2.0 Introduction

The spreadability of butter assumes importance in the context of consumer preference. The spreadability has been reported to be influenced by various factors. In this chapter a brief resume' is given on the earlier work carried out in finding the causes of lack of spreadability in butter and its improvement. The review has been made under the following headings:

2.1 Spreadability of butter
2.2 Objective measurements
   2.2.1 Penetration
   2.2.2 Cutting
   2.2.3 Extrusion
   2.2.4 Compression
   2.2.5 Spreading
2.2.6 Relationship to sensory assessment.
2.3 Relationship between structure and rheological behaviour.
2.4 Factors affecting butter spreadability
2.4.1 Composition of milk fat.
2.4.1.1 Effect of feed and season.
2.4.2 Treatment of the cream.
2.4.3 Mechanical treatment of the butter
2.4.3.1 Working of the butter
2.4.3.2 Setting of the butter.
2.5 Fractionation of butterfat.
2.6 Modification of butterfat
2.6.1 Polyunsaturated fatty acids
2.6.2 Interesterification
2.6.3 Isomerisation
2.6.4 Hydrogenation
2.6.5 Use of surface active agents.
2.7 Low calorie butter and spread.
2.8 Dry butter.

2.1 Spreadability of butter

The term spreadability has been used by consumers for many years to denote the ease with which butter may be spread on bread. This characteristic of butter has been the subject of investigation by many scientists in order to evolve an universally acceptable definition. Measurement of physical properties, grading of butter on score card basis, or correlating with some of the properties like viscosity, plasticity etc. had been some of the area in which work has been carried out in order to find out a suitable definition of spreadability of butter.
Because the spreading action may be accomplished in various ways, a universally acceptable definition for spreadability has been lacking. This is unfortunate because it has greatly retarded attempts to measure property with objective physical methods. Like many other terms spreadability is not a single physical property but rather a mixture of several. According to Scott Blair (1938) spreading capacity was a psychological composit in which a number of separate physical properties were concerned. The proportion of each factor concerned was not known. He stated that brittleness or shortness and hardness were the two probable principal factors involved in spreading capacity. Mulder (1939) stated that spreadability was dependent on the ease of sliding of fat globules and water droplets over each other, and that according to him was helped by the presence of much free liquid fat. McDowall (1953) defined spreadability as the ease of spreading on a flat surface under stress applied fairly rapidly. Thomson (1955) showed relationship between spreadability and plasticity. Three requisites have been suggested for plasticity (i) both solid and liquid phase must be present (ii) the solid phase must be well dispersed in order to hold the mass together by internal cohesive forces and (iii) the two phases should be present in the proper relationship. He further listed defects on the butter score card under body and texture which included leaky, crumbly, gummy, mealy, weak, sticky and ragged boring. He stated that most of these could be associated with the term
spreadability which did not appear on the score card. According to deMan (1961), the term spreadability was used with the idea of providing a numerical expression for the actual spreading properties. He stated that when butter was spread on bread, four factors were involved viz., (i) the adhesion between the knife and butter, (ii) the resistance to deformation of butter, (iii) the adhesion between butter and bread, (iv) the condition of the bread. According to him, the measurements with the spreadability testers, only factors one and two played a role and therefore the numerical value obtained was not strictly a measure of spreadability. The importance of factor (i) was small as compared to that of (ii) and that the quantity measured was thus essentially resistance to deformation in butter.

Many workers have studied the physical nature of butter, with particular respect to its use as a spread. Terms used in this field included elasticity, yield value and viscosity, which could be expressed in absolute terms, and also several of less specific nature such as spreadability, body, texture, consistency, firmness, softness and hardness. The term consistency, for instance, was used by Mulder (1953) to refer to the total physical property of butter; Olsson and Johansson (1962) used it for a subjective panel evaluation of butter as distinct from an instrumental determination of hardness. Instruments have been called "consistometers" expressing test results for specific mechanical conditions of operation as in Mulder (1942) and Kapsalis, et al (1960); Kramer and Twigg (1962) regarded
consistency as resistance to flow of a non-Newtonian fluid and state that this property should be properly reported as apparent viscosity. Many other instruments have been produced to determine the physical properties of butter. Most estimated the apparent viscosity in some way and in some cases one or more additional properties. These have been excellently reviewed by Mulder (1953) who used the better term firmness rather than the usual hardness for this property. He highlighted the problem of relating determinations under conditions of small deformation to those of large deformation, a problem in testing non-linear visco-elastic materials and pointed to the empirical nature of the test procedures. Since the order of non-linearity was not well documented for butter and since a large and rapid order of deformation was involved when spreading butter on bread, test procedures involving reasonably high shear rates were desirable. The firmness of butter was not the only property involved in its spreadability although the good correlation of instrumental determination with panel evaluation of butter demonstrated its importance. Additional estimation of the brittleness or plasticity of butter was of self evident value.

2.2 Objective measurements

Some of the physical properties of butter have been studied by using some special types of instruments. The measurement of physical property was considered important
in order to explain the spreadability of butter or the lack of it. The application of force to find out the variation in the stress and strain in the butter mass under different experimental conditions had led to the study of different physical parameters like penetration, cutting, extrusion, compression etc. of butter.

2.2.1 Penetration

The earliest recorded use of an instrument appeared to be in 1893 when Brulle loaded a rod until it rapidly penetrated the sample of butter. Since then, penetrometers have been widely used inspite of several obvious disadvantages. The main objection to the use of a penetrometer was that it had a very small area of application and unless the sample was uniform and homogenous, any recording was likely to be unrepresentative of the sample as a whole. While this could be overcome by taking many readings at different points for a single sample, but in doing so the main virtues of the method, its simplicity and quickness were lost. Inspite of this, a modified form of penetrometer proved to be one of the most successful devices which had been developed for testing butter. Kruisheer et al (1938) measured the force necessary to push a circular block of \(4\text{cm}^2\) cross section slowly into the surface of the butter. The block was 1 cm thick and the rate of penetration was supposed to be 2 cm min.\(^{-1}\) so that the upper surface of the block just became flush with the butter surface at the end of 30 seconds.
It was claimed that with a little practice, a steady penetration at this rate could be maintained manually. An automatic form of the apparatus was also designed so that the rate could be maintained mechanically. Kruisheer & den Herder's device was found to be insensitive to variation in the rate of penetration, therefore, it was used as a simple hand operated instrument. They then compared the readings obtained with this instrument with judgments given by professional Dutch graders and showed a good correlation. As a result of this work they were able to draw up specifications for acceptable limits of firmness of Dutch butter in terms of their instrumental readings. The instrument was manufactured commercially and received official acceptance in Holland and to some extent in Denmark. Vincent and Szabo (1947) measured spreadability of peanut butter by means of a similar penetrometer. Parekh (1974) used precision cone penetrometer for finding out the penetration value of butter made under different manufacturing conditions.

