Ghee: Its Chemistry, Processing and Technology

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Introduction

In India, preservation of milk and milk products is primarily achieved by heat induced desiccation. Ghee is obtained by clarification of milk fat at high temperature. Ghee is almost anhydrous milk fat and there is no similar product in other countries. It is by far the most ubiquitous indigenous milk product and is prominent in the hierarchy of Indian dietary. Being a rich source of energy, fat soluble vitamins and essential fatty acids, and due to long shelf life at room temperature (20 to 40C), 80% of ghee produced is used for culinary purposes. The remaining 20% is used for confectionery, including small amounts consumed on auspicious occasions like religious ceremonies (22).

Since buffalo milk constitutes more than 55% of the total milk production in India and because of its higher fat content (6-7%), ghee is manufactured mostly from buffalo milk. Due to lack of carotenoids in buffalo milk, ghee prepared from milk is white unlike cow ghee which has a golden yellow color. Because of its pleasing flavor and aroma, ghee has always had a supreme status as an indigenous product in India.

Physicochemical Characteristics

Chemically, ghee is a complex lipid of glycerides (usually mixed), free fatty acids, phospholipids, sterols, sterol esters, fat soluble vitamins, carbonyls, hydrocarbons, carotenoids (only in ghee derived from cow milk), small amounts of charred casein and traces of calcium, phosphorus, iron, etc. It contains not more than .3% moisture. Glycerides constitute about 98% of the total material. Of the remaining constitutents of about 2%, sterols (mostly cholesterol) occur to the extent of about .5%.

Ghee has a melting range of 28 to 44 C. Its butyrofractometer reading is from 40 to 45 at 40 C. The saponification number is not less than 220. Ghee is not highly unsaturated, as is evident from its iodine number of from 26 to 38. The Reichert-Meissl number (RM) of cow ghee varies from 26 to 29 whereas goat ghee is slightly less. Sheep and buffalo ghee on the other hand, have higher RM numbers of about 32. In general, ghee is required to have a RM number of not less than 28. It is, however, of interest that ghee from milk of animals fed cotton seeds has much lower RM numbers of about 20. Polenske number for cow ghee is higher (2 to 3) than buffalo ghee (1 to 1.5). No significant seasonal variations have, however, been recorded for their fat constants.

The fatty acid profile of glycerides of ghee is very complex and still not completely elucidated. Recently, Ramamurthy and Narayanan (13) published the fatty acid composition of buffalo and cow ghee.

Layer formation is typical in ghee if stored above 20 C. The chemical properties of these layers are significantly different as shown by Singhal et al (20) (Table 1). Significant differences are evident in the RM numbers of these layers. The liquid layer always has a higher RM number than the semisolid layers.

Preparation

Ghee making in India is mostly a home industry. Substantial amounts come from villages where it is usually prepared by the desi method. Recently, industry has manufactured improved ghee of more uniform quality. However, it still constitutes only a small fraction (a few thousand tons only) of the total annual production (450,000 metric tons) in India.

In general, ghee is prepared by four methods, namely, desi, creamery butter, direct cream and pre-stratification methods. The essential steps involved in the preparation of ghee by these methods are outlined in Figures 1 to 4 (6, 15). Basically, the high heat applied to butter or cream removes moisture. Both are usually clarified at 110 to 120 C. However, in southern India clarification is at 120 to 140 C.

The desi method consists of churning curdled whole milk (dahi) with an indigenous corrugated wooden beater, separating the butter, and clarifying it into ghee by direct open pan heating. Earthenware vessels are used to boil milk and ferment it with a typical culture to convert it to dahi which in turn is churned to separate the butter. The creamery butter and direct cream methods are more suitable

Received for publication July 1, 1972.

TABLE 1. Chemical constants of ghee layers.

