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Recent Advances in the Manufacture and Use of Butterfat or Ghee

By

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Introduction : Butterfat has always been highly valued as a food and much attention has been given to its conservation. The common methods of preserving it have been by the production of and storage of butter, or of the fat from which the other milk constituents have been removed. The problems of preservation of butter or butterfat for any great period of time are mainly related to spontaneous chemical reactions with the oxygen of the atmosphere and to enzymic spoilage and bacterial growth.

Dry butterfat in a variety of forms has long been an article of commerce. Butteroil or milk oil are the terms applied in the United States to the milk fat which remains after the curd and water have been removed from butter. Various other terms are in common use in other countries, — Australia, dehydrated butter (this term is not strictly correct, as dehydration implies only the removal of water); England, clarified butter ; Egypt, samna or masli ; France, beurre fondu ; Germany, Butter schmelz, floss Butter, geschmolzene Butter, Kuhschmelz, Rind schmelz : India, ghee ; Iran, Roghan ; and Switzerland, eingesottene Butter.

The manufacture of butter-oil is not new to the dairy industry of India or of the world. The pioneers in the manufacture and preservation of milk oil were the Hindus. For more than 1,000 years they purified butter and preserved it in stone jars for the anointing of idols and for use as a medicine (1). This form of preservation of butterfat is a necessity in tropical countries where the temperature is too high for the use of butter. In United States of America over three decades ago butter-oil was made commercially for the use of baking, ice cream and candy industries. But, competition among the manufacturers resulted in the use of low grade butter as a source of butter-oil, and the inferior quality of the product soon ruined the demand for butter-oil in these industries. However, this product was produced in large quantities during the periods of World war I and World war II for the use of armed forces in tropical countries. The manufacture of dehydrated butter in Australia and New Zealand originated early in 1641 because it offered a ready solution to the problem of utilisation of surplus whey and second grade butter, which under war conditions could not be marketed ocally or shipped overseas (2).

The development of the process of manufacture of butter-oil in foreign countries increased the supply of butterfat available to overseas consumers without appreciably decreasing its nutritional properties. Butteroil as compared to butter occupies less shipping space and weight and can be transported in unrefrigerated space without deterioration. The production of butter-oil also prevents the accumulation in cold storage of a product that would deteriorate in long distance transport and make stores available for other products. It has enabled the dairy companies to continue the separation of butterfat from whey, thereby avoiding drainage difficulties and continuous return of apporximately O. 75 $ per lb. for all butter delivered to companies in Australia. The apporximate saving to Australia in the season 1941–'42 was over £ 30,000 (3). The annual production of butter-oil in India amounts to 409,368 tons (4), and we are the largest producers of this food product in the world.

Manufacture: Numerous methods are available for the preparation of butterfat in small or large scale, either from cream or from butter, but they may be divided broadly into 4 main groups, (i) open pan evaporation method, (ii) separation from cream, (iii) vacuum pan drying of the butterfat and (iv) centrifugal separation of butter-oil from the melted fat.

(i) *Open pan Evaporation Method.* This process consists in melting the butter in a shallow pan and boiling it with continuous stirring for a considerable period of time over a free flame. The water is boiled off briskly at first and then more gradually. A scum of solid material forming on the top of the fat is skimmed off carefully from time to time. When all the water has been evaporated the temperature of the fat rises above 100°C and the curd chars to a brown colour. The butter has then been sufficiently boiled and is allowed to cool somewhat while the curd particles settle. The fat layer is carefully removed into suitable vessels as free from solid particles as possible and allowed to cool and crystallise. The hot butteroil may or may not be filtered through muslin into the containers. The method varies in minor details from place to place. In some places the butter is heated till the temperature goes up to 116 or 120°C.

This process of boiling down butter in an open atmosphere on an appreciable scale is relatively a very slow process since careful control is needed to prevent excessive frothing, even if very shallow pans are used. Through the butterfat prepared by this process has a very good keeping quality it acquires a cooked taste or a strong toffee flavour. However, even today this process is commonly used in India and other subtropical countries (5), because of the fact that the economic conditions and small holdings prevent them from using elaborate machinery on a reasonably profitable scale.