2.2.2 Cutting

Dolby (1941) proved that the load required for a wire to cut through a sample of butter at a given constant rate was a convenient measure of firmness. He used a very simple device consisted of loading weights on a pan until the wire cut through the butter sample at a required speed. Mohr et al (1951) developed a more sophisticated apparatus in which the wire was driven through butter at a constant speed and the counter thrust was measured.
De and Gupta (1971) compared the hardness of different butter samples by using Mohr's Butter hardness tester. They found that butter made from milk of cow and buffalo by the creamery method had a significant difference in their hardness values, buffalo butter showed greater hardness value (about two times) than cow butter prepared and tested under identical conditions.

2.2.3 Extrusion

In 1931 Griffiths described an instrument for determining the spreadability of butter which measured the force required to extrude a sample through an orifice. However, there was no record of his having used it or having justified the assumption that it did measure spreadability. Four years later, Valentine & Sargent (1935) described a similar apparatus for measuring the minimum force required to produce a visible movement of butter through an orifice i.e. a yield value. This was somewhat subjective determination since it depended upon judging by eye the instant of onset of movement. They reported that while - in general - a lower yield value corresponded to more easily spreadable butter, the instrumental readings did not agree entirely with a subjective judge's comments. Prentice (1954) reported that it was very difficult to observe the rate of extrusion at a constant pressure and that very small load variations could cause large variations in the extrusion rate. In one case, a 5% increase in load resulted in a change from no perceptible movement to an almost instantaneous extrusion of the entire sample. This type of
behaviour appeared to support Kruisheer and den Herder's postulated flow curve (1938). The difficulty of observing the onset of movement or of measuring the rate of flow was readily circumvented by causing the butter to flow at a known constant flow rate. This was done as in Mohr's sectility apparatus and in Kruisheer and den Herder's penetrometer, and the thrust required to extrude butter through an orifice could be measured (Prentice 1954). The force required to sustain motion at any instant during extrusion reported to be the sum of the two independent parts. One was that required to extrude butter through the orifice and remained constant as long as the properties of the sample and the rate of extrusion remained constant, the other was the force required to drive the sample within the instrument towards the orifice. Since the flow within the barrel was almost plug flow, this was effectively a force required to overcome friction at the walls and was proportional to the amount of sample in the barrel. This means that the total thrust required decreased as the extrusion proceeded until, just at the point of complete emptying, the frictional component disappeared and the indicated thrust was entirely that required to maintain extrusion. Valentine and Sargent (1935) overlooked this frictional component and the value they attempted to measure the sum of the yield value (extrusion) and the static friction. Once this was exceeded, the frictional component fell, suddenly at first, since sliding friction was lower than static friction, and then progressively as the surface area decreased so that the flow accelerated rapidly instead of
reaching a steady state as they had hoped. This unaccounted frictional component might also have contributed to the lack of agreement found with the judge's comments. Sherbon (1966) evaluated the spreading qualities of the butter by viscosity measurements using the lubricometer. This instrument measured the force required to drag a boat of known dimensions over a film of the sample. The product of force and time, lubricity was directly proportional to viscosity.

2.2.4 Compression

The other principal rheological study made on butter has been the study of compression under load. Some of the most early investigations of this nature were carried out by Davis (1937) who produced curves showing the behaviour of various butter samples under load. He demonstrated that the deformation was non-linear and that there was a slow recovery on removal of the load. From the permanent and the recovered deformations he calculated a viscosity and a modulus of elasticity. He defined the ratio of the two as "Springiness". Using a similar technique, Scott Blair (1938), Dolby (1942) and Mohr and Wellm (1948) attempted to express the firmness of butter as a viscosity, although Scott Blair pointed out that the value was highly dependent upon the conditions of the experiment and was only valid for those particular conditions. The calculation of any viscosity or elasticity from such data was spurious since there was no way of knowing what proportion of the energy at any instant was being dissipated (i.e. viscous) and what proportion
was being stored (i.e. elastic). It has been demonstrated more recently (Fukushima et al., 1964) that the compression and recovery behaviour might be approximately simulated by four component rheological model known as the "Burgers Body". This, however, did not predict the behaviour on subsequent loading nor was it consistent with the possibility of a yield value, real or apparent. A compression instrument was developed by Dixon (1966) not only for the measurement of firmness of the butter as shear strength but also for the flow characters of the butter. This was expressed as plasticity and was defined as percentage deformation to attain maximum strength.

2.2.5. Spreading

One another approach to the rheological testing of butter, which achieved a limited measure of success, was an attempt to imitate to some extent the shearing section of the knife when spreading. Coulter and Combs (1938) endeavoured to standardise the judgement of spreadability by controlling the angle at which the knife was held, in the crushing of a lump of butter of standard size. The spreadability was then assessed on an examination of the shape of the butter sample. Lacy (1937) attempted to simulate mechanically the spreading action of a knife by use of a spreading blade on a trolley, put across a layer of butter. But the instrument was never developed to the stage where it could be usefully employed to measure spreadibility. Baron (1952) recognized that although the hardness was directly related to the amount of pressure
required to spread butter, it was not the sole indication of its spreading properties. The test they used was partly subjective. Huebner and Thomson (1957) repeated this work with a slightly modified instrument in which the knife blade was inclined at 45° to the surface. They arbitrarily defined the characteristics measured with this instrument as spreadability, and those measured with the cutting wire as hardness. From the fairly close correspondence between the two tests, they concluded that hardness of butter was the principal, though not the only factor, affecting its spreadability. Wilster (1958) tested spreadability by cutting butter directly with an ordinary table knife.

2.2.6 Relationship to sensory assessment

Most of the rheological tests described were originally used as empirical and often arbitrary means of testing and controlling the consistency of butter. In few cases already mentioned the instrumental results were related to professional graders' comments. Prentice (1959) compared measurements made with a number of these empirical instruments and in addition, related them to subjective assessment of spreadability and firmness. The tests were conducted over a protracted period and a range of temperatures, and included butter of different origins. The subjective assessments were carried out for a small period by scientifically trained workers, whose judgements were checked for reproducibility and representativeness, against groups of ordinary consumers (mainly housewives). An analysis
of results showed that consumers were just about able to distinguish between the seven steps in the scale of spreadability which ranged from very difficult to very easy to spread. However, they were not quite so certain about the firmness scale where five or six steps probably would have been the optimum. Apart from this, the two terms were almost regarded as synonymous. Instrumental measurements generally gave a higher order of discrimination between samples, thus confirming the results of previous workers. As might be expected, a penetrometer gave occasional poor replication. Also, Mohr and Wellm's (1948) showed that the compression of a cylinder between parallel plates sometimes gave rise to considerable differences between duplicates. There was, in general, a fairly close correlation between all the objective and subjective tests, showing that there was some common factor involved. In particular, there was a close agreement between the extruder thrust (at the point of emptying), the resistance to the cutting wire and the subjective assessment of spreadability. Hofbier (1968) showed the FIRA-NIRD Extruder to be the most consistent instrument for measuring butter firmness and correlated well with subjective assessment of spreadability. Haighton (1969) observed that extrusion measurements were more sensitive to differences between samples within a batch than were the penetrometer measurements. He attributed this to inhomogeneities within the batch. Bindal et al. (1971) found that there were indeed differences occurring
during a production run. They also found that systematic differences in firmness arose during subsequent storage, the upper part of the block becoming firmer than the lower. These two factors accounting for all significant variations between samples taken from the same batch. Chari (1971) developed a constant stress rotation viscometer - a modified stormer's discometer - for measuring both yield stress and viscosity at tropical temperature. Kynast (1971) measured the stress at which butter flows by rotational viscometric methods. Burk and Fluckiger (1971) studied the merits of the FP3+FP31 apparatus for measuring flow and drip points of butter in assessing butter spreadability. It was concluded that FP3+FP31 was easy, rapid and accurate in operation but flow and drip point method was not sufficiently sensitive to reflect rheological differences clearly demonstrated by other methods. Same workers tested a chromatographic paper strip technique for measuring oiling off in butter and correlated with the extruder values obtained by using FIRA-NIRD Extruder and found that the harder the butter, the lower the degree of oiling off. Dixon (1974) compared several instruments used for measuring butter spreadability for their precision, relationship with each other and convenience of operation. It was found that the extrusion method had the best precision while the disc penetrometer method (Kruisheer-den Herder) was the most convenient to use. Parekh (1974) used a constant stress rotation viscometer at 13°C for measuring yield stress and viscosity of butter made under different manufacturing conditions.
2.3 Relationship between structure and rheological behaviour