Ghee sample		Analytical constants			
Number	Layer[a]	Reichert-Meissl number	Polenske number	Iodine number	Saponification number
1	a	40.3	1.7	39.2	240.1
	b	31.6	1.3	30.9	231.0
	c	30.9	1.2	28.7	230.6
	a	35.7	1.4	35.1	236.1
2	b	28.1	1.2	28.9	234.2
	c	..	..	..	..
	a	35.6	1.5	36.6	235.1
3	b	29.6	1.3	29.7	233.7
	c	24.4	1.2	24.2	225.0
	a	31.8	2.0	37.7	237.4
4	b	26.4	1.7	30.3	234.0
	c	20.1	1.5	26.7	228.4
	a	35.6	1.3	36.3	234.9
5	b	27.6	1.1	29.1	232.6
	c	22.3	1.0	26.0	227.1

[a] a. Liquid oily portion. b. Granular settled portion. c. Hard flake floating on top or sticking to sides.

for commercial operations because less fat is lost. Direct cream method is reportedly most economical for preparing ghee and the product has better keeping quality (9). In the pre-stratification method, advantages such as economy in fuel consumption and production of ghee with low acidity and comparatively longer shelf life, have been claimed (17). However, this method has not been adopted by industry.

Desi method accounts for more than 97% of ghee manufactured. However, with industrial interest, the creamery butter and direct cream methods are increasing. The relative

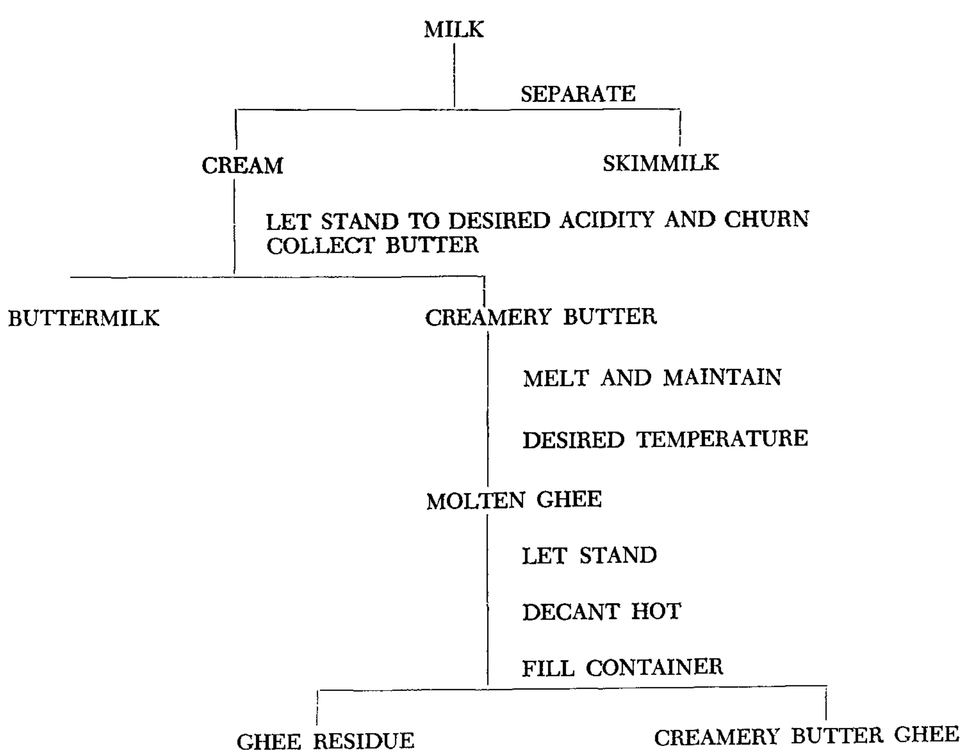

FIG. 1. Preparation of creamery butter ghee.