Besides boiling down butter as a whole, various modifications have been in use for preparation of butter-oil. Julien (6) melted butter on a water bath at 40°C till the serum containing the solids not fat got settled at the bottom. The liquid fat was separated by gravity and stored for a long period of time. The fat can be remade into butter by adding 20 to 30% of sweet or pasteurised milk and emulsifying under pressure. Since complete removal of water by melting and gravity separation is impossible, the butter-oil obtained by the preliminary gravity separation at a temperature of 60°C is heated to 106°C to remove the last trance of moisture (4). But this product would not be suitable for reconstitution as butter or milk because of the high heat treatment. A method of preserving the butter that will keep for at least one year is described in the International Review of Science and Practical Agriculture (8). Butter was heated at 40° or 45°C, the fat was separated and when still warm, salt was added and the product filtered and stored in a brown bottle. A method of reproducing butter from the stored butterfat is also described.

(ii) *Separation from Cream :* Backhaus & Schach (9) melted butter and mixed skim milk in an emulsor and separated the final product centrifugally. The resulting cream was made into butter. The Milk Oil Corporation (10) produced normal butterfat devoid of taste and odour by separating the cream from whole milk, diluting with water and passing through the separator. The resulting cream was whipped, diluted with water (4 volumes) and agitated with heating till the oil was isolated. The resulting product was passed through a whey separator and through an oil separator to produce a dry oil. French (11) isolated butterfat from cream using several washings with water and re-separation to break the emulsion. These procedures will be obviously slow and expensive for large-scale production. Further, it would involve heavy loss of fat in diluted skimmed serum. Subsequently French (12) proposed a method of souring the cream for 20 hours and boiling down the cream directly without difficulty. Other investigators (7, 9) have shown that the use of once washed cream (dilution with water and re-separation) and ripened cream shortens the time of cooking and increases the out-turn of ghee, thereby reducing the loss of fat in ghee residue. This procedure eliminates the intermediary step of making butter from cream. However, this product would not be suitable for reconstitution.

(iii) *Vacuum pan drying of Butterfat :* This procedure of removal of moisture from melted fat under vacuum speeds up evaporation, but is is difficult to remove the last traces of moisture. Further, the treatment is to be carried out in batches and would involve keeping fat hot for a considerable length of time, which might hamper the keeping quality of the butterfat. Though some patents have been taken on this procedure, it does not seem to have been commercially used to any extent.

(iv) *Centrifugal Separation of Melted Butterfat:* The use of specia type of centrifugal separators as a tool for the separation of butterfat has helped the dairy industry a great deal in recent years. Alexander (13) described a process of separating butter-oil from cream, and butter by subjecting them to a temperature corresponding to low steam pressure sufficient to dissolve the casein, and then separating the fat centrifugally. North (14) in the year 1924 took a number of patents on the preparation of butter-oil from cream, on the heat treatment of cream, washing and separation of curd matter and on the final dehydration of butterfat. Quite a number of other patents (15–22) were also issued in these years. The modern methods of making butter-oil may be classified under the following heads: (1) New Zealand method, (2) Australian method and (3) American method.