There has been a steady stream of papers relating firmness of butter to the degree of saturation of the butterfat, determined directly as the iodine number or indirectly by means of the refractive index. Not surprisingly, the greater the degree of unsaturation (and hence the proportion of fat normally liquid at any temperature), the softer the butterfat and hence the softer the butter. While correlations between iodine number, refractive index and firmness had often been shown to be statistically significant, the existence of an association was not precise enough for the degree of unsaturation to be useful for predicting the firmness of butter. It has been realized that the existence of crystals in the butterfat plays an important part in firmness. Mulder (1939, 1940) referred to the role of crystalline fat and attributed the variation in the properties which arose because of different pre-churning treatments of the cream, to the differences in size and proportion of fat which had crystallized. However, although dilatometric studies have shown a general correlation between the amount of fat present in the solid state and the firmness of butter, the agreement was insufficient to explain much of the observed behaviour. Sone et al (1966) observed that the size and shape of the triglyceride crystals affect the properties of butter. He has also obtained electron micrographs of butter showing crystals in a random orientation. Diener & Heldman (1963) showed that small-strain behaviour could be
represented by a model consisting of viscous, elastic and frictional elements. They envisaged the structure of butterfat as an aggregate of discrete granules within which was to be found the intact globular fat whose presence had been demonstrated by King (1947). These workers postulated that the granules could be deformed and also moved relative to one another. They ascribed the linear visco-elastic behaviour to the intact globules, elasticity to the membranes surrounding the globules, and viscosity to the fat retained within them. From the experimental measurements with a penetrometer and a dynamic bending instrument, Diener and Heldman (1968) were able to calculate five constants which adequately characterized the behaviour of butter. The identification of the rheological models with structural elements was only conjectural and was not altogether in keeping with other work which suggested that the fat globule membrane (Prentice 1969) had little elasticity and with Sone's (1966) observations that the extent of crystallisation in the extra globular fat was a major factor in plastic behaviour.

2.4 Factors affecting spreadability of butter

2.4.1 Composition of milkfat

Fat is a mixture of glycerides which are esters of glycerol and several fatty acids. The fatty acids may be saturated or unsaturated. Although many of the glycerides are triglycerides, there may also be di and mono-glycerides and
free fatty acids present in small quantities. The glycerides may be simple glycerides in which all the fatty acids in a molecule are same, or they may be mixed glycerides in which the molecule is composed of two or three different fatty acids. These may be made up of trisaturated, disaturated, monosaturated and triunsaturated glycerides, depending upon the type of fatty acid. There may also be isomers for a given combination of fatty acids depending upon their relative position in a triglyceride molecule. The pattern of distribution of fatty acids between triglyceride and within 1-, 2- and 3 positions of the triglyceride molecule is another important aspect in the structure of a fat. If the fatty acid distribution in a fat is known to be random, it is even possible to calculate the number and types of glycerides.

From the above consideration it is evident that a natural fat is very complex in its structure. This complexity increases enormously with the number of fatty acids constituting a fat. Milkfat contains far more number of fatty acids than any other common vegetable or animal body fats and is, therefore considered to be one of the most complex among fats.

Comparison of composition of buffalo and cow milkfat: 10:1 fatty acid was found only in traces or almost absent in buffalo milk fat whereas it was found to the extent of 0.24 to 43% in cow milk fat. The fatty acids 4:0, 16:0, 17:0 and 18:0 were present in significantly higher proportion in buffalo milkfat than in cow milk fat. On the other hand, the fatty
Table 2

Major fatty acid composition of buffalo and cow milk fats

(Ramamurthy and Narayana - 1971)

<table>
<thead>
<tr>
<th>Fatty acids</th>
<th>Buffalo milk-fat</th>
<th>Cow milk-fat</th>
</tr>
</thead>
<tbody>
<tr>
<td>4:0 (butyric)</td>
<td>4.4</td>
<td>3.2</td>
</tr>
<tr>
<td>6:0 (caproic)</td>
<td>1.5</td>
<td>2.1</td>
</tr>
<tr>
<td>8:0 (caprylic)</td>
<td>0.8</td>
<td>1.2</td>
</tr>
<tr>
<td>10:0 (capric)</td>
<td>1.3</td>
<td>2.6</td>
</tr>
<tr>
<td>10:1 (decinoic)</td>
<td>trace</td>
<td>0.3</td>
</tr>
<tr>
<td>12:0 (lauric)</td>
<td>1.8</td>
<td>2.8</td>
</tr>
<tr>
<td>14:0 (myristic)</td>
<td>10.3</td>
<td>11.9</td>
</tr>
<tr>
<td>16:0 (palmitic)</td>
<td>33.1</td>
<td>30.6</td>
</tr>
<tr>
<td>18:0 (stearic)</td>
<td>12.0</td>
<td>10.1</td>
</tr>
<tr>
<td>18:1 (oleic)</td>
<td>27.2</td>
<td>27.4</td>
</tr>
<tr>
<td>18:2 (linoleic)</td>
<td>1.5</td>
<td>1.5</td>
</tr>
<tr>
<td>18:3 (linolenic)</td>
<td>0.5</td>
<td>0.6</td>
</tr>
</tbody>
</table>
acids 6:0, 8:0, 10:0, 12:0, 14:0 and 14:1 were significantly higher in cow than in buffalo milkfat as shown in table 2.