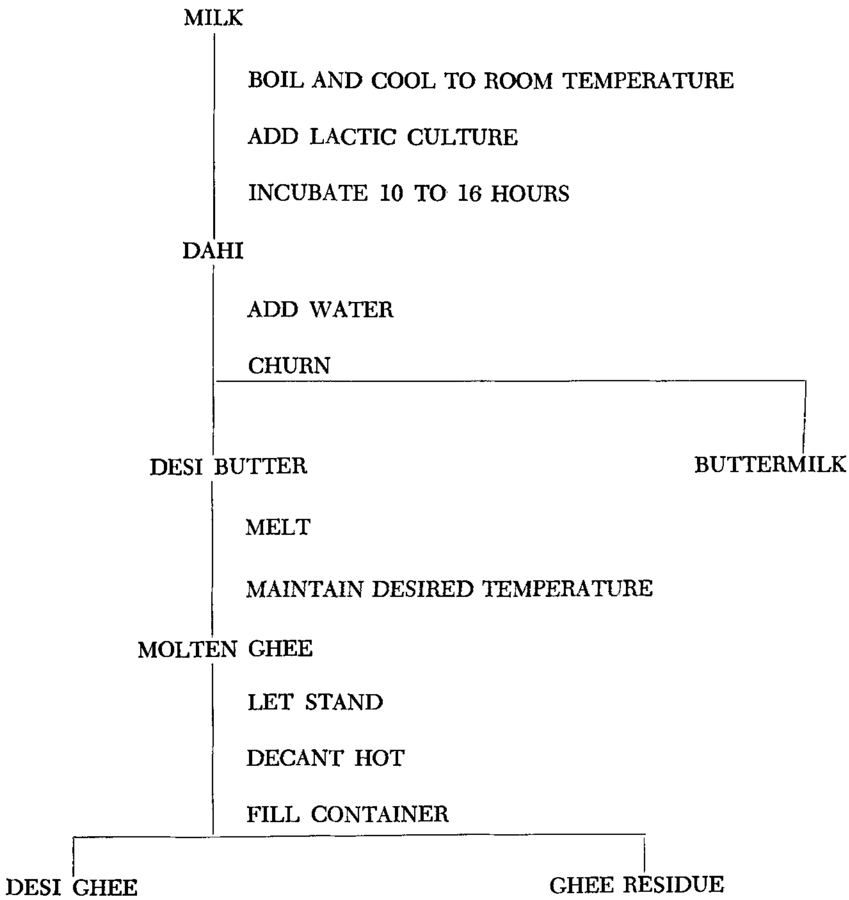

FIG. 2. Preparation of desi ghee.

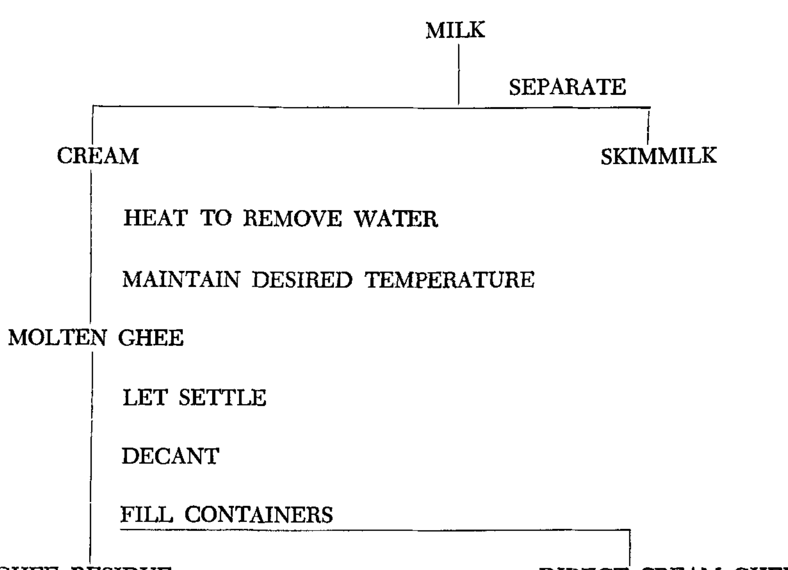

FIG. 3. Preparation of direct cream ghee.

