THE INFLUENCE OF NEUTRALIZERS UPON CERTAIN PROPERTIES OF THE CREAM AND BUTTER

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TABLE OF CONTENTS

INTRODUCTION

The practice of neutralizing cream received for buttermaking is now well established among commercial creameries. The benefits derived from neutralization have been recognized by the butter manufacturer since the universal acceptance and utilization of pasteurization. The modern creamery operator realizes that the acidity of the cream must be reduced or standardized before pasteurizing and churning in order to produce uniform butter throughout the seasons, to improve the flavor and keeping quality of the butter, and, to reduce fat losses.

In general, the neutralizing agents which are recommended as satisfactory for cream neutralization, may be classed either as lime or as soda neutralizers. The lime neutralizers may be calcium lime, which contains less than five per cent magnesium or magnesium lime which contains from 30 to 50 per cent magnesium. The soda neutralizers may be sodium carbonate, sodium bicarbonate, or various combinations of these two salts. Potassium carbonate is also used in a mixture with sodium carbonate and recently sodium hydroxide has been recommended for the neutralization of cream.

The new trend in neutralization has been to control the acidity and pH of cream and butter and the acidity of the butterfat within a definite narrow range in an effort to improve the original quality and keeping properties of butter. The increasing amount of butter research in recent years has contributed useful information. However, more information is needed relative to comparative values of the various neutralizers which are on the market, especially in regard to their efficiency of acid reduction and to their effect on the flavor, body and texture, and keeping properties of the butter. There also exist considerable divergency of opinion in regard to the extent to which the acidity should be reduced in the cream, butter and butterfat by the various neutralizers in order to produce butter of maximum quality. Therefore, this study was conducted in an effort to contribute further fundamental information regarding certain of these factors.

REVIEW OF LITERATURE

Influence of Neutralizers on Butter Score

One of the main objectives in using a neutralizer in cream is to produce a more desirable product than is produced when sour cream is pasteurized without first being subjected to acid reduction. Early work done by Dean (21) and Bouska (8) has shown that the pasteurization of high acid cream results in coagulation of the casein, causing the cream to become stringy or ropy and producing a butter with a high curd content and a scorched flavor. Hunziker (39) points out that the neutralizer does not, itself, improve the flavor of butter, but that the acid reduction merely assists in preventing the flavor damaging tendency of the combined action of high acid and high pasteurization temperatures. However, Dean (21) found that neutralizing cream of approximately 0.50 per cent to 0.15 per cent acidity, either before or after pasteurization, improved the score of the butter three points over that from unneutralized samples. Frandsen et.al. (26) reported that neutralizing very sour cream with lime improved the score of the butter from two to five points. Jackson (44), Mortensen (49) and Sproule and Grimes (67) are also among the early workers to report that the quality of butter could be improved by neutralization.

Procedure of Neutralization

Numerous investigators have expressed the belief that defects commonly attributed to neutralization are more likely to be due to faulty methods of adding the neutralizer than to the degree of neutralization or the kind of neutralizer used (Bouska (8), Fabricius (23), Fouts and Keith (25), Hunziker

(39) and Nelson (54). The procedure of adding a neutralizer to cream is discussed in detail by Hunziker (39).

The neutralizing solution: A major factor said to be the cause of neutralization defects is the strength of the neutralizing solution. Dean (21) experimented with milk-lime and obtained satisfactory results using a 25 per cent suspension. Hunziker (39), Walts and Libbert (71) and Stiritz and Ruehe (69) recommend suspensions of 10 to 20 per cent lime, pointing out that the weaker solutions gave better results. Bouska (8), Fabricius (23), and Fouts and Keith (25) observed that 10 to 15 per cent suspensions of lime were satisfactory.

Soda neutralizers are used in somewhat weaker solutions than limes. Fabricius (23), Hunziker (39), Stiritz and Ruehe (69), Fouts and Keith (25), and Walts and Libbert (71) suggest that 10 per cent solutions of the various neutralizers may be used without danger of neutralizer defects.

Neutralization temperature: The temperature of the cream when a neutralizer is added is another factor of major importance relative to neutralizing difficulties. Stiritz and Ruehe (69) pointed out that when a neutralizer was added to cream at a temperature below 90 - 100° F. a neutralizer flavor was imparted to the butter, whereas a temperature of 115° F. had a tendency to result in a scorched flavor in the butter. Fouts and Keith (25), Hunziker (39) and Walts and Libbert (71) also recommend a cream temperature of 90 - 100° F. and indicate that higher temperatures cause a neutralizer flavor. However, temperatures of 80 - 85° F. have been recommended by Nelson (54) and Fabricius (23).

Speed of reaction: Several investigators have noted a difference in the speed with which different neutralizers reduce the acidity of the cream.

These findings have resulted in recommendations that the cream be held for a short period of time after adding the neutralizer and before pasteurization heat is applied; the length of the period depending on the reaction speed of the neutralizer. Stiritz and Ruehe (69) conducted studies dealing with this factor and, on the basis of their findings, suggest the following minimum holding periods: one to two minutes for the sodas, four to five minutes for the calcium limes, and 10 to 15 minutes for magnesium limes. Welts and Libbert (71) also studied the speed of reaction using various neutralizers and consider the reaction sufficiently complete for acidity determinations after nine minutes when sodas are used, after 15 minutes when calcium limes are used, and after 20 minutes when magnesium limes are used for neutralization. They state that the above holding periods include a five-minute safety margin after the reaction has stopped.

Other workers recommend holding periods of fifteen to twenty minutes for limes and five to fifteen minutes for sodas (Fabricius (23), Fouts and Keith (25), Hunziker (39) and Nelson (54)).

Double neutralization: When cream high in acid is to be neutralized, the practice of neutralizing in two successive steps has been recommended by certain workers. When such a practice is followed, either the same neutralizer or a different neutralizer for each step may be utilized.

Stiritz and Ruehe (69) double-neutralized cream before pasteurization by adding various combinations of lime and soda neutralizers to reduce the acidity of the cream 0.60 per cent to 0.20 per cent. They found that a single neutralizer produced higher score butter than when two neutralizers were used, either mixed together or added separately. Jensen (47) conducted a similar experiment and concluded that there are no advantages to be gained by double neutralization.

Abbott (1), Fabricius (23), Fouts and Keith (25), Hunziker (39) and Nelson (54) suggest the procedure of adding enough lime to cream of over 0.60 per cent acidity to reduce the acidity to 0.35 per cent and then completing the neutralization with a soda neutralizer. Fabricius (23) and Hunziker (39) recommend that the second addition of a neutralizer be added to the cream after pasteurization. Fabricius (23) states that the above procedure is less apt to produce a neutralizer flavor in the butter than the practice of adding all of the neutralizer before pasteurization of the cream. Hunziker (39) concluded that double neutralization failed to appreciably improve the flavor of butter.

Fouts and Keith (25) experimented with high acid cream, in some cases over one per cent in acidity, using (a) various combinations of calcium lime and sodium carbonate or sodium bicarbonate, (b) various combinations of magnesium lime and sodium carbonate or sodium bicarbonate, and (c) calcium or magnesium lime and sodium carbonate. The butter made in their experiment had an average score of 88 to 89. They noted that butter made from cream neutralized with two-thirds magnesium lime and one-third sodium carbonate, added separately, scored 0.3 to 0.8 point higher than butter made from the same lots of cream neutralized by the other methods.

Physical Properties of Cream and Butter

Several investigators have pointed out that the addition of a neutralizer to cream brings about certain changes in the physical properties of cream and butter.

Hunziker (39) and later Fabricius (23) have pointed out that limes have a tendency to cause cream to thicken. The thickening effect is more pronounced in high acid cream due to the larger amount of lime necessary to reduce the acidity to a definite range. This increase in viscosity due to the addition of lime causes the cream to behave sluggishly in the vat, increasing the tendency for the cream to burn on the coils and results in a cooked flavor in the butter.

Sodas, however, tend to have a stabilizing effect on protein and thereby cause the cream to become thinner, according to Stiritz and Ruehe (69), Hunziker (39), Fabricius (23) and Davies (20).

Hunziker (39), Fabricius (23), and Davies (20) observed that the use of lime in high acid cream often caused a mealy texture in butter. Davies (20) noted that butter made from cream neutralized with lime was more susceptible to textural changes through small differences in methods of handling the cream and working the butter than when sodas were utilized. Since, in some cases, winter cream has been partly destabilized by freezing, Fabricius (23) recommends that soda neutralizers be used in winter cream as sodas tend to produce a smoother bodied butter than limes. Davies (20) believes that the excellent textural qualities of Dominian butters are due to the exclusive use of sodium bicarbonate.

Efficiency of Acid Reduction

The determination of the amount of a neutralizer to add to reduce the acidity of cream to the desired range is obtained on the basis of calculation involving the neutralization of lactic acid. Results have shown, however, that such calculations do not at all times give proper values.

Lime neutralizers: Numerous investigators, notable: Cox (12), Hunziker (39), Sommer and Menos (66), Walts and Libbert (71), and Wiley (76), have observed that when neutralizing cream with lime the calculated reduction in acidity is not obtained. Hunziker and Hosman (40) found that not all of the lime neutralizer added to cream reacted with the lactic acid present, but that a portion of the lime combined with the casein to form calcium caseinate. The reduction in acidity fell short of that theoretically calculated by about 20 per cent. Walts and Libbert (71) and Wiley (76) have confirmed and extended this work.

Wiley (76) reduced the acidity of cream from 0.40 per cent to 0.25 and 0.10 per cent, (pH 5.85 and 6.60) with lime, and observed only 75 and 86 per cent efficiency in the reduction. He (74, 75, and 76) attributed this lack of theoretical reduction to precipitation of tricalcium phosphate brought about by the excess calcium contributed by the neutralizer; this precipitation increasing the buffering power of the cream at the pH ranges to which the acidity is usually reduced. This is in agreement with the earlier suggestions of Sommer and Menos (66).

Soda neutralizers: Soda neutralizers react in cream to form carbon dioxide and, unless the carbon dioxide is driven off during pasteurization, the calculated reduction in acidity is not obtained. Walts and Libbert (71), Bird, Fabricius and Breazeale (7), and Wiley (76) observed that the calculated reduction in acidity was obtained when soda neutralizers were used to reduce the acidity of cream to 0.20 per cent acidity. However, McDowall and McDowell (50) used sodium bicarbonate to reduce the acidity of skimmilk from 0.40 per cent to 0 and obtained the theoretical reduction in acid to all points above 0.10 per cent, when the samples were heated for one minute at 190° F. or boiled. Attempts to reduce the theoretical acidity to 0 gave final acidities of 0.065 and 0.035, respectively, by the above methods of heating.

The following table shows the results obtained by Wiley (76) when sodium bicarbonate was used as the neutralizer:

Theoretical Reduction in Acidity	Actual Reduction in Acidity	pH	Percentage of Theoretical Reduction Obtained
0	0	4.90	-
0.17	0.17	5.71	100
0.29	0.28	6.02	97
0.38	0.38	6.40	100
0.44	0.44	6.63	100
0.49	0.465	6.83	95
0.52	0.47	6.95	90
0.57	0.48	7.10	84
0.67	0.52	7.39	78

The above results are the values obtained after flash pasteurization. He states that the failure to obtain the theoretical reduction in acidity at the lower acidites was due to the retention of carbon dioxide by the cream. McDowall and McDowell (50) gave a similar explanation for their failure to obtain the theoretical acid reduction with sodium bicarbonate.

Effect of pasteurization on the acid reduction by various neutralizers: Often it is desirable to determine the accuracy of neutralization soon after adding the neutralizer to the cream and before pasteurization. However, the titration values obtained at this point in the procedure do not give reliable information as to the extent of acid reduction in the cream at the end of the process (Hunziker (39), Stiritz and Ruehe (69), Walts and Libbert (71), Wiley (74) and McDowall and McDowell (50)). Pasteurization at 160° F. for fifteen minutes was found by Stiritz and Ruehe (69) to reduce the acidity from 0.065

to 0.075 per cent, when cream of 0.60 per cent acidity was neutralized to 0.20 with a soda neutralizer. Walts and Libbert (71) under similar conditions observed a reduction in acidity of 0.04 to 0.06 per cent.

Wiley (76) made a thorough study of the acid reduction in milk of 0.40 per cent acidity using sodium bicarbonate. A portion of his results follows:

Results with Sodium Bicarbonate

Before Pasteurization		After Flash Pasteurization at 180° F.	
Titratable Acidity Per Cent	pH	Titratable Acidity Per Cent	pH
0.57	4.89	0.56	4.90
0.42	5.65	0.40	5.72
0.39	5.99	0.29	6.02
0.35	6.13	0.19	6.40
0.33	6.23	0.13	6.63
0.315	6.27	0.105	6.83
0.305	6.32	0.10	6.95
0.30	6.42	0.09	7.10
0.29	6.47	0.05	7.39

He explains this failure to obtain the theoretical reduction in acidity before pasteurization to be due to the retention of carbon dioxide, and the greater the degree of neutralization desired the greater the amount of carbon dioxide that must be expelled during pasteurization. The reduction in acidity before pasteurization at low acidity ranges,was less than 50 per cent of the theoretical. Although this experiment was carried out with milk, Wiley (76) believes that the results can also be applied to the neutralization of cream. McDowall and McDowell (50) confirmed the above findings and give a similar explanation for the results obtained.

Wiley (76) found that the method of pasteurization affects the amount of carbon dioxide retained by the cream. The theoretical reduction in acidity was more nearly obtained by flash pasteurization and surface cooling than by the vat method when sodium bicarbonate was used, since a slightly greater amount of carbon dioxide was expelled.

Experiments on the influence of heat on the acid reduction of lime neutralized cream has been conducted by Stiritz and Ruehe (69), Walts and Libbert (71) and Wiley (76). These investigators found that pasteurization of cream neutralized with lime reduced the acidity in cream from 0.02 to 0.06 per cent. Stiritz and Ruehe (69) and Walts and Libbert (71) showed that large pasteurization reductions in acidity were obtained when magnesium lime was used as the neutralizer than when calcium limes were employed.

Effect of Neutralizers on the Composition of Butter

Data concerning the effect of the various neutralizers on the composition of the resulting butter are scarce.

McKay and Larson (52) concluded from work conducted by one of the authors that butter made from cream neutralized with lime to 0.25 per cent acidity contained no more lime than butter made from whole milk to which no lime had been added and contained less lime than a number of samples of dairy butter. However, Frandsen, et. al. (26) report analyses made by Bouska, as follows:

	Treatment of the Cream	Chemical Results	
		Casein	Lime
1.	Raw, very sour cream, no lime added	1.18	0.065
2.	Country butter	1.31	0.004
3.	Country butter	1.60	0.112
4.	Country butter	1.00	0.054
5.	Moderately sour, slightly neutralized with lime	0.69	0.068
6.	Moderately sour, slightly neutralized with lime	1.24	0.065
7.	Very sour, neutralized with lime	0.95	0.065
8.	Very sour, excessively neutralized with lime	1.16	0.126

They report that butter from cream neutralized with lime contained an average of 0.075 per cent of calcium oxide, while butter from untreated cream contained an average of 0.032 per cent calcium oxide. However, examination of these data show some of the untreated samples to give values as high as the neutralized samples. Therefore, from the data included in the above table, it would appear inaccurate to conclude that the neutralization of cream with lime increased the calcium oxide content of the butter. In this connection, Abbott (1), Breazeale, Fabricius, and Bird (10) and Hussong (43), have indicated that when cream is neutralized with lime, a portion of the lime reacts with the casein and is carried into the resulting butter.

Extent of Acid Reduction in Cream

Some controversy exists relative to practices in cream neutralization which deal with the extent to which the acidity of the cream may be reduced in order to obtain maximum keeping quality without having a detrimental effect upon the flavor and body of the butter.

Although Barlow (2) in 1922, found he could make butter scoring "choice" from cream which was neutralized to 0.2 per cent alkaline using sodium bicarbonate, the majority of workers, until recently have favored the reduction of the acidity of cream to 0.20 - 0.25 per cent acidity, notably; Jackson (44), Stiritz and Ruehe (69), Overman (56), Hunziker (39), Abbott (1) and Walts and Libbert (71). Abbott (1) suggests that the acidity of cream be standardized to 0.25 per cent, but that only sodium bicarbonate be used when the acidity of the original cream does not exceed 0.35 per cent.

Over-neutralization of cream will result in a neutralizer flavor in the butter and certain investigators have experimentd with various neutralizers to ascertain their affect on the flavor of butter when the acidity of cream is reduced to the desired range. Jackson (44) reduced the acidity of cream to 0.25 per cent, using calcium oxide, magnesium oxide, sodium carbonate, sodium bicarbonate and sodium hydroxide, and was unable to detect a noticeable difference in the scores of the butter. Similar findings were secured by Stiritz and Ruehe (69), who reduced the acidity of the cream to 0.20 per cent. However, these workers found that sodium bicarbonate always gave a slight bicarbonate flavor.

Walts and Libbert (71), Overman (57), Jensen (47) and Overman, Garrett and Ruehe (58) reduced the acidity of cream with several of the common lime and soda neutralizers, from approximately 0.60 per cent acidity to 0.25 per cent and observed no distinct difference in the initial score of the butter or the score of the butter after storage.

Newer trends in neutralization practices have resulted in a lower acidity standard in cream in an effort to improve the keeping quality of butter. Hood (37), in a review on new facts about butter, reports that Stenning of Australia recommends that cream with an acidity of 0.35 per cent be neutralized to 0.10 per cent, and when the original acidity of the cream is over 0.50 per cent to neutralize to 0.04 per cent. However, McDowall, Smith and McDowell (51) found that when neutralizing with sodium bicarbonate, high acid creams gave butter which showed soda flavors at lower pH values than the low acid creams. They concluded that the practice of neutralizing high acid cream to a lower acidity than low acid cream is not advisable.

The use of pH determinations have come into practice in recent years and have been suggested as being more reliable and accurate than titration methods in regard to neutralization practices. Golding (30) points out that the cream titration in which phenolphthalein is used as an indicator, is unreliable and believes that neutralization to a definite pH will give more satisfactory results. Nissen (55) found that the hydrogen ion determination of butter is a truer index of the previous treatment of the cream than any other method of measurement.

The exact point of acid reduction on the basis of pH has caused difficulty inasmuch as neutralizers have been found to give different pH values in the cream and butter even though the same titratable acidity is maintained in the cream. This is shown by the work of Hunziker and Cordes (42), Breazeale, Fabricius and Bird (10), Bird, Fabricius and Breazeale (7), Fabricius (23), Hussong (43) and Wiley (76).

The data obtained by Breazeale, Fabricius andBird (10) showing the pH of cream when neutralized to definite acidities with different neutralizers is presented in the following table:

Titratable Acidity of Cream	pH Values of Cream			
	Sodium Hydroxide	Sodium Sesquicarbonate	Trisodium Phosphate	Magnesium Lime
0.30	5.50	5.75	6.10	5.90
0.20	6.25	6.35	6.75	6.20
0.10	7.10	7.10	7.40	6.70

These workers found the pH of cream showed a definite relationship to the pH of the butter sera, the butter sera being 0.10 - 0.20 pH unit higher than the pH of the cream.

Fabricius (23) studied the extent of acid reduction in cream with lime and soda neutralizers and noted no difference in the scores of the butter when the cream was neutralized to a point low enough to produce butter with a pH of 6.9, after 5 per cent of starter was added to the cream. Wiley (77) was unable to detect a neutralizer flavor from sweet cream butter when neutralized with sodium bicarbonate to a pH of 7.3. Loftus-Hills et. al. (48), Parfitt and Brown (59) and McDowall, Smith and McDowell (51) found no relationship to exist between a neutralizer flavor and the pH of the butter. Parfitt and Brown (59) observed that samples of commercial butter, criticized as having either a slight or distinct neutralizer flavor, ranged in pH from 4.15 to 7.96.

Work conducted by Bird, Fabricius and Breazeale (7), Breazeale, Fabricius and Bird (10), Fabricius (23), McDowall, Smith and McDowell (51), Nelson (54) and Wiley (77) has shown that when pH of butter is kept within the range of 6.6 - 7.0, but preferably pH 6.7 - 6.8, butter of apparently better flavor and keeping quality is produced. Nelson (54) states that in the above range the greater part of the old cream flavors inherent in neutralized cream butters are eliminated. To obtain these recommended pH values in butter, Nelson found that in single neutralization of cream of less than 0.60 per cent acid with different neutralizers, the following titratable acidities must be secured at churning time: magnesium lime 0.13 to 0.15 per cent with upper limit preferable; Wyandotte C.A.S. (mixed soda), or sodium bicarbonate 0.18 to 0.20 with upper limit preferable; neutralene (sesquicarbonate) 0.24 to 0.25 per cent. In double neutralization of cream with over 0.60 per cent acidity, he recommends any one of the following combinations; magnesium lime with C.A.S. to 0.18 to 0.20 per cent acidity, calcium lime with neutralene to 0.25 per cent acidity or Anderson A with Anderson B to 0.22 per cent acidity.

Fabricius (23) presents the following data showing the churning acidity of cream and pH of the butter sera when various neutralizers were used in cream of approximately 0.6 per cent acidity, and when the pH of the butter was maintained within recommended narrow limits.

Neutralizer	pH	Churning Acidity
Lime	6.96	0.115
C.A.S.	6.98	0.135
Sodium Carbonate	6.87	0.160
Sesquicarbonate	6.99	0.160
Caustic Soda	6.94	0.115

These values show the churning acidity and serum pH after five per cent of starter had been added. Fabricius states that in order to obtain the above churning acidities, the cream would have to be neutralized to slightly lower acidities, since, in general, "the addition of each one per cent of starter to cream raises its titratable acidity 0.01 per cent and lowers the pH about 0.10 per cent".

Wiley (76) found when neutralizing cream of 0.40 per cent acidity with lime or sodium bicarbonate the pH values in cream were practically identical. At the higher acidities and for a given titratable acidity, lime gave a pH value of 0.1 unit higher than sodium bicarbonate.

