EFFECT OF TEMPERATURE AND TIME
OF
HOLDING CREAM ON EXHAUSTIVENESS
OF CHURNING

BY
AWADEH NAARESH PANDAY
B. SC. (AG.) UNIVERSITY OF ALLAHABAD

THESIS
SUBMITTED IN PART FULFILLMENT OF THE REQUIREMENTS OF THE
MASTER OF SCIENCE IN DAIRY TECHNOLOGY
DEGREE OF THE
UNIVERSITY OF ALLAHABAD ALLAHABAD U. P.

1970

ALLAHABAD AGRICULTURAL INSTITUTE
DEPARTMENT OF DAIRY TECHNOLOGY
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Allahabad Agricultural Institute
Department of Dairy Technology

Roll No. 1

Enrollment No. R/2528
CERTIFICATE OF ORIGINAL WORK

This is to certify that Mr. Awadh Naresh Pandey, B.Sc.(Agr.) of the University of Allahabad, planned this study, carried out the experimental work involved, analysed the data, and prepared this report on:

"Effect of Temperature and Time of Holding Cream on Exhaustiveness of Churning".

These he did in part fulfillment of the requirements for the MASTER OF SCIENCE IN DAIRY TECHNOLOGY degree of the University of Allahabad.

Date: 26.6.1970

C. BRAVE (Guide)
Associate Professor
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INTRODUCTION
INTRODUCTION

Butter is one of the oldest as well as one of the most important universal articles of diet. It is essentially an emulsion of water and brine in partially solidified milk fat brought about by churning of milk or cream. It is composed principally of milk fat, moisture, curd and salt with small amount of air. Butter fat is one of the main constituents of milk or cream which is most valuable, less perishable and more suitable for economic disposition in its journey from cow to consumer.

The earliest reference to butter making dates back to time immemorial. According to Benno Martin (1836-1923), a pioneer German dairy scientist, butter making dates back to 2,000 B.C. References are made in ancient Indian scriptures of the use of butter as a food in India as early as in 2,000 B.C. Hindus offered it as a sacrifice in their worship. Greeks and Romans did not eat it, but used it for medicinal purposes. They considered that scot of burned butter was usually good for sore eyes. Romans also used butter as ointment for skin and hair. The word butter is mentioned in the Old Testament of Bible seven times. In England and Scotland it was used as fuel in lamps.

In the early days, before the establishment of butter factories, butter was made on farms and marketed in earthen jars. However, on the factory scale butter manufacturing was started first time in the year 1855, by George Cough in Hamptonsburg, New York.

Butter is one of the important energy giving foods. It furnishes about 3,400 calories of heat energy per pound (0.4556 kg.), and
its digestibility is 97.8%, as reported by Bnsiker (16). It is an
excellent source of fat soluble vitamins A and D. According to Roadhouse
and Henderson (31), butter fat also provides unsaturated fatty acids
which are considered important for human body.

The consumption of creamery butter is mostly confined to
cities and towns where it is easily available. In India, country butter
referred as Makhan or Deshi butter, obtained from whole milk curd churn-
ing it with crude indigenous devices, is extensively made in villages.
Although very little Makhan is utilised for direct consumption as such,
it forms an important intermediate product in the manufacture of Ghee.

Composition of creamery butter is slightly different from
that of deshi butter. According to the Prevention of Food Adulteration
Act (34), "Creamery Butter means the product obtained from cow or buff-
fare milk or a combination thereof or from cream or curd obtained from
cow or buffare milk or a combination thereof with or without the
addition of common salt and annatto or carotene as colouring matter.
It shall be free from other animal fats, wax and mineral oils, vege-
table oils and fats. No preservative except common salt and no
colouring matter except annatto or carotene shall be added. It shall
contain not less than 80.0 percent by weight of milk fat, not more
than 1.5 percent by weight of curd and not more than 3.0 percent by
weight of common salt. Diacetyl may be added as a flavouring agent
but, if so used, the total diacetyl content shall not exceed 4.0
parts per million. Calcium hydroxide, sodium bicarbonate, sodium
carbonate, sodium polyphosphate (as linear phosphate with a degree
of polymerisation up to 6 units) may be added for regulating the
hydrogen ion concentration in the finished product, not exceeding 0.2 percent by weight of butter as a whole.

Deshi butter means "the product obtained from cow or buffalo milk or a combination thereof or curd obtained from cow or buffalo milk or a combination thereof without the addition of any preservative including common salt, any added colouring matter or any added flavouring agent. It shall be free from other animal fats, wax and mineral oils, vegetable oils and fats. It shall contain not less than 76.0 percent of milk fat by weight".

The production of butter is one of the major functions of most dairies in the world. Table I taken from Commonwealth Economic Committee Report on Dairy Produce (5) indicates the production of butter in the various countries of the world.

Table I: Production of butter in the various countries of the world in 1962.

<table>
<thead>
<tr>
<th>Countries</th>
<th>Production in thousand metric tons</th>
</tr>
</thead>
<tbody>
<tr>
<td>United Kingdom</td>
<td>59.60</td>
</tr>
<tr>
<td>Australia</td>
<td>202.60</td>
</tr>
<tr>
<td>New Zealand</td>
<td>217.36</td>
</tr>
<tr>
<td>Kenya</td>
<td>30.70</td>
</tr>
<tr>
<td>Canada</td>
<td>166.20</td>
</tr>
<tr>
<td>Irish Republic</td>
<td>61.20</td>
</tr>
<tr>
<td>West Germany</td>
<td>454.70</td>
</tr>
<tr>
<td>U.S.S.R.</td>
<td>925.20</td>
</tr>
<tr>
<td>Denmark</td>
<td>164.20</td>
</tr>
<tr>
<td>India</td>
<td>87.80 (1961)</td>
</tr>
<tr>
<td>Countries</td>
<td>Production in thousand metric tons</td>
</tr>
<tr>
<td>--------------</td>
<td>-----------------------------------</td>
</tr>
<tr>
<td>Netherlands</td>
<td>10.0</td>
</tr>
<tr>
<td>Sweden</td>
<td>90.0</td>
</tr>
<tr>
<td>Japan</td>
<td>13.70</td>
</tr>
</tbody>
</table>

It is clear from the above table that U.S.S.R. is leading butter producing country of the world. In U.S.A., out of 2459 million gallons of total milk produced, 317 million gallons is converted into creamery butter. White and Methur (37) reported that in India, only 6.3 percent of the total milk produced is converted into creamery butter and 43.3 percent into Deshi butter.

Table 2  Production of Butter and Cheese in India
(Taken from The Foreign Trade of India (26))

<table>
<thead>
<tr>
<th>Year</th>
<th>In thousand metric tons</th>
</tr>
</thead>
<tbody>
<tr>
<td>1951</td>
<td>72.20</td>
</tr>
<tr>
<td>1956</td>
<td>81.20</td>
</tr>
<tr>
<td>1961</td>
<td>87.50</td>
</tr>
</tbody>
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Cheese

<table>
<thead>
<tr>
<th>Year</th>
<th>In thousand metric tons</th>
</tr>
</thead>
<tbody>
<tr>
<td>1940</td>
<td>525.40</td>
</tr>
<tr>
<td>1951</td>
<td>384.70</td>
</tr>
<tr>
<td>1961</td>
<td>445.70</td>
</tr>
</tbody>
</table>
From Table - 2, it is clear that the production of creamery butter in India has been increasing; ghee production on the other hand has been showing a decline. The fact that India has been importing butter indicates that the production of creamery butter has not been sufficient to meet the demand. The demand is likely to increase further with steady increase in the purchasing power of people in the country. However, due to stringent economic measures, the quantum of import of butter has been steadily declining from last few years, as is clear from the Table - 3, taken from Monthly Statistics of the Foreign Aid Trade of India (25).

<table>
<thead>
<tr>
<th>Year</th>
<th>Quantity in metric tons</th>
<th>Value in Rs.(lakhs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1963-64</td>
<td>6.0</td>
<td>0.29</td>
</tr>
<tr>
<td>1964-65</td>
<td>7.0</td>
<td>0.45</td>
</tr>
<tr>
<td>1965-66</td>
<td>0.76</td>
<td>0.04</td>
</tr>
<tr>
<td>1966-67</td>
<td>0.60</td>
<td>0.04</td>
</tr>
<tr>
<td>1967-68</td>
<td>3.97</td>
<td>0.30</td>
</tr>
<tr>
<td>1968-69</td>
<td>0.68</td>
<td>0.05</td>
</tr>
</tbody>
</table>

With the ambitious dairy development projects under Five Year Plans, it is hoped that the production of creamery butter will increase to a great extent in the years to come. Moreover due to accepted national policy of toning high fat milk to a lower fat percentage for fluid consumption, appreciable quantities of surplus fat would always be available for conversion into creamery butter. On the other hand in flush period, varying quantities of surplus milk is available almost in all dairies, for conversion into products. In fact
making butter in surplus season acts as balancing wheel of the dairy industry as stated by Hmaler (16).