The higher content of 4:0 acid and lower contents of 6:0 to 12:0 fatty acids observed in buffalo milk fat than in cow milk fat were consistent with the higher Reichert-Meissl (R.M.) value and lower polenske value extensively reported in the literature (Doctor et al., 1940; Rangappa & Achaya, 1948; Basu et al., 1962) for buffalo milkfat. The average total saturated fatty acids in buffalo and cow milk fats were 67.9% and 66.1%. Thus the levels of saturated fatty acid contents of these two fats were similar. However, the amount of 16:0 and 18:0 fatty acids were significantly higher in buffalo milk fat than in cow milk fat. This was explained the higher melting point observed for buffalo milkfat than those of cow milkfat, (Ghose, 1920; Godbole & Sadgopal, 1939; Albonics et al., 1968).

It is also seen from the table 2 that all the fatty acids showed wide variation in both buffalo and cow milk fats. The greater variation being observed in the fatty acids 14:0, 16:0, 18:0 and 18:1. Much work had been reported on the composition of cow milkfat (Hilditch and Thomsen 1936; Hawke, 1957; Smith et al., 1961, Jensen et al., 1962; deMan 1964, Nakanishi and Nakau, 1965). Very few references were available on the composition of buffalo milkfat (Achaya and Banerjee, 1945; Anantakrishnan et al 1946; Ramamurthy & Narayana, 1972).

One of the major problems faced by the butter maker has been the production of a consistent quality product throughout the year. The consistency of butter depends to a larger extent
Table 3

Analytical constants of buffalo milk fat
(Ganguli, N.C. 1974)

<table>
<thead>
<tr>
<th>Constants</th>
<th>Buffalo butterfat</th>
<th>Cow butterfat</th>
</tr>
</thead>
<tbody>
<tr>
<td>Butyrorefractometer Index</td>
<td>42.0</td>
<td>43.2</td>
</tr>
<tr>
<td>Saponification value</td>
<td>230.1</td>
<td>227.3</td>
</tr>
<tr>
<td>Reichert value</td>
<td>32.34</td>
<td>26.67</td>
</tr>
<tr>
<td>Polenske value</td>
<td>1.41</td>
<td>1.76</td>
</tr>
<tr>
<td>Kirschner value</td>
<td>28.52</td>
<td>22.16</td>
</tr>
<tr>
<td>Iodine value</td>
<td>29.43</td>
<td>33.78</td>
</tr>
<tr>
<td>Solidifying point (°C)</td>
<td>15.0-23.0</td>
<td>15.0-23.5</td>
</tr>
<tr>
<td>Melting point (°C)</td>
<td>32.0-43.5</td>
<td>28.5-41.0</td>
</tr>
<tr>
<td>Colour</td>
<td>0.8</td>
<td>8.8</td>
</tr>
<tr>
<td>(Yellow units/g Tintometer)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
on the fatty acid composition and glyceride structure of the butterfat. Dolby (1954) had estimated that 80% of the variation in the physical characteristics of butter was due to changes in the composition of milk fat. The remaining variation could be attributed to the method of manufacture. Table 3, shows the variation in analytical constants of milkfat both for buffalo and cow. A comparison of the important categories of butterfat in India, those of cow and buffalo was made by Doctor et al (1947). The cow butterfat had a lower R.M. value, saponification value and higher iodine value as compared to buffalo butterfat. Ramamurthy (1972) reported that in buffalo milkfat the percentage of long chain triglycerides and short chain triglycerides ranged from 51 to 57 and 43 to 49 respectively. Similarly in cow milkfats ranged from 60 to 64 and 36 to 40 respectively. Parekh (1974) reported that butter made from buffalo cream gave higher yield stress and viscosity; lower penetration and iodine value as compared to butter made from cow cream. Butter made from cow cream was judged better for its spreadability as compared to butter made from buffalo cream.

2.4.1.1 Effect of feed and season

In principal butter producing areas of Northern and Central Europe, the cows were able to feed on natural pasture only during the summer months. In the winter, they were kept indoors and fed on stored or artificial rations. The effect of this was seen in the tendency of winter butter to be firmer
and less easy to spread. The situation was reversed in areas with a mediterranean-type climate, where natural pasture became less than adequate and needed supplementing during the dry summer months. This problem had arisen in New Zealand, a country which has been traditionally producing firm butter at all times, and manifested itself in some winter butters having a tendency to be excessively firm. In countries such as Great Britain, where the climate has been temperate but with a random pattern of weather variation super imposed on the seasonal changes, there has been perhaps less of a problem.

Mugal et al (1948) showed that feeding two cows on identical rations containing cottonseed oil caused R.M. value to decrease by 30 and 17% and iodine value to increase by 27 and 42% in the milkfats. Similarly two buffaloes fed with groundnut oil showed R.M. value to decrease by 27 and 45% and iodine value increased by 28 and 45% in the ghee (butterfat). Patel and Ray (1949) reported that exclusive feeding of cottonseed with green fodder increased the refractive index and iodine value and lowered the R.M. value and polenske value significantly. Jensen et al (1962) reported the average percentage of 14:0, 16:0 and lower fatty acids 14:0 to 12:0 in both buffalo and cow milk fats were minimum in summer. On the other hand, the 18:0 and 18:1 acids exhibited maximum in summer, then declined through monsoon and were minimum in winter in both buffalo and cow milk fats.
Lowering of R.M. value and polenske value in the summer had been repeatedly recorded in various Indian studies such as those of Plyman and Aiyer (1921), Das Gupta (1939), Murthy (1955) and Kehn et al (1956). Ghee (Butterfat) of northern origin showed sharp fall of iodine value in winter compared to year round change. Sampath and Anantakrishnan (1956) observed that the iodine value fluctuation was more jerkey than the R.M. value with the peak during April-May and the trough in January-March.

2.4.2 Treatment of the cream

The rheological properties of butter are mainly dependent upon its fat system, although the gas phase also may play a role. In particular, a proper proportion of liquid fat in the free fat phase appears to be essential. If there is not enough of the embedding material to accommodate all the fat globules and crystals, as well as the moisture droplets, the butter will be hard, short, brittle and crumbly. On the other hand, an excess of liquid fat in continuous phase is undesirable too, since it causes a soft butter. The object of temperature treatment of cream before churning has been to adjust the state of crystallization so that the correct amount of liquid fat is present in the globules. With fat of high iodine value (high oil content), the crystallization before churning should be as complete as possible so that the amount of oil left free is only just sufficient to permit churning to take place, i.e. surplus oil in the finished butter should be retained in the fat globules.
With fat, of low iodine value a smaller proportion of the fat should be crystallised and the crystallization should be arranged so as to give as complete separation as possible of high and low melting fractions. The maximum amount of the oil friction is thus allowed to escape into the free fat.