In other work, Wiley (77) found the pH value of butter sera to vary from 0.0 to 0.2 units higher than the cream from which it was made. Hussong (43) noted that lime-neutralized cream produced butter with a slightly higher pH than the cream from which it was made. Hunziker and Cordes (42) neutralized cream of 0.50 per cent acidity to 0.15 per cent acidity with lime and soda. The pH of the butter was 6.89 and 6.58, respectively. They found that the pH values of butter and buttermilk were equal up to 6.7, but above this the pH of the butter was higher than of the buttermilk. In addition, these workers noted a close agreement between the pH of the cream and buttermilk.

Fat Losses in Buttermilk and Churning Time

When cream is to be pasteurized, and its acidity prior to heating increases above 0.35 per cent, Sproule and Grimes (67) found that increasing fat losses in the buttermilk also occur. Hunziker (39) states that the pasteurization of high acid cream causes the curd to lock up a portion of butter fat, which will be lost in the buttermilk. However, this loss can be avoided by proper neutralization of the cream to 0.35 per cent acidity, or lower, before pasteurization.

Stiritz and Ruehe (69) studied the effect of neutralizers on the fat loss in the buttermilk and reported that soda ash caused a slightly higher fat loss in the buttermilk than either lime or sodium bicarbonate.

Bird et. al. (7) report that the churning loss under practical conditions, when expressed as percentage of total fat churned, was minimal in the region of pH 6.7 to 7.0 (titratable acidities of 0.10 to 0.15 per cent) regardless of the neutralizer used. They state that, "This indicates that casein, once acid coagulated, is not dispersed in a condition comparable to that of sweet cream until the cream is nearly at a neutral point." However, Derby, Breazeale and Bird (22) concluded that, under practical conditions, there is apparently no close correlation between churning time and pH, or churning time and fat loss, and that the minimum fat loss is not secured.

Keeping Quality of Butter

Effect of the neutralizer: Some of the early investigators noted that the type of neutralizer used influenced the keeping quality of butter in storage. Stiritz and Ruehe (69) noted that when rancidity oxidative developed during storage, sodium carbonate had been used as the neutralizer. They considered this to be due to the fact that sodium carbonate tends to saponify the fat. Jensen (47) recently found that butter made from cream neutralized with sodium bicarbonate scored higher when fresh, but declined more rapidly in storage than butter made from cream neutralized with lime. Walts and Libbert (71) report that butter made from cream neutralized with lime scored slightly higher than that neutralized with other alkalies, after 90 days storage at 0o F. However, these workers conclude that no one neutralizer showed any distinct advantage in regard to the keeping quality of butter. Jackson (44), Hunziker (39), Jensen (47), Loftus-Hills, et. al. (43), Overman (57), and Overman, et. al. (58) came to similar conclusions.

Relationship of acidity and pH of cream and butter to general keeping quality: The recent trend to reduce the acidity of cream to a narrow and relatively low range has resulted in studies to determine the exact range of pH and titratable acidity necessary to secure maximum keeping quality in the butter. Certain of these findings are reported in the earlier section dealing with the range of acid reduction.

Acidity of cream: Although the majority of the recent investigators have studied the relationship of pH to keeping quality, White, Tremble and Wilson (72) and White (73) recently found that butter made from cream of 0.15 to 0.25 per cent acidity deteriorated less after twelve months storage at 0° F. than butter from cream containing 0.28 to 0.31 per cent acidity.

The former authors state that the acidity of the cream when churned, rather than the acidity previous to treatment, is the factor affecting the keeping quality of butter. However, Hunziker and Cordes (42) point out that the original quality of the cream and its titratable acidity must be considered in determining the keeping quality of butter relative to the storage flavor, but that the churning acidity of the cream and cream serum are an index to a dependable control of fishiness. They found that neutralizing cream to an acidity of 0.25 per cent gave commercial butter of desirable keeping quality.

pH values: Gilmour and Arup (29) experienced difficulty with the keeping quality of butter with pH values lower than 6.7. Bendixen (5) reports that butter in the range pH 6.2 - 6.8 scores highest when fresh than butter of either higher or lower pH. After one month in storage at a temperature of 35.6 - 41° F. the butter with pH values lower than 6.2 dropped the most in score, or 1.1 points. Bird, Fabricius and Breazeale (7), Fabricius (23), and McDowall, Smith and McDowell (51) recommend butter pH values of 6.7 - 7.5, 6.9 - 7.0, and 6.8 - 7.0, respectively for maximum keeping quality. Parfitt and Flake (24), however, found butter in the range of pH 6.5 - 7.0 decreased the greatest in score on storage, whereas that in the range of pH 6.0 to 6.5 decreased the least. Hussong (43) and Loftus-Hills, et. al. (48) found that maximum keeping quality was obtained at somewhat higher pH values than those generally recommended, i.e. pH 7.0 - 7.2 and pH 7.0 - 7.5, respectively.

Hunziker and Cordes (42) studied the relationship of pH to keeping quality and concluded that, "The determination of the pH of butter would not give any definite indication of the churning acidity or serum acidity of the cream at churning, which is the only dependable means of controlling keeping quality". They made butter of dependable keeping quality using lime, and lime and soda, even though the pH was as low as 6.0, and state that "butter with a pH as low as 5.7 may mean poor keeping quality only if churned from neutralized cream".

Changes of pH on storage: Bendixen, Prouty and Ellington (3), (4) observed that the pH value of butter serum changed little during storage, sometimes increasing and sometimes decreasing, and found no relationship to exist between changes in pH values and the keeping quality of the butter. Breazeale, et. al. (10) and Bird (7) noted that the pH of butter from cream neutralized with non-buffered alkalies (limes) increased slightly in storage. However, the change was never over 0.2 pH unit. The latter author found that the initial pH of the butter correlates better with keeping quality than with the initial score of the butter.

Bendixen (5) observed the pH change of butter in the range of 5.3 - 7.6 and noted that, after one month storage at 35.6 - 41° F. the changes were small; more than one-half of the samples changing less than 0.2 pH. The changes in pH seemed to be of little significance in indicating the keeping quality of the butter. Loftus-Hills, et. al. (48) found the pH of butter to increase 0.16 unit during three months storage at 12° F. They concluded that the pH determination was of more value as an index to keeping quality than the titration of the butter, butter fat, or butter serum.

Acidity of butter and butterfat: Bouska (11) and Hunziker (39) have shown that the average titratable acidity of good butter ranges from 0.02 to 0.05 per cent lactic acid. Bouska states that in butter with acidities above 0.1 per cent the fat is unstable, and below 0.02 per cent the protein is broken down. Hunziker (39) found that butter of 0.118 to 0.150 per cent acidity becomes fishy after 33 days storage. He states that under normal conditions of manufacture the acidity of cream and butter shows a close correlation.

Bird, et. al. (7), Grimes (18), Loftus-Hills, et. al. (48) and Overman (58) concluded that the titratable acidity of butter fat increased little during storage and appeared to have a negligible effect on the deterioration of the butter. However, Bendixen (6) used the ratio of the acid value of the butter fat to the acid value of the butter, which he called the "acid ratio", as an index of keeping quality in butter. He states that "acidity develops independently in butter and in butter fat during storage at 32 - 41° F. for one month". The greater the increase in acid ratio during this storage period the poorer the keeping quality of the butter. Although the test is not specific in every case Bendixen believes that trends may be noticed that will give valuable information.

Fishy flavor: Perhaps one of the most prevalent flavor defects of storage butter is that described as fishy and voluminous literature has been published in regard to the cause and mechanism of its development. The majority of the early workers have ascribed the fishy flavor in butter to the breakdown of lecithin to give trimethylamine (Supplee (70), Cusick (13), Sommer and Smit (64), Dahlberg (14), and Sommer (65)). However, Davies (17) has recently suggested that the causative agent is trimethylamine oxide, rather than trimethylamine.

Holm (46), states that spontaneous oxidation aids in the development of fishiness, but the exact role of oxidation is not clear. Rogers, et.al. (61), Supplee (70), Cusick (13), Sommer and Smit (64), Hunziker (39), and

Davies (16, 18, 19), conclude that acidity was a major factor in the development of fishiness. Davies states that high acidity in butter results in the liberation of oleic acid, which takes up oxygen and diffuses with water to form peroxides. The peroxides attack the choline residue of butter lecithin to liberate trimethylamine. Davies and Gill (17) found that trimethylamine oxide was reduced when heated with linseed oil, and that some nitrogen entered into organic combination. A fishy flavor was thereby produced.

Rogers, Thompson and Keithley (61) made an early observation of butter held at -10° F. and noted fishiness in only 1.5 per cent of those made from cream below 0.30 per cent acidity, whereas 49.3 per cent of the butters made from cream above 0.30 per cent or above in acidity developed a fishy flavor. Supplee (70), Cusick (13), Sommer and Smit (64), Sommer (65), and Dahlberg (14) observed that a definite acid condition was necessary for the breakdown of lecithin and the formation of trimethylamine, and that salt in butter had a marked accelerating effect on the reaction. Sommer and Smit (64) believe that the accelerating action of salt on the development of the fishy flavor was due to its solvent action on lecithin. These workers also observed that acid not only catalyzes the hydrolysis and oxidation of lecithin but also increases the solubility of metals in the cream. These dissolved metals then may exert a catalytic effect. They found that neutralization of cream to 0.25 per cent acidity was effective in reducing fishiness. Other workers have made similar observations. (Abbott (1), Hunziker (39), McKay and Larson (52), Fouts and Keith (25) and White (73)). Holm (35) states that fishiness does not occur in butter made from cream of less than 0.20 per cent acidity. Fabricius (23) found that a large amount of starter could be added to cream neutralized to 0.10 per cent acidity without danger of fishy flavor development.

Tallowiness: The development of a tallowy flavor in butter is an oxidative process involving chiefly oleic acid. Oxygen is absorbed at the double bond of the acid and the reaction proceeds the carbon chain is split to form peroxides, aldehydes, ketones and acids, some of which have an intense tallowy flavor and odor. Although in the oil and fat industry this reaction is termed rancidity, and is not differentiated from hydrolytic spoilage. Rancidity in the dairy industry is due to a hydrolytic reaction setting fatty acids free to cause the disagreeable flavor.

Some peroxides are early formed in the oxidation of fat, their determination has been utilized as a means of predicting the susceptibility of the fat to oxidative changes, and as a method of measuring the degree of oxidation which has taken place. These peroxides may be measured by their ability to liberate iodine from postassium iodide in acid solution.

Stebnitz and Sommer (68) observed that a slight tallowy flavor appeared in butterfat with the first test for peroxides in some samples, whereas in others a tallowy flavor was not detected until a peroxide value of six was reached. Holm (35) and Holm, et. al. (36) state that an acid medium appears to be the major factor concerned in the formation of peroxides in butter. They used the rate of peroxide formation as a measure of the keeping quality of butter from cream ranging from 0.13 to 0.41 per cent acidity. The butters were stored at temperatures of 20° to -17° C. for a period of two months to one year. They found that as the storage temperature was increased the rate of peroxide formation was increased and the score of the butter progressively decreased. The fresh butter gave no peroxide value. The butter had original scores of 91 - 92 and at the end of the storage periods the butter from the low acid creams (0.13 and 0.19 per cent acidity) showed less deterioration and had lower peroxide values than butter from cream of 0.31 and 0.41 per cent acidity.

Coe and LeClerc (11) are of the opinion that the peroxide determination is of no value as an index to the extent of oxidative rancidity and found that cottonseed oil and corn oil protected from light may possess a very high peroxide value and yet be free from oxidation. Oils that were exposed to light became oxidized at a much lower peroxide value. In this connection Loftus-Hill, et. al. (48) concluded that peroxide determinations were of no value in determining the keeping quality of butter. Samples developing a tallowy flavor in storage at 12° F. for three months had a peroxide value of 0.40, while the peroxide value of the remainder of the samples were not significantly different.

Overman, Garrett and Ruehe (58) measured the rate of oxygen uptake of butterfat made from cream treated differently. They concluded that the rates of oxidation of different butter varied so irregularly that there was no correlation to keeping quality. Their results show that the neutralization of cream with magnesium lime had no affect on the rate of oxidation of butterfat.

Tallowiness in butter is accelerated by heat, light, moisture, oxygen, certain heavy metals, and acid. Hood (37) and Davies (19) observed that tallowiness follows fishiness as the oxidation of fat progresses.

A number of investigators have pointed out that a definite acid condition is essential for the development of a tallowy flavor, notably, Guthrie (32), Davies (19, 19), Holm (35), Holm, et.al. (36), Hood (37), Hunziker (39, 41), and Wright and Overman (78). Controlling the acidity of cream at churning time within the range of 0.15 and 0.32 per cent acidity was found by Hunziker (39) to be effective in preventing tallowiness in storage butter. Fabricius (23) states that a considerable amount of starter may be added to sweet cream of 0.20 per cent or less acidity, when neutralized to 0.10 per cent acidity after pasteurization, without danger of metallic or oily flavor development. Holm (35) and Holm, et.al. (36) report that tallowiness was not observed in samples of butters made from creams of 0.13 and 0.19 per cent acidity, when stored at -17° C. for one year. Samples of butter made from 0.30 and 0.40 per cent acid cream possessed tallowy flavors relatively early in the storage period.

The treatment of the cream previous to churning, such as the development of acidity, improper neutralization, exposure to ultra violet light, or contamination with metals from faulty utensils, is a major factor in regard to susceptibility to oxidative changes in the butter (Davies (15, 19), Greenbank and Holm (27, 28), Holm and Greenbank (33), Holm, Greenbank and Deysher (34), Hunziker (41), Overman, et. al. (58), and Wright and Overman (78)).

Free fatty acid accelerate the oxidation of butterfat according to Greenbank and Holm (28), Holm and Greenbank (33, 34), and Hunziker (41). The development of lactic acid in cream liberates free fatty acids in the butterfat according to Hunziker (41). The fatty acids then accelerate tallowiness in the butterfat.

<u>Miscellaneous observations of keeping quality:</u> Jacobsen (45, 46), Nelson (53), and Parsons (60) have shown that storing butter at 21° C. for one week will give an indication of the ability of the butter to hold up

in storage. Parsons (60) also found that holding butter for 14 days at 60° F. to be a valuable method of determining keeping quality. Using the short storage test, Jacobsen (45, 46) noticed no defects in salted butter after storage, other than tallowiness.

Loftus-Hills, et. al. (48) found no relationship between the curd content, salt content, or brine concentration and keeping quality.

Overman (58) found no correlation between the index of refraction, Hanus iodine number, saponification number, soluble acids, insoluble acids, or acetyl value, and the keeping quality of butter.

SCOPE OF INVESTIGATION

This study was conducted in view of the lack of information pertaining to certain factors involved in the practice of neutralizing cream. Data were secured with the following purposes in view:

(a) To compare the different neutralizers which are recommended for acid reduction in cream on the following bases:

(1) Speed of acid reduction;

(2) Influence of pasteurization on acid reduction;

(3) Efficiency of acid reduction;

(4) pH changes in the cream;

(5) pH of the butter serum and buttermilk;

(6) Acidity of the butter, butterfat and buttermilk;

(7) Quality of fresh and stored butter;

(8) Composition of the butter;

(9) Fat tests of the buttermilk.

(b) To determine the influence of different neutralizers and the degree of acid reduction on the keeping quality of butter as indicated by:

(1) The pH of the fresh and stored butter;

(2) The acidity of the fresh and stored butter, and butterfat;

(3) Changes in peroxide value.

The experimental work involved the use of sodium carbonate, Wyandotte C.A.S. (a mixture of sodium carbonate and sodium bicarbonate), sodium bicarbonate, Recto (chiefly sodium and potassium carbonates), sodium hydroxide, Peerless lime (calcium hydrate lime), and Allwood lime (magnesium oxide lime), for neutralizing sour cream.

EXPERIMENTAL

Procedure

The cream used in this experiment was obtained from the College Creamery and was similar in quality to that received by the average commercial creamery. The average acidity of the cream, calculated as lactic acid, was 0.50 per cent, the pH 4.80, and the fat test by the Babcock method was usually 30 to 35 per cent.

Laboratory studies: Laboratory studies on neutralization were conducted in an effort to determine the speed of reaction of various neutralizers in sour cream, and to ascertain the accuracy with which they reduce the acidity of the cream to different calculated acidity ranges. Precautions were taken in the procedure and apparatus so as to resemble the regular commercial holder method of neutralization and pasteurization.

The apparatus consisted of a ten quart metal vessel, a steam heated water bath, and a motor driven propeller for agitating the cream. The propeller speed was adjusted so as to agitate the cream similar to that of the ordinary coil type pasteurizer, in order to avoid errors, in acid reduction due to the retention or expulsion of carbon dioxide.

Ten pound samples of cream were used and a series consisted of four such samples of the same cream. The samples were neutralized on the basis of calculation to reduce the acidity to the following percentages: 0.25, 0.15, 0.10 and 0.05. The neutralizers used in this portion of the study were Recto, Wyandotte C.A.S., Peerless lime, Allwood lime, sodium hydroxide, sodium carbonate and sodium bicarbonate. The amount of neutralizer to use in each case was calculated by using the factor (the weight of the alkali required to neutralize one pound of lactic acid), submitted by the manufacturers of the commercial products. these factors were as follows: Recto 0.77, Wyandotte C.A.S. 0.776, Peerless lime 0.510, and Allwood lime 0.30. With the other neutralizers used in this study the factors were determined by neutralization of lactic acid. These factors were as follows: sodium hydroxide 0.490, sodium carbonate 0.60, and sodium bicarbonate 0.934.

Before adding a soda neutralizer to cream the required amount of the dry neutralizer was carefully weighed and then diluted to 10 per cent with water of 100° F.

Ten per cent stock dilutions of the limes were prepared. The Allwood lime was slaked in hot water and allowed to stand at least over night before using. The required amount of the stock dilution of a lime neutralizer was carefully weighed and was at room temperature when added to the cream.

Two series of acid reduction trials were conducted using each neutralizer, except in the case of sodium bicarbonate, which was used in four series.

The procedure followed throughout the process of neutralization and pasteurization was standardized to avoid variation in the results and to allow for comparisons of the influence of the different neutralizers on the factors studied. The cream was heated to 90° F. and the original acidity and p^H were determined of a sample taken from the thoroughly mixed cream. The neutralizing solution was then slowly sprinkled over the agitated cream. Acidity determinations were then made on the cream after 5, 10, 15 and 20 minutes.

Following the 20-minute holding period at 90° F. the cream was heated to 145° F. and held for 30 minutes before cooling to 60° F. A standardized period of 20 minutes was used for heating the cream from neutralization to pasteurization temperature of 145° F. A similar period of time was required to cool the cream back to 60° F. The acidity of the cream was determined at the beginning and at the end of the 30 minute holding period, and at the close of the process. In addition, pH determinations were conducted at the end of the process. The neutralized cream was held for approximately two hours before the pH was determined.

The pH of the cream was determined in duplicate by the Quinhydrone electrode using a Leeds-Northrup portable potentiometer and bright platinum electrodes, frequently cleaned with hot hydrochloric acid. The acidity of the cream in each case was determined in duplicate by adjusting the cream to room temperature and accurately weighing nine gram samples which were then titrated to the phenolphtholein end-point with 0.10 N sodium hydroxide.

Commercial studies: Further studies on neutralization were conducted on a commercial basis in which each sample of the cream was also churned. A coil type, 50-gallon Cherry-Burrell pasteurizer was used for processing the cream. The churning was accomplished by a 100-pound Cherry Single Roll Junior Churn.

In these studies 1000 pounds of cream were used for each series of neutralization trials. The cream was divided into five portions to be neutralized to different theoretical acidities. The same points of theoretical acid reduction were again studied as in the laboratory studies and in addition a theoretical acid reduction to 0.0 per cent was studied.

The neutralizing agents used in the laboratory studies were again used in this portion of the experiment, with the exception of sodium bicarbonate. Three series of trials were completed for each neutralizer used.

The procedure followed in these studies was practically identical with that of the laboratory studies. Also, the data obtained were collected in the same manner. However, this cream was cooled to 45° F. at the end of the pasteurization and neutralization process and held at this temperature for 24 hours before churning; at which time the pH and acidity were again determined. The pH and acidity determinations throughout these studies were made as outlined previously.

<u>Butter studies</u>: Each lot of cream processed in the commercial neutralization studies was adjusted to 47° F. and churned. Usually 45 to 60 minutes were required to churn the cream. The churning temperature was standardized in order to allow comparisons of the effect of different neutralizers on the fat loss in the buttermilk under practical conditions. A standard procedure of washing and salting and working the butter was followed to minimize variations in the quality of the butter as far as these factors were concerned.

The churning process was stopped when the butter granules reached the size of large wheat kernels. The buttermilk was then drained and a sample was taken for fat tests by the butyl alcohol method, and for pH and acidity measurements. Although the pH of the buttermilk was determined by the method outlined for cream, the acidity of the buttermilk was determined by the titrating a nine ml. instead of a nine-gram sample.

Following the draining of the buttermilk, the butter was washed by spraying with water until the water was clear at the drain and then a volume of water equal to the volume of the buttermilk was added to the churn. The washing was completed by running the churn in high for 15 revolutions and in low, with the roll in motion, for five revolutions. After the butter was carefully drained to remove the excess water, salt was added at the rate of 2.5 per cent of the expected butter. The moisture content of the butter was adjusted to 16.5 per cent.

Three samples of the butter from each churning were taken to be used for making various observations. An eight-ounce sample was used to secure the score, acidity, pH, and composition of the fresh butter. A six-ounce sample was taken in a glass jar fitted with a glass stopper and stored for 10 days at 72° F. Following this storage period, the score, acidity, and pH of the butter were determined. A five pound sample of the fresh butter was stored in a cardboard carton at 0° F. and a portion of it was used for determining the peroxide value and butterfat acidity after one month. The remainder of the five pound sample was used for determining the score, pH, and acidity of the butter and butterfat after six months storage.

The acidity of the butter and butterfat were determined in duplicate by the A.O.A.C. method (80). Twenty gram samples were weighed into dry 250 ml. beakers and 50 ml. of neutral ethyl alcohol was added. The samples were heated to boiling and titrated over a white background to a definite pink, permanent for one minute.