Among all the studies on different dairy products, the production and grading of butter has been a subject of detailed study for a number of decades in countries advanced in dairying. Consequently butter marketed from any of the exporting countries is not of tailor made uniformity in flavour, colour, body and texture, etc. For factory method of butter production, all the operations should be standardised at a very high degree of precision. In India very little work has so far been done on butter.

With increasing consumer's consciousness for quality, the sale of any product depends on consumer's preference. For butter, the main attributes any consumer looks for are body, texture, flavour and colour. Physically an ideal butter has a firm compact body which will stand up well.

In most of the commercial dairies in the country, butter is made more or less under the conditions followed in foreign countries. Since India is a tropical country, and the composition of butter fat usually available in commercial dairies is different from the milk fat in western countries, it is possible that the churning temperatures and holding periods recommended for western countries may not be suitable under Indian conditions.

The present project was, therefore, undertaken to find out and recommend suitable churning temperature and holding period that would:

(a) Minimise losses of fat in buttermilk
(b) Yields butter with desirable body and texture.

(c) Takes minimum churning time compatible with minimum fat losses in buttermilk.
STATEMENT OF PROBLEM
STATEMENT OF PROBLEM

The experimental work was done at Student's Training Dairy, Allahabad Agricultural Institute, Allahabad. The experiment was planned and conducted as follows:

Raw cream from village milk collected at collection centres was standardised for fat and acid, it was then pasteurised and cooled to the different churning temperatures.

Before churning the cream was held for different holding periods at the churning temperatures after which it was churned.

The variables considered in the experiment were:

(a) The period of holding cream at the churning temperature.

(b) The Temperature of churning.

Thus in the experiment the temperature at which cream was held was same as the churning temperature.

(a) Holding period of cream:
   (i) 2 Hours
   (ii) 6 Hours
   (iii) 10 Hours

(b) Churning temperature of cream:
   (i) 9.5 to 9.9°C (47 to 49°F)
   (ii) 10.5 to 11.1°C (51 to 52°F)
   (iii) 12.7 to 13.3°C (55 to 56°F)

Number of churning temperature  = 3
Number of holding periods  = 3
Number of replications  = 8
Total number of trials conducted

$3 \times 3 \times 3 = 27$ trials.

The observations recorded were as follows:

(1) Fat percent of buttermilk.

(ii) Time taken for churning.

The whole experiment was spread over a period of 6 months. The experiment was started from the last week of August 1969 and it was completed in the month of January 1970.

Since season is one of the important factors affecting fat losses in buttermilk and time taken for churning, the whole experiment was divided into two phases A and B. The phase A consisted of 3 replications, which were completed in the months of September and October. The range of room temperature during phase A was 30 to $32.2^\circ C$.

The phase B consisted of 5 replications, which were completed in the months of December and January. During this phase, the range of room temperature was $18.3$ to $21.2^\circ C$.

Throughout the experiment, the fat percent of buttermilk has been taken as a measure of exhaustiveness of churning.
REVIEW OF LITERATURE
REVIEW OF LITERATURE

Hansiker (16) stated, that, the ease with which cream churns, the exhaustiveness of churning and the firmness of the resulting butter depends upon different factors, like size of fat globules, viscosity of cream, pasteurisation temperature, temperature to which cream is cooled before churning, period of holding and churning temperature, etc.

Totman et al. (33) stated that the main object in butter making is to churn the cream exhaustively, i.e. to leave as little fat in buttermilk as possible, and to produce butter with a firm body with a reasonable amount of working to incorporate moisture thoroughly.

The effect of temperature of cooling and period of holding has been studied by several workers. McDowall (29) stated, that, cream shall be cooled promptly after pasteurisation and shall be held below churning temperature when holding period was 2 to 4 hours. He also indicated that butterfat should be supercooled for proper crystallisation and that the completeness of the crystallisation depends upon the time of holding cream at the chilling temperature. Similar results have been reported by Totman et al. (33).

Samuelson (32) in his study showed, that, rapid cooling to a low temperature to initiate the crystallisation of fat followed by slower crystallisation at higher temperature gives larger crystals and lower fat losses in buttermilk. He also stated that fat losses in buttermilk was very low when cream is churned at 8°C.

Dixm (3) in his experiments showed that deep cooling of cream avoids higher fat losses in buttermilk, and that when the cream was
cooled to 8 to 10°C. below churning temperature, butter firmness was considerably increased, plasticity decreased and the butter obtained was brittle in texture.

Hunsiker (16) stated that in order to make possible formation of butter, at least partial solidification of the milk fat is necessary. At the usual churning temperature milk fat exists partially in solid and liquid state. He stated, that, churning of uncooled cream results in higher fat losses, yielding butter of unsatisfactory weak body. The clumping of fat globule is increased by lowering the temperature of cream below 37.7°C. and it is maximum at 6.6 to 7.7°C.

Jack and Brunner (20) reported, that, the more fat that is in solid state, the greater is the time required for churning. They also showed that, the churning time depends upon the cooling procedure used rather than on the percentage of solidified fat.

Mersanov (21) in his experiment on Volume dilatometric examination of various samples of buffalo milk fat subjected to different temperature treatments showed that; ratio of solid to liquid fat necessary for normal butter making is achieved by aging cream at 6 to 10°C. for 2½ to 2 hours when churning temperature is 15 to 18°C.

Experiments conducted on physical properties of milk fat by Delien (10) in the Department of Dairy Science, University of Alberta, Canada, showed that, rapid cooling of milk fat results in the formation of very small crystals, whereas slow cooling results in the formation of relatively larger crystals.

Mcdowall (22) stated, that when the butter fat in cream is
In solidified state, cohesion of fat globules is inhibited. He also stated that weak cooling of cream in certain season of the year results in defects like mealy and leaky butter.

Nabar, Srinivasan and Iya (30) in their experiment showed that cream cooled to 4.4°C was very viscous and somewhat difficult to handle. This difficulty was not encountered in churning the cream cooled to 20°C. They also observed that, the butter made from cream cooled to 4.4°C had slightly greasy and sticky surface.

Hamaker (16) stated that, when time taken for churning is too less, the butter is soft, and the buttermilk test is abnormally high. This is usually due to insufficient cooling of cream or not holding it long enough at the cooling temperature.

Jack and Brunner (19) in their experiment found that, as the temperature of cream is lowered within the churning limits, the churning time increases, because, milk fat becomes solidified. Raising the churning temperature by 2 degrees above this limit may shorten the churning time from 40 minutes to 20 minutes.

McDowall (26) stated that, when the churning temperature is not much higher than the usual chilling temperature (4.4°C.), the fat loss in buttermilk is not high.

McDowall (29) also showed that, when cream was held at 4.4°C. and churned in three lots at 4.4°C., 7.2°C. and 10°C., the rate of fat losses were the same, but, if the churning temperature was higher than 10°C., then the fat losses increased.

Mohr and Mohr (27) reported that, summer butter of good consistency was produced by aging cream for 24 hours at 4°C.
churn:ing it at 5 to 10°C.

Dennan and Wood (9) in their investigation found, that, at higher rate of cooling, there was an increase in the solid fat content.

Tulman et al. (33) stated, that, body and texture of butter may suffer, if extreme conditions are resorted to in order to gain efficiency in exhaustive churning. They also stated, that, no creamery-men will churn at temperatures so low that 2 or 3 hours are required to churn; the extra cost of labour and power would be greater than the extra saving in fat. The churning conditions must fit into the balanced programme and all costs and quality must be considered.

Wilson (35) in his preliminary churning experiment conducted over a period of two years, found, that, cooling the cream to a very low temperature (4-6°C.) resulted in crumbly and sticky conditions of butter.

Esckes, Combs and Macy (12) stated that short period churning causes considerably higher fat losses in buttermilk and the resulting butter is of weaker body. On the other hand prolongation of the churning period results in low fat loss in buttermilk and yields butter with more firm and waxy character.

Akhundov and Meshedov (1) in their experiment found, that, buffalo cream containing 35 to 35 percent butter fat pasteurised at 90 to 95°C. was best suited for butter making. According to them optimum churning temperature was 14 to 17°C. and the time of churning 25 to 30 minutes.

Holland and Harrington (15) reported that as the churning
temperature increases, the time of churning is reduced. They also found that there is an optimum relationship between the amount of liquid and solid fat for churning to take place. If the amount of either is increased from this value, the churning time is lengthened. When fat becomes totally liquid or solid then there is no churning.

According to Bales, Combs and Macy (12), typical churning temperature under factory conditions is 8.5°C. (43°F.) in summer and 12.2 to 13.5°C. (54 to 56°F.) in winter, at these temperatures the churning period is 30 to 45 minutes.