Workers in Europe have claimed that it was possible by suitable control of manufacturing conditions to counteract the effect of variation in butterfat composition and thus to produce butter of uniform consistency throughout the year. They have stressed the importance for this purpose of correct temperature treatment of cream before churning. Samuelsson and Pettersson (1937) noted that cream cooled to 46°F (7.78°C) for 2 hours and then heated to 61°F (16.1°C) yielded a butter which was softer and more greasy than that from cream which had not received a preliminary deep cooling. They found that temperature treatment of cream i.e. cooling followed by reheating, was an advantage in making winter butter (fat of low iodine value and high melting point) but not with summer butter (fat of high iodine value and low melting point). Van Dam and Hovinga (1938) confirmed this observation by showing that cream ripened at 66°F (18.9°C) after holding at 46°F (7.78°C) gave a softer butter than cream ripened at the same temperature without previous holding at a lower temperature. They also found that cream held at 46°F (7.78°C) and subsequently ripened at different temperatures, the cream ripened at 54°F (12.2°C) gave firmer butter than that ripened at 66°F (18.9°C). Storgards (1938) obtained softer
butter from cream held at 57°F (13.9°C) than from cream held at 46°F (7.78°C). By centrifuging the butter granules from each churning, he was able to obtain samples of the free oil in the butter and found that the oil from the softer butter (cream held at 57°F) had the higher iodine value. Rapidly cooled fat was found by Adriani & Tamsma (1941) to contain a maximum of crystalline fat at a given temperature, while fat which had been cooled in stages contained a minimum. On the basis of these findings they recommended that summer cream should be rapidly cooled to 57°F (13.9°C) and held at this temperature, while winter cream, after cooling to 57°F (13.9°C) and holding at this temperature for 8 hours, should be warmed to 72°F (22.2°C) for 1 hour, then cooled again to 57°F (13.9°C) and held at this temperature overnight. Andersen (1949) showed by similar methods that only 30% of the fat was crystallized in cream which had been held at 61°F (16.1°C), after souring at 66°F (18.9°C). If, however, the cream was first cooled to 46°F (7.78°C), before souring at 66°F (18.9°C) and holding at 61°F (16.1°C), 49% of the fat was in the solid state. From the survey of the hardness, consistency grade and iodine value of butter, Olsson (1948) concluded that, while there was a certain correlation between iodine value of butterfat and hardness and consistency of butter, "suitable treatment of the cream could completely eliminate the impairing influence on the consistency of low or high iodine value". In a latter paper Olsson (1950) recommended that for summer butter (iodine value of fat 39-43) cream should be cooled after ripening instead of
before ripening, suitable temperatures being 70-70-43-47°F (21.1-21.1-6.11-8.33°C). He also noted that summer cream cooled to a low temperature 41-46°F (5-7.78°C) for 18-20 hours gave butter with good consistency, but in this case it was necessary for the cream to be churned fresh or for the butter to be "chemically ripened". Dolby (1954) showed that butter from cream held at 60°F (15.6°C) and churned at 45°F (7.22°C) was much softer and contained more free oil than butter from cream held and churned at 45°F (7.22°C). If the cream was precooled to 45°F (7.22°C) before being held at 60°F (15.6°C) without precooling, but the difference disappeared after storage. It contained rather less free oil, but the softening point of the oil was lower. Fat losses in churning which were high where cream was held at 60°F (15.6°C) were reduced almost to normal when cream was precooled before being held at 60°F (15.6°C). Cream slowly cooled to 45°F (7.22°C) yielded butter which was softer and contained more free oil than that from cream cooled rapidly to 45°F (7.22°C) and held at that temperature. The butter, however, was not so soft as that from cream held at 60°F (15.6°C). In the case of winter butter Samuelsson and Pettersson (1937) developed a Alnarp method of cream cooling. In this method the cream was quickly cooled to 80°C after pasteurization and was held at this temperature for 2 hours. Then it was warmed up to about 190°C using water at 250°C. After 5-7 hours at this temperature (when cream was also ripened), it was cooled to 160°C and kept until churning at the same temperature. Because of the temperature used the method was
called the 8-19-16 method. Subsequent investigation in many countries have confined the advantages of the Alnarp method when compared with delayed or slow cooling of cream after pasteurization, the 8-19-16 method caused lesser fat losses in churning (Samuelsson, 1952), gave a more stable butter texture (Mohr et al 1955) and resulted in less hardening during storage (Mohar and Von Drachenjels 1957) as well as superior spreadability. The Alnarp method also prevented the greasy appearance of butter which might result from slow cooling (Dolby 1959). A modified method for hard fat cream has been proposed by Dolby (1959) so that the cream should be processed under conditions more suitable for large scale operation such as applies in New Zealand. He suggested that the precooling time could be reduced from 1-2 hours to as short as 8 seconds, if the temperature was lowered from 6-8°C to below 4°C (Alnarp modified method). By this method most of the crystallisation was achieved in 30-60 minutes, when the cream was cooled in a vat or by a single passage through an external heat exchanger. Dixon (1967, 1969), in both pilot scale and commercial experiments, found that the advantages of the Alnarp method over slow cooling also apply for modified method. In another trial, continuing over a season, he found that with soft as well as hard fats the modified Alnarp schedule improved spreadability compared with direct cooling to churning temperature. Dixon (1970) indicated that when using the modified Alnarp method of cream treatment to improve spreadability of butter, the temperature of the cream precooling and
of the rewarming medium were not critical. 50°C was recommended as suitable for precooking temperature. For the rewarming stage the use of the regeneration was recommended as it required simpler plant and the process could be introduced with practically no extra heating or refrigeration costs. He (1971) examined the cream cooling schedule, cold washing of the butter granules and vacuum reworking of the butter for their influence on butter spreadability. He found that the benefits of the modified Alnarp Regeneration Treatment (MART) cream cooling and cold washing were additive to the churned butter but the advantage of cold washing was lost after reworking. Reworking did not reduce the superior spreading of butter from cream given MART cooling over that from direct cold cream before granules were cold-washed.

Parekh (1974) reported that Modified Alnarp cream cooling method gave less yield stress and viscosity, and more penetration value and better spreadability butter as compared to the simple cooling.