The pH determinations of the butter serum were made in duplicate by the Quinhydrone method. The butter serum for the determination was obtained by melting approximately 50 grams of butter in a water bath at 105° F. The melted butter was then placed in a large test tube which was fitted with a cork and centrifuged in an inverted position. The butterfat was then solidified in cold water with the tube in an inverted position and the serum was readily obtained by removing the cork.

The peroxide values were determined in duplicate by the Wheeler method (79) as modified by Stebnitz and Sommer (68). Approximately five grams of filtered butterfat was dissolved in 50 ml. of a solvent mixture of 60 per cent glacial acetic acid and 40 per cent chloroform. One ml. of freshly prepared saturated potassium iodide solution was added. The mixture was stirred by rotating the flask for exactly one minute and then 100 ml. of distilled water were added. The sample was titrated with 0.01 N sodium thiosulphate. Toward the end of the titration three ml. of a one per cent starch solution were added as an indicator. Vigorous shaking of the flask was necessary to remove the last traces of iodine from the chloroform layer.

Complete analysis of the butter was made in duplicate by the Kohman method as outlined by American Butter Institute (81).

The butter was scored by at least two and usually four experienced butter judges. Samples were prepared for scoring by tempering to approximately 50° F., and were numbered in such a manner as to mask their identity. Each judge scored the butter independently. When the scores placed on a sample of butter by the different judges varied more than one-half point, the sample was rescored.

RESULTS

Speed of acid reduction: In an effort to study the speed at which the neutralizers reduced the acidity of the cream, acidity determinations were made after the addition of the neutralizers at intervals of 5, 10, 15, and 20 minutes. The average results secured in all neutralization trials which involved the theoretical reduction to ranges from 0.0 per cent to 0.25 per cent acidity are presented in Table 1. Sodium bicarbonate was not used for neutralizing cream to a calculated acidity of 0.0 per cent; therefore, the average figures shown are proportionately higher than those given in case of the other neutralizers.

Table 1. The Average Rate at Which Different Neutralizers Reduce the Acidity of Cream*.

Neutralizer	Titratable acidity as per cent lactic acid				
	Original	Time after adding the neutralizer at 90° F.			
	acidity	5 min.	10 min.	15 min.	20 min.
Sodium carbonate	0.490	0.287	0.280	0.270	0.265
Recto	0.522	0.311	0.300	0.294	0.287
Sodium hydroxide	0.510	0.146	0.143	0.142	0.142
Wyandotte C.A.S.	0.480	0.300	0.386	0.274	0.264
Calcium lime	0.520	0.166	0.159	0.156	0.150
Magnesium lime	0.505	0.221	0.208	0.193	0.185
Sodium bicarbonate	0.494	0.349	0.337	0.330	0.324

* These figures show the average rate of acid reduction (three series of trials) when the cream was neutralized to desired acidities ranging from 0.25 to 0.0 per cent. The original data may be found on Tables I to VII, inclusive, in the Appendix.

The greater part of the acid reduction in cream occurs within five minutes after the addition of the neutralizer. These results show that when sodium hydroxide or calcium lime were used that approximately 95 to 98 per cent of the total acid reduction, during the 20 minute holding period, occurs within the first five minutes, while with the other neutralizers only

85 to 90 per cent occurs within the first five minutes of the holding period. Cream neutralized with sodium hydroxide decreased only 0.004 per cent in acidity during the last 15 minutes of the holding period whereas, cream treated with the other neutralizing agents showed greater decreases in acidity. The greatest decrease (0.036 per cent) during the last 15 minutes of the holding period occurred in the cream neutralized with Wyandotte and magnesium lime.

The extent of acid reduction with a sodium carbonate or bicarbonate neutralizer influences the period of time required for the acid reduction in the cream to proceed to completion. This is clearly shown by the individual neutralization trials on Tables I to VIII in the Appendix. These data show that when a large amount of a carbonate or bicarbonate neutralizer was added to cream further acid reduction continued for a longer period of time than when only a small amount of neutralizer was added. Cream neutralized to a theoretical acidity of 0.25 per cent with any one of these neutralizers decreased approximately 0.02 per cent in acidity during the last 15 minutes of the holding period, while cream neutralized to a theoretical acidity of 0.0 per cent decreased approximately 0.04 per cent during the last 15 minutes of the holding period.

Although the calculated extent of acid reduction in the cream was the same for each neutralizer except sodium bicarbonate the data show that distinct variations occurred in the titratable acidities of the cream after five minutes and at the end of the holding period. The limes and the sodium hydroxide reduced the acidity of the cream nearer the desired acidity before pasteurization than did the other neutralizers.

Effect of pasteurization: The effect of pasteurization on the acid reduction of neutralized cream is shown in Table 2. These results show that the acidity of cream neutralized with any of the neutralizers was reduced by pasteurization and also that the acid of the cream continued to decrease during the 24-hour holding period at 45° F. following pasteurization.

Table 2. The Effect of Pasteurization on The Acid Reduction of Cream by Different Neutralizers*.

	Titratable acidity as per cent lactic acid				
Neutralizer	Before heating	145° F.	145° F.30 min.	Cooled	24 hours
Sodium carbonate	0.265	0.206	0.183	0.178	0.164
Recto	0.287	0.221	0.191	0.181	0.160
Sodium hydroxide	0.142	0.127	0.120	0.118	0.098
Wyandotte C.A.S.	0.264	0.205	0.171	0.166	0.160
Calcium lime	0.150	0.144	0.140	0.138	0.130
Magnesium lime	0.185	0.147	0.132	0.128	0.121
Sodium bicarbonate	0.324	0.246	0.219	0.211	-

* These figures show the average acid reduction (series of three trials) due to pasteurization when the acidity of the cream was neutralized to desired acidities ranging from 0.25 to 0.00 per cent. The original data may be found on Tables I to VII, inclusive, in the Appendix.

Pasteurization had the least effect on the acid reduction of cream neutralized with calcium lime and sodium hydroxide. The average reduction in acidity by these two neutralizers over the range studied was only 0.012 and 0.024 respectively. Cream neutralized with magnesium lime was reduced 0.057 per cent in acidity due to pasteurization. The other neutralizers used were carbonates and bicarbonates, or both, and the cream neutralized with these compounds showed an average reduction in acidity of 0.10 per cent, due to pasteurization.

The data on the individual trials shown in the Appendix on Tables I to VII show that when the cream was neutralized to the lower acidities the influence of pasteurization on the acid reduction was greater than when the cream was neutralized to higher acidities. The difference in the amount of

acid reduction due to pasteurizing the neutralized cream was more pronounced in the case of the carbonate and bicarbonate neutralizers. Attempts to neutralize the acidity of the cream to 0.25 per cent with a carbonate neutralizer resulted in an average reduction of 0.06 per cent due to pasteurization. However, when efforts were made to reduce the acidity to 0.00 per cent, pasteurization caused the acidity of the cream to show an average decrease of approximately 0.13 per cent. In like manner, the more of a lime neutralizer that was added to cream the greater the acid reduction due to pasteurization; although the effect was not so pronounced as in the case of the carbonate neutralizers.

There was a noticeable decrease in the acidity of all of the processed cream after holding at 45° F. for 24 hours. The average decrease was 0.01 per cent and was more pronounced in cases where the cream was neutralized with the soda neutralizers. The data on Tables I to VIII in the Appendix show that the pH of the cream usually increased approximately 0.1 unit during the 24-hour holding period. However, the cream that was neutralized to a theoretical acidity of 0.0 showed no change in pH during the holding period.

<u>Efficiency of acid reductions:</u> The determination of the amount of a neutralizing agent to add to cream is obtained on the basis of calculation involving the neutralization of lactic acid. However, the results secured in this study show that the calculated reduction in the acidity of cream is not always obtained when the various neutralizers are used for acid reduction. The actual acidity obtained may either be higher or lower than that desired as shown in Table 3. In addition to showing the actual acidity changes, Table 3 also shows the percentage of the theoretical reduction obtained.

Table 3. The Efficiency of Acid Reduction by Different Neutralizers When Reducing the Acidity of Cream to Different Desired Acidities*.

Neutralizer	Titratable acidity (per cent)				
			Time after processing		Per cent
	Original	Desired	30 min.	24 hours	Efficiency
Sodium carbonate		0.25	0.253	0.243	103.5
	0.448	0.15	0.183	0.170	93.3
		0.10	0.157	0.150	85.6
		0.05	0.147	0.138	78.0
		0.00	0.120	0.120	73.2
Recto		0.25	0.252	0.220	110.3
	0.540	0.15	0.197	0.175	93.6
		0.10	0.155	0.148	89.1
		0.05	0.155	0.147	80.2
		0.00	0.132	0.122	77.4
Sodium hydroxide		0.25	0.210	0.187	123.2
	0.522	0.15	0.130	0.105	112.1
		0.10	0.107	0.090	102.4
		0.05	0.075	0.065	96.8
		0.00	0.470	0.045	91.4
Wyandotte C.A.S.		0.25	0.247	0.253	98.8
	0.507	0.15	0.175	0.170	94.4
		0.10	0.147	0.142	89.7
		0.05	0.125	0.128	82.9
		0.00	0.120	0.105	79.3
Calcium lime		0.25	0.246	0.245	102.0
	0.511	0.15	0.151	0.135	104.2
		0.10	0.121	0.121	94.9
		0.05	0.098	0.090	91.3
		0.00	0.059	0.060	88.3
Magnesium lime		0.25	0.200	0.193	121.1
	0.520	0.15	0.162	0.153	99.5
		0.10	0.125	0.125	94.1
		0.05	0.080	0.078	94.1
		0.00	0.630	0.065	87.5
Sodium bicarbonate		0.25	0.277		91.0
	0.494	0.15	0.225		80.0
		0.10	0.175		82.5
		0.05	0.165		76.0

* Average of three trials. The original data may be found on Tables I to VII, inclusive, in the Appendix.

Attention should be called to the fact that in case of the limes the factors for calculating the amount of neutralizer to use were those recommended by the manufacturer, and these factors made allowance for only

80 per cent efficiency by calcium lime and magnesium lime.

The results show that there is a distinct variation from the linear reduction in acidity by each of these neutralizers. When the acidity of the cream was reduced to the lower ranges the divergencies from the theoretical acidity became progressively greater. However, attempts to reduce the acidity of the cream to the higher ranges with sodium hydroxide, calcium lime or magnesium lime resulted in final acidities lower than the desired acidity.

From these data it is apparent that near quantitative reduction in acidity may be expected when cream is neutralized to an acidity of 0.20 per cent with any one of the neutralizers used. However, only 75 to 80 per cent efficiency was obtained when the carbonate neutralizers were used in an attempt to reduce the acidity of the cream to 0.0 per cent.

Sodium hydroxide proved to be the most efficient agent for reducing the acidity of the cream. However, the acidity of the cream was lower than that theoretically expected when an attempt was made to neutralize the cream to 0.25 and 0.15 per cent. On the other hand when attempts were made to reduce the acidity of the cream to 0.0 only 91.4 per cent of that theoretically expected was obtained. The other neutralizers show a similar trend to that of sodium hydroxide in efficiency of acid reduction, although the variation from the sodium hydroxide curve was much greater in the cases where carbonate neutralizers were used.

An exception to the general trend of efficiency of acid reduction occurred in the case of calcium lime. Here a greater percentage of the theoretical reduction was obtained at 0.15 per cent acidity than at 0.25 per cent acidity.

Sodium bicarbonate proved to be the least efficient of the neutralizers studied for reducing the acidity of cream. Although this neutralizer was not used in the commercial trials, similar results would doubtless have been secured.

<u>pH and acidity in cream:</u> Often it is desirable to neutralize cream to a definite pH in order to facilitate a more accurate control on the properties of the resulting butter. Cream neutralized on the basis of calculation with different neutralizers to different desired acidities may vary considerably in pH value. The results secured in this study dealing with this point are presented in Table 4.

Table 4. The pH and Acidity of Cream When Different Neutralizers Are Used to Reduce the Acidity to Different Desired Acidities*.

		Desired acidity (per cent)				
Neutralizer		0.25	0.15	0.10	0.05	0.00
Sodium carbonate	Acidity	0.243	0.17	0.150	0.138	0.12
	pH	6.00	6.48	6.79	6.95	7.14
Recto	Acidity	0.220	0.175	0.148	0.141	0.122
	pH	6.27	6.80	7.04	7.17	7.33
Sodium hydroxide	Acidity	0.187	0.105	0.090	0.065	0.045
	pH	6.39	7.14	7.26	7.69	8.01
Wyandotte C.A.S.	Acidity	0.253	0.170	0.142	0.128	0.105
	pH	6.26	6.95	7.03	7.27	7.43
Calcium lime	Acidity	0.245	0.135	0.121	0.090	0.060
	pH	6.07	6.46	6.63	6.95	7.70
Magnesium lime	Acidity	0.193	0.153	0.125	0.078	0.065
	pH	6.20	6.36	6.82	7.52	7.82
Sodium bicarbonate	Acidity	0.277	0.225	0.175	0.165	
	pH	5.94	6.42	6.76	6.92	

* These determinations were made 24 hours after processing (with the exception of sodium bicarbonate), and are the averages of three or more trials. The data for each individual trial may be found on Tables I to VII, inclusive in the Appendix.

Sodium hydroxide was found to be the most effective for raising the pH of the cream; with the calcium and magnesium lime being only slightly less effective. These three neutralizers gave pH values of 8.01, 7.70 and

7.82 respectively when they were used in reducing the acidity of the cream to a theoretical acidity of 0.0 per cent. The cream neutralized to theoretical acidities of 0.0 with the carbonate neutralizers had pH values as low as 7.14 to 7.43. Although these results show that the pH of the cream will fall in the range of pH 6.7 to 7.2 regardless of the neutralizer used when the cream is neutralized on the basis of calculations to 0.10 per cent acidity. If a pH of near 7.0 is desired in the cream the titratable acidity of the cream, treated with the different neutralizers, will vary from 0.09 per cent in the case of calcium lime to 0.165 per cent in the case of sodium bicarbonate.

These results show that a relatively uniform inverse relationship exists between the pH and the acidity of the cream neutralized with each of the neutralizers. However, an exception is apparent in case of the cream neutralized with calcium lime, since a distinct buffering occurs in the region of pH 6.0 to 6.4.

pH of cream, buttermilk and butter: Further determinations were conducted to determine the influence of the different neutralizers on the relationship of the pH of the cream to the pH of the fresh butter and also to the buttermilk. These data are shown in Table 5. The results reveal that there was a relatively uniform relationship among these three values regardless of the neutralizer used. Over the range of acidities studied the pH of the butter persisted approximately 0.15 unit above the pH of the cream from which it was made. However, the buttermilk persisted at a pH of approximately 0.10 unit less than its corresponding cream.

Table 5. The Influence of the Different Neutralizers On The pH of The Cream, Butter, and Buttermilk And The Acidity of The Cream, Buttermilk, Butter and Butterfat**

Neutralizer Used	Desired acidity	pH			Acidity				Score of the fresh butter
		Cream at churning	Butter-milk	Butter Serum	Cream at churning	Butter-milk	Butter degree	Butterfat degree*	
Sodium carbonate	0.25	6.00	5.86	6.06	0.243	0.310	1.245	0.875	89.80
	0.15	6.48	6.35	6.62	0.170	0.210	1.110	0.825	89.64
	0.10	6.79	6.70	7.02	0.150	0.147	1.010	0.800	89.90
	0.05	6.95	6.84	7.07	0.138	0.128	0.960	0.790	89.29
	0.00	7.14	7.03	7.33	0.120	0.103	0.860	0.640	89.17
Recto	0.25	6.27	6.12	6.39	0.227	0.280	1.385	0.975	89.56
	0.15	6.47	6.63	7.03	0.175	0.172	1.250	0.800	89.53
	0.10	7.04	6.88	7.30	0.148	0.143	1.125	0.700	89.54
	0.05	7.17	7.05	7.48	0.147	0.125	1.015	0.700	89.71
	0.00	7.33	7.25	7.60	0.122	0.118	0.810	0.610	89.46
Sodium hydroxide	0.25	6.40	6.31	6.54	0.185	0.240	1.275	0.950	89.00
	0.15	7.15	7.01	7.25	0.105	0.125	1.135	0.700	89.30
	0.10	7.26	7.12	7.47	0.090	0.103	0.835	0.625	89.31
	0.05	7.69	7.50	7.73	0.065	0.062	0.765	0.500	88.83
	0.00	8.01	7.73	7.85	0.045	0.050	0.560	0.350	88.78
Wyandotte C.A.S.	0.25	6.26	6.06	6.55	0.253	0.280	1.335	0.975	89.20
	0.15	6.95	6.66	7.01	0.170	0.190	1.175	0.835	89.55
	0.10	7.03	6.86	7.21	0.142	0.177	1.025	0.785	89.65
	0.05	7.26	7.11	7.44	0.128	0.127	0.935	0.735	89.38
	0.00	7.43	7.30	7.70	0.105	0.103	0.765	0.650	89.58
Calcium lime	0.25	6.07	5.92	6.33	0.245	0.272	1.435	1.350	89.31
	0.15	6.46	6.42	6.71	0.135	0.128	1.325	1.250	89.61
	0.10	6.63	6.65	7.05	0.121	0.114	1.260	1.075	89.28
	0.05	6.95	6.80	7.62	0.089	0.099	1.045	0.725	89.30
	0.00	7.70	7.58	7.89	0.060	0.550	0.770	0.450	89.60
Magnesium lime	0.25	6.20	6.16	6.71	0.19	0.222	1.460	1.085	89.55
	0.15	6.36	6.39	6.84	0.153	0.165	1.400	1.025	89.59
	0.10	6.82	6.70	7.29	0.125	0.115	1.210	0.837	89.36
	0.05	7.52	7.42	7.64	0.078	0.077	1.090	0.615	88.78
	0.00	7.82	7.67	7.97	0.0583	0.045	0.865	0.425	88.34

* The acid degree of the butterfat was determined on one or more representative series of samples after one month storage at 0° F.

** The data on the individual trials are shown on Tables XI, XII and XIII in the Appendix.

Acidity of cream, buttermilk, butter and butterfat: The acidities of the buttermilk, butter and butterfat were also determined. These results are shown in Table 5.

In comparing the acidity of the buttermilk to the acidity of the corresponding cream it is of interest to note a reversal in the relationship as the acidity of the cream is decreased. In each case, except the cream neutralized with sodium hydroxide, the buttermilk was found to be higher in acidity than its corresponding cream when the cream was theoretically reduced to 0.15 per cent acidity. Below this acidity the buttermilk was lower in acidity than its corresponding cream. The acidity of the buttermilk was found to be from 0.02 to 0.05 per cent higher than the acidity of the cream when the acidity of the cream was 0.15 per cent, and was found to be equal to or lower than the acidity of the cream when the acidity of the cream was lower than 0.15 per cent.

In studying the influence of the different neutralizers on the relationship between the acidity of the cream and the acid degree of the butter, it was found that considerable variation occurred due to the use of different types of neutralizing agents. However, the data shown on Table 5 reveal a relatively uniform relationship between these two values for each type of neturalizer used. These results also show that, as the acidity of the cream was reduced, the acid degree of the butter also was reduced, regardless of the neutralizer used.

When cream was neutralized to 0.13 per cent acidity with the carbonate neutralizers the acid degree of the butter was approximately 1.0. The cream neutralized on the basis of calculation to 0.0 per cent acidity had an actual acidity of from 0.10 to 0.118 and the acid degree of the butter ranged from 0.765 to 0.860.

Here again sodium hydroxide proved to be the most effective in reducing the acid degree of the butter, although the acid degree of the butter at the higher acidity ranges studied differed only slightly from those of the carbonate butters. The butter from cream theoretically reduced to 0.0 per cent acidity with sodium hydroxide had an acid degree of 0.560, which was the lowest obtained by any of the neutralizers used. This was to be expected, since the sodium hydroxide was more efficient in reducing the acidity of the cream.

Calcium lime and magnesium lime proved to be the least effective in reducing the acid degree of the butter at the higher acidity ranges studied. However, these neutralizers reduced the acidity of the cream nearer the theoretical acidity than did the carbonate neutralizers. In like manner the limes reduced the acidity of the cream lower when the cream was theoretically reduced to 0.0 per cent acidity than did the carbonate neutralizers, although the acid degree of the butter was approximately the same.

The acid degree of the butterfat was determined approximately one month after the cream was churned and determinations were made on one or more representative series of the samples. The data on Table 5 also show that the different types of neutralizers influenced the acid degree of the butterfat in approximately the same relationship that they influenced the acid degree of the butter. When the acidity of the cream was theoretically reduced to 0.25 and 0.15 per cent, the acid degree of the butterfat from the cream treated with calcium lime or magnesium lime was higher than the acid degree of the butterfat from the soda neutralized cream. However, the cream neutralized to a theoretical acidity of 0.0 per cent with calcium lime or magnesium lime gave an acid degree in the butterfat lower than that from cream treated in like manner with a carbonate neutralizer.

Cream neutralized to a theoretical acidity of 0.0 per cent with sodium hydroxide had a pH of 8.01 and butterfat with an acid degree of 0.350. This was lower than the acid degree of butterfat from cream reduced to the same theoretical acidity with other neutralizers.

From these results it is apparent that in order to maintain an acid degree of near 0.800 in the butterfat the acidity of the cream should be neutralized to 0.12 per cent with the lime neutralizers or 0.15 per cent with the soda neutralizers. An acid degree of 0.800 in the butterfat corresponds to an acid degree of approximately 1.150 in the butter, regardless of the neutralizer used.

Score of fresh butter: Each sample of the fresh butter was scored, so as to reveal any influence of the neutralizers on the quality of the fresh butter and also to determine the extent to which cream should be neutralized for butter of maximum quality. The average score of the butter made from the cream neutralized to each of the desired acidities is shown in Table 5. In addition, the pH and acidity results are reported in this table.

The judges gave particular attention to old cream and neutralizer flavors, and also, to the body of the butter. The average score and the criticisms of the individual samples of butter are shown on Tables XVII, XVIII and XIX in the Appendix. There were no distinct differences in the score of the butters made from cream treated with the various neutralizers. However, the butter made from cream treated with the soda neutralizers scored approximately 0.2 point higher than the butter from cream treated with the limes.