Totman et al. (33) recommended the usual churning temperature to be between 7.2 to 12.7°C., but under certain conditions a wider range may be adopted such as 4.4 to 15.5°C. (40 to 60°F.).

He also stated, that, optimum churning time should be 40 to 60 minutes.

According to Derby (11) as reported by Mortenson (22), sweet cream churned after immediate cooling gave higher fat loss in buttermilk compared to sweet cream containing starter and held overnight.

Mortenson, Cassaler and Cooper (23) in their experiment found that the butter fat, lost in buttermilk when churning sweet raw cream is slightly greater than when churning cream pasteurised while sweet.

Wilster (36) reported, that, cream for butter making should be pasteurised at 145 to 150°F. for 30 minutes.

Combs and Coulter (4) in their studies found that the average fat test of sweet cream buttermilk samples was 0.6403 percent compared to 0.7920 percent in case of sour cream buttermilk samples.

According to Bird and Derby (3) as reported by Mortenson (22)
the fat losses in buttermilk were minimum when cream was churned at 37.5 percent fat.

Bumsiker (16) stated that higher churning temperature results in over churning, and the butter is likely to have higher moisture content.

Tutman et al. (33) stated that the fat test of buttermilk provided a reliable check on churning efficiency; they also stated that buttermilk fat losses usually may range from 0.4 to 0.7 percent, but these losses can be reduced to 0.2 to 0.07 percent by taking proper care.
METHODS AND MATERIALS
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Equipment and Apparatus:

Churn: Electrically driven, wooden, roll-less churn. Churning capacity 80 kg.

Multipurpose Vat: Alfa-Laval, made of stainless steel, jacketed, fitted with electrically driven agitator.
Capacity 300 litres.

Milk Can: Aluminium alloy can. Capacity 40 litres.

Platform balance: Capacity 100 kg. with accuracy of 100 grams.

Graduated Cylinder: 100 ml.

Metal thermometer: Graduated in °F.

Strainer: Used for straining cream

Scotch hand: Used for taking out butter from churn.

Apparatus for testing solidity of cream:

White porcelain cup.

Graduated pipette - 10 ml.

Burette - 50 x 0.1 ml. with stand.

Graduated Cylinder - 25 ml.

Glass rod.

Apparatus for determination of fat content of cream and buttermilk:

Gerber Centrifuge - Original Gerber, electrically driven, 200 r.p.m.

Chemical balance - For weighing cream for fat test.

Milk Sampler - For taking sample of buttermilk.
Figure 3
Centrifuge

Figure 4
Butter Moisture Testing Balance
Plunger - For stirring the cream for sampling.
Double bulb acid pipette - 10 ml.
Milk pipette - 11 ml.
Amyl Alcohol Pipette - 1 ml.
Cream butyrometer - Original Gerber.
Water bath Thermostatically controlled.
Rubber stoppers for butyrometer.

Apparatus required for butter moisture test:
Sample bottles - 250 ml. wide mouth glass stoppered bottles.
Spatula - Stainless Steel.
Butter trier - For sampling butter.
Stove - For heating to evaporate the moisture of butter.
Butter moisture balance - Original Gerber, complete with weighing cup, tongs etc.

REFERENCES:
N/10 Sodium hydroxide - Solution.
1% Phenolphthalein indicator solution.
Sulphuric acid Sp. gr. 1.825.
Amyl Alcohol Sp. gr. 0.905.

Experimental Technique:
The raw cream used in the experiments was obtained from Student's Training Dairy, Allahabad Agricultural Institute, Allahabad. The cream was from village milk, collected at the milk collection centres.
The technique of the experiment was divided into the following steps:
1. Sampling and testing cream for fat.
2. Standardization of cream for fat.
3. Neutralization of cream.
4. Pasteurization of cream.
5. Holding of the cream at the churning temperatures for the required periods.
6. Churning of cream.
7. Testings:
   (a) Buttermilk for fat content.
   (b) Butter for moisture content.

1. Sampling and testing cream for fat:

   a. Sampling of cream: The technique followed for sampling cream was, as per the procedure laid down in IS:1224 - 1958 (17).

   A known amount of cream was taken into the Multipurpose vat and gently stirred by running the agitator. In case of thick cream, it was warmed to a temperature between 30 to 40°C, to facilitate thorough mixing. Care was taken to ensure that the cream was not stirred vigorously to cause undue froth or churning. The sample was taken in a wide mouth glass stoppered. 250 ml. sample bottle. The bottle was kept tightly stoppered and opened only when the sample was to be tested.

   b. Determination of fat % of cream by Gerber Method:

   The fat % of cream was determined as per the procedure
laid down in IB 1224-1953 (17), modified as sugges-
ted by Davis (7).

For determination of fat percent in the cream, Original
Gerber cream butyrometers were used which are marked
to read 0-70 percent fat in cream.

1. Mixing of sample: Mixed the sample of cream thoroughly.
if necessary placed the sample bottle in waterbath
at 30 - 40°C.

2. Weighing of sample: Weighed 5.0 grams of the sample
with a chemical balance in a clean dry cup of the
butyrometer. Fitted the cream cup to the butyrometer,
and added 6.0 ml. hot distilled water.

3. Addition of acid and alcohol: Added 10 ml. of Gerber
Sulphuric Acid in the butyrometer with the help of
10 ml. pipette, and then added 1.0 ml. ethyl alcohol.
If necessary, added more hot distilled water to bring
the contents of the butyrometer to the desired level.

4. Insertion of Stopper: Closed the other end of the
butyrometer firmly with a rubber stopper without
disturbing the contents.

5. Mixing the Content: Shook the butyrometer until the
contents were thoroughly mixed and no white undissolved
curd particles were visible. Inverted once or twice
during the process.

6. Temperature Adjustment: Transferred the butyrometer
quickly with the cup downward into the water bath having
a temperature of 65° ± 2°C. and left it there for not less than 5 minutes. Care was taken to keep the level of the water in the water bath above the top of the fat column in the butyrometer.

(vii) Centrifuging: Took the butyrometer out of the water bath, dried it with the cloth and transferred it to the centrifuge. Placed two butyrometers symmetrically so as to balance the centrifuge. Centrifuged at 1200 r.p.m. for five minutes. Stopped the centrifuge gradually. Transferred the butyrometers, cup downwards, into the water bath having a temperature of 65° ± 2°C. and allowed the butyrometers to stand in the water bath for at least 3 minutes.

(viii) Reading of Butyrometer: Before taking the reading, adjusted the position of the fat column to bring the lower end of the column on to a main graduation mark. Noted the scale readings corresponding to the lowest point of fat miniscus and the surface of separation of the fat and acid, the difference between the two readings gave the percentage by weight of the fat in the cream. Recorded the reading.

2. Standardisation of cream for fat: The cream was standardised to 38 percent fat by adding required amount of water.

The amount of water required for standardisation of the cream was calculated by Pearson Square Method as follows;

(a) Draw a square.
(b) The fat percent desired (35 percent) in the standardized cream was placed in the centre of the square.

c) Wrote the fat percent of the cream at the top left hand corner.

d) Wrote the percent fat of the material used for standardizing at the bottom of left hand corner.

(e) Subtracted diagonally the smaller figure from the larger.

(f) The difference obtained on the right hand corners gave the proportion in which the cream and water should be mixed.

**Example:** Calculate, how much water should be added to 150.00 kg. cream testing 50 percent fat to obtain standardized cream testing 35 % fat.

![Diagram of cream and water](attachment:diagram.png)

In 35 kg. cream add 15 kg. water.

Therefore in 150kg. cream add \( \frac{15 \times 150}{35} \approx 55.71 \) kg. water

Total amount of standardized cream testing 35 % fat

\[ 150 + 55.71 = 205.71 \text{ kg.} \]

After standardization, the cream was again tested for fat percent.

5. Neutralisation of cream: The neutralisation of cream means reduction of lactic acid in sour cream. It is in fact standardisation of cream.
for acid, by adding suitable alkali.

For all the trials the acidity of the cream was standardised within a range of 0.144 to 0.153 percent by adding sodium bicarbonate. The important steps in neutralisation of cream were as follows:

(a) **Determination of acidity of cream:** The acidity of the cream was determined according to the prescribed procedure in the Laboratory Manual of Dairy Chemistry (2) and IS : 1479 (Part I) - 1960 (18)

   (i) Took a well mixed representative sample of cream.

   (ii) Weighed 10 grams of the sample in a procelain cup.

   In another cup took the same amount of cream as control.

   (iii) Added 10 ml. of freshly boiled and cooled distilled water.

   (iv) Added 1.0 ml. of phenolphthalein indicator solution.

   (v) Titrated the content of one cup, by stirring the contents with a glass rod, against N/10 sodium hydroxide solution till the first appearance of faint pink colour which persisted for 10 to 15 seconds. The other cup with the cream served as a blank and facilitated observation of change of colour of cream from opaque white to a faint pink.