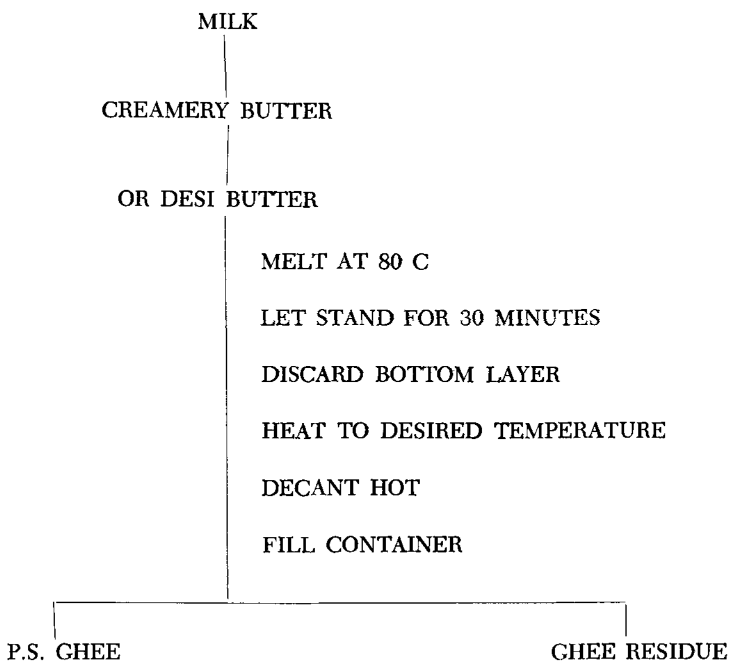

FIG. 4. Preparation of ghee by pre-statification.

merits of these methods have been discussed by Srinivasan and Anantakrishnan (22) and are summarized in Table 2.

Recently, continuous ghee making equipment has been fabricated at the National Dairy Research Institute at Karnal (11). The equipment is a three-stage pressurized, swept surface separator. This mechanical process is more sanitary than existing methods.

Quality of Ghee

The quality of ghee depends on milk, cream, dahi or butter, methods of preparation, temperature of clarification, storage conditions, and type of animal feed.

These factors in turn will determine the physicochemical characteristics of ghee. The principal measurements of ghee quality are: peroxide value, acidity, and flavor.

Peroxide value and acidity. The quality of ghee on storage has been measured by acid and peroxide values (10). However, peroxide value varies considerably at the organoleptic threshold of rancidity. More recently, Gaba and Jain (7) showed that the thiobarbituric acid value (TBA value) is a more reliable in-

TABLE 2. Relative merits of different methods of making ghee.

Method	Adaptability	Flavor and texture	Keeping quality	Vitamin content	Economics of production
Desi method	Rural home industry	Characteristic maximum flavor attractive body and texture	Poor	Almost absent	Does not involve additional cost
Creamery butter method	Large scale milk industry	Flat flavor, Ripened cream, better flavor	Good	Much more than Desi ghee	Requires special labor and costly equipment
Direct cream method	Large scale milk industry	Flat flavor, Ripened cream, better flavor	Excellent	Maximum	Same as creamery butter method

dex of oxidative rancidity of ghee. They found that the TBA value of buffalo ghee was always higher than that of cow ghee.

Flavor. The most important factor controlling the intensity of flavor in ghee is the temperature of clarification (6). Ghee prepared at 120 C or above has an intense flavor which is usually referred to as cooked or burnt. In contrast, ghee prepared at around 110 C has a somewhat mild flavor, often referred to as curdy. The desi method generally produces ghee with the most desirable flavor.

The acidity of the cream or butter affects the flavor of ghee. Sweet cream-butter yields ghee with a flat flavor whereas cream or butter having an acidity of .15 to .25% (lactic acid) as in ripened cream-butter, produces ghee with a more acceptable flavor. However, the rate of deterioration in the market quality of ghee is least in ghee from unripened cream-butter and most in that prepared from ripened cream-butter.