The criticisms placed on the butter made from cream treated with each of the soda neutralizers were similar throughout the acidity range studied. Old cream and neutralizer flavors were noticed in some of the butter samples made from cream neutralized to each of the theoretical acidities. In general, the appearance of a neutralizer flavor was less frequent in the butter from cream neutralized to theoretical acidities above 0.10 per cent. The appearance of an old cream flavor was spasmodic, but the cream neutralized to theoretical acidities of 0.10 and 0.15 per cent produced butter less apt to be criticised for the old cream flavor.

When comparing the criticisms placed on the butter from lime neutralized cream with those of the butter made from the soda neutralized cream, it was apparent that a neutralizer flavor was detected in a greater number of the lime butters. The lime neutralizers caused limey and bitter flavors to appear throughout the acidity range studied. The lime butters were often criticised for mealiness, and this defect was more common when the cream had been neutralized with calcium lime.

These data show that the butter score does not show a specific relationship to the acidity of the cream. However, it is apparent from these results that the majority of the high score butters were made from cream neutralized to desired acidities of 0.10 and 0.15 per cent, regardless of the neutralizer used. This corresponds to an acid degree in the butter of approximately 1.150 and to an acid degree in the butterfat of approximately 0.800.

The results on Table 6 show that the pH of the cream was not specific in its relationship to the score of the fresh butter, however, more of the highest scoring butters were in the range of pH 6.7 to 7.2.

Table 6. The Relationship Of The pH Of The Cream To The Score Of The Fresh Butter

pH of the cream when churned	Average score of the fresh butter * 88 - 88.5	88.5 - 89	89 - 89.5	89.5 - 90	90 - 90.5	90.5 - 91
5.8 - 6.2			1	2	1	
6.2 - 6.7		3	6	7	2	
6.7 - 7.2		2	11	7	6	
7.2 - 7.7	2	6	9	7	4	1
7.7 - 8.2	2	7	5	1	2	1

* The specific score and criticism of each of these samples may be found on Tables XVII, XVIII and XIX in the Appendix.

<u>Composition of the butter:</u> A complete analysis was made of each sample of butter in an effort to determine the influence of different neutralizers on the general composition of the butter. The results are shown in Table 7.

Table 7. The Influence Of The Different Neutralizers On The Average Curd Content Of The Butter*.

Desired acidity	Sodium carbonate	Recto	Sodium hydroxide	Wyandotte C. A. S.	Calcium lime	Magnesium lime
			per cent curd			
0.25	0.74	0.76	0.91	0.83	0.69	0.82
0.15	0.77	1.02	0.88	0.89	1.03	0.94
0.10	0.93	0.82	0.91	0.97	1.20	0.74
0.05	0.83	0.83	0.99	0.85	1.34	0.99
0.00	0.82	0.86	0.88	1.03	1.31	0.88
Avg.	0.82	0.86	0.91	0.93	1.11	0.87

* The curd content of each sample of butter made is shown on Table X in the Appendix.

These results show that the curd content of butter was influenced by the type of neutralizer used and also the extent acid reduction in the cream. Cream treated with calcium lime averaged approximately 0.25 per cent higher in curd content than the other butters. The curd content of the butter increased slightly as the cream was neutralized to lower acidities regardless of the neutralizer used, although this effect was more pronounced in the butter made from cream treated with calcium lime. Cream neutralized to a theoretical acidity of 0.0 per cent with calcium lime

increased the curd content of the butter 0.60 per cent over the curd content of butter from cream neutralized to a theoretical acidity of 0.25 per cent with the same neutralizer. A similar increase in the extent of acid reduction in cream treated with the other neutralizers increased the curd content of the butter only 0.10 per cent.

Fat Test of buttermilk: Very little is known in regard to the influence of different neutralizers on the fat loss in the buttermilk. In this study the temperature and fat content of the cream were standardized in order to observe the influence of the neutralizer on the fat loss in the buttermilk. The results shown on Tables VIII and IX in the Appendix reveal that relatively uniform differences occurred over the acidity range studied in all churnings from any one neutralizer. Table 8 shows the average fat test of the buttermilks from cream neutralized with the different neutralizers.

Table 8. The Influence Of The Different Neutralizers On The Fat Test Of The Buttermilk*.

Desired acidity	Sodium carbonate	Recto	Sodium hydroxide	Wyandotte C. A. S.	Calcium lime	Magnesium lime
			Per cent fat			
0.25	0.650	0.640	0.720	1.100	0.840	0.850
0.15	0.550	0.627	0.600	0.780	0.610	0.820
0.10	0.560	0.620	0.590	0.640	0.590	0.730
0.05	0.493	0.630	0.600	0.730	0.515	0.620
0.00	0.440	0.670	0.630	0.707	0.435	0.570
Avg.	0.540	0.637	0.628	0.791	0.598	0.718

* The above figures are an average of the three series of trials, the original data are shown on Tables VIII to IX in the Appendix.

These data show that as the acidity of the cream was reduced below 0.25 per cent there was a slight reduction in the fat loss in the buttermilk regardless of the neutralizer used. The buttermilk from cream theoretically reduced to 0.25 per cent acidity had an average test of 0.80 per cent, while the buttermilk from the cream neutralized to a theoretical

acidity of 0.0, had an average fat test of 0.59 per cent. However, there was only a slight difference in the amount of fat in the buttermilks from creams neutralized to theoretical acidities of from 0.10 to 0.0 per cent.

The greatest fat losses occurred when the cream had been neutralized with Wyandotte C. A. S., and the lowest fat losses occurred when the cream had been treated with sodium carbonate.

Changes of pH during storage: The changes in the pH of the butter during storage are shown on Table 9. These changes are small and many of them are within experimental error.

When observing the change of pH in the butter stored for ten days at 72 ° F. it was noted that each sample decreased, the average decrease being approximately 0.20 unit. This decrease was relatively uniform and does not show relationship to the pH of the butter when fresh. The butter made from cream treated with the soda neutralizers showed practically identical changes in pH during the short storage period. The butter from cream treated with calcium lime decreased the least in pH, indicating that the high curd content of these butters contained some residual lime. However, the magnesium lime butters showed the greatest decrease in pH of any of the butter made, or approximately 0.35 unit.

The changes of pH occurring in the butter during the six months storage period were irregular, some increasing and some decreasing. In general, these changes were small and occurred throughout the acidity range studied. One exception is of interest; each of the butters made from cream treated with sodium carbonate increased in pH. These butters also increased slightly in score during the six months holding period at 0°F., while the other butters lost in score.

Table 9. The Influence Of The Different Neutralizers On The Changes In pH Of The Butters During Storage*.

Neutralizer	Desired acidity in the cream	Fresh	After 10 days at 72° F.	After 6 months 0°F.
Sodium carbonate	0.25	6.06	5.96	6.11
	0.15	6.62	6.48	6.74
	0.10	7.02	6.82	7.12
	0.05	7.07	6.94	7.35
	0.00	7.33	7.16	7.63
Recto	0.25	6.39	6.24	6.51
	0.15	7.03	6.48	7.04
	0.10	7.30	6.85	7.26
	0.05	7.48	7.08	7.36
	0.00	7.60	7.15	7.55
Sodium hydroxide	0.25	6.54	6.34	6.31
	0.15	7.25	7.10	6.91
	0.10	7.47	7.19	7.05
	0.05	7.73	7.54	7.54
	0.00	7.85	7.74	7.87
Wyandotte C.A.S.	0.25	6.55	6.29	6.46
	0.15	7.01	6.91	7.06
	0.10	7.21	7.11	7.23
	0.05	7.44	7.36	7.50
	0.00	7.70	7.43	7.60
Calcium lime	0.25	6.35	6.37	6.55
	0.15	6.71	6.69	6.72
	0.10	7.05	6.98	7.13
	0.05	7.62	7.22	7.42
	0.00	7.89	7.88	7.72
Magnesium lime	0.25	6.71	6.32	6.72
	0.15	6.84	6.66	6.90
	0.10	7.29	6.97	7.28
	0.05	7.64	7.25	7.71
	0.00	7.87	7.57	7.95

* Average of three series of trials. The original data are shown on Tables XIV and XV in the Appendix.

Change in acid degree of butter during storage: The acid degree of all the butter was determined before and after storage and these values, along with the change during storage, are shown in Table 10.

Table 10. The Influence Of The Different Neutralizers On The Changes In Acid Degree Of The Butter During Storage*.

Neutralizer	Desired acidity in the cream	Acid degree of butter: After 10 days 72°F.	Change in 10 days	After 6 months 0°F.	Change in 6 months
Sodium carbonate	0.25	1.335	+ 0.100	1.320	+ 0.075
	0.15	1.215	+ 0.105	1.210	+ 0.100
	0.10	1.115	+ 0.105	1.140	+ 0.130
	0.05	1.060	+ 0.100	0.995	+ 0.035
	0.00	1.000	+ 0.140	0.910	+ 0.050
Recto	0.25	1.550	+ 0.165	1.490	+ 0.105
	0.15	1.400	+ 0.150	1.305	+ 0.055
	0.10	1.310	+ 0.160	1.210	+ 0.085
	0.05	1.190	+ 0.175	1.105	+ 0.090
	0.00	0.960	+ 0.150	0.945	+ 0.135
Sodium hydroxide	0.25	1.425	+ 0.140	1.350	+ 0.075
	0.15	1.215	+ 0.080	1.120	- 0.015
	0.10	1.140	+ 0.275	0.970	+ 0.135
	0.05	0.935	+ 0.170	0.805	+ 0.040
	0.00	0.800	+ 0.240	0.630	+ 0.070
Wyandotte C.A.S.	0.25	1.450	+ 0.115	1.285	- 0.050
	0.15	1.335	+ 0.160	1.100	- 0.075
	0.10	1.160	+ 0.135	1.030	+ 0.005
	0.05	1.040	+ 0.105	0.960	+ 0.025
	0.00	0.825	+ 0.060	0.805	+ 0.040
Calcium lime	0.25	1.555	+ 0.120	1.640	+ 0.205
	0.15	1.500	+ 0.175	1.490	+ 0.165
	0.10	1.425	+ 0.165	1.330	+ 0.070
	0.05	1.285	+ 0.240	1.145	+ 0.100
	0.00	0.725	- 0.045	0.835	+ 0.065
Magnesium lime	0.25	1.800	+ 0.340	1.660	+ 0.200
	0.15	1.700	+ 0.300	1.615	+ 0.215
	0.10	1.575	+ 0.365	1.410	+ 0.200
	0.05	1.490	+ 0.300	1.260	+ 0.170
	0.00	1.165	+ 0.300	1.085	+ 0.220

* These figures are the average of the three series of trials. The original data are shown on Tables XIV and XV in the Appendix.

The butter made from cream treated with magnesium lime increased in acid degree from 0.300 to 0.365 during ten days storage at 72° F., while the other butter showed an average increase in acid degree of approximately 0.150. The increase in acid degree of the butter, during the short holding period, was apparently not related to the acid degree of the fresh butter nor to the keeping quality of the butter.

There was also an increase in the acid degree of the butter when stored for six months at 0° F. This increase averaged approximately 0.10. The lime butter showed the greatest increase in acid degree with the magnesium lime butter showing the greatest (0.20) increase.

Change in acid degree of butterfat during storage: The acid degree of one or more representative series of samples of the butterfat was determined after one month of storage and the acid degree of allthe butterfat was determined after six months of storage. The change in acid degree during five months of storage was noted in those samples which had been determined after one month of storage. Many of these changes in acid degree were within experimental error, however, relatively uniform changes occurred in the butterfat from each of the neutralizers. Table 11 shows that the acid degree of the butterfat generally increased approximately 0.05 when the butter was made from cream neutralized to a theoretical acidity above 0.10 per cent, indicating that there was a small amount of fat hydrolysis. However, the butterfat of butter made from cream neutralized to a theoretical acidity of 0.10 per cent, or below, generally decreased approximately 0.05 in acid degree.

The butterfat decreasing in acid degree was from butter found to be higher in curd content. This indicates that the decrease in acid degree may be due to residual alkali.

These results do not reveal any relationship between the change in acid degree of the butterfat during storage to the change in acid degree of the butter or change in pH of the butter during storage.

Table 11. The Influence Of The Different Neutralizers On The Changes In Acid Degree Of The Butterfat During Storage***.

Neutralizer	Desired acidity in the cream	Acid degree of butterfat: After one month 0° F. **	Acid degree of butterfat: Change in storage 5 months 0° F.	Acid degree of butterfat: Average for all after 6 months 0°F.*
Sodium carbonate	0.25	0.875	+ 0.025	0.895
	0.15	0.825	- 0.035	0.850
	0.10	0.800	- 0.015	0.795
	0.05	0.790	- 0.055	0.710
	0.00	0.640	- 0.040	0.590
Recto	0.25	0.975	+ 0.015	1.045
	0.15	0.800	+ 0.050	0.890
	0.10	0.700	- 0.025	0.760
	0.05	0.700	- 0.065	0.715
	0.00	0.610	0.000	0.585
Sodium hydroxide	0.25	0.950	0.000	1.015
	0.15	0.700	- 0.025	0.780
	0.10	0.625	- 0.075	0.640
	0.05	0.500	- 0.115	0.485
	0.00	0.350	- 0.050	0.380
Wyandotte C.A.S.	0.25	0.975	+ 0.065	0.995
	0.15	0.825	+ 0.100	0.875
	0.10	0.785	+ 0.015	0.780
	0.05	0.735	- 0.065	0.645
	0.00	0.650	- 0.050	0.575
Calcium lime	0.25	1.350	+ 0.150	1.070
	0.15	1.250	- 0.015	0.930
	0.10	1.075	- 0.015	0.720
	0.05	0.725	- 0.040	0.520
	0.00	0.450	- 0.100	0.250
Magnesium lime	0.25	1.085	+ 0.065	1.140
	0.15	1.025	+ 0.055	1.050
	0.10	0.835	- 0.030	0.805
	0.05	0.615	- 0.028	0.525
	0.00	0.425	- 0.013	0.385

* Average of the three series of trials.
** Values of one or more representative series of samples.
*** The original data may be found in the Appendix on Tables XIV and XV.

Changes in the score during storage: The butters were scored after ten days storage at 72° F. and after six months storage at 0°F. to study the influence of the different neutralizers on the keeping qualities. The judges observed the butter for its general quality and made special note of any specific defects attributable to the kind of neutralizer used or the degree of acid reduction in the cream. These results are shown on Table 12.

Table 12. The Influence Of The Different Neutralizers On The Score Of The Butter*.

Desired acidity	S.C.	Recto	S.H.	W. C.A.S.	C.L.	M.L	Avg. score of all butters at each desired acidity
	Score when fresh						
0.25	89.80	89.56	89.00	89.20	89.31	89.55	89.40
0.15	89.64	89.53	89.30	89.55	89.61	89.56	89.53
0.10	89.60	89.54	89.31	89.65	89.28	89.36	89.46
0.05	89.27	89.71	88.83	89.38	89.30	88.78	89.21
0.00	89.17	89.46	88.78	89.58	89.60	88.34	89.15
Avg.	89.49	89.56	89.24	89.47	89.42	89.12	
	Score after 10 days at 72° F.						
0.25	87.84	89.67	88.78	89.20	88.99	88.03	88.75
0.15	88.54	89.56	89.00	88.83	89.01	88.30	88.87
0.10	89.75	89.17	89.11	89.30	88.94	88.58	89.14
0.05	88.67	89.25	89.45	89.27	88.81	88.47	88.98
0.00	89.50	89.21	89.22	88.82	88.50	88.61	88.97
Avg.	88.86	88.86	89.37	89.11	89.08	88.85	
	Score after 6 months at 0° F.						
0.25	90.2	88.83	89.50	89.10	88.90	88.77	89.22
0.15	89.77	88.46	88.93	89.10	88.50	89.06	88.97
0.10	89.43	88.43	88.70	88.50	88.60	88.70	88.73
0.05	89.27	88.90	88.27	88.40	88.65	88.93	88.74
0.00	89.60	88.90	88.30	88.80	87.30	88.83	88.62
Avg.	89.65	88.70	88.74	88.78	88.39	88.86	

* Average of three series of trials. The original data is shown on Tables XIV and XV in the Appendix.

** Neutralizer

S.C. - Sodium carbonate
C.L. - Calcium lime
S.H. - Sodium hydroxite
M.L. - Magnesium lime
W. C.A.S.- Wyandotte C.A.S.

From these scores it is difficult to draw sweeping conclusions, since the average score of the butters varied within a narrow range. These data show that the difference in the average score of all the butter made from cream neutralized to each of the theoretical acidities varied within 0.4 point after the short storage period and within 0.6 point after the six month holding period. However, speaking of all the butter made, it was noted that general trends are apparent in regard to the relationship of acid reduction in the cream to the change in score during storage.

When observing the change in score of the butter during 10 days storage at 72° F. it was noted that the butter from cream neutralized to theoretical acidities below 0.15 per cent held their score better and scored higher than the butter made from cream neutralized to higher theoretical acidities. However, the butter from cream neutralized to a theoretical acidity of 0.10 per cent scored approximately 0.2 point higher than any of the other butters.

The influence of the different types of neutralizers on the keeping quality of the butters are also apparent. Low acidity seems to be important for good keeping quality during the short holding period as brought out previously. Sodium hydroxide was the most efficient agent for reducing the acidity of the cream and butter, and it was noticed that the butter made from cream treated with this neutralizer scored highest, after the short holding period, by an average of 0.40 point. The butters made using sodium hydroxide show a slight increase in score during the short holding period, while the other butters lost in score and there was no apparent difference in their keeping qualities.

The criticisms of the butter after the short holding period are shown on Tables XVI, XVII and XVIII in the Appendix. There was no definite change in the appearance of a neutralizer flavor in the butters during the short holding period regardless of the neutralizer used. The samples that were criticized for a neutralizer flavor, when fresh, were also critized for this flavor after storage. The criticism of mealiness, which was apparent in the butter from cream treated with lime, also persists in these samples after storage. Tallowiness and fishiness were common criticisms of the storage butter, although tallowiness appeared in a greater number of samples than did fishiness. Neither of these criticisms show a specific relationship to acidity or to the neutralizer used. However, tallowiness appeared in the butters low in acid more often than in the high acid samples.

The influehce of the different neutralizers on the keeping quality of the butter stored for six months at 0° F. was not the same as that noted for the short holding period. During this storage period the butter made from cream treated with sodium carbonate increased in score 0.16 point, while the other butters lost from 0.26 to 1.03 point in average score. The butter made from cream treated with calcium lime showed the greatest loss in score.

The criticisms of the butter after six months storage are shown on Tables XVI, XVII and XVIII in the Appendix. The common criticism of the butter after this storage period was an old cream flavor. This flavor was more frequent in the butter after storage than before storage and was used for describing the defect in many of the samples of butter that were criticized for a neutralizer flavor when fresh. The neutralizer flavor became less frequent after the six months storage period. Tallowiness and fishiness appeared in some of the butter samples, but did not show any specific relationship to the acidity of the cream from which the butter was made, and were more frequent in the butters made from cream treated with the limes. Mealiness was also a frequent criticism of the lime butters.

When comparing the change in the score of the butter during the two storage periods it was noticed the butters do not change in score with the same relationship to the acidity of the cream from which the butter was made. The butter made from cream neutralized to the lower acidities lost approximately 0.6 point in the long storage period, while the butter made from cream neutralized to a theoretical acidity of 0.25 per cent lost only 0.18 point. This change is a reverse of the change noted during the short holding period.

<u>Change in peroxide value</u>: The peroxide value of two representative series of samples of the butterfat was determined after one month of storage at 0° F. and the peroxide value of all the butterfat was determined after six months storage at 0° F. The average of these values are shown in Table 13.

Table 13. The Influence Of The Different Neutralizers On The Change In Peroxide Value of Butterfat During Storage*.

Desired acidity of cream	Sodium carbonate		Recto		Sodium hydroxide	
	one mo. 0°F.	6 mo. 0°F.	one mo. 0°F.	6 mo. 0°F.	one mo. 0°F.	6 mo. 0°F.
0.25	0.046	1.544	0.267	0.874	0.410	0.618
0.15	0.099	1.427	0.199	0.875	0.373	0.536
0.10	0.099	1.579	0.199	0.763	0.296	0.595
0.05	0.099	1.577	0.199	0.779	0.235	0.594
0.00	0.106	1.603	0.199	0.743	0.197	0.559
	Wyandotte C.A.S.		Calcium lime		Magnesium lime	
0.25	0.149	0.784	0.254	0.679	0.193	1.122
0.15	0.149	0.747	0.316	0.800	0.124	1.116
0.10	0.162	0.727	0.297	0.832	0.148	1.065
0.05	0.160	0.721	0.334	0.746	0.172	1.067
0.00	0.161	0.733	0.289	0.801	0.173	0.989

* These figures are an average of the two series of samples after one month of storage and three series of samples after six months of storage. The original data are shown on Tables XIV and XV in the Appendix.

The individual results shown on Tables XIV and XV in the Appendix reveal that the variation in peroxide value between the different series of samples by each neutralizer was negligable and that all of the individual samples from any one neutralizer changed uniformly regardless of the acidity of the cream when churned.

These data show that the change in peroxide values during five months storage is of no value in predicting the keeping quality of butter. Samples of butter criticised as tallowy were no higher in peroxide value than the other butter. The butter made from cream treated with sodium carbonate scored highest after six months storage at 0° F. and were also found to be the highest in peroxide value which was approximately 1.550. During the five months storage, the butter made from cream treated with sodium carbonate increased 1.450 in peroxide value, while the other butter increased approximately 0.60 in peroxide value.

DISCUSSION

Studies on the speed at which different neutralizers reduce the acidity of cream reveal that after adding any one of the neutralizers the acidity of the cream continues to decrease throughout a 20-minute holding period. These findings are not entirely in harmony with those reported by Stiritz and Ruehe (69), or by Walts and Libbert (71).