**Calculation:**

Titratable acidity (as lactic acid per 100 ml. of milk) $= \frac{97.4}{V_2}$

where

$V_1$ = Volume in ml. of the standard sodium hydroxide required for titration.
N = Normality of the standard sodium hydroxide solution; and

\[ V_2 = \text{Volume in ml. of cream taken for the test.} \]

(b) Procedure of Neutralisation of Cream:

The cream was neutralised according to the procedure given by Wilster (36).

(i) Accurately weighed the required amount of neutraliser and dissolved it in warm water, 10 to 15 times by weight of the neutraliser. Allow the solution to stand for few minutes.

(ii) Prepared the cream in the multipurpose vat by gently agitating and heating to 21 to 25°C. (70 to 80°F.) to ensure that it was free from lumps and no unmixed heavy cream remained in the bottom of the vat. Stirred with plunger if necessary.

(iii) After 15 minutes slowly sprinkled the neutraliser solution on the cream in the vat. Kept the cream constantly stirred.

(iv) Pasteurised the cream about fifteen minutes after adding the neutraliser.

4. Pasteurisation of Cream

Pasteurised the cream in the multipurpose vat about 15 minutes after adding the neutraliser. For pasteurisation the cream was heated to 65.5°C. (150°F.); and was held at this
temperature for 30 minutes. During pasteurisation cream was stirred thoroughly but gently by the agitator fitted in the multipurpose vat. After 30 minutes holding at the pasteurisation temperature, the cream was cooled down to the desired churning temperature in the same vat with chilled water flowing in the jacket of the vat.

5. Holding of cream at churning temperature:

After cooling the cream to the churning temperature, it was held in the same vat for the required holding periods (2 hours, 6 hours and 10 hours). After the end of the desired holding periods, 60 kg. cream was drawn from the vat for each churning.

6. Churning of cream:

(a) Preparation of churn: For washing the churn, about 40 litres of 1.5 percent of sodium carbonate solution with 30 ml. Teepol was taken in the churn; the temperature of the solution was 55°C. The lid of the churn was properly clamped and it was revolved for 15 minutes. The churn was stopped and the detergent solution was drained out. The churn was then washed by taking 60 litres of scalding water in the churn and revolving it for 10 minutes. Finally the churn was filled to about 2/3 of its capacity with pasteurised chilled water at 15°C, and revolved till the temperature of the churn came down to 2°C below the required churning temperature.
(b) Loading the churn: The required quantity of cream (60 kg.) was poured into the churn through a fine mesh strainer.

(c) Addition of colour: Added annato butter colour at the rate of 2 ml. per kg. of fat in the cream just before churning started. The amount of colour added was calculated as follows:

\[
\begin{align*}
\text{Amount of cream churned} & = 60 \text{ kg.} \\
\text{Fat test of cream} & = 35 \text{ percent} \\
\text{Amount of fat in cream} & = \frac{35 \times 60}{100} = 21 \text{ kg. fat} \\
\text{Amount of colour added} & = 2 \text{ ml. per kg. fat} \\
& = 21 \times 2 = 42 \text{ ml.}
\end{align*}
\]

The colour was measured by means of 100 ml glass measuring cylinder.

(d) Closed the lid of the churn and clamped it tight.

(e) Started the churn and recorded the time churning started.

(f) After about 5 minutes, stopped the churn and removed gases through the air vent. Started the churn again.

(g) Stopped the churn as soon as the spy glass was cleared. This was the breaking stage. Recorded the time and the temperature of the churn contents.

(h) Added break water (20 kg.) at the rate of 1/3 of the quantity of cream taken for churning. Temperature of break water was 2.2°C (40°F) below the churning
temperature of the cream. Started the churn again.

(1) Stopped the churn when butter granules became equal to the size of pea grain. Recorded the time and temperature of churn contents.

(j) Drained out the buttermilk and collected a sample of the butter milk for fat test.

(k) Added the wash water at 22°C (42°F.) below the churning temperature of cream. The amount of wash water taken was equal to the amount of cream taken for churning. Rotated the churn 15 times and drained out the wash water.

(1) Added butter salt at the rate of 2 percent of the expected yield of butter. Expected yield of butter was calculated at 20 percent overrun.

The amount of salt added was calculated as follows:

Total fat in the cream = 21.0 kg.
Amount of overrun @ 20 percent = 21 x 0.2 = 4.2 kg.
Expected amount of butter = 21.0 + 4.2 = 25.2 kg.
Amount of salt added = 25.2 x 0.02 = 0.504 kg.

Sprinkled the required amount of salt evenly on the butter granules in the churn.

(a) Closed the lid of the churn and again revolved the churn for working the butter. Worked the butter till all the moisture was evenly incorporated and there were no free moisture droplets on the surface.

(b) Took a representative sample of butter with the help
of the butter trier and tested it for moisture content. If the moisture content of the butter was less than the legal maximum calculated amount of water was added and the butter was worked again to incorporate all the added water. Took another sample of the butter and tested it for moisture content.

(c) Removed the butter from the churn and packed it in parchment papers.

7. Testing:

(a) Buttermilk for fat percent, and

(b) butter for moisture percent.

(a) Determination of fat percent in buttermilk: The fat percent of the buttermilk was determined according to the IS : 1224 - 1958 (17), modified as suggested by Davis (6).

For determination of fat in buttermilk, Original Gerber skim milk butyrometers which are graduated to read 0.01 to 0.5 percent fat were used:

(i) Preparation of butyrometers: Took two clean, dry, skim milk butyrometers and 20 ml. of sulphuric acid was taken into each butyrometer by the help of 10 ml. double bulb and pipette. Care was taken not to wet the neck of butyrometer with the sulphuric acid.

(ii) Mixing of samples: Took a well mixed representative sample of buttermilk and warmed it to 27°C.

(iii) Addition of the sample: Measured 22.0 ml. of sample into each of the butyrometer by the help of 11.04 ml.
pipette. Care was taken not to wet the neck of the butyrometers.

(iv) Addition of Amyl Alcohol: 2.0 ml. of amyl alcohol was added into each butyrometer by means of 1.0 ml. amyl alcohol pipette.

(v) Insertion of stoppers: The necks of the butyrometers were firmly closed with the stoppers without disturbing the contents.

(vi) Mixing of the contents: Shook the butyrometers carefully until the contents were thoroughly mixed, and curd particles dissolved completely. Inverted the butyrometers once or twice during mixing.

(vii) Temperature adjustment: The butyrometers were placed for five minutes in a water bath having a temperature of 65 ± 2°C.

(viii) Centrifuging: After five minutes the butyrometers were removed from the water bath and placed in the centrifuge and centrifuged at 200 r.p.m. for four to five minutes.

After centrifuging for five minutes, the butyrometers were again placed in the water bath for at least three minutes.

(ix) Reading the butyrometers: Adjusted the position of fat column to bring the lower end of the column on to a main graduation mark. Noted the scale reading corresponding to the lowest point of fat miniscus and
the surface of separation of the fat and acid. The 
difference between the two readings gave the percentage 
by weight of fat in buttermilk.

If the fat column was not clear, centrifuged 
once again.

(b) Determination of moisture content in the butter: For testing 
the moisture content of the butter, Gerber moisture balance 
which is calibrated to read moisture percent directly was 
used. The moisture percentage of the butter was determined 
as follows:

(i) Obtained a representative sample of butter from the 
churn in a wide mouth, glass stoppered sample bottle.

(ii) Cleaned, dried and cooled the weigh cup to room 
temperature and placed it on the balance pan.

(iii) Balanced the scale by adjusting the balancing screw, 
if necessary.

(iv) Hung the large rider on the top near the pointer 
and small rider on the graduated scale at zero.

(v) Added to the weigh cup just enough butter to bring 
the instrument again into balance.

(vi) Using the tongs removed the weigh cup containing the 
weighed sample and placed it on the stove, supported 
on wire guage. Lifted the cup with the tongs from 
time to time. Shook the cup so as to mixed the contents 
to avoid foaming and spluttering as heating progressed.
Continued heating as described until the sample stopped frothing and boiling. Further, heating was done with great care till the curd settled down in the bottom of the cup and turned a light amber colour.

(vii) Cooled the cup and its content by shaking the cup or placing it for short intervals on a clean, dry, cold surface. When the cup and its contents were cooled down to room temperature, replaced the cup on the pan of the balance.

(viii) By removing the small rider on the graduated beam, balanced the scale. The graduation of the beam at which the small rider balanced the scale showed the moisture percentage of the butter sample. The reading was recorded.
RESULTS AND DISCUSSIONS
RESULTS AND DISCUSSIONS

The word exhaustiveness of churning has been used by Hansi-ker (16) and Tutman et al. (33), it means, to leave as little fat in buttermilk as possible. The fat test of buttermilk provides a reliable check on the churning efficiency. In those trials, the fat test of buttermilk has been taken as a test for exhaustiveness of churning.