1. New Zealand Method for the Manufacture of Butteroil from Butter: For continuous large-scale production of butterfat the use of centrifugal separation is preferable to attempts to separate fat directly from cream or by the use of vacuum pan. McDowall *et al* (23) evolved a process of manufacture of butterfat, wherein (i) the fat was kept hot for the minimum length of time and (ii) the process was continuous so that the work of dealing with the incoming butter and the filling into containers go forward without interruption. Though the procedure is elaborate it serves as a typical procedure for the preparation of butteroil on a large scale and an outline of the working of the plant installed at Kings Wharf, Auckland, is of great use for a clear understanding of the steps involved in the manufacture of butteroil. The butter from 56 lb. prints was extruded from the bulk-butter packer into a closed stainless steel melter-cylinder (4 feet long and 23 inch diameter having a capacity of 3 tons of butter per hour, tilted at an angle of 10° to facilitate the flow of fat) into which steam was injected, the cylinder being provided with a safety-valve to blow off at 0·75 lb. pressure. The melted butter was drawn into a jacketed melter-vat of capacity about 50 gallons. The fat-water mixture from the melter-vat was pumped up to the top into a battery of separating cylinders which has two perforated plates one of which acts as a filter. This cylinder was just a large version of an ordinary laboratory separating funnel. A certain amount of gravity separation of the serum takes place in this cylinder. The serum was run off into a serum tank of about 130 gallon capacity. The fatty portion from the separating cylinder was passed through a first series of two 920M De Laval direct drive model separators with milk top discs at 140°F and then to a steel pasteuriser (Burnard Pasteuriser modified by Murray Deodorisers Ltd.,). The pasteuriser raised the temperature of the butterfat, improved the degree of separation and acted as a pump to lift the fat for delivery into the second series of separators. The fat from these separators was discharged at an equaliser hopper tray into the floating tank. This was necessary because the flow of the dehydrator was much more than that of a single unit series of separators.

The nearly dry fat was run down the steam-jacketed walls of a vacuum pan where it was finally dried at a vacuum of 29" and at a temperature of 190—200°F. of the fat. This high temperature of evaporation was necessary because, water is soluble in hot fat and its removal necessitates a high temperature. The dry fat was then passed through a specially built rotary cooler to the filler line. Filling was done by automatically controlled drip-proof valves to within a few oz. of the correct weight. The weights were then adjusted and the tins (of four gallon capacity) hermetically sealed and stored at 45°F for crystallisation prior to export.

The serum from the separating cylinders and from the first and second series of separators was reseparated twice before being discarded, the recovered fat being retreated by the above process. The maximum hourly rate of one unit plant was 1·75 tons of butterfat and the daily production was 1002 cases or equivalent to the treatment of 42 tons of butter.

The fat loss in the process of manufacture ranged from 0·9 to 1·3 %. The labour cost for a one unit plant was 2 pies per lb. of butterfat. The total cost of treatment including packaging which was the major item was 1·5 as. per lb. of butterfat. A two-unit plant installed at King's Wharf, working for 120 hours per week has a capacity of 12,500 tons of butter or 10,000 tons of butterfat per annum.

Whey butter was found more easy to handle than creamery butter. The authors advise the use of 4% NaOH to creamery butter to adjust the pH of the serum to 8·5. The bowls of the separator require cleaning once in 8 hours if salted butter is used and 17 hours if neutralised unsalted butter is used. The final product contained moisture 0·02 to 0·04% and acidity 0·1 to 0·33%. They found no loss of vitamin A during the processing. The vitamin D content of the butterfat was increased from 20 to 60 i. u., per oz. by the addition of calciferol dissolved in butterfat at the rate of 1/1300 gm. per tin of 38 lb. capacity. This was added by means of a plunger pump at 110°F. The authors are of opinion that the efficient use of the separating cylinders is the key to the successful high speed drying of the butterfat due to (i) oiling off of emulsion, (ii) removal of the serum diminishes the load of the separators and (iii) less frequent sludging of the separator bowl.

As early as 1922 the Glaxo Manufacturing Company prepared considerable amounts of dehydrated butterfat by melting butter and separating in cream separators followed by treatment in Sharples Clarifier and in 1924 the New Zealand Co-operative Dairy Company used a similar procedure. The production was discontinued because of the poor local demand.