The results show that 85 to 98 per cent of the total acid reduction taking place during a 20-minute holding period occurs within the first 5 minutes regardless of the neutralizer used. When the cream was neutralized with calcium lime or sodium hydroxide little acid reduction occurred after the first 5 minutes of the holding period. Magnesium lime was found to be the slowest in action of the neutralizers studied. The average acid reduction by this neutralizer during the last 15 minutes of the 20-minute holding period was found to be 0.036. Stiritz and Ruehe (69) and Walts and Libbert (71) found that magnesium lime was slow to dissolve; therefore, was slower in action than the other neutralizers. However, the cream treated with the carbonate or bicarbonate neutralizer decreased from 0.02 to 0.04 per cent in acidity during the last 15 minutes of the holding period and the greater the amount of one of these neutralizers added to cream, the greater the decrease in acidity during the last 15 minutes of the holding period.

In agreement with Wiley (76) and McDowall and McDowell (50) the carbonate and bicarbonate neutralizers do not reduce the acidity of cream before heating to the same extent as the sodium hydroxide and limes. Only 50 per cent of the theoretical reduction in acidity was obtained at the end of the 20-minute holding period when the attempts were made to reduce the acidity of the cream to 0.0 per cent with the carbonate and bicarbonate neutralizers.

From these data it seems unnecessary to hold cream more than 5 minutes after adding the neutralizer before applying pasteurizing heat as has been the practice recommended by most of the investigators.

The results shown previously in this paper bring out the fact that pasteurization decreases the acidity of the neutralized cream. These findings have also been reported by Wiley (76), Stiritz and Ruehe (69), Walts and Libbert (71), and McDowall and McDowell (50). Wiley (76) and McDowall and McDowell (50) state that the carbonic acid formed, when carbonate and bicarbonate neutralizers are added to cream, is broken down during pasteurization to reduce the acidity of the cream. When these compounds are used to reduce the acidity of cream to a theoretical acidity of 0.0 per cent, pasteurization causes an acid reduction of as much as 0.13 per cent. Pasteurization was found to reduce the acidity of cream neutralized with either calcium lime, sodium hydroxide or magnesium lime as follows: 0.015, 0.03 and 0.05 per cent, respectively. Stiritz and Ruehe (69) and Walts and Libbert (71) obtained values similar to these when using limes.

The recent trend of reducing the acidity of cream to a low range has resulted in a variation from linear reduction in acidity by the different neutralizers as shown in Fig. I. Carbonate and bicarbonate neutralizers gave near linear reduction in acidity when neutralizing cream to 0.25 per cent. This was also shown by Wiley (76) and Bird, Fabricius and Breazeale (7). McDowall and McDowell obtained a linear reduction in acidity to an acidity of 0.10, using bicarbonate, however, they used small samples and heated the cream to 190° F. for one minute, which, no doubt, removed more of the carbon dioxide from the cream than the holder method of pasteurization. In this study only 83 to 90 per cent of the theoretical reduction in acidity was obtained when attempts were made to reduce the acidity of cream to 0.10 per cent with the carbonate and bicarbonate neutralizers, whereas less than 80 per cent of the theoretical acid reduction was obtained when attempts were made to reduce the acidity of the cream to 0.0 per cent. Wiley (76) reported similar data using sodium bicarbonate.

The factors for calculating the amount of the lime neutralizers to add to cream were those recommended by the manufacturers and made allowance for only 80 per cent efficiency. The results show that a uniform reduction in acidity was not obtained with the limes over the range studied. Magnesium lime gave an actual acidity in the cream greater than the theoretical when used for reducing the acidity of cream to a range above 0.10 per cent. However, at a theoretical acidity of 0.0 per cent, only 92 per cent efficiency was obtained. Calcium lime gave an actual acidity in the cream near that desired when the cream was neutralized to either 0.25 per cent or 0.15 per cent. The factor, allowing for only 80 per cent efficiency, proved to be correct at this range. This substantiates the findings of Hunziker and Hosman (40), Walts and Libbert (71) and Wiley (76). However, when calcium lime was used to reduce the acidity of cream to a range lower than 0.15 per cent, the factor was incorrect, as only 90 per cent of the theoretical reduction was obtained.

The limes were found to cause the cream to thicken and after processing the cream was difficult to strain. Fabricius (23) noted a similar effect and states that this was due to the destabilizing action of the lime on the protein in cream.

Fig. I. The Efficiency of Acid Reduction by Different Neutralizers When Reducing the Acidity of Cream to Different Desired Acidities.

The cream treated with each of the neutralizers to a theoretical acidity above 0.0 was found to decrease 0.01 per cent in acidity and increased 0.10 unit in pH during 24-hours storage. The cream neutralized to a theoretical acidity of 0.0 per cent did not change in acidity or pH during the 24-hour storage period. McDowall and McDowell (50) found that neutralized cream lost carbon dioxide during storage, thereby decreasing the acidity.

The relationship of the pH of the cream to the theoretical acidity to which the cream was reduced is shown in Fig. II. The different carbonate neutralizers usually gave pH values corresponding within 0.2 pH unit at each of the theoretical acidities. The pH value of the cream neutralized with sodium hydroxide, calcium lime or magnesium lime also varied within a narrow range. However, the variation between the two groups may be as much as 0.4 pH unit at each of the theoretical acidities. These findings are in agreement with the work of Fabricius (23), Hunziker and Cordes (42) and Hussong (43). These results show that cream neutralized with the carbonate neutralizers to a theoretical acidity of 0.10 per cent will give pH values in the cream of, from 6.7 to 7.0. However, cream neutralized to 0.10 per cent acidity with the other three neutralizers gave pH values as follows: sodium hydroxide, 7.26; calcium lime, 6.63; and magnesium lime, 6.82.

The different neutralizers were found to have practically no influence on the relationship of the pH of the cream to the pH of the buttermilk and butter sera. The pH of the butter was found to persist at 0.15 pH unit above, and the buttermilk at 0.10 pH unit below their corresponding cream regardless of the neutralizer used. Breazeale, Fabricius and Bird (10) report similar findings. These results are also in accord with reports by

Fig. II. The Relationship of the pH of the Cream to the Theoretical Acidity to Which the Cream was Reduced.

Hunziker and Cordes (42) and Loftus-Hill, et. al. (43) and the pH of the butter does not give any indication as to the acidity of the cream at churning.

The acidity of the cream is in the serum portion and it was found that the acidity of the buttermilk was from 0.02 to 0.05 per cent higher than the acidity of the corresponding cream when the cream was neutralized to acidities as low as 0.15 per cent. However, when the cream was neutralized to acidities lower than 0.15 per cent the acidity of the buttermilk was usually lower than the acidity of the cream. This was probably due to the more distinct end-point in the titration of the cream at these low acidities.

Information concerning the relationship of the acidity of the cream to the acidity of the butter and butterfat is very meager. The results reported previously in this paper and shown graphically in Fig. III reveal that as the acidity of the cream was reduced the acid degree of the butter and butterfat was also reduced, although variations occurred when the different neutralizers were used. The acid degree of the butter and butterfat from cream treated with the different carbonate neutralizers were found to follow the same trend throughout the acidity range studied. This was also found to be the case when the cream was treated with the different lime neutralizers. However, a greater difference between the acid degree of the butter and butterfat was noted when the carbonate neutralizers and sodium hydroxide were used than when the limes were used for reducing the acidity of the cream to 0.25 and 0.15 per cent acidity. The results show that the limes were not as effective as the other neutralizers in reducing the acid

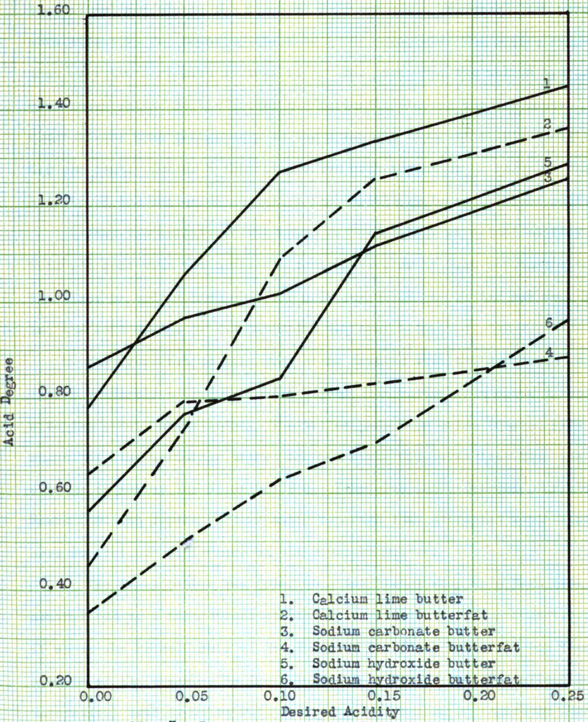

Fig. III. The Relationship of the Acidity of the Cream to the Acid Degree of the Butter and Butterfat.

degree of the butter or butterfat at the higher ranges, i.e. above a theoretical acidity in the cream of 0.05 per cent. However, they were more effective for reducing the acidity of cream over the entire range than were the carbonate neutralizers. The limes and the sodium hydroxide gave lower values in the butter and butterfat than did the carbonate neutralizers when the acidity of the cream was theoretically reduced to 0.0 per cent. Sodium hydroxide was the most effective in reducing the acidity of the butterfat at theoretical acidities below 0.25 per cent.

When the acidity of the cream was reduced to an actual acidity of 0.13 per cent with the carbonate neutralizers or to 0.10 per cent with the limes or sodium hydroxide the acid degree of the butter was near 1.0 and the acid degree of the butterfat was near 0.80.

The fresh butter made from cream treated with the carbonate neutralizers uniformly scored 0.2 point higher than butter from cream treated with the other neutralizers. The butter made from cream treated with magnesium lime uniformly scored approximately 0.3 point less than the average of any of the other butters. Fabricius (23), Overman, Garrett and Ruehe (58) and Jensen (47) recently reported that different neutralizers have no distinct difference on the score of butter.

The fresh butter was found to score higher when made from cream neutralized to a theoretical acidity of from 0.15 to 0.10 per cent. Fig. IV shows the relationship of the score of the fresh butter to the theoretical acidity of the cream. The fresh butter made from cream neutralized to a theoretical acidity below 0.10 with sodium hydroxide or magnesium lime were of inferior quality.

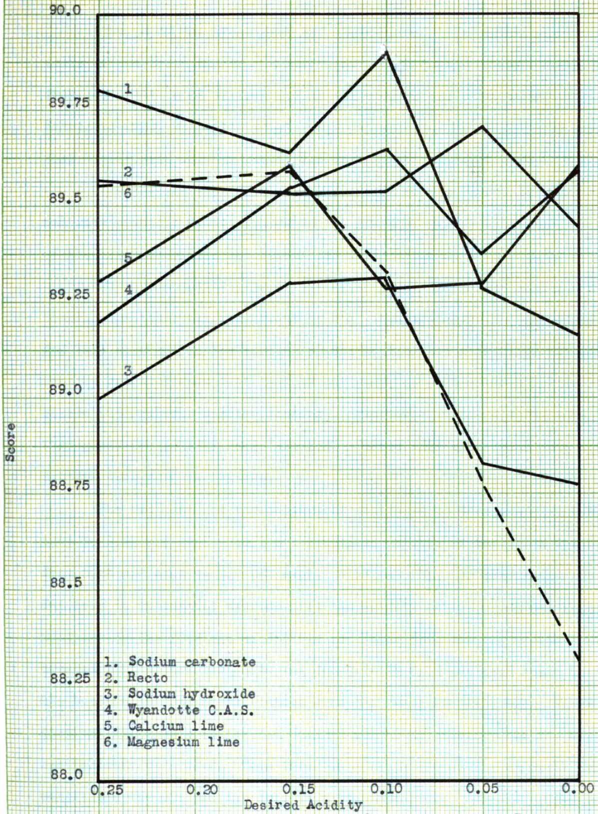

Fig. IV. The Relationship of the Score of the Fresh Butter to the Theoretical Acidity of the Cream.

The pH of the cream does not show a specific relationship to the score of the fresh butter. However, more high scoring butter was made from cream with a pH of from 6.7 to 7.2 than at any other equal pH range. Fabricius (23), McDowall, et.al. (51), Nelson (54) and Wiley (77) found that butter with maximum flavor was made from cream with a pH of 6.6 to 7.0.

The results show that the acid degree of the butter or butterfat do not show specific relationships to the score of the fresh butter. A survey of the literature does not reveal any information in this regard.

The common criticisms of the fresh butter were old cream and neutralizer. Mealiness was also found in the lime butters. The old cream flavor was less apparent in the samples of butter from the cream neutralized to an acidity range of from 0.15 to 0.10 per cent, or a pH of from 6.7 to 7.2, Nelson (54) reports similar findings. Mealiness in the lime butters occurred throughout the acidity range studied. Davies (20) also found that lime butters were poor in texture.

The fat test of the buttermilk was found to decrease from 0.80 per cent to 0.59 per cent when the theoretical acidity of the cream was decreased from 0.25 per cent to 0.0 per cent. Bird, et. al. (7) also found that the fat loss in buttermilk decreased as the acidity of the cream was reduced. Contrary to the findings of Stiritz and Ruehe (69) the buttermilk from cream treated with sodium carbonate was found to be 0.15 per cent lower in fat than the buttermilk from cream treated with the other neutralizers. There was no distinct difference in the fat content of the buttermilk when the other neutralizers were used. From these data it is apparent that under practical conditions the minimum fat loss in buttermilk is not reached, which is in agreement with Derby, Breazeale and Bird (22).

A complete analysis of all the butter revealed that the curd content of the butter was increased as the acidity of the cream was reduced. Butter made from cream treated with calcium lime was slightly lower in the curd than the other butters when the cream was neutralized to 0.25 per cent acidity. However, the average curd content of all the butter made from cream treated with calcium lime averaged 0.25 per cent higher than the average curd content of the other butter.

The curd content of the lime butter was increased 0.6 per cent and the curd content of the other butters was increased 0.10 per cent when the cream was neutralized to a theoretical acidity of 0.0 per cent over that from cream neutralized to 0.25 per cent. Frandsen et. al. (26) found the curd content of butter from cream neutralized with lime was increased slightly although their data were not conclusive. McKay and Larson (52) report that one of the authors found that lime neutralizers did not increase the curd content of butter. However, these authors are probably reporting data on the analysis of butter made from cream neutralized to 0.25 per cent acidity.

Observations on the change in score of the butter when stored for 10 days at 72° F. reveal that low acidity was necessary for good keeping quality under these conditions. Sodium hydroxide was found to reduce the acidity of the cream lower than the other neutralizers and the sodium hydroxide butter scored approximately 0.4 points higher than the other butter after storage. There was no distinct difference in the score of the butter made from cream treated with the other neutralizers at the end of the short storage period. In general, the butter from cream neutralized to a theoretical acidity below 0.15 per cent held their score better than the butter from cream neutralized to higher acidities.

The butters stored for this short holding period decreased approximately 0.2 in pH and the acid degree of the butter increased from 0.10 to 0.30. The magnesium lime butter showed the greatest increase in acid degree. The butter from cream treated with calcium lime decreased the least in pH. This butter was also found to be high in curd indicating the presence of residual alkali.

Tallowiness and fishiness were noted in some of the samples of butter after the short holding period. However, these flavors did not show specific relationship to the acidity or pH of the butter before storage. Tallowiness was more frequent among the butters from cream treated with the lime neutralizers. Jacobsen (45, 46) noted that the only defect occurring in salted butter during a similar holding period was tallowiness.

The influence of the neutralizer was apparent on the score of the butter after six months at 0° F. The butter from cream treated with sodium carbonate was found to increase in score by 0.15 point while the other butter lost from 0.26 to 1.00 point in score during storage. The calcium lime butter lost the most in score during the six months storage period.

The butter from cream neutralized to a theoretical acidity of 0.25 per cent were found to hold its score better and score higher after six months storage than the butter from cream reduced to lower acidities. The butter showing the best keeping quality was from cream with a pH of 6 to 7, although some of the samples with poor keeping quality were in this range. These results agree with the findings of Hunziker and Cordes (42) and

Parfitt and Flake (24). Other investigators have reported maximum keeping quality at higher pH values.

The changes in pH occurring in the butter during the six months storage period were irregular, some increasing and others decreasing, and were found to show no definite relationship to keeping quality. This is in agreement with the findings of Bendixen, et. al. (3). However, the butter from cream treated with sodium carbonate was found to increase slightly in pH during storage. This butter also increased 0.16 point in score during storage. The changes of pH during storage were small and many of them were within experimental error. Contrary to the findings of Breazeale, et. al. (10) and Bird (7), the lime butters did not increase in pH during storage. The changes of pH during storage were not related to the curd content of the butter.

The acid degree of the butter was found to increase by an average of 0.150 during six months storage. This increase was relatively uniform and appeared to have only a slight effect on the keeping quality of the butter. Bird, et. al. (7), Loftus-Hills, et. al. (48), and others reported similar findings. However, the butter from cream treated with magnesium lime was found to increase in acid degree approximately 0.10 more than the other butters and was also found to decrease 0.50 point more in score than the other butters during six months storage. Butter of good quality had an acid degree of from 1.200 to 1.500 when all of the neutralizers were used with the exception of sodium carbonate. The sodium carbonate butter showed better keeping quality than the other butter and had an acid degree of from 1.0 to 1.34. These values are higher than those recommended by Hunziker (39) and Bouska (11).

In general, the acid degree of the butterfat was found to increase uniformly during the six months in storage in the butter made from cream neutralized to a theoretical acidity above 0.10 per cent. The increase in acid degree was only 0.05, which indicates a slight hydrolysis of the butterfat. This increase in acid degree occurred in the butter showing the best keeping quality. However, an increase or decrease in acid degree during storage did not appear to be correlated with keeping quality. The butterfat from cream neutralized to a theoretical acidity of 0.10 per cent, or below was found to decrease from 0.05 to 0.10 in acid degree during the six months storage period. This butterfat was from the butter showing the greatest decrease in score during storage and was also from butter found to be higher in curd than the other butter.

A comparison of the change in acid degree of the butter and butterfat reveals that acidity develops independently in the butter and butterfat, Overman (58) reports a similar finding.

When comparing the changes in score, acid degree of the butter, and pH of the butter during the 10-day storage period at 72° F., with the keeping quality of the butter during the six months atorage period at 0° F., it was concluded that the short storage period was of no value in predicting the keeping quality of the butter. The butters scoring highest after the short storage period were among the low scoring butters after the six months storage period, which is in contrast with the findings of Jacobsen (45, 46), Nelson (53) and Parsons (60).

The results show that changes in peroxide value of butterfat during storage were of no value in predicting the keeping quality of butter made from cream neutralized to theoretical acidities ranging from 0.25 to 0.0

per cent. This agrees with the findings of Loftus-Hill, et. al. (48) and Coe and LeClerc (11), but not with the results reported by Holm (35) and Holm, et. al. (36). However, the latter authors worked with a greater range of acidity than the one included in this study. The results reported herein show that the peroxide value of butterfat develops uniformly at each of the acidities studied. The peroxide value of the butterfat from cream treated with sodium carbonate developed uniformly throughout the acidity range studied, although the values were higher than the values of the other butterfat. The butters from cream treated with sodium carbonate increased 1.450 in peroxide value during the last five months of the six months storage period, while the butterfat from cream treated with the other neutralizers increased only 0.6 in peroxide value during the same period. However, as previously noted, the sodium carbonate butter increased slightly in score during the six months storage period and the other butter lost in score. None of the sodium carbonate butters were criticized as tallowy, while some of the samples of the other butters were found to have a tallowy flavor after storage even though they gave lower peroxide values. Stebnitz and Sommer (68) also found that tallowiness may occur in butterfat with a low peroxide value.

SUMMARY

The experimental work herein reported involved the use of seven neutralizing agents for reducing cream of 0.50 per cent acidity to acidities varying from 0.25 to 0.0 per cent. The neutralizers used were sodium carbonate, Wyandotte C.A.S. (a mixture of sodium carbonate and sodium bicarbonate), sodium bicarbonate, Recto (chiefly sodium and potassium carbonates), sodium hydroxide, Peerless lime (calcium hydrates), and Allwood lime (magnesium oxide and calcium hydrate).

When these common types of neutralizers were added to cream at 90° F., the acidity of the cream continued to decrease throughout a 20-minute holding period. However, the reduction in acidity occurring within the first five minutes of the holding period when using lime or sodium hydroxide was from 95 to 98 per cent of that desired, and when using magnesium lime, or the carbonate and bicarbonate neutralizers, was 85 to 90 per cent.

The average reduction in acidity due to pasteurizing the cream at 145° F. for 30 minutes was from 0.01 to 0.12 per cent, depending on the kind and the amount of the neutralizer added to the cream.

The actual final reduction in the acidity of cream treated with sodium hydroxide, calcium lime or magnesium lime was greater than that desired when the cream was neutralized to theoretical acidities above 0.10 per cent. However, when the cream was neutralized to a theoretical acidity of 0.0 per cent the actual reduction in the acidity of the cream by these neutralizers was from 88 to 91 per cent of the theoretical. The carbonate and bicarbonate neutralizers gave a linear reduction in the acidity of the cream to 0.25 per cent but less than 80 per cent of the theoretical reduction was obtained when attempts were made to reduce the acidity of the cream to 0.0 per cent.

Cream neutralized to theoretical acidities of 0.25, 0.15, 0.10, and 0.05 with each of the different neutralizers was found to decrease 0.01 per cent in acidity and increase 0.10 unit in pH during 24 hours storage at 45° F.

The pH of the cream was found to vary considerably when the different neutralizers were used for reducing the acidity of the cream to each of the theoretical acidities. However, the pH of the cream usually varied within 0.4 unit when the different neutralizers were used for reducing the acidity of the cream to approximately the same titratable acidity. When cream was neutralized to the same titratable acidity with the carbonate neutralizers the pH of the cream varied within 0.2 unit. If a pH of near 7.0 is desired in the cream the titratable acidity of the cream when treated with the different neutralizers was found to be as follows: sodium carbonate, 0.13; Recto, 0.15; sodium hydroxide, 0.11; Wyandotte C.A.S., 9.14; calcium lime, 0.09; magnesium lime, 0.11; and sodium carbonate, 0.16.