Effect of temperature and time of holding cream on fat percentage of buttermilk during Phase - A. (Range of room temperature 30-32.2°C)

On perusal of the data, presented in Table - 4, it is indicated that the average fat percentage of buttermilk after 2 hours, 6 hours, and 10 hours holding periods at 8.3 to 8.9°C, churning temperature was 0.21%, 0.16%, and 0.13%; at 10.5 to 11.1°C, it was 0.29%, 0.22%, and 0.16% whereas at 12.7 to 13.3°C, it was 0.42%, 0.35%, and 0.28% percent respectively. This indicates that, at all the churning temperature, the fat loss in buttermilk was highest when cream was held only for 2 hours; whereas at the same churning temperatures after 10 hours holding period, the fat loss in buttermilk was minimum. It is also obvious from the data, that, the fat lost in buttermilk increased as the temperature of churning became higher and vice-versa. Thus it was seen that, fat loss in buttermilk was directly proportional to the temperature of churning and inversely so to the time of holding. This is also clear from Figures 5 and 6.

The "F" value obtained as shown in analysis of variance
Table 4

Shrinking percent fat in butter milk at different chilling temperatures and holding periods during phase A (room temperature range 30-32°C)

<table>
<thead>
<tr>
<th>Temperature</th>
<th>3.5 - 8°C 6h</th>
<th>8°C - 11°C 6h</th>
<th>11°C - 12°C 6h</th>
</tr>
</thead>
<tbody>
<tr>
<td>Holding Period</td>
<td>2 hours</td>
<td>6 hours</td>
<td>2 hours</td>
</tr>
<tr>
<td>Replicate 1</td>
<td>0.20</td>
<td>0.25</td>
<td>0.24</td>
</tr>
<tr>
<td>Replicate 2</td>
<td>0.25</td>
<td>0.25</td>
<td>0.21</td>
</tr>
<tr>
<td>Replicate 3</td>
<td>0.23</td>
<td>0.23</td>
<td>0.22</td>
</tr>
<tr>
<td>Total</td>
<td>0.65</td>
<td>0.48</td>
<td>0.39</td>
</tr>
<tr>
<td>Average</td>
<td>0.22</td>
<td>0.16</td>
<td>0.13</td>
</tr>
</tbody>
</table>
Average Fat Percentage of Butter-milk and Churning Time at Different Holding Periods at 8.3-8.9°C in Phase A and B.
SHOWING AVERAGE FAT-PERCENTAGE OF BUTTER-MILK

AT

DIFFERENT CHURNING TEMPERATURES AND HOLDING PERIODS.
Table - 5 indicates that, both churning temperature and holding period had significant effect (at 5% level of probability) on fat lost in buttermilk. It is also clear that there was no significant difference in fat lost in buttermilk due to replications (at 1% level of probability).

**Table - 5**

Showing analysis of variance for testing the effect of holding period and churning temperature on fat percent of buttermilk

<table>
<thead>
<tr>
<th>Source of Variation</th>
<th>D.F.</th>
<th>S.S.</th>
<th>M.S.S.</th>
<th>Variance ratio</th>
<th>5%</th>
<th>1%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Replicates</td>
<td>2</td>
<td>0.027</td>
<td>0.00635</td>
<td>3.75</td>
<td>3.63</td>
<td>6.23</td>
</tr>
<tr>
<td>Treatment</td>
<td>6</td>
<td>0.225</td>
<td>0.02815</td>
<td>3.60</td>
<td>2.59</td>
<td>3.99</td>
</tr>
<tr>
<td>Error</td>
<td>22</td>
<td>0.0270</td>
<td>0.00129</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>26</td>
<td>0.2649</td>
<td>0.03619</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Notes:**
1. Replicates are non significant at 1% level of probability.
2. Treatments are significant at 5% level of probability.

While considering the effect of holding cream for different periods at a particular temperature, it was observed that, the difference in values of the average fat percentage of buttermilk compiled in Table - 6, when compared with the critical difference (0.071) shows that, there is no significant difference (at 5 percent level of probability) in fat percentage of buttermilk, when cream was churned after 2 hours and 6 hours holding at 8.3 to 8.9°C. Similarly the
<table>
<thead>
<tr>
<th>Churning Temperature °C</th>
<th>8.3-8.9</th>
<th>D.5-11.1</th>
<th>8.3-8.9</th>
<th>D.5-11.1</th>
<th>8.3-8.9</th>
<th>D.7-15.3</th>
<th>D.7-15.3</th>
<th>D.7-15.3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Holding Period</td>
<td>10 hrs.</td>
<td>10 hrs.</td>
<td>6 hrs.</td>
<td>2 hrs.</td>
<td>6 hrs.</td>
<td>10 hrs.</td>
<td>2 hrs.</td>
<td>6 hrs.</td>
</tr>
<tr>
<td>Av. fat %</td>
<td>0.15</td>
<td>0.26</td>
<td>0.15</td>
<td>0.17</td>
<td>0.26</td>
<td>0.26</td>
<td>0.26</td>
<td>0.26</td>
</tr>
</tbody>
</table>

Note: The values which are underlined are non significant.
difference in fat lost in buttermilk was non significant when cream
was churned after 6 hours and 10 hours holding at this temperature.
The difference in the average fat percentage of buttermilk was however
significant at all the churning temperatures under study, when cream
was churned after 2 hours and 10 hours holding. This trend was also
found at all the other churning temperatures at these holding periods.

While considering the effect of different churning tempera-
tures on exhaustiveness of churning, it was observed that, when hold-
ing period was only 2 hours, the buttermilk had significantly lower
average fat percentage if cream was churned at 8.3 - 8.9°C, which
was the lowest of the three churning temperatures studied. Therefore
it appears that after 2 hours holding, cream churns most exhaustively
at 8.3 - 8.9°C.

It is also observed from the table - 6 that, on churning
cream at 10.5 - 11.1°C, after 6 hours holding, the average fat test
of buttermilk was significantly different from the average fat test
of buttermilk obtained when cream was churned at 12.7 - 13.3°C, after
the same holding period. Similarly a significant difference in average
fat percentage of buttermilk was found when cream was churned at 8.3
- 8.9°C and 2.7 - 3.3°C, after 6 hours holding. In both the cases the
fat losses in buttermilk were more at higher temperature. The dif-
ference in average buttermilk fat loss was however nonsignificant when
cream was churned after 6 hours holding at 8.3 - 8.9°C. Thus same
exhaustiveness in churning was achieved at either of the two tempera-
tures when holding period was 6 hours. Normally when there is no ad-
ditional gain in exhaustiveness by churning cream at the lower tempe-
temperature (8.3 - 8.9°C), the higher temperature (10.5 - 11.1°C) may be preferred, because, the refrigeration and other costs involved would be comparatively lower at this temperature. However it was observed that, when cream was churned at 8.3 - 8.9°C, the body and texture of the butter obtained was much better than when it was churned at 10.5 - 11.1°C. Therefore churning at 8.3°C would be better.

In case of 10 hours holding period it was observed that, statistically there was no difference in average fat loss in buttermilk by churning cream at 8.3 - 8.9°C and 10.5 - 11.1°C. But churning cream at 12.7 - 13.3°C, resulted in significantly higher average fat loss in buttermilk than churning cream at 8.3 - 8.9°C. Thus when holding period was 10 hours, the churning was most exhaustive at 8.3 - 8.9°C. Churning at 8.3 - 8.9°C had the additional advantage of yielding butter of better body and texture.

**Effect of holding period and churning temperature on fat percentage of buttermilk during Phase - B.** (Range of room temperature 13.3-21.1°C.)

The data obtained from 45 trials conducted during Phase - B, revealed that, other conditions remaining same, there was a general tendency for greater fat loss in buttermilk with higher churning temperatures and lesser fat loss in buttermilk with longer holding period. This trend is clear from Figure - 7.

A comparison from the data given in tables 4 and 7, indicates that, during phase - B under similar conditions of holding period and churning temperature, the fat percentage of buttermilk was almost half of what it was during phase - A. This fact is also elucidated by Figure - 8. Of the several possible reasons for comparatively
Fig. 1.

Showing Average Fat Percentage of Buttermilk at Different Churning Temperatures and Holding Periods.
Fig. 8.