2. **Australian method of the manufacture of butteroil from butter.** A method suitable for Australian conditions of preparing butterfat was developed by Loftus Hills (24) at Longwarry. Based on this work a large commercial plant was installed at Brisbane by the Queensland Butter Board and soon after another one at Sydney by the Producer's Co-operative Distributive Society Ltd. Butter cubes (56 lb.) were melted in half ton lots by direct exposure to steam and then passed by gravity to three stainless steel 250 gallon neutralising vats fitted with agitators where it was neutralised with NaOH to pH 10 in the serum. The melted butter was then pumped to three Titan self-desludging separators. The serum was run through a cream separator to recover small quantities of fat. The fat from the centrifuges was drawn by vacuum into the first dehydrator (a large size modified Vacreator) having a vertical stainless cylinder 22" diameter and 4 feet high. A vacuum of 29" was maintained, the butterfat was sprayed in at the top, the moisture content reduced to below 0·2% and the temperature kept below 160°F. The dried butterfat was pumped to a Sharples centrifuge used as a clarifier where traces of salt and curd are removed. The butteroil was then drawn into the second dehydrator similar to the first and the moisture content reduced to less than 0·05%. The second dehydrator was used as deaerator at a high temperature. The fat was then passed through the tubular cooler using water as cooling media, filled in tins, head-space displaced with nitrogen and then sealed.

The differences of this process as compared to the New Zealand procedure are that (i) the melting of the butter in an open chamber by direct steam causes dilution of butter by about 17% and (ii) the serum was adjusted to pH 10 instead of pH 8·5.

3. American method for the manufacture of butteroil. Wilster (43) suggested a method of production of butterfat using either cream or butter as starting material. Cream was separated at 120°F by using a specially constructed centrifugal separator to give a high fat product having 90 to 95% fat. This was re-separated to yield an oil containing 1·0 % moisture and passed through a Vacreator at 195°F under partial vacuum, to steam distillation, and to partial cooling in a chamber kept at nearly complete-vacuum. This treatment removes all traces of moisture and improves the keeping quality. The time of vacreation was only 3 seconds. The moisture free oil was solidified in a Votator (Vogt Freezer) constructed like a continuous ice cream freezer and stored in tin containers.

The butteroil was also prepared from butter by diluting with warm water, neutralising the free fatty acids and passing through the separators as mentioned above for cream.

Uses of Butteroil : The idea of separating the major constituents of milk and subsequent dehydration of the same with a view to conserve them and reconstitution of the ingredients to milk and other dairy products made great progress in the industry during recent years. Butter-oil properly prepared is a delicately flavoured product that can be used in as many ways as butter is used. It can be used in liquid form in cooking or baking or even as a liquid spread. Pure butter-oil and skim milk powder constitute all the nutrients found in butter and they could be shipped without refrigeration to tropical climates, held for an year or so if desired, and then made into good butter with the aid of little cold water (25).

(a) *Making reconstituted butter :* To produce butter with normal butter characteristics, particularly from body and texture standpoints, it would be necessary to make reconstituted cream and then churn it. Of course, such a method would necessitate an emulsor and churning equipment. Secondly, crystallisation of butter-fat in water could be effected in a mixing equipment containing the liquid oil, skim milk powder, salt and water and then the granules could be worked after crystallisation. Thirdly, skim milk can be added to the butter-oil and the solidification of the butter-oil can be effected by cooling and agitation. It is obvious that there would be pronounced differences between the better prepared from the butter-oil allowed to crystallise without agitation or whon crystallised by dropping into cold water and then solidified as described above (26). The smooth and much more spreadable butter can be obtained only if the emulsion is stirred through the solidification procoss. If this is not done the resultant butter would be short-grained and sandy. A. number of patents have also been granted in this field (27–33).

(b) *Making concentrated hardened butter :* Wiley & Coombes (44) made a successful attempt to produce "tropical spread" which would keep in good condition without refrigeration in tropical climate. This had a compositiion 1 % salt, 2 % skim milk powder, 77 % dry butter-fat and 20 % hydrogenated butter-fat. Later, hydrogenated groundnut oil with iodine value below 2 was substituted for hydrogenated butter-fat. The method