2.4.3. Mechanical treatment of the butter

2.4.3.1 Working of the butter

Other means of improving the spreadability of butter and avoiding crumbliness has been the application of vacuum either during the working or to the finished product. The vacuum working of winter butter in roller-less stainless steel churns has been widely used in Denmark. It was important to maintain proper vacuum, too high a vacuum may cause the appearance of oil drops on the butter surface. In Australia vacuum plasti-
Cizing of butter in the Abel-machine before printing has been practised (Gunnis, 1958). In trials with the Silkeborg vacuum-mixing machine, Pedersen and Fisker (1943) found that open crumbly and leaky winter butter could be considerably improved, while the quality of soft summer butter was definitely lowered. There has been a trend in the butter industry towards the reworking of the butter prior to printing. Special machinery available for this purpose include the continuous butter homogeniser, "Microfix" (Mohr, 1958) which operated at atmospheric pressure, and sigma blade batch mixers which operated either at high speeds under vacuum (Gunnis 1958), or at slower speeds under atmospheric pressure. Due to the reworking of butter the softening effects which lasted for sometime amounted to an improvement in spreadability. The regain in firmness appeared to be due to thixotropic changes in the small crystalline structure. Stone (1961) reported that much of the firmness was recovered after 10 days. Stone et al. (1962) suggested that part of the crystal structure melted from internal friction during reworking. This hardening or setting of butter after reworking could be prevented by storage at -10°C to -12°C (Kacherauskis and Motekaitis, 1964) and maximised at 55°F (12.8°C) (Mulder 1953). The pattern of hardening appeared to be similar whether the butter was fresh or reworked. Many investigators have found some permanent decrease in butter firmness with reworking. Black (1968) showed that both firmness and plasticities were improved (although in opposite directions).
by vacuum reworking and printing. He further showed that firmness and plasticity were improved by allowing butter to be well set after churning and before reworking i.e. firmness was reduced and plasticity increased. He found, using a low vacuum (10 inches), a softer butter could be obtained than having a high vacuum (25 inches), but the plasticity was reduced. Soft and hard fat butters showed equal improvement in plasticity after reworking and hard fats showed a slightly greater improvement in firmness than did soft fats. Taylor and Dolby (1970) reported that reworking of butter after storage caused a marked permanent reduction in hardness which was greater with butters which were hard rather than soft originally. Taylor et al (1971) investigated hardness of butter held for various times after manufacture at either 5°C or -10°C using a pilot scale Sigma-blade reworker. The reduction in hardness produced by reworking increased with the extent of setting before reworking. Storage of butter at -10°C for all, but a few days of the storage had no significant effect on the reduction in hardness after reworking. Parekh (1974) reported vacuum working (10 inches) of butter gave less yieldstress and viscosity, higher penetration value and was better spreadable as compared to the normal working.

2.4.3.2 Setting of the butter

Butter possesses the remarkable and consistent property of undergoing a hardening process, after completion of manufacturing, that is called setting. The influence of cream cooling methods and of churning and wash water temperatures on the
hardness of the butter have been studied extensively. Reports have been published on the extent of setting (Huebner and Thomsen, 1957, Mulder, 1939, 1950), and the influence of such factors as storage temperature (Mulder, 1939, 1945; Huebner and Thomsen, 1957), working (Prentice, 1953; Lagoni and Samhammer, 1956) and the manufacturing methods (Mulder, 1940; DeMan and Wood, 1959). DeMan and Wood (1959) showed extent of setting largely dependent on initial hardness, the harder butter displaying the greater degree of setting. However, setting was always less in continuously made butter when compared with conventional butter made in the same season. Rapid cooling of the cream resulted in a harder conventional butter with an increased extent of setting. The extent of setting could be permanently lessened by printing and the decrease was influenced by the initial butter hardness. A complete interruption of setting was effected by freezing but setting resumed its normal course on removal of the butter to higher temperature storage. Taylor and Dolby (1966) concluded that vacreation of cream affected setting rate of butter partly by a reduction in size of fat globules and partly by some other modification of globule membranes so that stability of globules was reduced and change in crystal structure of butter resulted. Dixon (1966) found that a pilot scale machine gave similar results to a commercial one and that time of reworking had no significant effect on reduction of hardness—evidently only a small amount of working was needed to break down the structure in the butter.
A comparison of the effect of storage times of 2 to 17 days and reworking temperatures of 4.5°C and 12.5°C (Dixon, 1967b) showed the greatest reduction of hardness with the longer holding time and lower working temperature. In later work (Dixon, 1970), a holding temperature of 19°C with a reworking temperature of 7°C was found to give the greatest reduction in hardness but this combination caused some inhomogeneity in the butter.

2.5 Fractionation of butterfat

This relatively new process of dividing butterfat into fractions of different melting points and the possibilities of controlling the hardness of butter has been studied in a number of countries.

Schulz et al. (1966) fractionated butteroil by cooling it in several steps from 50°C to 4.5°C and filtering off the solidified portions. Various possibilities were proposed for employing this process for different purposes such as the manufacture of butter comparatively rich in oleic and linoleic acids for dietetic applications, low melting butter for use in the production of readily wettable dried whole milk or for producing butter of increased hardness for marketing in the tropics. Dixon (1966) reported that butter can be made spreadable at low temperatures by increasing the proportion of the butterfat which is liquid at the temperatures used. It is apparent that an increase in the proportion of low-molecular-weight triglycerides as well as an increase in the Iodine number is responsible for the improved spreadability. Dolby
(1970) studied the details of chemical composition of fractions of milkfat separated by a commercial processes. He reported that butter of considerably improved spreadability at low temperatures could be produced by using a milkfat fraction of low melting point for manufacture of recombined butter. To obtain a good spreadability below 10°C, however, the softening point of milkfat must be lowered considerably and a suitable fraction would represent only a small portion of the original fat. A definite improvement in the standing-up quality of butter at high temperatures required a much small change in softening point. Jebson (1970) fractionated milkfat into high and low melting point components by Alfa Laval pilot plant using statistical cox experimental design. He reported that fractionation system provides a continuous economical method of modifying the physical properties of milkfat to make it more suitable for various purposes. Fjaervø (1970) has described continuous process for fractional crystallisation of milkfat. He stated that fractionation may be of interest in connection with the manufacture of bakery butter, of butter for tropical areas, of butter with improved spreadability, and of tailor made milkfats to suit the chocolate and ice cream industry as well as food industry in general. Norris et al (1971) reported that liquid and solid fractions obtained by a commercial process from milkfat of softening point 33.5-34°C had a softening point values 22-23°C and 36-38°C respectively. They have also reported that unsaturated and short chain fatty acids were present in increased concentration in the liquid fraction and long chain
saturated acids in the solid fraction. There was some concentra-
tion of carotene and Vitamin A and to a lesser extent cholesterol 
in the liquid fraction. Crystallization and melting curves 
determined by a differential scanning calorimeter showed that 
while the liquid fraction was melted at 25°C the solid fraction 
contained an increased proportion of fat melting between 30 and 
40°C. In addition to these the high melting triglycerides, the 
solid fraction also contained some 65% of fat in the liquid 
phase at the original crystallisation temperature of 25°C. 
Sherbon et al (1972) reported the melting properties of milkfat 
fractions obtained by double fractionation using commercial 
process. Refractionation of the solid fat obtained using the 
Alfa Laval process did not materially change the resulting 
solid fats if the fractionation temperature was kept below 28°C. 
Only a small amount of liquid phase was obtained and it had 
melting properties similar to intact milkfat. Raising the 
refractionation temperature to 31-32°C resulted in a solid 
phase that was more saturated and with a higher softening point. 
The small amount of liquid fat that resulted contained more 
high melting fats than other liquid fractions, but the general 
shape of the thermogram remained similar to intact milkfat. 
McGillivray (1972) pointed out that the fractionation of milkfat 
is a relatively simple process of holding milkfat at a certain 
temperature at which a portion would crystalline and the remain-
ing liquid is then mixed with surface active agents and can be 
separated in an oil separator. The process was initially used 
for the production of soft butters (spreadable straight from
the refrigerator), and hard butters for use in tropical areas where home refrigeration not common, or in other warmer conditions. Flavour and other desirable characteristics of milk-fat retained in both fractions. Jebson et al (1974) investigated solvent crystallisation for fractionation from the available range of food grade organic solvents, acetone and iso-propanol were selected for study. Milk fat was dissolved in the solvent (1:4 W/W) and crystallization was carried out at a specific temperature depending on the particular solvent used (e.g. 10°C for acetone). The resultant filtrate was then allowed to crystallize at a lower temperature (e.g. -15°C for acetone). The milkfat fraction recovered from the filtrate of the lower temperature crystallization was blended with the precipitate from the upper temperature crystallization in the ratio 3:1 (W/W). A butter made from this blend proved to have the required spreadability in the temperature range of 5 to 20°C. Dixon and Black (1974) tried to manufacture a butter of controlled firmness by using fractionated milkfat. They have observed that low melting fat of lower softening point was necessary. Kankare and Antila (1974) reported that the spreadability of butter at a low temperature could be improved by adding the liquid milkfat fraction L_{12} to milk fat.