Showing Average Fat Percentage of Butter Milk at Different Temperatures and Holding Periods in Phase A and B
<table>
<thead>
<tr>
<th>Temperature</th>
<th>1.5 - 8.9°C</th>
<th>1.5 - 11.5°C</th>
<th>1.5 - 12°C</th>
<th>1.5 - 12°C</th>
<th>1.5 - 12°C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Holding period</td>
<td>2 hours</td>
<td>6 hours</td>
<td>2 hours</td>
<td>6 hours</td>
<td>6 hours</td>
</tr>
<tr>
<td>Replicate 1</td>
<td>0.58</td>
<td>0.53</td>
<td>0.24</td>
<td>0.23</td>
<td>0.20</td>
</tr>
<tr>
<td>Replicate 2</td>
<td>0.58</td>
<td>0.53</td>
<td>0.24</td>
<td>0.23</td>
<td>0.20</td>
</tr>
<tr>
<td>Replicate 3</td>
<td>0.58</td>
<td>0.53</td>
<td>0.24</td>
<td>0.23</td>
<td>0.20</td>
</tr>
<tr>
<td>Replicate 4</td>
<td>0.58</td>
<td>0.53</td>
<td>0.24</td>
<td>0.23</td>
<td>0.20</td>
</tr>
<tr>
<td>Replicate 5</td>
<td>0.58</td>
<td>0.53</td>
<td>0.24</td>
<td>0.23</td>
<td>0.20</td>
</tr>
<tr>
<td>Total</td>
<td>0.58</td>
<td>0.53</td>
<td>0.24</td>
<td>0.23</td>
<td>0.20</td>
</tr>
<tr>
<td>Average</td>
<td>0.58</td>
<td>0.53</td>
<td>0.24</td>
<td>0.23</td>
<td>0.20</td>
</tr>
</tbody>
</table>
higher fat losses in buttermilk during phase - A, the higher room
temperature and the nature of fat may be important.

It is seen from table - 7 that, during phase - B with 2 hours,
6 hours and 10 hours holding periods the average fat content of buttermilk was 0.136, 0.140 and 0.050 percent at 8.3 - 8.9°C, churning temperature, 0.176, 0.130 and 0.072 percent with 10.5 - 11.1°C, churning temperature and at was 0.230 - 0.175 and 0.150 percent respectively
when churning temperature was 12.7 - 13.3°C.

The table - 8 shows that, there was negative correlation
between churning time and fat percentage of buttermilk, and that the
correlation was maximum with 10 hours holding period at all the churning temperature under study.

Table - 8
Showing coefficient of correlation between churning time and
fat losses

<table>
<thead>
<tr>
<th>Churning temperature</th>
<th>8.3 - 8.9°C</th>
<th>10.5 - 11.1°C</th>
<th>12.7 - 13.3°C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Holding period</td>
<td>2 Hrs; 6 Hrs; 10 Hrs; 2 Hrs; 6 Hrs; 10 Hrs; 2 Hrs; 6 Hrs; 10 Hrs</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Correlation</td>
<td>-0.84 -0.60 -0.98 -0.69 -0.95 -0.98 0.83 -0.83 -0.95</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The statistical analysis of the data presented in table - 9,
revealed that, both holding period and churning temperature of cream
had significant effect (at 5% level of probability) on fat content
of buttermilk.

The critical difference value (0.033) when compared with the
Table 9

<table>
<thead>
<tr>
<th>Source of variation</th>
<th>D.F.</th>
<th>S.S.</th>
<th>M.S.S.</th>
<th>Variance ratio</th>
<th>F&lt;sub&gt;5 %&lt;/sub&gt;</th>
<th>F&lt;sub&gt;1 %&lt;/sub&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>Replication</td>
<td>4</td>
<td>0.0021</td>
<td>0.00053</td>
<td>0.75</td>
<td>2.69</td>
<td>4.02</td>
</tr>
<tr>
<td>Treatment</td>
<td>8</td>
<td>0.1153</td>
<td>0.0144</td>
<td>20.5</td>
<td>2.27</td>
<td>3.27</td>
</tr>
<tr>
<td>Error</td>
<td>32</td>
<td>0.0224</td>
<td>0.0007</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Total</td>
<td>44</td>
<td>0.1598</td>
<td>0.01553</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Notes: (1) Replicates are non significant at 5% and 1% level of probability.
(2) Treatments are significant at 5% level of probability.

Critical difference: 0.033
<table>
<thead>
<tr>
<th>Churning Temperature °C.</th>
<th>8.3-8.9</th>
<th>8.5-11.1</th>
<th>12.7-15.3</th>
<th>12.7-15.3</th>
<th>12.7-15.3</th>
<th>12.7-15.3</th>
<th>12.7-15.3</th>
<th>12.7-15.3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Holding Period</td>
<td>10 hrs</td>
<td>10 hrs</td>
<td>10 hrs</td>
<td>6 hrs</td>
<td>2 hrs</td>
<td>6 hrs</td>
<td>6 hrs</td>
<td>2 hrs</td>
</tr>
<tr>
<td>Av. fat %</td>
<td>0.05</td>
<td>0.072</td>
<td>0.150</td>
<td>0.136</td>
<td>0.314</td>
<td>0.175</td>
<td>0.176</td>
<td>0.23</td>
</tr>
</tbody>
</table>

| 8.3-8.9                 | 10 hrs  | 0.05    | 0.022    | 0.030    | 0.066    | 0.09     | 0.125    | 0.126    |
| 8.5-11.1                | 10 hrs  | 0.072   | 0.033    | 0.063    | 0.068    | 0.103    | 0.104    | 0.158    |
| 12.7-15.3               | 10 hrs  | 0.130   | 0.066    | 0.06     | 0.094    | 0.039    | 0.039    | 0.094    |
| 12.7-15.3               | 6 hrs   | 0.036   | 0.035    | 0.036    | 0.09    | 0.035    | 0.036    | 0.094    |
| 12.7-15.3               | 6 hrs   | 0.173   | 0.001    | 0.001    | 0.009    | 0.001    | 0.001    | 0.009    |
| 12.7-15.3               | 6 hrs   | 0.23    | 0.054    | 0.054    | 0.054    | 0.054    | 0.054    | 0.054    |

Notes: The values which are underlined are non significant.
difference in average of fat percent of buttermilk as presented in table - D, clearly shows that, when cream was churned after only 2 hours holding; at all the churning temperatures under study, the difference in fat content of buttermilk was significant; the fat loss being minimum at 8.3 - 8.9°C.

The table D further indicates that, when cream was churned after 6 hours holding at 8.3 - 8.9°C. and D.5 - 11.1°C. the difference in average fat loss in buttermilk was non significant; but when cream was churned at 12.7 - 13.3°C., the buttermilk had significantly higher fat percent compared to when it was churned at D.5 - 11.1°C. Since churning cream after 6 hours holding at D.5 - 11.1°C. had similar effect on exhaustiveness as churning cream at 8.3 - 8.9°C., it would be more economical to churn the cream at D.5 - 11.1°C. instead of at 8.3 - 8.9°C.

The table - D also indicates that, when cream was churned at D.5 - 11.1°C. and 12.7 - 13.3°C. after 10 hours holding period, the difference in average fat percent of buttermilk was significant; the losses being lower at D.5 - 11.1°C. Similarly the difference in average fat percent of buttermilk was significant when cream was churned at 8.3 - 8.9°C. and 12.7 - 13.3°C.; the fat loss was less at 8.3 - 8.9°C. However, the difference in average fat percent of buttermilk was non significant when cream was churned at 8.3 - 8.9°C. and D.5 - 11.1°C. after 10 hours holding period. This indicated that, as far as exhaustiveness of churning was concerned both the churning temperature were equally good. But, since the cost involved in cooling cream to 8.3 - 8.9°C.; and holding it for 10 hours would be more than the cost of
cooling it to 10.5 - 11.1°C and holding for the same period, it may be more economical to hold and churn the cream at 10.5 - 11.1°C. It was moreover observed that the body and texture of the butter was much superior when cream was churned at 10.5 - 11.1°C compared to the butter obtained by churning cream at 8.3 - 8.9°C.

Effect of temperature and time of holding cream, on time taken for churning, during Phase - A (room temperature range 30 - 32.2°C)

It can be seen from the table - 11, that for the 27 trials during phase - A, the average churning time at 8.3 - 8.9°C, after 2 hours, 6 hours and 10 hours holding was 30.6, 37.6 and 42.3 minutes, at 10.5 - 11.1°C, churning temperature was 24.0, 31.6 and 36.6 minutes and at 12.7 - 13.3°C., it was 17.3, 27.6 and 36.6 minutes respectively. This indicates that, while holding period was directly proportional to the time taken for churning, there was an inverse relation between temperature at which cream was churned and the churning time. This is clear from Figure - 9.

As far as exhaustiveness of churning was concerned, churning time showed a negative correlation to fat losses in buttermilk, as can be seen from table - 8. It was thus clear that, more the time taken for churning lesser was the fat loss in buttermilk. This relationship is clearly shown in Figure - 10.