The pH of the butter was approximately 0.15 above the pH of the corresponding cream regardless of the neutralizer used. However, the pH of the buttermilk averaged approximately 0.10 below the pH of the corresponding cream.

As the acidity of the cream was reduced the acid degree of the butter and butterfat ware also reduced, although variations occurred due to the use of the different neutralizers. The sodium hydroxide was found to be the most effective of the neutralizers studied in reducing the acid degree of the butter and butterfat, while calcium and magnesium lime were found to be the least effective. When the acidity of the cream, treated with the different neutralizers, fell within the range of 0.25 to 0.15 per cent the acid degree of the butter was from 1.1 to 1.45 and the acid degree of the butterfat was from 0.80 to 1.20.

When fresh, the butter made by using the carbonate neutralizers usually scored slightly higher than the other butter. The fresh butter usually scored highest when the cream had been reduced to a theoretical acidity of from 0.15 to 0.10 per cent, or a pH of 6.7 to 7.2. However, neither of these values showed a definite relationship to the score of the fresh butter. The acid degree of the butter and butterfat also showed no definite correlation to the score of the fresh butter.

The average fat test of the buttermilk was found to decrease from 0.80 per cent to 0.59 per cent when the theoretical acidity of the cream was reduced from 0.25 per cent to 0.0 per cent.

The curd content of the butter increased as the acidity of the cream was decreased. The butter from cream treated with calcium lime had an average curd content of 0.25 per cent higher than the other butter.

In general, the butter from cream neutralized to theoretical acidities below 0.15 per cent held their score better during 10 days storage at 72° F. than the butter from cream neutralized to higher acidities. During this short storage period the butter decreased 0.2 pH unit and increased from 0.10 to 0.30 in acid degree. Neither of these changes appeared to be related to the change in score.

The butter from cream treated with sodium carbonate was found to have better keeping quality than the butter from cream treated with the other neutralizers. In fact this butter increased 0.15 point in score during six months storage at 0° F., while the other butter lost in score. The calcium lime butter lost the most in score.

The butter from cream neutralized to a theoretical acidity of 0.25 per cent with the different neutralizers scored higher after six months storage than the butter from cream neutralized to lower acidities. The butter showing the best keeping quality was from cream with a pH of from 6.0 to 7.0.

When the butter was stored for six months at 0° F., the pH increased in some samples and decreased in others; the acid degree of the butter showed a relatively uniform increase of 0.150; the acid degree of the butterfat increased slightly when the butter was made from cream neutralized to theoretical acidity above 0.15, but decreased in the other butter. None of these changes showed a definite relationship to keeping quality.

The changes in pH, acid degree, and score of the butter during 10 days storage at 72° F. show no definite relationship to the keeping quality of the butter during six months storage at 0° F.

The change in peroxide value of butterfat during the last five months of a six months storage period was relatively uniform at all acidities; this change was not related to the change in score.

CONCLUSIONS

The speed at which the acid of cream is reduced before pasteurization is practically the same regardless of the neutralizer used. Within five minutes after the addition of the neutralizer 85 to 98 per cent of the acid reduction occurs.

The vat method of pasteurization reduces the acidity of cream treated with the different neutralizers. This reduction in acidity is usually from 0.02 to 0.06 per cent depending on the kind and the amount of neutralizer used. However, this reduction in acidity may be as much as 0.13 per cent when a large amount of a carbonate or bicarbonate neutralizer is added to cream.

The calculated reduction of the acidity of cream treated with the different neutralizers is not always obtained. If the cream is neutralized with magnesium lime or sodium hydroxide the actual reduction in the acidity of cream may be greater than that desired when the cream is theoretically reduced to 0.25 and 0.15 per cent acidity. When the different neutralizers are used to theoretically reduce the acidity of cream below 0.10 per cent linear reduction is not obtained. The carbonate and bicarbonate neutralizers are less than 80 per cent efficient when cream is theoretically reduced to 0.0 per cent acidity.

Cream neutralized to either the same titratable acidity or to the same theoretical acidity varies in pH value when different neutralizers are used.

As the acidity of the cream is reduced with the different neutralizers, the acid degree of the butter and butterfat are also reduced, and the curd content of the butter is increased. Calcium and magnesium lime are the least efficient in reducing the acid degree of the butter and butterfat at the high acidity ranges. Sodium hydroxide is the most efficient for reducing these two values when the acidity of cream is reduced to a low range.

When the different neutralizers were used, the acidity and pH of cream, the pH of butter, and the acid degree of the butter and butterfat, did not show any specific relationship to the quality of the butter.

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APPENDIX

TABLE I. ACIDITY AND pH VALUES OF CREAM NEUTRALIZED WITH SODIUM CARBONATE.*

Desired acidity	Titratable acidity as per cent lactic acid: Original cream	Period after adding the neutralizer: 5 min.	10 min.	15 min.	20 min.	145°F.	145°F. 30 min.	Cooled	24 hrs.	pH of cream: Original cream	After past.	After 24 hrs.
	0.550	0.340	0.330	0.330	0.330	0.285	0.280	0.280		4.80	5.95	
	0.550	0.345	0.340	0.335	0.330	0.295	0.295	0.290		4.63	5.91	
0.25	0.465	0.340	0.335	0.330	0.330	0.290	0.270	0.360	0.260	4.80	5.57	5.90
	0.470	0.340	0.335	0.330	0.320	0.285	0.270	0.260	0.240	4.82	5.91	6.05
	0.410	0.330	0.330	0.320	0.320	0.280	0.250	0.240	0.230	5.11	5.97	6.05
Avg.	0.489	0.339	0.333	0.329	0.326	0.288	0.273	0.266	0.243	4.83	5.88	6.00
	0.550	0.300	0.300	0.290	0.280	0.240	0.185	0.185		4.80	6.42	
	0.550	0.320	0.320	0.310	0.305	0.240	0.185	0.185		4.63	6.42	
0.15	0.465	0.300	0.290	0.285	0.285	0.230	0.190	0.185	0.170	4.80	6.34	6.37
	0.470	0.300	0.290	0.285	0.280	0.230	0.190	0.185	0.170	4.82	6.45	6.60
	0.410	0.300	0.280	0.280	0.270	0.220	0.185	0.180	0.170	5.11	6.45	6.48
Avg.	0.489	0.304	0.296	0.287	0.284	0.232	0.187	0.184	0.170	4.83	6.42	6.48
	0.550	0.290	0.290	0.280	0.260	0.225	0.195	0.190		4.80	6.64	
	0.550	0.260	0.255	0.255	0.250	0.180	0.175	0.175		4.63	6.58	
0.10	0.465	0.280	0.270	0.260	0.260	0.175	0.160	0.155	0.140	4.80	6.91	6.97
	0.470	0.280	0.270	0.265	0.265	0.180	0.165	0.165	0.160	4.82	6.65	6.70
	0.410	0.270	0.265	0.260	0.260	0.170	0.160	0.150	0.150	5.11	6.70	6.71
Avg.	0.489	0.276	0.270	0.264	0.259	0.192	0.171	0.167	0.150	4.83	6.70	6.79
	0.550	0.250	0.240	0.240	0.240	0.200	0.170	0.160		4.80	6.70	
	0.550	0.240	0.220	0.215	0.210	0.200	0.180	0.165		4.63	6.70	
0.05	0.465	0.280	0.275	0.260	0.245	0.160	0.150	0.150	0.145	4.80	6.80	6.84
	0.470	0.280	0.270	0.250	0.240	0.160	0.150	0.150	0.140	4.82	6.93	7.08
	0.410	0.270	0.270	0.250	0.240	0.160	0.150	0.140	0.130	5.11	6.90	6.92
Avg.	0.489	0.264	0.255	0.243	0.235	0.176	0.160	0.154	0.138	4.83	6.81	6.95
	0.465	0.250	0.240	0.230	0.230	0.145	0.125	0.120	0.120	4.82	7.03	7.12
0.00	0.470	0.260	0.240	0.230	0.220	0.145	0.125	0.120	0.120	4.82	7.07	7.23
	0.410	0.250	0.240	0.220	0.210	0.145	0.125	0.120	0.120	5.11	7.00	7.08
Avg.	0.448	0.253	0.240	0.227	0.220	0.145	0.125	0.120	0.120	4.91	7.03	7.14

* First two trials in each series conducted on small laboratory basis, others conducted on larger commercial scale.

TABLE II. ACIDITY AND pH VALUES OF CREAM NEUTRALIZED WITH RECTO (SODIUM AND POSTASSIUM CARBONATE).*

Desired acidity	Titratable acidity as per cent lactic acid: Original cream	Period after adding the neutralizer: 5 min.	10 min.	15 min.	20 min.	145°F.	145°F. 30 min.	Cooled	24 hrs.	pH of cream: Original cream	After past.	After past.
	0.500	0.360	0.350	0.355	0.350	0.310	0.280	0.270		5.10	6.00	
	0.490	0.355	0.350	0.345	0.340	0.305	0.280	0.270		5.30	5.95	
	0.580	0.360	0.355	0.350	0.340	0.280	0.270	0.260	0.230	4.70	6.17	6.30
0.25	0.490	0.360	0.350	0.350	0.340	0.280	0.260	0.250	0.200	4.82	6.06	6.15
	0.550	0.360	0.350	0.350	0.340	0.280	0.260	0.245	0.190	4.62	6.24	6.35
Avg.	0.522	0.359	0.351	0.350	0.342	0.291	0.270	0.259	0.207	4.90	6.08	6.27
	0.500	0.330	0.320	0.320	0.310	0.260	0.225	0.220		5.10	6.32	
	0.490	0.320	0.315	0.300	0.300	0.255	0.215	0.215		5.30	6.37	
	0.580	0.320	0.300	0.290	0.290	0.240	0.230	0.220	0.180	4.70	6.78	6.90
0.15	0.490	0.300	0.290	0.270	0.270	0.230	0.220	0.190	0.185	4.82	6.51	6.60
	0.550	0.310	0.300	0.280	0.280	0.240	0.220	0.180	0.160	4.62	6.76	6.90
Avg.	0.522	0.316	0.305	0.292	0.290	0.245	0.222	0.205	0.175	4.90	6.55	6.47
	0.500	0.300	0.300	0.290	0.285	0.230	0.185	0.175		5.10	6.57	
	0.490	0.295	0.290	0.280	0.280	0.220	0.175	0.170		5.30	6.65	
	0.580	0.300	0.290	0.290	0.280	0.200	0.180	0.160	0.150	4.70	6.96	7.10
0.10	0.490	0.290	0.280	0.270	0.270	0.180	0.160	0.150	0.145	4.82	6.92	6.96
	0.550	0.300	0.300	0.290	0.290	0.200	0.160	0.155	0.150	4.62	6.96	7.05
Avg.	0.522	0.298	0.292	0.284	0.281	0.206	0.172	0.162	0.148	4.90	6.82	7.04
	0.500	0.285	0.280	0.275	0.270	0.210	0.140	0.140		5.10	6.83	
	0.490	0.290	0.290	0.280	0.270	0.200	0.140	0.140		5.30	6.82	
	0.580	0.310	0.290	0.280	0.270	0.200	0.180	0.160	0.150	4.73	7.12	7.23
0.05	0.490	0.280	0.270	0.255	0.250	0.180	0.165	0.160	0.150	4.82	7.14	7.14
	0.550	0.300	0.280	0.270	0.270	0.200	0.170	0.145	0.140	4.62	7.05	7.14
Avg.	0.522	0.293	0.282	0.272	0.260	0.198	0.159	0.149	0.147	4.90	6.99	7.17
	0.580	0.300	0.270	0.270	0.265	0.180	0.140	0.140	0.120	4.70	7.23	7.30
	0.490	0.300	0.270	0.270	0.260	0.150	0.120	0.115	0.115	4.83	7.40	7.36
0.00	0.550	0.300	0.270	0.270	0.260	0.170	0.140	0.140	0.130	4.62	7.30	7.32
Avg.	0.540	0.300	0.270	0.270	0.262	0.167	0.167	0.132	0.122	4.71	7.31	7.33

* First two trials in each series conducted on small laboratory basis, others conducted on larger commercial scale.

TABLE III. ACIDITY AND pH VALUES OF CREAM NEUTRALIZED WITH SODIUM HYDROXIDE.*

Desired acidity	Titratable acidity as per cent lactic acid: Original cream	Period after adding the neutralizer: 5 min.	10 min.	15 min.	20 min.	145° F.	145°F. 30 min.	Cooled	24 hrs.	pH of cream: Original cream	After past.	After past.
	0.450	0.245	0.245	0.245	0.245	0.235	0.230	0.230		4.70	5.93	
	0.530	0.245	0.240	0.240	0.240	0.240	0.230	0.225		4.70	6.24	
0.25	0.540	0.255	0.255	0.255	0.255	0.230	0.220	0.210	0.185	4.80	6.24	6.32
	0.535	0.260	0.255	0.255	0.255	0.230	0.220	0.210	0.185	4.75	6.38	6.47
	0.490	0.250	0.250	0.250	0.250	0.230	0.200	0.210	0.185	4.82	6.32	6.40
Avg.	0.509	0.251	0.249	0.249	0.249	0.231	0.220	0.217	0.185	4.75	6.22	6.40
	0.450	0.170	0.170	0.170	0.170	0.155	0.155	0.150		4.70	6.74	
	0.530	0.180	0.180	0.175	0.175	0.155	0.155	0.155		4.70	6.80	
0.15	0.540	0.160	0.160	0.160	0.160	0.140	0.130	0.130	0.105	4.80	7.10	7.02
	0.535	0.160	0.155	0.155	0.155	0.140	0.130	0.130	0.100	4.75	7.11	7.22
	0.490	0.160	0.160	0.160	0.160	0.140	0.130	0.130	0.110	4.82	7.10	7.20
Avg.	0.509	0.166	0.165	0.164	0.164	0.146	0.140	0.139	0.105	4.75	6.97	7.15
	0.450	0.125	0.125	0.125	0.125	0.120	0.115	0.110		4.70	6.90	
	0.530	0.125	0.125	0.125	0.125	0.120	0.120	0.115		4.70	7.12	
0.10	0.540	0.150	0.140	0.140	0.140	0.120	0.110	0.110	0.085	4.80	7.22	7.24
	0.535	0.150	0.150	0.150	0.150	0.125	0.110	0.110	0.085	4.70	7.23	7.29
	0.490	0.140	0.130	0.130	0.130	0.110	0.110	0.100	0.100	4.82	7.20	7.25
Avg.	0.509	0.138	0.134	0.134	0.134	0.119	0.113	0.111	0.090	4.75	7.13	7.26
	0.450	0.095	0.095	0.095	0.095	0.080	0.075	0.075		4.70	7.34	
	0.530	0.085	0.085	0.085	0.085	0.080	0.080	0.075		4.70	7.50	
0.05	0.540	0.100	0.095	0.095	0.095	0.090	0.080	0.075	0.065	4.80	7.62	7.70
	0.535	0.105	0.105	0.105	0.100	0.090	0.080	0.075	0.060	4.70	7.72	7.77
	0.490	0.100	0.090	0.090	0.090	0.080	0.075	0.075	0.070	4.82	7.52	7.60
Avg.	0.509	0.097	0.094	0.094	0.093	0.084	0.078	0.075	0.065	4.75	7.54	7.69
	0.540	0.080	0.075	0.070	0.070	0.060	0.050	0.045	0.045	4.82	7.96	7.98
	0.535	0.080	0.075	0.070	0.070	0.060	0.050	0.050	0.045	4.70	7.98	8.08
0.00	0.490	0.075	0.070	0.070	0.070	0.060	0.050	0.045	0.045	4.82	7.94	7.98
Avg.	0.522	0.078	0.073	0.070	0.070	0.060	0.050	0.047	0.045	4.78	7.96	8.01

* First two trials in each series conducted on small laboratory basis, others conducted on larger commercial scale.

TABLE IV. ACIDITY AND pH VALUES OF CREAM NEUTRALIZED WITH WYANDOTTE C.A.S.(SODIUM CARBONATE & SODIUM BICARBONATE)*

		Titratable Acidity as Per Cent Lactic Acid								pH of cream		
Desired:	Original:	Period after adding the neutralizer								Original:	After	After
acidity:	cream	5 min.	10 min.	15 min.	20 min.	145° F.	145° F. 30 min.	Cooled	24 hrs.	cream	past.	past.
	0.490	0.330	0.320	0.315	0.310	0.300	0.270	0.260		4.80	6.16	
	0.390	0.325	0.320	0.315	0.310	0.285	0.270	0.265		4.90	6.04	
0.25	0.470	0.330	0.320	0.320	0.320	0.270	0.260	0.255	0.260	4.80	6.10	6.20
	0.560	0.350	0.350	0.320	0.310	0.270	0.250	0.240	0.240	4.70	6.28	6.38
	0.490	0.330	0.320	0.320	0.320	0.270	0.250	0.245	0.260	4.85	6.05	6.20
Avg.	0.480	0.330	0.326	0.318	0.314	0.279	0.260	0.253	0.253	4.81	6.13	6.26
	0.490	0.320	0.300	0.280	0.260	0.220	0.210	0.205		4.80	6.55	
	0.390	0.260	0.260	0.250	0.240	0.210	0.180	0.175		4.90	6.63	
0.15	0.470	0.290	0.280	0.280	0.270	0.200	0.180	0.175	0.170	4.80	6.92	6.97
	0.560	0.330	0.320	0.310	0.300	0.220	0.180	0.170	0.160	4.70	6.92	6.98
	0.490	0.300	0.300	0.290	0.280	0.200	0.180	0.180	0.180	4.85	6.65	6.90
Avg.	0.480	0.300	0.292	0.282	0.270	0.210	0.186	0.181	0.170	4.81	6.73	6.95
	0.490	0.310	0.300	0.290	0.280	0.215	0.145	0.145		4.80	6.88	
	0.390	0.260	0.260	0.240	0.230	0.205	0.145	0.145		4.90	6.90	
0.10	0.470	0.290	0.280	0.270	0.270	0.180	0.140	0.135	0.135	4.80	6.98	6.94
	0.560	0.320	0.320	0.290	0.290	0.220	0.150	0.150	0.150	4.70	7.10	7.10
	0.490	0.300	0.280	0.270	0.260	0.180	0.160	0.155	0.140	4.85	6.92	7.05
Avg.	0.480	0.296	0.288	0.272	0.266	0.200	0.148	0.148	0.142	4.81	6.96	7.03
	0.490	0.290	0.260	0.240	0.225	0.205	0.145	0.145		4.80	7.08	
	0.390	0.270	0.250	0.240	0.205	0.170	0.120	0.173		4.90	7.19	
0.05	0.470	0.280	0.250	0.240	0.230	0.160	0.120	0.115	0.125	4.80	7.13	7.20
	0.560	0.310	0.290	0.260	0.240	0.200	0.140	0.130	0.130	4.70	7.33	7.30
	0.490	0.290	0.260	0.260	0.250	0.180	0.140	0.130	0.130	4.85	7.23	7.30
Avg.	0.480	0.288	0.262	0.248	0.230	0.183	0.133	0.127	0.128	4.81	7.19	7.26
	0.470	0.270	0.250	0.230	0.225	0.140	0.120	0.120	0.105	4.80	7.45	7.36
0.00	0.560	0.290	0.260	0.260	0.250	0.160	0.130	0.120	0.105	4.70	7.42	7.44
	0.490	0.300	0.280	0.260	0.250	0.155	0.135	0.120	0.105	4.80	7.40	7.48
	0.507	0.287	0.263	0.250	0.242	0.152	0.128	0.120	0.105	4.77	7.42	7.43

* First two trials in each series conducted on small laboratory basis, others conducted on larger commercial scale.

TABLE V. ACIDITY AND pH VALUES OF CREAM NEUTRALIZED WITH PEERLESS LIME (CALCIUM LIME)*.

	Titratable acidity as per cent lactic acid									pH of cream		
Desired	Original	Period after adding the neutralizer								Original	After	After
acidity	cream	5 min.	10 min.	15 min.	20 min.	145° F.	145° F. 30 min.	Cooled	24 hrs.	cream	past.	past.
	0.525	0.290	0.275	0.275	0.275	0.260	0.260	0.260		4.70	5.93	
	0.540	0.280	0.280	0.280	0.280	0.270	0.265	0.260		4.70	5.93	
0.25	0.545	0.270	0.260	0.260	0.260	0.250	0.240	0.240	0.240	4.60	5.85	6.02
	0.520	0.270	0.260	0.260	0.255	0.255	0.255	0.250	0.250	4.70	5.92	6.12
	0.500	0.280	0.270	0.260	0.260	0.250	0.250	0.240	0.250	4.66	5.90	6.10
	0.480	0.270	0.270	0.270	0.260	0.260	0.260	0.255	0.240	4.88	5.88	6.05
Avg.	0.520	0.277	0.270	0.268	0.265	0.259	0.253	0.253	0.245	4.71	5.91	6.07
	0.525	0.195	0.195	0.190	0.190	0.185	0.165	0.165		4.70	6.43	
	0.540	0.185	0.185	0.185	0.185	0.165	0.160	0.160		4.70	6.46	
0.15	0.545	0.190	0.190	0.185	0.165	0.150	0.150	0.150	0.135	4.60	6.47	6.45
	0.520	0.190	0.190	0.185	0.170	0.160	0.155	0.150	0.130	4.70	6.55	6.47
	0.500	0.185	0.180	0.175	0.160	0.150	0.150	0.145	0.140	4.66	6.52	6.45
	0.480	0.190	0.180	0.175	0.165	0.160	0.160	0.155	0.135	4.88	6.32	6.48
Avg.	0.520	0.189	0.187	0.183	0.173	0.162	0.157	0.154	0.135	4.71	6.46	6.46
	0.525	0.165	0.160	0.145	0.145	0.140	0.130	0.130		4.70	6.74	
	0.540	0.140	0.135	0.135	0.135	0.135	0.135	0.135		4.70	6.80	
	0.545	0.145	0.130	0.130	0.125	0.125	0.125	0.120	0.120	4.60	6.70	6.60
0.10	0.520	0.150	0.140	0.145	0.125	0.125	0.125	0.115	0.120	4.70	6.76	6.62
	0.500	0.150	0.125	0.125	0.120	0.120	0.120	0.120	0.120	4.66	6.74	6.65
	0.480	0.165	0.155	0.155	0.150	0.150	0.130	0.130	0.125	4.88	6.58	6.66
Avg.	0.520	0.153	0.141	0.139	0.133	0.133	0.128	0.125	0.121	4.71	6.72	6.63
	0.525	0.115	0.110	0.105	0.105	0.105	0.105	0.105		4.70	6.95	
	0.540	0.115	0.110	0.110	0.105	0.105	0.100	0.095		4.70	7.08	
	0.545	0.125	0.120	0.115	0.115	0.115	0.105	0.095	0.080	4.60	7.03	7.00
0.05	0.520	0.130	0.115	0.115	0.105	0.105	0.105	0.105	0.100	4.70	6.95	6.92
	0.500	0.110	0.100	0.100	0.095	0.085	0.085	0.085	0.080	4.66	6.95	6.90
	0.480	0.130	0.120	0.120	0.115	0.115	0.105	0.105	0.095	4.88	6.94	6.98
Avg.	0.520	0.121	0.113	0.111	0.107	0.105	0.101	0.098	0.089	4.71	6.98	6.95
	0.545	0.085	0.070	0.065	0.060	0.050	0.050	0.050	0.050	4.60	7.94	7.90
	0.520	0.100	0.100	0.090	0.085	0.085	0.080	0.080	0.080	4.70	7.30	7.30
0.00	0.500	0.080	0.070	0.060	0.055	0.055	0.050	0.050	0.050	4.66	8.05	8.01
	0.480	0.100	0.100	0.095	0.095	0.090	0.065	0.055	0.060	4.88	7.61	7.60
Avg.	0.511	0.091	0.085	0.078	0.074	0.061	0.059	0.060	0.060	4.71	7.73	7.70

* First two trials in each series conducted on small laboratory basis, others conducted on larger commercial scale.