used is as follows. The dry butter-fat was pumped to jacketed stainless steel vacuum mixing vats (34' diameter and 4' high with a capacity 100(lb) fitted with propeller-type agitators and maintained at 140°F. To this 4% skim milk powder, 2% finely ground salt which had been treated with anhydrous sodium carbonate, 3% hydrogenated groundnut oil and 0. 2 p. p. m., of diacetyl are added, vacuum applied with vigorous agitation. The mixture was then passed through a deaerator at 29" vacuum and pumped to a cooler consisting of a stainless steel drum 20" diameter and 4' long fitted with scrapers, which rotates in a jacketed stainless steel cylinder. The fat wat passed through the space between the drum and the cylinder. The temperature of mixing was reduced rapidly from 140°F to 78°F at the rate of 40 lb. per min. Rate of cooling and agitation are important in determining the texture of the finished product. The mixture was super-cooled and directed to an automatic filling machine (made by D. W. Bsngham & Co., Proprietary Ltd., Melbourne), and worked at a rate of 40 one-pound tins per min. The cans are vacuum sealed. About 11,000,000 lb. of this product was supplied to Allied Forces in the South-west Pacific area during 1945.

(c) *Making reconstituted milk.* (i) *Early attempts:* The making of cream (34) out of melted butter and liquid skim milk with the use of a homogeniser became universal among all milk and ice-cream dealers in America in the beginning of 1906. The cream they produced would not whip, when added to coffee, would rise in the form of a foam, and the milk would not form the natural cream line. In 1912, instead of an homogeniser an emulsor was used for reconstitution. In this case the fat from the reconstituted milk would rise to the top of the bottle forming a hard layer or cake. Thus, the early attempts to produce satisfactory reconstituted milk from dried milk (skim) and butter were failures due to the fact that the dried skim milk produced in those years was only cooler dried (185-200°). Subsequently, attempts to produce reconstituted milk with the use of spray-dried skim milk was a success.

The character of the finished product depends on the quality of the raw materials used. The butter produced in those years varied enormously in their composition and condition. A milkfat of highest quality and uniformity required control at the source of production complete dehydration and packaging under hermetically sealed condition. To achieve this end, the Milk Oil Corporation concentrated their attention during the years 1918 to 1928, when more than 38 patents were granted to them over foreign countries and America. In 1923 the health authorities found that all milk dealers were using homogenisers in making cream out of butter for ice-cream and sometimes were making cream and milk to make up for occasional shortages. To prevent this, the health authorities prohibited the installation of any type of homogeniser or emulsor in any milk plant except with special permit. Homogenisers were allowed only for ice-cream manufacturers.

However, the discovery by physicians and health authorities in 1939 that homogenised milk had great merit for medicinal purposes restored the use of homogenisers in milk plants.

(ii) *Recent attempts:* In brief, the preparation of reconstituted milk (35) consists of heating and mixing together butter-oil, dried skim milk (spray process) and water in the same proportion as found in normal fresh milk. After heating and holding at pasteurisation temperature (143°F for 30 min.) the mixture is pumped through a homogeniser at 2500 lb. pressure to effect uniform combination of the ingredients. After homogenising, the product is pumped over a tubular cooler. Apart from a cooked flavour, the reconstituted milk compares favourably with fresh milk provided proper ingredients are used. Various other methods for the reconstitution of milk have been proposed (36–42).

As high quality butter-oil and dried milk (skim) properly packaged have an extremely good keeping quality at warm temperatures and for long periods, these ingredients can be used advantageously for reconstituted milk, provided the necessary mixing, pasteurising, homogenising, steam and refrigeration facilities and cooling equipment are available.

The installation of equipments for the large-scale manufacture of butter-oil in some of the main ghee producing centres in India offers great opportunities. Butter which is poor in quality because of high free fatty acids content (a common defect in India) or protein decomposition, or any other physical defect can be used satisfactorily for the production of a fairly good quality butter-oil (45). Butter which is poor in quality because of tallowiness, metallic flavours or excessive oiliness cannot be reprocessed into a butter-oil of satisfactory quality. The butter-oil produced by the large-scale process could be stored for over 9 months without development of oxidised flavour (and for a longer period with certain anti oxidants, particularly those containing catechol nuclei) and suitable for reconstitution in times of need. The reconstituted milk prepared from materials that are comparable in quality and storage conditions are more satisfactory than reconstituted dry whole milk (45).

Summary: The methods of manufacture, properties and uses of butter-oil are discussed.

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