The flavor of stored ghee is influenced by the method of preparation and by temperature of clarification. In ghee made at 110 C, the original flavor is maintained for several months, but once deterioration begins, market quality is lost quicker than in ghee prepared at the higher temperatures of clarification. Flavor in ghee is retained longer when butter contains 1% NaCl.

Elucidation of complex chemical entities responsible for ghee flavor is being pursued at this Institute (2) and sponsored by U.S. Public Law 480 funds. Some of the important findings to date are reported.

There is a general similarity in the gross patterns of volatile carbonyls isolated from differently produced ghee. Of the 11 carbonyls in most of the ghee produced, six have been tentatively identified as propanone, butanone-2, pentanone-2, heptanone-2, octanone-2 and nonanone-2. Small but significant differences in the quality and quantity of volatile carbonyls in different types of ghee have been reported.

The use of ripened cream butter in the preparation of ghee improves the flavor, but the impact on the pattern of carbonylic compounds in ghee appears to be less marked.

About 95% of the carbonyls in ghee are nonvolatile. Cow ghee contains more volatile carbonyls. The total carbonyls of buffalo ghee is higher than that of cow ghee irrespective of the method of preparation and temperature of clarification.

The ketoglycerides constitute 50 to 60% of the total carbonyls in ghee, buffalo ghee (4.4 μmoles/g) having a higher proportion than cow ghee (2.4 μmoles/g).

Oct-2-enal and dec-2-enal are the main alk-2-enals in the volatile as well as monocarbonyls in ghee. The patterns of alkanals from cow and buffalo ghee are similar and consist of ethanal, pentanal, hexanal, heptanal, octanal, nonanal, decanal, undecanal and dodecanal.

Changes on Storage

Ghee undergoes physicochemical changes, dependent primarily on the temperature of storage. Crystallization occurs with the formation of solid, semi-solid and liquid layers. Ghee (cow and buffalo) kept either in a metal or glass container at 20 C or below, solidifies uniformly with fine crystal (3). Above 20 C and below 30 C, solidification is a loose structure. The liquid portion had a significantly higher RM number than the granular solid or hard flaky portion of the same ghee. A similar trend in the iodine number in these layers also occurs. Detailed investigation on layer formation by Singhal et al (18) suggested that it would be preferable to store ghee below 20 C to avoid layer formation. Ghee stored at high temperature is also susceptible to oxidative deterioration, rancidity, and off flavor. Due to inadequate storage facilities in India, much ghee loses its market acceptability.

Shelf life of ghee is also dependent on the method of preparation. The keeping quality of desi ghee is better than that of direct cream or creamery butter ghee. Ramamurthy et al. (14) claim that milk phospholipids in ghee improves its shelf life. Ghee having more residue, which is a source of phospholipids, has a longer storage life.

Packaging and Marketing

Packing of ghee is permitted ordinarily in 17, 4, 2 and 1 kg tinned cans (1). Excepting 17 kg cans, others must contain the net weight of ghee, e.g. 4, 2, or 1 kg. Permission is also given to pack ghee in 1 kg and half kg returnable glass bottles. Special permission of the Agricultural Marketing (Agmark) Adviser to the Government of India is necessary for packing in any other size package.

Most ghee is marketed in 4-gallon tin containers. Cans are filled to brim with no air space to improve storage quality. Antioxidants like butyl hydroxyl anisole (BHA) are permitted to prolong shelf life. The agencies engaged in India in ghee assembling and distribution are producers, village merchants, itinerant traders, cooperative societies, state dairies, retailers, and some private and public dairy enterprises.

Ghee Grading and Standards

The grading of ghee in India is in general done by Agmark Adviser to the Government of India under provisions of Agricultural Produce (Grading and Marketing) Act of 1937. All ghee graded by Agmark has to be pure and prepared from only cow and buffalo milk. Regional specifications also exist in such grading due to variation in compositional properties of ghee influenced by the type of animal feed (1).