TABLE VI. ACIDITY AND pH VALUES OF CREAM NEUTRALIZED WITH ALLWOOD LIME (MAGNESIUM LIME) *.

Desired Acidity	Original cream	Titratable acidity as per cent lactic acid — Period after adding the neutralizer: 5 min.	10 min.	15 min.	20 min.	145°F.	145° F. 30 min.	Cooled	24 hrs.	pH of Cream: Original cream	After past.	After past.
	0.490	0.315	0.310	0.280	0.265	0.225	0.225	0.225		4.80	6.04	
	0.475	0.310	0.300	0.280	0.260	0.225	0.220	0.220		4.82	6.08	
0.25	0.560	0.310	0.300	0.300	0.260	0.225	0.205	0.200	0.190	4.65	6.13	6.23
	0.510	0.290	0.280	0.270	0.255	0.220	0.205	0.200	0.190	4.65	6.17	6.14
	0.490	0.285	0.280	0.270	0.255	0.220	0.205	0.200	0.190	4.70	6.10	6.23
Avg.	0.505	0.302	0.294	0.280	0.259	0.223	0.212	0.209	0.190	4.72	6.10	6.20
	0.490	0.230	0.225	0.220	0.220	0.185	0.180	0.175		4.80	6.40	
	0.475	0.235	0.235	0.230	0.230	0.180	0.160	0.155		4.82	6.42	
0.15	0.560	0.250	0.230	0.230	0.230	0.185	0.165	0.160	0.145	4.65	6.40	6.38
	0.510	0.250	0.240	0.230	0.220	0.185	0.165	0.160	0.150	4.65	6.49	6.38
	0.490	0.260	0.240	0.240	0.240	0.190	0.170	0.165	0.165	4.70	6.38	6.32
Avg.	0.505	0.245	0.234	0.230	0.228	0.185	0.168	0.163	0.153	4.72	6.42	6.36
	0.490	0.210	0.200	0.180	0.170	0.130	0.130	0.130		4.80	6.75	
	0.475	0.210	0.200	0.180	0.150	0.130	0.125	0.115		4.82	6.74	
0.10	0.560	0.210	0.205	0.185	0.170	0.140	0.105	0.095	0.105	4.65	7.10	7.05
	0.510	0.245	0.220	0.200	0.190	0.150	0.130	0.130	0.130	4.65	6.70	6.63
	0.490	0.245	0.230	0.210	0.200	0.155	0.145	0.140	0.140	4.70	6.56	6.78
Avg.	0.505	0.224	0.211	0.191	0.176	0.141	0.127	0.122	0.125	4.72	6.77	6.82
	0.490	0.190	0.185	0.170	0.155	0.125	0.090	0.090		4.80	7.18	
	0.475	0.180	0.170	0.150	0.135	0.105	0.080	0.080		4.82	7.14	
0.05	0.560	0.200	0.190	0.150	0.140	0.095	0.075	0.070	0.070	4.65	7.60	7.65
	0.510	0.175	0.160	0.140	0.140	0.095	0.075	0.070	0.075	4.65	7.64	7.60
	0.490	0.180	0.170	0.160	0.160	0.110	0.105	0.100	0.090	4.70	7.35	7.30
Avg.	0.505	0.185	0.175	0.154	0.146	0.106	0.085	0.082	0.078	4.72	7.38	7.52
	0.560	0.165	0.145	0.120	0.110	0.070	0.060	0.055	0.050	4.65	8.08	8.05
0.00	0.510	0.155	0.140	0.120	0.110	0.075	0.060	0.060	0.055	4.65	7.86	7.90
	0.490	0.170	0.150	0.130	0.120	0.090	0.080	0.075	0.070	4.70	7.55	7.50
Avg.	0.520	0.163	0.145	0.123	0.113	0.078	0.067	0.063	0.058	4.67	7.83	7.82

* First two trials in each series conducted on small laboratory basis, others conducted on larger commercial scale.

TABLE VII. ACIDITY AND pH VALUES OF CREAM NEUTRALIZED WITH SODIUM BICARBONATE*.

Desired acidity	Original cream	Titratable acidity as per cent lactic acid — Period after adding the neutralizer: 5 min.	10min.	15 min.	20 min.	145° F.	145° F. 30 min.	Cooled 24 hrs.	pH of cream: Original cream	After past.	After past.
	0.530	0.410	0.400	0.400	0.400	0.295	0.270	0.270	4.85	5.98	
	0.520	0.390	0.390	0.390	0.390	0.300	0.280	0.280	4.88	5.95	
0.25	0.445	0.360	0.360	0.355	0.350	0.275	0.275	0.275	5.12	6.04	
	0.480	0.365	0.360	0.355	0.355	0.295	0.290	0.285	4.72	5.80	
Avg.	0.494	0.381	0.377	0.375	0.374	0.291	0.279	0.277	4.89	5.94	
	0.530	0.350	0.330	0.320	0.310	0.270	0.260	0.220	4.85	6.43	
	0.520	0.350	0.340	0.320	0.320	0.270	0.240	0.230	4.88	6.48	
0.15	0.445	0.340	0.320	0.315	0.315	0.250	0.220	0.220	5.12	6.57	
	0.480	0.350	0.300	0.320	0.320	0.260	0.230	0.230	4.72	6.22	
Avg.	0.494	0.347	0.323	0.319	0.316	0.263	0.237	0.225	4.89	6.42	
	0.530	0.350	0.340	0.320	0.320	0.210	0.190	0.180	4.85	6.84	
	0.520	0.340	0.330	0.320	0.300	0.220	0.170	0.170	4.88	6.84	
0.10	0.445	0.335	0.320	0.320	0.310	0.230	0.200	0.180	5.12	6.76	
	0.480	0.335	0.320	0.300	0.285	0.220	0.190	0.170	4.72	6.65	
Avg.	0.494	0.340	0.328	0.315	0.304	0.220	0.188	0.175	4.89	6.76	
	0.530	0.340	0.320	0.310	0.300	0.200	0.175	0.165	4.85	6.98	
	0.520	0.340	0.330	0.320	0.300	0.200	0.175	0.165	4.88	7.08	
0.05	0.445	0.330	0.320	0.315	0.310	0.225	0.180	0.170	5.12	6.96	
	0.480	0.300	0.315	0.300	0.290	0.210	0.160	0.160	4.72	6.68	
Avg.	0.494	0.327	0.321	0.311	0.300	0.209	0.173	0.165	4.89	6.92	

* All of the above trials were conducted on small laboratory basis.

TABLE VIII. THE ACIDITY, PH AND FAT TEST OF BUTTERMILK

Desired acidity in the cream	Sodium Carbonate			Recto		
	Acidity	pH	Fat Per Cent	Acidity	pH	Fat Per Cent
	0.330	5.76	0.640	0.280	6.16	0.560
	0.300	5.92	0.720	0.290	6.04	0.560
0.25	0.300	5.91	0.600	0.270	6.16	0.800
Avg.	0.310	5.86	0.650	0.280	6.12	0.640
	0.220	6.25	0.580	0.150	6.70	0.600
	0.200	6.42	0.640	0.200	6.48	0.560
0.15	0.210	6.37	0.440	0.165	6.70	0.720
Avg.	0.210	6.35	0.550	0.172	6.63	0.627
	0.140	6.88	0.520	0.140	6.90	0.600
	0.160	6.60	0.640	0.140	6.84	0.560
0.10	0.140	6.63	0.520	0.150	6.90	0.700
Avg.	0.147	6.73	0.560	0.143	6.88	0.620
	0.135	6.78	0.480	0.125	7.05	0.780
	0.130	6.88	0.520	0.125	7.05	0.480
0.05	0.120	6.85	0.480	0.125	7.06	0.640
Avg.	0.128	6.84	0.493	0.125	7.05	0.630
	0.100	7.02	0.400	0.120	7.22	0.800
	0.100	7.08	0.500	0.115	7.26	0.520
0.00	0.110	7.00	0.420	0.120	7.28	0.700
Avg.	0.103	7.03	0.440	0.118	7.25	0.670
	Sodium Hydroxide			Wyandotte C.A.S.		
	0.245	6.25	0.700	0.260	6.01	1.100
0.25	0.230	6.35	0.720	0.250	6.17	1.100
	0.240	6.32	0.740	0.6330	6.00	1.100
Avg.	0.240	6.31	0.720	0.280	6.06	1.100
	0.130	6.90	0.460	0.190	6.53	0.700
0.15	0.120	7.12	0.740	0.190	6.88	0.760
	0.120	7.10	0.680	0.190	6.56	0.880
Avg.	0.123	7.04	0.600	0.190	6.66	0.780
	0.110	7.10	0.460	0.180	6.78	0.680
0.10	0.090	7.20	0.740	0.180	7.00	0.660
	0.110	7.06	0.580	0.170	6.80	0.580
Avg.	0.103	7.12	0.590	0.177	6.86	0.640
	0.060	7.50	0.400	0.120	7.10	0.660
0.05	0.060	7.57	0.760	0.130	7.18	0.680
	0.065	7.42	0.640	0.130	7.04	0.680
Avg.	0.062	7.50	0.600	0.127	7.11	0.730
	0.050	7.70	0.460	0.100	7.33	0.600
0.00	0.050	7.84	0.760	0.100	7.35	0.620
	0.040	7.65	0.660	0.110	7.22	0.900
Avg.	0.050	7.73	0.630	0.103	7.30	0.707

TABLE IX. THE ACIDITY, PH AND FAT TEST OF BUTTERMILK

Desired acidity in the cream	Calcium Lime			Magnesium Lime		
	Acidity	pH	Fat Per Cent	Acidity	pH	Fat Per Cent
	0.270	5.95	1.000	0.235	6.14	0.760
0.25	0.280	5.90	0.800	0.230	6.34	0.800
	0.280	5.90	1.040	0.230	6.00	1.000
	0.260	5.93	0.620	0.000	0.00	0.000
Avg.	0.272	5.92	0.840	0.232	6.16	0.85
	0.125	6.44	0.550	0.165	6.30	0.860
	0.125	6.55	0.460	0.160	6.52	0.720
0.15	0.130	6.50	0.860	0.170	6.32	0.880
	0.130	6.34	0.580	0.000	0.00	0.000
Avg.	0.128	6.46	0.610	0.165	6.39	0.820
	0.105	6.65	0.660	0.090	6.94	0.760
	0.120	6.78	0.600	0.125	6.70	0.720
0.10	0.120	6.70	0.650	0.130	6.46	0.720
	0.110	6.46	0.460	0.130	6.46	0.720
Avg.	0.114	6.65	0.590	0.115	6.70	0.730
	0.090	6.91	0.380	0.065	7.48	0.620
	0.105	6.54	0.560	0.075	7.60	0.600
0.05	0.090	6.74	0.540	0.100	7.18	0.640
	0.110	6.99	0.580	0.000	0.00	0.000
Avg.	0.100	6.80	0.515	0.770	7.42	0.620
	0.040	7.72	0.300	0.040	7.81	0.600
	0.070	7.20	0.410	0.045	7.81	0.560
0.00	0.050	7.95	0.450	0.050	7.40	0.540
	0.060	7.45	0.580	0.000	0.00	0.000
Avg.	0.055	7.58	0.435	0.045	7.67	0.570

TABLE X. INFLUENCE OF THE VARIOUS NEUTRALIZERS ON THE COMPOSITION OF THE BUTTER.

Neutralizer used	Desired acidity	Moisture 1	Moisture 2	Moisture 3	Butterfat 1	Butterfat 2	Butterfat 3	Salt 1	Salt 2	Salt 3	Curd 1	Curd 2	Curd 3
Sodium Carbonate	0.25	15.50	16.85	16.60	81.33	80.00	80.35	2.40	2.40	2.35	0.77	0.75	0.70
	0.15	15.75	16.46	15.70	81.13	80.63	81.10	2.47	2.15	2.30	0.65	0.75	0.90
	0.10	16.90	16.70	17.42	79.90	80.35	79.20	2.30	2.20	2.23	0.90	0.75	1.15
	0.05	16.55	17.52	17.00	80.40	79.33	79.85	2.20	2.30	2.35	0.85	0.85	0.80
	0.00	16.42	16.47	16.85	80.68	80.38	80.03	2.17	2.30	2.25	0.73	0.85	0.87
Sodium Hydroxide	0.25	17.05	16.45	15.95	79.85	80.40	81.00	2.33	2.35	2.35	0.77	0.80	0.70
	0.15	16.90	17.85	16.35	79.75	79.03	80.58	2.35	2.15	2.07	1.10	0.97	1.00
	0.10	16.95	16.30	16.77	79.70	80.55	80.30	2.33	2.45	2.15	1.02	0.70	0.88
	0.05	18.15	17.70	15.78	78.85	79.15	81.37	2.13	2.28	2.10	0.87	0.87	0.75
	0.00	16.90	17.12	17.02	79.98	79.43	80.10	2.32	2.27	2.28	0.80	1.18	0.60
Recto	0.25	16.85	16.25	16.75	80.45	80.05	80.05	1.90	2.03	2.17	0.80	0.90	1.03
	0.15	17.35	16.90	16.30	79.55	80.05	80.30	2.20	2.30	2.37	0.90	0.75	1.00
	0.10	16.65	16.75	16.75	80.50	80.05	80.20	2.05	2.22	2.10	0.80	0.97	0.95
	0.05	16.90	17.55	16.95	80.20	79.10	79.85	1.90	2.32	2.25	1.00	1.03	0.95
	0.00	16.85	17.10	17.40	80.40	79.70	79.50	2.00	2.20	2.20	0.75	1.00	0.90
Wyandotte C.A.S.	0.25	16.10	16.40	16.45	80.35	80.80	80.95	2.55	1.90	2.00	1.00	0.90	0.60
	0.15	16.60	16.70	16.90	80.35	80.37	80.30	2.18	2.20	1.90	0.87	0.90	0.90
	0.10	16.50	16.70	17.95	80.00	80.30	79.25	2.38	2.10	1.90	1.12	0.90	0.90
	0.05	17.70	16.85	16.65	79.10	80.05	80.45	2.30	2.05	2.05	0.90	1.05	0.90
	0.00	16.55	16.70	16.85	80.05	80.00	80.12	2.45	2.20	2.00	0.95	1.10	1.03
Calcium Lime	0.25	16.70	17.55	16.70	80.45	79.50	80.30	2.05	2.23	2.50	0.80	0.77	0.50
	0.15	16.60	17.70	16.95	79.88	79.30	80.05	2.42	2.00	2.00	1.10	1.00	1.00
	0.10	17.75	16.50	16.70	79.15	80.45	80.15	1.80	1.80	2.10	1.30	1.25	1.05
	0.05	18.30	18.45	16.60	78.18	78.20	80.35	2.25	1.90	1.75	1.27	1.45	1.30
	0.00	17.20	16.75	16.70	80.45	79.90	80.15	1.37	1.90	1.70	0.98	1.50	1.45
Magnesium Lime	0.25	16.40	17.15	14.95	80.30	79.40	82.52	2.45	2.55	1.85	0.85	0.90	0.70
	0.15	17.00	16.40	17.60	79.95	80.17	79.10	2.18	2.45	2.33	0.87	0.98	0.97
	0.10	17.00	17.15	17.50	79.75	79.55	79.55	2.40	2.37	2.40	0.75	0.93	0.55
	0.05	19.80	17.92	16.22	76.75	78.72	80.72	2.35	2.33	2.20	1.10	1.03	0.85
	0.00	16.50	17.00	16.35	80.42	79.70	80.37	2.23	2.25	2.52	0.85	1.05	0.75

TABLE XI. THE INFLUENCE OF SODIUM CARBONATE OR RECTO ON THE RELATIONSHIP OF THE pH AND ACIDITY OF THE CREAM, BUTTER AND BUTTERMILK AND ACIDITY OF THE BUTTERFAT TO THE SCORE OF FRESH BUTTER.

Desired acidity	pH: Cream at churning	pH: Butter-milk	pH: Butter serum	Acidity per cent: Cream at churning	Acidity per cent: Butter-milk	Acid degree: Butter	Acid degree: Butter-fat	Score of fresh butter
				Sodium Carbonate				
	5.90	5.76	5.93	0.26	0.33	1.250	0.875	90.10
0.25	6.05	5.92	6.12	0.24	0.30	1.250		89.50
	6.05	5.91	6.14	0.225	0.30	1.200		89.75
Avg.	6.00	5.86	6.06	0.242	0.31	1.235	0.875	89.80
	6.37	6.25	6.51	0.17	0.22	1.150	0.825	89.92
0.15	6.60	6.42	6.67	0.17	0.20	1.100		89.25
	6.48	6.37	6.68	0.17	0.21	1.075		89.75
Avg.	6.48	6.35	6.62	0.17	0.21	1.110	0.825	89.64
	6.97	6.88	7.12	0.14	0.14	0.950	0.800	90.33
0.10	6.70	6.60	6.86	0.16	0.16	1.100		89.38
	6.71	6.63	7.07	0.15	0.14	0.975		90.00
Avg.	6.79	6.70	7.02	0.15	0.15	1.010	0.800	89.90
	6.84	6.78	6.94	0.145	0.14	1.000	0.790	89.50
0.05	7.08	6.88	7.10	0.140	0.13	0.975		88.50
	6.92	6.85	7.18	0.130	0.12	0.900		89.88
Avg.	6.95	6.84	7.07	0.138	0.13	0.960	0.790	89.29
	7.12	7.02	7.30	0.12	0.10	0.640	0.640	89.50
0.00	7.23	7.08	7.34	0.12	0.10	0.900		88.75
	7.08	7.00	7.34	0.12	0.10	0.850		89.25
Avg.	7.14	7.03	7.33	0.12	0.10	0.860	0.640	89.17
				Recto				
	6.30	6.16	6.43	0.23	0.28	1.375	0.975	89.12
0.25	6.15	6.04	6.28	0.20	0.29	1.350		89.90
	6.35	6.16	6.46	0.19	0.28	1.425		89.70
Avg.	6.27	6.12	6.39	0.21	0.28	1.138	0.975	89.56
	6.90	6.70	7.10	0.18	0.15	1.235	0.800	89.25
0.15	6.60	6.48	6.84	0.185	0.200	1.175		90.00
	6.90	6.70	7.14	0.160	0.165	1.350		89.33
Avg.	6.80	6.63	7.03	0.175	0.172	1.250	0.800	89.53
	7.10	6.90	7.34	0.150	0.14	1.175	0.700	89.40
0.10	6.96	6.84	7.20	0.145	0.14	1.000		89.90
	7.05	6.90	7.37	0.150	0.15	1.275		89.33
Avg.	7.04	6.88	7.30	0.148	0.143	1.150	0.700	89.54
	7.23	7.05	7.47	0.159	0.125	1.125	0.700	89.25
0.05	7.14	7.05	7.38	0.150	0.125	0.950		89.90
	7.14	7.06	7.60	0.140	0.125	0.975		90.00
Avg.	7.17	7.05	7.48	0.147	0.125	1.015	0.700	89.71
	7.30	7.22	7.52	0.120	0.120	0.900	0.612	88.87
0.00	7.36	7.26	7.45	0.115	0.115	0.700		89.50
	7.32	7.28	7.84	0.130	0.120	0.825		90.00
Avg.	7.33	7.25	7.60	0.122	0.118	0.810	0.612	89.46

TABLE XII. THE INFLUENCE OF SODIUM HYDROXIDE AND WYANDOTTE C.A.S. ON THE RELATIONSHIP OF THE pH AND ACIDITY OF THE CREAM, BUTTER AND BUTTERMILK AND ACIDITY OF THE BUTTERFAT TO THE SCORE OF THE FRESH BUTTER.