2.3 Modification of butterfat

2.3.1 Polyunsaturated fatty acids

An interesting alternative to the modification of the composition of milkfat has been the development in Australia
of polyunsaturated dairy products through feeding to cows. Suitable polyunsaturated vegetable fats in a coating protects them from hydrogenation in the rumen, fat which permits normal digestion in the abomasum and intestines. The idea was developed originally with a view to produce polyunsaturated butter and other dairy products and it has been possible to produce milkfat containing up to 30% polyunsaturated fatty acids. The development of methods for the production of ruminant meats and milk, the fat of which contains high levels of linoleic acid (18:2) has been described by Scott et al. (1970). This supplement was first produced by formaldehyde treatment of spray dried casein-vegetable oil emulsions. A considerable cheaper supplement has since been produced by drying an emulsion of oilseeds and casein treated with formaldehyde. Dairy products and milk produced by cows fed these protected lipids are known as "Alta" products. Buchanan et al. (1970) showed that "Alta" butter could be produced from "Alta" cream by modification of normal churning technique. "Alta" butter had lower softening points, higher iodine values and higher linoleic acid than conventional butter. Buchanan and Rogers (1973) produced butter from "Alta" cream with suitable modification of conventional churning techniques. The churning and working times were decreased and draining of the buttermilk was much more difficult than with conventional cream. The churning time could be increased slightly by lowering the churning temperature and by using cream with a low fat content. They also found that there were no serious problems in producing...
"Alta" butter in a continuous phase inversion process from salted or unsalted 80% fat cream. Kieseker et al (1974) tried for commercial scale manufacture of dairy products from milk containing high levels of linoleic acid.

2.6.2 Interesterification

This treatment, carried out under relatively milk conditions at a temperature of about 50°C, results in a randomisation of fatty acid residues in the glyceride molecules. In directed intersterification the reaction is carried out at a lower temperature where part of the fat is crystallised and the interchange of fatty acid residues occurs only in those glycerides that are in the liquid state. According to the Weihe and Greenbank random interesterification and directed interesterification decrease the penetration value, i.e. increase the hardness at 10°C, 15°C and 20°C, at 15°C. The melting point of the butterfat was raised from 34.0°C to 43.0°C. Mickle (1960) changed the molecular structure of milk fat as a means of improving the spreadability of butter. He carried out an interesterification reaction in which directly exchange of fatty acids between glyceride molecule on fresh sweet cream butter at 45°C for 30 minutes in the presence of 0.5% sodium methoxide was done. DeMan (1961) showed that a considerable hardness of intersterified butterfat resulted in a marked increased hardness and the proposals to make use of this process to produce more spreadable, i.e. softer, butter was apparently
based on a misconception. Kacherguskis, D. (1966) reported experiments on the inter-esterification of milkfat using varying amounts of sodium ethoxide as a catalyst as a means of changing the physical and mechanical properties of milkfat for specific purposes.

2.6.3 Isomerisation

An approximately one-third of the fatty acids in butterfat could be oleic acid, the steric configuration around the double bond should influence the hardness of the fat. It has been found that a considerable proportion of the unsaturated fatty acids in milkfat occur in the high-melting transform, probably as a result of hydrogenation in the rumen (DeMan, 1961).

2.6.4 Hydrogenation

Catalytic hydrogenation of a fat transforms unsaturated fatty acid residues into saturated ones by the addition of hydrogen to the double bond. Complete hydrogenation of butterfat yields a waxy product with a melting point of over 50°C. The effect of addition of some hydrogenated to unmodified butterfat was studied by deMan (1961). It might possibly be useful when added in small quantities to influence crystallisation behaviour by supplying a large number of crystal centres, thus counteracting the tendency toward mixed crystal formation.

2.6.5 Use of surface active agents

Recently, attempts have been made to improve the spreadability of butter and decrease its hardness by addition of certain substances, particularly surface active ones (Kapsalis
et al., 1963). Among the effective additives were lecithin, Myverol 18-71, Span 80, Tween 40 and Atmos 300, applied either along or in combination (in concentrations on the fat basis from 0.25% to 3.0%). Buttermilk solids and skimmilk solids were also effective. The spreadability was improved by 10 to 44% and the hardness decreased by 3 to 31% (as estimated after 2 days at 13°C). However, on storage of the butter the beneficial effects diminished. There were also difficulties with the incorporation of additives into butter and off-flavours appeared at concentrations above 1%.

According to Nabar et al. (1969), additive Tween-80 was found to reduce the oiling off although both Tween-80 and Gelatin were found to increase the hardness value.