The statistical analysis of the data presented in table - 2 revealed that, both holding period and temperature of churning had significant effect (at 5% level of probability) on churning time. It was also clear that, there was no significant difference in churning time due to replications.
### Table - 11

<table>
<thead>
<tr>
<th>Temperature</th>
<th>$e_5 - 80.5^\circ C$</th>
<th></th>
<th>$D_0.5 - 11.7^\circ C$</th>
<th></th>
<th>$D_0.7 - 13.5^\circ C$</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Holding Period</td>
<td>2 hours</td>
<td>6 hours</td>
<td>10 hours</td>
<td>2 hours</td>
<td>6 hours</td>
<td>10 hours</td>
</tr>
<tr>
<td>Replicate 1</td>
<td>27</td>
<td>35</td>
<td>45</td>
<td>22</td>
<td>30</td>
<td>45</td>
</tr>
<tr>
<td>Replicate 2</td>
<td>30</td>
<td>37</td>
<td>50</td>
<td>25</td>
<td>30</td>
<td>50</td>
</tr>
<tr>
<td>Replicate 3</td>
<td>33</td>
<td>40</td>
<td>50</td>
<td>25</td>
<td>35</td>
<td>45</td>
</tr>
<tr>
<td>Total</td>
<td>92</td>
<td>112</td>
<td>145</td>
<td>72</td>
<td>95</td>
<td>140</td>
</tr>
<tr>
<td>Average</td>
<td>30.6</td>
<td>37.6</td>
<td>42.3</td>
<td>24</td>
<td>31.6</td>
<td>46.6</td>
</tr>
</tbody>
</table>
Fig. 9

Showing average churning-time at different temperatures and holding periods.
Fig 10.

AVERAGE PERCENTAGE OF BUTTERMILK AND CHURNING TIME

AT DIFFERENT HOLDING PERIODS AT 10.5 - 11°C IN PHASE 'A' AND 'B'
Table 12

Showing analysis of variance for testing the effect of holding period and temperature of shunning on shunning time

<table>
<thead>
<tr>
<th>Source of variation</th>
<th>D.F.</th>
<th>S.S.</th>
<th>M.S.S.</th>
<th>Variance ratio</th>
<th>F Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Replications</td>
<td>2</td>
<td>24.90</td>
<td>62.45</td>
<td>4.69</td>
<td>3.65</td>
</tr>
<tr>
<td>Treatments</td>
<td>8</td>
<td>2319.96</td>
<td>289.99</td>
<td>21.8</td>
<td>2.59</td>
</tr>
<tr>
<td>Error</td>
<td>26</td>
<td>213.44</td>
<td>13.30</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Total</td>
<td>26</td>
<td>2653.30</td>
<td>365.74</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

Notes: (1) Replications are non significant at 1% level of probability.
(2) Treatments are significant at 5% level of probability.

Critical difference = 6.51
### Table - 13

Showing comparison of differences of average churning time with the critical difference (6.5)

<table>
<thead>
<tr>
<th>Churning Temperature °C</th>
<th>12.7-13.3</th>
<th>D.5-11.1</th>
<th>2.7-3.3</th>
<th>3.8-3.9</th>
<th>D.5-11.1</th>
<th>2.7-3.3</th>
<th>3.8-3.9</th>
<th>D.5-11.1</th>
<th>3.8-3.9</th>
</tr>
</thead>
<tbody>
<tr>
<td>Holding Period</td>
<td>2 hrs</td>
<td>2 hrs</td>
<td>6 hrs</td>
<td>2 hrs</td>
<td>6 hrs</td>
<td>10 hrs</td>
<td>6 hrs</td>
<td>10 hrs</td>
<td>6 hrs</td>
</tr>
<tr>
<td>Av. Churning time</td>
<td>17.3</td>
<td>24.0</td>
<td>27.6</td>
<td>30.6</td>
<td>31.6</td>
<td>36.6</td>
<td>37.6</td>
<td>46.6</td>
<td>43.5</td>
</tr>
<tr>
<td>12.7-13.3 2 hrs</td>
<td>17.3</td>
<td>6.7</td>
<td>13.3</td>
<td>14.3</td>
<td>19.3</td>
<td>20.3</td>
<td>29.3</td>
<td>32.0</td>
<td></td>
</tr>
<tr>
<td>D.5-11.1  2 hrs</td>
<td>24.0</td>
<td>6.7</td>
<td>13.3</td>
<td>14.3</td>
<td>19.3</td>
<td>20.3</td>
<td>22.6</td>
<td>24.3</td>
<td></td>
</tr>
<tr>
<td>2.7-3.3   6 hrs</td>
<td>27.6</td>
<td>13.3</td>
<td>3.6</td>
<td>6.6</td>
<td>7.6</td>
<td>12.6</td>
<td>15.3</td>
<td>22.6</td>
<td></td>
</tr>
<tr>
<td>3.8-3.9   6 hrs</td>
<td>30.6</td>
<td>13.3</td>
<td>6.6</td>
<td>10.0</td>
<td>10.0</td>
<td>19.9</td>
<td>20.7</td>
<td>17.6</td>
<td></td>
</tr>
<tr>
<td>12.7-13.3 10 hrs</td>
<td>36.6</td>
<td>13.3</td>
<td>10.0</td>
<td>10.0</td>
<td>19.9</td>
<td>20.7</td>
<td>17.6</td>
<td>16.9</td>
<td></td>
</tr>
<tr>
<td>D.5-11.1  10 hrs</td>
<td>37.6</td>
<td>13.3</td>
<td>10.0</td>
<td>10.0</td>
<td>19.9</td>
<td>20.7</td>
<td>17.6</td>
<td>16.9</td>
<td></td>
</tr>
<tr>
<td>2.7-3.3   10 hrs</td>
<td>46.6</td>
<td>13.3</td>
<td>10.0</td>
<td>10.0</td>
<td>19.9</td>
<td>20.7</td>
<td>17.6</td>
<td>16.9</td>
<td></td>
</tr>
<tr>
<td>3.8-3.9   10 hrs</td>
<td>43.5</td>
<td>13.3</td>
<td>10.0</td>
<td>10.0</td>
<td>19.9</td>
<td>20.7</td>
<td>17.6</td>
<td>16.9</td>
<td></td>
</tr>
</tbody>
</table>

**Notes:** The values which are underlined are non-significant.
The critical difference value (6.3) when compared with the difference in average time of churning as given in table - 13, clearly shows that, when cream was churned after 2 hours holding, the difference in churning time was highly significant at all the churning temperatures. The time being lesser at higher churning temperatures, but since exhaustiveness of churning increased with increase in time taken for churning, it would be better to churn at 8.3 - 8.9°C when holding period was 2 hours.

When cream was churned after 6 hours holding period at 8.3 - 8.9°C, and 10.5 - 11.1°C, the difference in churning time was not significant. On the other hand after the same holding period, the difference in churning time was significant at 8.3 - 8.9°C, and 12.7 - 13.5°C churning temperatures. Although after 6 hours holding at 8.3 - 8.9°C, cream took longer time to churn, churning cream at this temperature was more exhaustive. Since statistically the differences in churning time and buttermilk fat losses were non significant when cream was churned at 8.3 - 8.9°C and 10.5 - 11.1°C, the higher of the two churning temperatures would be preferred for reasons already discussed.

It can be seen from the table - 13, that when cream was churned after 10 hours holding period at 8.3 - 8.9°C and 10.5 - 11.1°C, the difference in average churning time was non significant. But, when cream was churned at 10.5 - 11.1°C, and 12.7 - 13.3°C after the above holding period, the difference in churning time was significantly high. It is therefore clear that, churning cream after 10 hours holding at 8.3 - 8.9°C and 10.5 - 11.1°C required
significantly longer churning time as compared to churning at 12.7 - 13.3°C. Although there was no significant difference in churning time and fat losses in buttermilk when cream was churned after 10 hours at 8.3 - 8.9°C and 10.5 - 11.1°C, the quality of butter was much better at the lower churning temperature. Therefore churning at 8.3 - 8.9°C would be preferred. The above findings concur with the findings of Oakland, Combe and Macy who stated that short period churning causes considerably higher fat losses in buttermilk and resulting butter is of weaker body. On the other hand prolongation of the churning period results in lesser fat losses and gives more exhaustive churning.

Effect of temperature and time of holding cream on time taken for churning, during phase - B (room temperature range 13.3 - 21.7°C)

On perusal of the data, obtained from 45 trials during phase B, and presented in table - 14, it is indicated that, the average churning time at 8.3 - 8.9°C, after 2 hours, 6 hours, and 10 hours was 66.0, 20.0 and 84.4 minutes, at 10.5 - 11.1°C, it was 49.0, 91.6, and 149.8 minutes and at 12.7 - 13.3°C, it was 34.2, 62.5, and 87.3 minutes respectively. It is clear from figure 11, that under similar conditions of holding and churning temperature the churning time during phase - B, was about twice as much as during phase A. This may be due to comparatively lower room temperature and nature of the fat during phase - B.