	Sodium Hydroxide							Score of
Desired	pH			Acidity per cent		Acid degree		fresh
Acidity	Cream at churning	Butter-milk	Butter serum	Cream at churning	Butter-milk	Butter	Butter-fat	butter
	6.32	6.25	6.46	0.185	0.245	1.225	0.950	89.20
0.25	6.47	6.35	6.56	0.185	0.230	1.350		88.67
	6.40	6.32	6.60	0.190	0.240	1.275		89.17
Avg.	6.39	6.31	6.54	0.187	0.240	1.283	0.950	89.05
	7.02	6.90	7.24	0.105	0.130	1.175	0.700	88.83
0.15	7.22	7.12	7.30	0.100	0.120	1.150		88.83
	7.20	7.10	7.20	0.110	0.120	1.075		90.25
Avg.	7.14	7.04	7.25	0.105	0.123	1.135	0.700	89.30
	7.24	7.10	7.50	0.085	0.110	0.875	0.625	89.34
0.10	7.29	7.20	7.36	0.085	0.090	0.850		88.83
	7.25	7.06	7.55	0.100	0.110	0.875		89.75
Avg.	7.26	7.12	7.47	0.090	0.103	0.865	0.625	89.31
	7.70	7.50	7.76	0.065	0.06	0.750	0.500	89.00
0.05	7.77	7.57	7.64	0.060	0.06	0.750		89.00
	7.60	7.42	7.80	0.070	0.65	0.800		88.50
Avg.	7.69	7.50	7.73	0.065	0.62	0.765	0.500	88.83
	7.98	7.70	7.90	0.045	0.050	0.550	0.350	88.67
0.00	8.08	7.84	7.84	0.045	0.050	0.550		89.17
	7.98	7.65	7.80	0.045	0.040	0.575		88.50
Avg.	8.02	7.73	7.85	0.045	0.047	0.560	0.350	88.78
	Wyandotte C. A. S.							
	6.20	6.01	6.48	0.260	0.26	1.375	0.975	89.00
0.25	6.38	6.17	6.78	0.240	0.25	1.250		89.70
	6.20	6.00	6.40	0.260	0.33	1.375		89.00
Avg.	6.26	6.06	6.55	0.253	0.28	1.333	0.975	89.23
	6.97	6.53	6.94	0.17	0.19	1.150	0.835	89.40
0.15	6.98	6.88	7.05	0.16	0.19	1.175		90.12
	6.90	6.56	7.04	0.18	0.19	1.200		89.12
Avg.	6.95	6.66	7.01	0.17	0.19	1.175	0.835	89.54
	6.94	6.78	7.18	0.135	0.180	1.025	0.785	89.12
0.10	7.10	7.00	7.19	0.15	0.180	1.100		90.12
	7.05	6.80	7.25	0.14	0.170	0.950		89.70
Avg.	7.03	6.86	7.21	0.145	0.177	1.025	0.785	89.65
	7.20	7.10	7.30	0.125	0.120	0.950	0.735	90.40
0.05	7.30	7.18	7.35	0.130	0.130	1.000		89.12
	7.30	7.04	7.68	0.130	0.130	0.850		88.62
Avg.	7.27	7.11	7.44	0.128	0.127	0.935	0.735	89.38
	7.36	7.33	7.57	0.105	0.100	0.775	0.650	91.12
0.00	7.44	7.35	7.76	0.105	0.100	0.775		89.12
	7.48	7.22	7.78	0.105	0.110	0.750		88.50
Avg.	7.43	7.30	7.70	0.105	0.103	0.765	0.650	89.58

TABLE XIII. THE INFLUENCE OF CALCIUM AND MAGNESIUM LIME ON THE RELATIONSHIP OF THE pH AND ACIDITY OF THE CREAM, BUTTER AND BUTTERMILK AND ACIDITY OF THE BUTTERFAT TO THE SCORE OF THE FRESH BUTTER.

Desired Acidity	pH: Cream at churning	pH: Butter-milk	pH: Butter serum	Acidity per cent: Cream at churning	Acidity per cent: Butter-milk	Acid Degree: Butter	Acid Degree: Butter-fat	Score of fresh butter
Calcium Lime								
	6.02	5.95	6.13	0.240	0.270	1.650	1.350	89.00
0.25	6.12	5.90	6.40	0.250	0.280	1.375		89.67
	6.10	5.90	6.40	0.240	0.280	1.375		89.50
	6.05	5.93	6.40	0.240	0.260	1.350		88.56
Avg.	6.07	5.92	6.33	0.245	0.272	1.440	1.350	89.18
	6.45	6.44	6.92	0.135	0.125	1.500	1.250	89.50
0.15	6.47	6.55	6.62	0.130	0.125	1.250		90.00
	6.45	6.50	6.65	0.140	0.130	1.275		90.00
	6.48	6.34	6.65	0.135	0.130	1.275		89.94
Avg.	6.46	6.46	6.71	0.135	0.1275	1.325	1.250	89.61
	6.60	6.65	7.08	0.120	0.105	1.400	1.075	89.00
0.10	6.62	6.78	7.05	0.120	0.120	1.150		89.30
	6.65	6.70	6.88	0.120	0.120	1.300		90.00
	6.66	6.46	7.18	0.125	0.110	1.200		88.81
Avg.	6.63	6.65	7.05	0.121	0.114	1.260	1.075	89.28
	7.00	6.91	7.60	0.080	0.090	1.125	0.725	88.50
0.05	6.92	6.54	7.72	0.100	0.105	0.975		89.80
	6.90	6.74	7.57	0.080	0.090	1.100		90.30
	6.98	6.99	7.60	0.095	0.110	0.975		88.87
Avg.	6.94	6.80	7.62	0.090	0.099	1.045	0.725	89.37
	7.90	7.72	7.91	0.050	0.040	0.725	0.45	89.00
0.00	7.30	7.20	8.06	0.080	0.070	0.750		90.00
	8.01	7.95	7.72	0.050	0.050	0.800		90.50
	7.60	7.45	7.88	0.060	0.060	0.800		88.87
Avg.	7.70	7.58	7.89	0.060	0.055	0.770	0.45	89.60
Magnesium Lime								
	6.23	6.14	6.68	0.190	0.235	1.500	1.085	89.50
0.25	6.14	6.34	6.70	0.190	0.230	1.450		89.42
	6.23	6.00	6.74	0.200	0.230	1.425		89.75
Avg.	6.20	6.16	6.71	0.193	0.232	1.458	1.085	89.55
	6.38	6.30	6.74	0.145	0.165	1.450	1.025	89.67
0.15	6.38	6.52	6.88	0.150	0.160	1.375		89.34
	6.32	6.36	6.90	0.165	0.170	1.375		89.75
Avg.	6.36	6.39	6.84	0.153	0.165	1.400	1.025	89.59
	7.05	6.94	7.40	0.105	0.090	1.150	0.835	89.34
0.10	6.63	6.70	7.35	0.130	0.125	1.200		89.50
	6.78	6.46	7.10	0.140	0.130	1.275		89.25
Avg.	6.86	6.70	7.29	0.125	0.115	1.210	0.835	89.36
	7.65	7.48	7.78	0.070	0.065	1.050	0.615	89.00
0.05	7.60	7.60	7.81	0.075	0.075	1.000		88.34
	7.30	7.18	7.31	0.090	0.100	1.225		89.00
Avg.	7.52	7.42	7.64	0.078	0.800	1.092	0.615	88.78
	8.05	7.81	8.16	0.050	0.040	0.925	0.425	88.67
0.00	7.90	7.81	8.04	0.055	0.045	0.825		88.34
	7.50	7.40	7.70	0.070	0.050	0.850		88.00
Avg.	7.82	7.67	7.97	0.065	0.045	0.865	0.425	88.34

TABLE XIV. THE INFLUENCE OF SODIUM CARBONATE, RECTOR AND SODIUM HYDROXIDE ON THE ACIDITY, pH AND PEROXIDE VALUE OF THE STORED BUTTER.

Desired Acidity	Acid Degree: Butterfat: 6 months 0° C.	Acid Degree: Butter: 10 days 72° F.	Acid Degree: Butter: 6 months 0° C.	pH of Butter: 10 days 72° F.	pH of Butter: 6 months 0° C.	Peroxide Value: One month 0° C.	Peroxide Value: 6 months 0° C.
				Sodium Carbonate			
	0.900	1.425	1.375	5.79	5.92		1.132
0.25	0.960	1.350	1.385	6.03	6.25	0.0499	1.703
	0.825	1.225	1.200	6.05	6.16	0.0973	1.808
	0.860	1.300	1.225	6.40	6.60		1.254
0.15	0.900	1.250	1.250	6.49	6.85	0.0993	1.307
	0.790	1.100	1.150	6.56	6.77	0.0988	1.721
	0.785	1.150	1.050	6.99	7.11		1.331
0.10	0.900	1.175	1.200	6.69	7.02	0.0989	1.520
	0.700	1.025	1.025	6.88	7.24	0.0995	1.885
	0.735	1.150	1.025	6.82	7.24		1.520
0.05	0.750	1.075	1.050	7.00	7.34	0.0996	1.531
	0.650	0.950	0.915	7.00	7.48	0.0986	1.681
	0.600	1.100	0.950	7.11	7.53		1.704
0.00	0.650	1.000	0.925	7.18	7.70	0.0992	1.349
	0.525	0.900	0.850	7.18	7.65	0.1133	1.756
				Recto			
	0.960	1.500	1.375	6.38	6.68		0.981
0.25	1.025	1.450	1.550	6.08	6.38	0.2589	1.045
	1.150	1.600	1.540	6.27	6.48	0.2743	0.597
	0.850	1.350	1.275	6.48	7.10		1.136
0.15	0.875	1.300	1.300	6.32	7.05	0.1998	0.832
	0.950	1.550	1.335	6.65	6.96	0.1984	0.658
	0.675	1.300	1.185	6.90	7.48		0.986
0.10	0.735	1.175	1.135	6.68	7.15	0.1989	0.611
	0.875	1.450	1.310	6.98	7.14	0.1995	0.691
	0.635	1.250	1.085	7.11	7.55		0.981
0.05	0.775	1.200	1.075	6.88	7.20	0.1982	0.656
	0.735	1.125	1.160	7.24	7.35	0.1991	0.702
	0.610	0.975	1.010	7.14	7.58		0.926
0.00	0.450	0.900	0.750	7.06	7.56	0.1993	0.651
	0.700	1.000	1.075	7.24	7.52	0.1990	0.652
				Sodium Hydroxide			
	0.950	1.350	1.250	6.41	6.58	0.249	0.580
0.25	1.075	1.500	1.450	6.24	6.05	0.571	0.679
	1.025	1.475	1.350	6.37	6.30		0.596
	0.675	1.225	1.060	7.11	7.25	0.198	0.501
0.15	0.725	1.250	1.110	7.14	6.80	0.547	0.633
	0.960	1.175	1.185	7.05	6.67		0.475
	0.550	1.100	0.885	7.30	7.33	0.199	0.569
0.10	0.675	1.125	0.965	7.29	6.95	0.394	0.627
	0.700	1.200	1.050	6.98	6.87		0.590
	0.385	0.825	0.735	7.72	7.48	0.199	0.699
0.05	0.500	1.025	0.850	7.52	7.55	0.272	0.529
	0.575	0.950	0.835	7.36	7.58		0.553
	0.300	0.700	0.560	7.91	7.98	0.198	0.503
0.00	0.385	0.850	0.700	7.68	7.70	0.197	0.630
	0.450	0.850	0.635	7.62	7.92		0.544

TABLE XV. THE INFLUENCE OF WYANDOTTE C.A.S., CALCIUM LIME AND MAGNESIUM LIME ON THE ACIDITY, pH AND PEROXIDE VALUE OF THE STORED BUTTER.

Desired Acidity	Acid Degree: Butterfat 6 months 0° C.	Acid Degree: Butter 10 days 72° F.	Acid Degree: Butter 6 months 0° C.	pH of Butter 10 days 72° F.	pH of Butter 6 months 0° C.	Peroxide Value One month 0° C.	Peroxide Value 6 months 0° C.
			Wyandotte C.A.S.				
	1.040	1.500	1.475	6.15	6.22		0.796
0.25	1.110	1.450	1.300	6.40	6.72	0.099	0.748
	0.835	1.400	1.075	6.31	6.45	0.199	0.808
	0.935	1.350	1.200	6.85	7.08		0.822
0.15	0.975	1.350	1.175	6.92	7.05	0.099	0.730
	0.710	1.330	0.925	6.96	7.05	0.199	0.690
	0.800	1.200	1.075	7.24	7.25		0.614
0.10	0.885	1.250	1.100	7.18	7.25	0.997	0.765
	0.660	1.025	0.910	7.00	7.20	0.234	0.804
	0.600	1.125	1.050	7.47	7.52		0.643
0.05	0.835	1.125	1.050	7.30	7.50	0.197	0.748
	0.500	0.850	0.775	7.32	7.48	0.124	0.772
	0.600	0.925	0.900	7.40	7.52		0.627
0.00	0.650	0.775	0.835	7.48	7.68	0.198	0.825
	0.475	0.775	0.675	7.40	7.58	0.124	0.749
			Calcium Lime				
0.25	1.500	1.875	1.825	6.18	6.43		0.726
	0.950	1.375	1.550	6.33	7.03	0.164	0.630
	0.800	1.025	1.550	6.62	6.70	0.345	0.680
	1.025	1.425	1.625	6.35	6.05		0.691
	1.235	1.750	1.710	6.64	6.85		0.707
0.15	0.785	1.350	1.375	6.65	6.95	0.324	0.702
	0.685	1.500	1.500	6.80	6.90	0.299	0.918
	0.975	1.400	1.375	6.67	6.20		0.873
	1.060	1.550	1.560	6.75	7.06		0.808
0.10	0.675	1.375	1.310	6.88	7.01	0.345	0.727
	0.675	1.400	1.425	6.85	7.00	0.248	0.897
	0.460	1.375	1.035	7.26	7.45		0.896
	0.685	1.300	1.200	7.12	7.42		0.621
0.05	0.540	1.275	1.175	7.23	7.00	0.298	0.686
	0.625	1.350	1.375	7.24	7.25	0.370	1.023
	0.225	1.225	0.825	7.30	8.00		0.655
	0.350	0.800	0.800	7.47	7.76		0.681
0.00	0.250	0.700	0.685	8.05	7.56	0.296	0.714
	0.185	0.700	1.060	7.84	7.55	0.272	1.210
	0.210	0.700	0.785	8.15	8.00		0.600
			Magnesium Lime				
	1.125	1.665	1.685	6.46	6.56		0.737
0.25	1.125	1.950	1.650	6.12	6.80	0.287	1.361
	1.175	1.775	1.650	6.37	6.79	0.099	1.269
	1.050	1.575	1.650	6.60	6.80		0.832
0.15	0.985	1.800	1.625	6.75	6.96	0.149	1.259
	1.110	1.725	1.575	6.94	6.94	0.099	1.257
	0.660	1.450	1.300	7.14	7.42		0.758
0.10	0.810	1.675	1.475	6.90	7.24	0.146	1.262
	0.950	1.600	1.450	6.86	7.18	0.149	1.175
	0.425	1.300	1.200	7.34	7.84		0.879
0.05	0.400	1.650	1.150	7.44	7.92	0.195	1.143
	0.750	1.525	1.425	6.96	7.38	0.149	1.179
	0.325	1.100	1.000	7.58	8.04		0.624
0.00	0.325	1.100	1.150	7.65	8.00	0.197	1.236
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

TABLE XVI. THE INFLUENCE OF SODIUM CARBONATE AND RECTO ON THE KEEPING QUALITY OF BUTTER.

Desired:	Fresh		After 10 days at 72° F.		After 6 mo. at 0° C.	
acidity	Score	Criticism*	Score	Criticism*	Score	Criticism*
			Sodium Carbonate			
	90.1	SN OC	89.00	OC	90.00	SN OC
0.25	89.5	OC	87.50	F OC	90.30	OC
	89.75	SN OC	87.00	F	90.30	OC SN
	89.92	OC	88.62	SN OC	89.50	SN
0.15	89.25	N OC	87.75	F OC	90.30	SN OC
	89.75	OC	89.25	F SN	89.50	SN
	90.33	OC	89.50	OC	89.80	OC N
0.10	89.38	SN	89.75	OC	89.00	N
	90.00	OC	90.00	OC SN	89.50	OC SN
	89.50	SN	89.00	SN T	89.80	OC N
0.05	88.50	SN	89.25	SN T	89.00	N
	89.88	SN	87.75	F N	89.30	OC
	89.50	OC SN	89.25	SN	90.30	OC SN
0.00	88.75	OC	89.25	N OC	89.00	N
	89.25	N	90.00	OC	89.50	N SN
			Recto			
	89.12	SN OC	90.00	SN	88.50	F
0.25	89.90	SN	89.00	SN OC	89.50	OC
	89.70	N	89.00	SN T	88.50	SN M
	89.25	SN OC	90.50		89.00	OC
0.15	90.00	SN	89.50	SN	88.70	OC
	89.33	N	88.67	SN T	87.70	N F
	89.40	SN	88.75	T	89.50	OC
0.10	89.90	SN	89.75	SN	88.00	OC F
	89.33	N	89.00	SN T	87.80	OC N
	89.25	SN	89.25	N	89.50	OC
0.05	89.90	SN	88.83	SN	88.50	OC T
	90.00	N	89.67	SN	88.70	OC N
	88.87	SN	88.75	N T	89.30	N T
0.00	89.50	SN T	89.20	SN	88.70	F N
	90.00	SN	89.67	SN	88.70	SN M

Key to Flavor Criticisms:

- SN - Slight neutralizer
- N - Definite neutralizer
- OC - Old cream
- T - Tallowy or oxidized
- F - Fishy
- M - Mealy

TABLE XVII. THE INFLUENCE OF SODIUM HYDROXIDE AND WYANDOTTE C.A.S. ON THE KEEPING QUALITY OF BUTTER.

Desired acidity	Fresh Score	Fresh Criticism*	After 10 days at 72° F. Score	After 10 days at 72° F. Criticism*	After 6 mo. at 0° C. Score	After 6 mo. at 0° C. Criticism*
			Sodium Hydroxide			
	89.20	SN OC	88.83	SN	89.2	SN OC
0.25	88.67	SN OC	89.50	OC	90.0	SC
	89.17	N	88.00	SN T	89.30	OC
	88.83	SN	88.67	SN	88.70	SN OC
0.15	88.83	SN	89.34	OC	89.30	N OC
	90.25	N	89.00	SN T	88.80	OC
	89.34	SN	89.17	T	89.00	OC N
0.10	88.83	SN	90.00	SN	89.10	OC
	89.75	N	88.17	T	88.00	N F
	89.00	SN	89.17	N	88.20	OC N
0.05	89.00	SN	90.50	SN	88.30	OC N
	88.50	N	88.67	SN	88.30	OC N
	88.67	SN	89.33	T	88.30	OC N
0.00	89.17	SN T	90.00	SN	88.80	OC N
	88.50	SN	88.34	SN T	87.80	OC
			Wyandotte C.A.S.			
	89.00	N	88.80	OC N	88.50	OC N
0.25	89.70	OC N	88.00	OC	89.20	SN OC
	89.00	SN	90.70		89.70	Sn OC
	89.40	N	89.00	OC SN	89.00	OC N
0.15	90.12	OC N	87.50	OC F	89.80	N OC
	89.12	SN	90.00	SN	89.50	OC T
	89.12	T N	89.75	OC SN	89.00	OC SN
0.10	90.12	OC N	88.00	OC T	88.80	OC SN
	89.70	N	90.12		87.80	OC F
	90.40	N	89.00	T	87.80	F OC
0.05	89.12	M T	89.00	N OC	89.20	OC
	88.62	SN	89.80	OC	88.20	F OC
	91.12		88.25	T	89.30	OC N
0.00	89.12	SN T	89.25	N	88.50	OC N
	88.50	SN T	89.00	N T	88.70	OC N

Key to Flavor Criticism:

SN - Slight neutralizer
N - Definite neutralizer
OC - Old cream
T - Tallowy or oxidized
F - Fishy
M - Mealy

TABLE XVIII. THE INFLUENCE OF CALCIUM LIME AND MAGNESIUM LIME ON THE KEEPING QUALITY OF BUTTER.

Desired	Fresh		After 10 days at 72° F.		After 6 mo. at 0° C.	
acidity	Score	Criticism*	Score	Criticism*	Score	Criticism*
			Calcium Lime			
	89.00	N	87.83	SN F	89.50	M
0.25	89.67	N	90.00	SN	89.50	M N OC
	89.50	N M	89.00	SN M	88.50	M N OC
	88.56	N	89.12	SN	88.00	N OC
	89.50	N	88.20	N OC	89.00	N M
0.15	90.00	N M	89.70	SN M	89.00	SN OC M
	90.00	N	89.60	N M	88.50	SN M T
	88.94	N M	88.56	SN M	87.50	N T
	89.00	N	87.83	N OC F	89.00	N M
0.10	89.30	N M	89.70	N OC M	88.00	OC N
	90.00	SN M	89.60	N M	88.00	OC SN M
	88.81	SN M	88.62	N T	87.90	N OC
	88.50	N	88.30	N OC	89.30	N M
0.05	89.80	N	89.80	SN T	89.50	SN M
	90.30	SN	89.00	N M	88.30	OC SN T
	88.87	N T	88.12	N T	87.00	F N
	89.00	SN	88.30	N T	88.50	N M
0.00	90.00	N	89.10	N T	89.30	N SN
	90.50	SN	89.30	SN T	89.00	N M T
	88.87	N T	87.30	N T	87.30	F N T
			Magnesium Lime			
	89.50	SN OC	87.83	N OC F	88.00	OC
0.25	89.42	SN OC	87.75	N T	88.80	OC
	89.75	M	88.50	OC	89.50	OC N
	89.67	M	88.17	OC T	90.00	SN
0.15	89.34	SN OC	87.75	T	89.00	F
	89.74	M	89.00	OC	88.20	F M
	89.34	OC SN	88.00	N T	89.30	N OC
0.10	89.50	SN	88.50	N OC	88.80	N OC
	89.25	OC N	89.20	OC	88.00	F
	89.00	M N	88.67	OC N	88.80	N OC
0.05	88.34	M N	87.75	N	89.00	F
	89.00	OC	89.00	OC N	89.00	N OC M
	88.67	SN M	88.50	N T	88.80	OC
0.00	88.34	SN M	88.75	N	88.50	OC F
	88.00	OC	88.75	OC T	89.20	M N

Key to Flavor Criticism:
- SN - Slight neutralizer
- N - Definite neutralizer
- OC - Old cream
- T - Tallowy or oxidized
- F - Fishy
- M - Mealy