2.7 Low calorie Butter and Spread

An interesting trend has been the development of a spreadable product called "half butter" containing approximately 40% milkfat. It could be produced either by incorporating water and milk protein into butter which enables binding as well as improving flavour and nutritional characteristics, or by using cream as the starting product. This "butter" may be constituted by the water-in-fat emulsion when butter is used for fat-in-water emulsion when cream is used. A process for the manufacture of a dairy product with 25-40% fat reported from Australia (Hall Sandford and Co. Pvt. Ltd., 1970) involved mixing a fruit-containing product (cream) with dried milk, adding an emulsifier and stabilizer, pasteurising and homogenizing the mixture, and
then cooling. The product which was claimed to be spreadable at room temperature contained about 25-40% fat and 10-15% solid-not-fat. Another method patented in the United Kingdom (Eldridge and Linteris, 1970) for the preparation of flavoured spreads thoroughly mixed a fat, as in melted butter, with a liquid fruit preserve preparation which consisted of Strawberry juice concentrate, sugar, pectin etc. and allowed it to gel. The product had a jam-like consistency, very good flavour and satisfactory storage life. The production of a reduced fat dairy spread, involving the emulsification of reconstituted calcium reduced dried skim milk into butter at a temperature of 70°C (21.1°C) has been reported from Canada by Bullock et al. (1971). The machinery used in the production included a scraped surface cooler plant and recirculation of a part (about 44%) of the product during manufacture necessary to achieve a good dispersion of the serum in the butter. A low calorie butter was patented in Switzerland (Sozzi, 1971) using streptococcus diacetilactis culture. The process included pasteurisation of normal cream, concentration by resereparation to about 60% fat, heating to 90°C and finally the addition of suitable mixture of skimmilk and streptococcus diacetilactic culture to reduce pH to about 5.4 and lowering of the fat content to approximately 50%. The product contained about 2% protein and 48% moisture. A flavoured sweetened butter had been patented in Soviet Union by Protsenko et al. (1972). The process involved the production of high fat cream (about 82% fat) by the resereparation technique, and the addition of
buttermilk which has been evaporated to a solid level of 48% and more, a sweetening agent (e.g. sucrose) and a flavouring such as cocoa and vanillin. The mixture was then made into butter. The ingredients were suitably chosen to give a product with 50-52% butterfat and 10% or more milk solid-not-fat, the moisture content was 22-25%. According to reports a "Gourmet" butter with 20% moisture and 78% fat has been available in the Soviet Union for sometime and a variant with 25% moisture was introduced on a large scale. A procedure developed in Czechoslovakia permitted the manufacture of a low calorie butter (about 30% less than normal butter, Forman Matouskova, 1973), which was claimed to have the properties of ordinary butter and was made without the use of emulsifiers or preservatives. The process developed by the Dairy Research Institute in Prague, involves churning cream which has been partially ripened to a titrable acidity of about 11°SH in a Czechoslovak continuous buttermaking machine of the KM type. The desired high moisture content of 40% was achieved either directly by appropriate adjustment of the machine or by the addition of extra water. The butter which contained 56% fat, 4% solid-not-fat and 40% moisture, had a pronounced taste and aroma and kept the "ripened cream" flavour for about a month when stored at a temperature of 60°C. Voss (1973) reported that in order to guarantee good binding effects, spreadability and stability of products with a butter like structure, approximately 6% milk proteins may be added. Foreman et al (1974) studied
the manufacture of butter of a reduced calorific value (with reduced fat contents and increased moisture) and they found two commercial processes for the manufacture of butter with 35 to 55% moisture. Demoor et al (1974) investigated oil-in-water and water-in-oil emulsion type of butter, the latter yielded with better keeping quality and adequate spreadability.

2.8 Dry Butter

As name implies, this product is a concentrate containing a very high proportion of butterfat and very little moisture. In large scale experiments carried out in Germany, 17 tons of 80% cream and cold stored butter were spray dried to concentrates containing less than 0.1% moisture, with about 2.1% and 1.3% SNF respectively. In organoleptic tests the product from the cream was awarded higher scores, the butter was comparatively easy to spread and could be applied directly on to bread. The product from the cream kept satisfactorily in tins for 24 months at 7-15°C. Among uses mentioned for these concentrates are spreading on toast or bread, tossing vegetables, frying preparation of sauces and making cakes and pastry in the household and catering industry. In addition the product could be made into butter by emulsification with water. The dry butter could also be used for processing into other products i.e. ice cream, concentrated milk, processed cheese for fat fractionation in the manufacture of dietetic dairy products and in the baking industry.
The manufacture of powder containing 80% butterfat originated in Australia (Hansen 1963). Such a product has advantages in transport, storage and blending. He prepared spray dried butter powder with addition of citrate, emulsifiers, sodium caseinate and silicates. Its final composition was 82% milkfat, 3.5% glycerol monostearate, 6.7% milk solid-not-fat, 6.7% sodium caseinate citrate mixture, 0.5% Sodium Aluminium silicate and 0.6% moisture. Schulz and Voss (1966) mentioned that dried butter may be rehydrated and processed into butter which gave the product having the flavour and consistency typical of butter made from ripened cream. Schulz et al (1966) had developed a dry butter with good spreadability. The product was made either from butter or from 80% fat fresh cream. The melted butter, or reseparated cream was heated to 80°C and dried in a Niro spray drier with a reduced volume of air and entry temperature of about 120°C. The water evaporated instantly, while the liquid butter, containing less than 0.1% moisture, flows down the walls of the drying chamber and was then cooled in a special Alfa tubular cooler, first to approximately 30°C and then to 5°C. The product was then held for 15 minutes in order to harden it, before it was worked or homogenized in a Microfix. Butter packed in tins kept significantly better than that packed in cartons during storage. The keeping quality for the product made from concentrated cream, remained satisfactory after storage in tins for upto 24 months at 7°C or
15°C; whereas the product made from butter kept less than 12 months. At 30°C, samples kept for up to 6 months but developed a 'burnt' flavour after short period of storage. Heiber (1966) reported that dry butter manufactured by the above method kept satisfactorily in tins for 3 years at 8°C and could subsequently be made into butter, whipping cream or coffee cream. Studies on the manufacture of a spray dried butter with special reference to the loss of volatile fatty acids during drying has been reported by Boudreau et al (1966). These trials involved the manufacture of a spray dried butter with fat content of approximately 80%; 50 lb batches of butter were heated and volatile fatty acids were added individually to different batches in quantities calculated to represent 10% lipolysis. A solution of 10 lb dried skim milk in 20 lb water was then added to the butter, and the resultant mixture was homogenized and spray dried. The recoveries of added fatty acids in powders spray dried at a nozzle pressure of 2500 psi ranged from 25.8% for C₄ chain acids to 77.0% for C₁₂ chain acids. Fatty acid retention was improved by spray drying at a nozzle pressure of 500 psi. Tripp et al (1966) studied preparation of high milkfat powders and the relationship of processing variables to physical stability. They produced spray dried 80% milkfat powder without the aid of protein stabilizing treatments (pH adjustment and salt addition), or powder cooling devices. They reported that homogenisation treatment or the substitution of certain carbohydrate materials
for milk solids-not-fat improved physical stability. Show et al (1957) described the improvements in powder removal from the drier and fluidized bed cooler. The two stage cooling reduced the tendency of the powder to cake in the bags on standing. He also reported the results of experiments on the effect of manufacturing conditions on baking performance. Good results in a test recipe were obtained with oil based powders prepared from emulsions which were homogenised at medium pressure and spray dried hot at 60% total solids. Further improvements were obtained by increasing the emulsifier content from 1.5% to 3%. The baking performance of the cream powders was not as good as that of the oil powders, but was improved when the protein content of the powder was reduced from 8% to 5%. Both types of powders gave optimum results in a commercial cake mix containing additional emulsifier. Damerow and Kohl (1971) reported that cream of about 84% butterfat is produced by centrifugation and the remaining water is evaporated in special units with simultaneous phase reversal from fat-in-water emulsion to water-in-fat emulsion. The product which contained less than 0.1% moisture was cooled in special equipment with concurrent production of a suitable structure and was packaged, nitrogen could be injected to improve the consistency. The concentrate could be used as the basic material for the production of butter as well as in the manufacture of other milk products such as fresh cheeses, Yoghurt, milk and cream. The buttermaking stages comprised of mixing the molten concentrate with water and dried skimmilk,
pasteurization, conversion into butter, in the same cooling equipment as used in the concentrate manufacture and packaging.