The International Dairy Federation (IDF) has recently drafted a standard for ghee whereby it is defined as a product exclusively obtained from milk, cream, or butter from various animal species, by processes which result in almost the total removal of moisture and solids-not-fat. It must consist of a mixture of higher melting point fats in liquid form. It should contain not more than .3% moisture. Milk fat (mostly glycerides) constitutes 99.5% of the total solids. This IDF standard is being examined for its final acceptance.

Cotton Tract Ghee

During certain seasons large quantities of cotton-seeds are fed to lactating animals in cotton growing areas (Saurashtra and Madhya Pradesh). The composition of ghee prepared from the milk of such animals differs significantly from that from milks of animals fed on a concentrate mixture of oilcakes, grains, bran, etc. Dastur (5) proposed a special standard for ghee from such areas and it is often referred to as cotton tract ghee. The RM number requirement for cotton tract ghee is lower (eg. 20) than that for ghee from other areas.

Ghee Adulteration and its Detection

It is a common practice to adulterate ghee with cheaper vegetable and animal body fats. Hydrogenated vegetable fats, popularly known as vanaspati ghee in this country, have often been used to adulterate ghee. However, the legal requirement that all vanaspati ghee marketed in this country must contain a specified amount of sesame oil which can be easily detected by Bauduin test[1]. Bomer's[2] phytosterol acetate test based on the structural differences between phytosterols (e.g. sitosterol) and animal sterols (e.g. cholesterol) has also been occasionally used. More recently, Ramamurthy et al (12) reported a thin layer chromatographic method for detecting ghee adulteration with vegetable oils and fats.

Detection of animal body fats in ghee is more difficult. An opacity method based on differential melting point ranges for common animal body fats (43 to 50 C) and ghee (30 to 44 C) has been developed by Singhal et al (20). It is claimed to detect 5% animal body fats in ghee. However, this test is useless for cotton tract ghee which has a melting point near that of animal body fats. The methylene blue reduction test developed by these authors (19), overcame this difficulty because only cotton tract ghee decolorizes methylene blue.

Butteroil Versus Ghee

The main differences between ghee and butteroil have been recently summarized by Ganguli (8). Butteroil has a bland flavor whereas ghee has a pleasing flavor. Ghee has less moisture, contains more protein solids and differs in fatty acid and phospholipid as compared to butteroil. Butteroil is prepared by melting butter at not exceeding 80 C, whereas ghee is manufactured at 100 to 140 C. Butteroil can be reconstituted with skimmilk powder whereas ghee cannot be.

Conclusion

The ghee industry, though large, is still a home industry in India. Increasing demand of this milk product requires overhauling all production and marketing practices. Development of continuous ghee making equipment is urgently needed so that hygienically prepared ghee with uniform quality can be made available at an economical price.

Acknowledgment

The authors are indebted to Dr. D. Sun-

[1] This test is used for the detection of adulteration of ghee with vanaspati ghee (which contains 5% sesame oil). Five grams of fat are mixed with 5 ml of concentrated HCl and 7 to 8 drops of 2% furfural solution in ethanol (95%). Mixture on shaking develops red color if vegetable ghee is present.

[2] This test is also performed for the detection of vegetable ghee. Vegetable ghee contains phytosterol unlike animal fat which has cholesterol. The acetate derivative of phytosterol has a higher melting point than the cholesterol derivative. Hence, ghee adulterated with vegetable ghee will have an increased melting point of the steryl acetates (125 to 140 C) compared to ghee (114 to 115 C).

daresan, Director, National Dairy Research Institute, Karnal, for his interest in the preparation of this manuscript. Thanks are also due to Dr. B. H. Webb, USDA, Washington, D.C. for his suggestion to write this article. We express our appreciation to Dr. E. O. Herreid, editor-in-chief, Journal of Dairy Science, for inviting one of us (NCG) to write this paper.

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