It can be seen from figure 12, and 13, that, longer the period of holding more was the time taken for churning, and lower the churning temperature, longer was the time required for churning.
<table>
<thead>
<tr>
<th>Temperature</th>
<th>1.5 - 6.5°F</th>
<th>2.5 - 11.5°F</th>
<th>2.5 - 25.5°F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Holding Period</td>
<td>1 hour</td>
<td>1 hour</td>
<td>1 hour</td>
</tr>
<tr>
<td>Replicate 1</td>
<td>20</td>
<td>25</td>
<td>30</td>
</tr>
<tr>
<td>Replicate 2</td>
<td>30</td>
<td>35</td>
<td>40</td>
</tr>
<tr>
<td>Replicate 3</td>
<td>40</td>
<td>45</td>
<td>50</td>
</tr>
<tr>
<td>Replicate 4</td>
<td>50</td>
<td>55</td>
<td>60</td>
</tr>
<tr>
<td>Replicate 5</td>
<td>60</td>
<td>65</td>
<td>70</td>
</tr>
<tr>
<td>Total</td>
<td>230</td>
<td>240</td>
<td>250</td>
</tr>
<tr>
<td>Average</td>
<td>46</td>
<td>50</td>
<td>54</td>
</tr>
</tbody>
</table>
Fig. II.

Showing Average Churning Time at Different Churning Temperatures and Holding Periods in Phase 'A' and 'B'
FIG. 12.

AVERAGE FAT PERCENTAGE OF BUTTER-MILK AND CHURNING TIME AT DIFFERENT HOLDING PERIODS AT 12.7-13.3°C IN PHASE A AND B.
Fig-13.

Showing Average Churning Time at Different Churning Temperature & Holding-periods.
### Table 15

**Shaping analysis of variance for testing the effect of holding period and shaping temperature on time of shaping during phase 6**

<table>
<thead>
<tr>
<th>Source of variation</th>
<th>D.F.</th>
<th>S.S.</th>
<th>M.S.S.</th>
<th>Variance ratio</th>
<th>P. Value 5%</th>
<th>P. Value 1%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Replication</td>
<td>4</td>
<td>475.7</td>
<td>23.62</td>
<td>2.31</td>
<td>2.69</td>
<td>4.02</td>
</tr>
<tr>
<td>Treatments</td>
<td>8</td>
<td>7942.2</td>
<td>992.75</td>
<td>13.5</td>
<td>2.27</td>
<td>3.47</td>
</tr>
<tr>
<td>Error</td>
<td>32</td>
<td>1705.6</td>
<td>53.26</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Total</td>
<td>44</td>
<td>10116.5</td>
<td>1071.78</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

**Notes**

1. Replicates are non-significant at 5% level of probability.
2. Treatments are highly significant at 5% level of probability.

Critical difference = 9.4
The "F" value in analysis of variance table - 15 shows that, holding period and churning temperature both had significant effect on churning time.

The difference in average time taken for churning as compiled in the table - 16, when compared with the critical difference (9.4) shows that, at all the churning temperatures under study, when cream churned after 2 hours holding, the difference in churning time was highly significant. The time of churning was more at the lower churning temperature.

It has already been discussed earlier that, when holding period was 2 hours, the churning was most exhaustive at 8.3 - 8.9°C. It was observed that, the average time taken for churning was maximum at 8.3 - 8.9°C, with 2 hours holding period.

It was also observed during the phase - B, that, when cream was held for 2 hours, the body and texture of butter was better when cream was churned at 8.3 - 8.9°C, as compared to butter obtained by churning at other temperatures.

It is evident from table - 16, that when cream was churned after 6 hours holding period at 8.3 - 8.9°C, and D.5 = 11.1°C, the difference in average churning time was highly significant, the churning time being less at D.5 = 11.1°C. As has already been indicated in the discussion earlier, there was no significant difference in fat lost in buttermilk whether the cream is churned at 8.3 - 8.9°C, or D.5 = 11.1°C, after 6 hours holding. Therefore, it would be more economical to churn the cream at D.5 = 11.1°C, specially when there was additional advantage of getting butter comparatively better in
### Table - X

**Showing comparison of differences of average churning time with the critical difference (9.6)**

<table>
<thead>
<tr>
<th>Churning Temperature (°C)</th>
<th>2 hrs</th>
<th>2 hrs</th>
<th>6 hrs</th>
<th>2 hrs</th>
<th>10 hrs</th>
<th>6 hrs</th>
<th>6 hrs</th>
<th>10 hrs</th>
<th>10 hrs</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.7-13.5</td>
<td>34.2</td>
<td>49.0</td>
<td>62.5</td>
<td>66.0</td>
<td>87.5</td>
<td>91.6</td>
<td>120</td>
<td>149.6</td>
<td>164.6</td>
</tr>
<tr>
<td>12.5-11.1</td>
<td>14.8</td>
<td>28.3</td>
<td>31.8</td>
<td>53.3</td>
<td>57.4</td>
<td>59.3</td>
<td>85.3</td>
<td>115.6</td>
<td>120.4</td>
</tr>
<tr>
<td>12.5-11.1</td>
<td>2 hrs</td>
<td>55.5</td>
<td>38.5</td>
<td>42.6</td>
<td>71.0</td>
<td>10.3</td>
<td>82.1</td>
<td>85.0</td>
<td>29.2</td>
</tr>
<tr>
<td>8.5 - 8.9</td>
<td>2 hrs</td>
<td>66.0</td>
<td>54.0</td>
<td>31.5</td>
<td>35.6</td>
<td>84.0</td>
<td>28.4</td>
<td>58.2</td>
<td>71.0</td>
</tr>
<tr>
<td>8.5 - 8.9</td>
<td>6 hrs</td>
<td>91.6</td>
<td>33.5</td>
<td>65.3</td>
<td>72.3</td>
<td>65.3</td>
<td>29.8</td>
<td>44.4</td>
<td>14.4</td>
</tr>
</tbody>
</table>

Notes: Values which are underlined are non-significant.
body and texture.

When cream was churned after 10 hours holding period, at the three churning temperatures under study, the churning time was significantly more at 8.3 - 8.9°C. It has already been discussed that, when cream was churned at 8.3 - 8.9°C and D.5 - 11.1°C, the fat losses in buttermilk were statistically same. Therefore it would be better to churn the cream at D.5 - 11.1°C, because at this temperature time taken for churning was lesser than at 8.3 - 8.9°C.
SUMMARY AND CONCLUSIONS
SUMMARY AND CONCLUSION

In most of the commercial dairies in the country, the procedure per se for butter making is more or less similar to that followed in the foreign countries. India is a tropical country and in consequence the composition of butter fat usually available in commercial dairies is different from the milk fat in the temperate countries. In this investigation an attempt has been made to find out and recommend suitable holding period and holding and churning temperature for obtaining maximum exhaustiveness of churning with minimum churning time.

Raw cream from village milk, collected at milk collection centres was standardized for fat percent acid, it was then pasteurized and cooled to the churning temperatures under study. Before churning the cream was held for the different holding periods at the churning temperatures after which it was churned.

The variables considered in the study were, three different holding periods, viz. 2 hours, 6 hours, and 10 hours and three churning temperatures 8.3 - 8.9°C, 10.3 - 11.1°C, and 12.7 - 13.5°C. The total number of treatment combinations were 9 and they were repeated 8 times, resulting in a total of 72 trials.

Since season in one of the important factors affecting the churnability of cream, the whole experiment was divided into two phases, A and B. Phase A consisted of 27 trials, completed in the months of September and October during which the room temperature ranged from 30.0 - 32.2°C. The phase B on the other hand consisted
of 45 trials completed in the months of December and January during which the room temperature ranged between 18.3 - 21.1°C.

The data obtained were subjected to statistical analysis for "F" test, critical difference and coefficient of correlation.

From the results of analyses, the following conclusions may be drawn:

1. Holding period and churning temperature, both affected the exhaustiveness of churning. The longer the holding period, more was the time taken for churning and more was the exhaustiveness of churning and vice versa. Similarly lower the churning temperature, longer was the time taken for churning and lesser was the fat loss in the buttermilk and vice versa.

2. Under identical conditions of only holding and churning temperatures, the churning time during phase B were approximately twice as much as during phase A. On the other hand, fat losses in the buttermilk were approximately twice that of phase A.

3. Fat losses were considerably reduced when holding period was only 2 hours with cream held and churned at 8.3 - 8.9°C, irrespective of the phase (A or B).

4. Most suitable temperature for holding and churning cream subjected to a holding period of 6 hours for minimizing fat losses was found to be 8.3 - 8.9°C, for phase A and
$D_0 = 11.1^\circ C,$ for phase B.

5. With the holding period of 10 hours, the cream held and churned at a temperature of $8.3 - 8.9^\circ C$ and $D_0 = 11.1^\circ C$ in phase A and B respectively, the exhaustiveness was significantly higher than that recorded with 2 hours holding period and only relatively higher than that obtained with 6 hours holding.
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ACKNOWLEDGEMENTS

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