experimental method that was relatively soft, waxy and smooth spreading when the melting point of the milkfat was high and the iodine value low.

4. It was possible to manufacture butter that was hard, crumbly, sticky and had a poor spreading property with the control procedure when the melting point of the milkfat was low and the iodine value was high.

5. Use of wash water below 45° F. aided in obtaining butter that had a desirable body and texture.

6. Printing of the butter with a screw-type printer after the butter was hardened lessened the hardness values and slightly improved the spreading property.

7. The smooth spreading property of the butter from the cream that was temperature-treated was not lost during storage at -10° F. even when it was stored at this temperature for several months.

8. Changes in the flavor score of both the experimental and control butter were similar during storage of the butter at various temperatures.

9. The use of the cream-temperature treatment in connection with the manufacture of butter in commercial butter manufacturing plants could easily be adopted either with or without automation. This method involves a slight departure from the usual procedure but it could be adopted quite readily. It should be pointed out, however, that if full benefit is to be derived from this treatment, expert workmanship and attention to details on the part of the buttermaker is absolutely necessary.

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