Paper 7: Technology of Milk and Milk Products

Module no. 10: Technology of Ghee making – Direct cream, Creamery butter, Continuous method

Introduction

The word ghee is evolved from Sanskrit word óghrutô. Ghee is a common Indian name for clarified butter fat. The word itself stems from the old Sanskrit óghrô which means bright or to make bright.

FSSAI specifications for ghee

According to Food Safety and Standards Authority of India (FSSAI) ghee means the pure clarified fat derived solely from milk or curd or from desi (cooking) butter or from cream to which no colouring matter or preservative has been added. The standards of quality of ghee produced in a State or Union Territory in India is as shown in Table 1A and 1B. Ghee may contain butylated hydroxyl anisole (BHA) at concentration not exceeding 0.02%. Baudouin test should be negative. Positive test indicates presence of dalda (hydrogenated vegetable fat) as an adulterant in ghee.

Table 1A. FSSAI specifications for ghee

State or Union Territory#	Particulars of ghee			
	Moisture (%), Max.	FFA (% oleic acid), Max.	B.R. reading at 40°C	R.M. value, Min.
Delhi	0.5	3.0	40.0-43.0	28.0
Jammu and Kashmir	0.5	3.0	40.0-43.0	26.0
Gujarat: Non-cotton tract	0.5	3.0	40.0-43.5	24.0
Gujarat: Cotton tract	0.5	3.0	41.5-45.0	21.0
Kerala	0.5	3.0	40.0-43.0	26.0
Andhra Pradesh	0.5	3.0	40.0-43.0	24.0
Uttar Pradesh	0.5	3.0	40.0-43.0	26.0
Dadra and Nagar Haveli	0.5	3.0	40.0-43.0	24.0
Daman and Diu	0.5	3.0	40.0-43.5	24.0

Few states and Union Territory quoted; FFA ï Free fatty acids, BR ï Butyro-refractometer reading, RM ï Reichert Meissl.

Table 1B. Microbiological specifications for ghee as per FSSAI

Type of count	Permissible limit
Total plate count, Max. cfu/g	5000
Coliform count	Absent in 1 g
Yeast and mold count	Absent in 1 g

Anaerobic spore count	Absent in 1 g
E. coli	Absent in 1 g
Staph. aureus	Absent in 1 g
Salmonella	Absent in 25 g
Shigella	Absent in 25 g
Listeria monocytogenes	Absent in 1 g

Agmark certification of ghee

In India, ghee is marketed from organized dairies under Agmark certification, wherein there are three grades based on the Free Fatty Acids (FFA) contents: Special (Max. 1.4% FFA), General (Max. 2.5% FFA) and Standard (Max. 3.0% FFA) (Table 2). Irrespective of the grade of ghee, the BR reading and Polenske value should lie between 40.0-43.0 and 1.0-2.0 respectively. The Reichert Meissl (RM) value should be minimum 28.0, whereas the moisture content should not exceed 0.3%. Baudouin test should be negative.

General characteristics: Ghee shall be pure, clarified milk fat only and shall have a natural, sweet pleasant odour, agreeable taste and free from rancid or other objectionable flavor. On melting, ghee shall be clear, transparent and free from sediment or foreign colouring matter. The phenolphthalein test, the phytosterol acetate test and test for presence of nonmilk animal fats shall be negative. The physico-chemical constants of ghee shall be characteristic of the type of milk (cow, buffalo or their admixture) from which it is produced and of the season of the year and the place or district where it is produced.

Colour: White with or without yellowish or greenish tint, and shall be uniform throughout.

Texture (below fats melting point): The solid phase should be of well defined granular structure. Marking provisions: The grade designation mark (i.e. special, standard, general) in the form of label shall be securely affixed to each sealed container of ghee. The grade designation mark in the form of replica shall be clearly an indelibly printed or embossed on such containers as permitted by the Agricultural Marketing Adviser.

Table 2. Grade designation of ghee as per AGMARK

Grade designation	Color of lettering showing the grade	Color of the circular border of the label
Special	Red	Red
General	Green	Green
Standard	Chocolate	Chocolate

In addition to the grade designation mark, each container shall be clearly marked with the following particulars namely:

(i) Name of the packer, (ii) C.A. Number, (iii) Place of packing, (iv) Melt number, (v) Date of Packing, and (vi) Net weight of ghee.

Methods of preparation

Ghee can be made by any of the following techniques:

(i) Indigenous method (via Makkhan)
(ii) Direct cream heating method
(iii) Creamery butter method ï with or without pre-stratification and
(iv) Continuous method.

The creamery butter (CB) and direct cream (DC) method are more suitable for commercial operations, since less fat is lost. DC method gives longer shelf life to ghee compared to CB method. Pre-stratification method is advantageous with regard to economy in fuel consumption and preparation of ghee with lower acidity.

In principle, ghee making involves three distinct operations:
i) Concentration of milk fat
ii) Heat clarification of fat rich milk portion
iii) Removal of residue from the pure heat clarified fat

During the moisture removal process by heat, ghee acquires its characteristic flavor and the SNF content is converted to denatured brown ghee residue. Clarification by heat is done either on an open fire or in a steam-jacketed hemispherical kettle. During initial heating of butter, extensive frothing takes place, which must be controlled to avoid losses associated with boil-over. As the moisture evaporates and frothing subsides, caramelization of curd particles is noticeable. At this stage frothing completely subsides and emission of moisture bubble also ceases. Heating is discontinued as soon as curd particles attains desired golden yellow or brown colour. The residue is allowed to settle and clarified fat is decanted. The ghee residue can be separated by (a) decantation, (b) cloth or pressure filtration, or (c) centrifugal clarification techniques.

Indigenous method: Makkhan (traditional unsalted butter made by hand churning of whole milk dahi at room temperature) is placed in a steam jacketed vessel (ghee boiler) and heated to about 110-120^oC with constant stirring to evaporate practically all of the moisture. Next, the ghee residue is separated from ghee by filtration and the ghee packaged in suitable containers (tin cans, pouches).

Direct cream heating method: Cream is taken in a ghee boiler and heating is continued till temperature of about 110-120^oC is attained. This is followed by removal of ghee residue by stack filters, pressure filters and centrifugal separators. The ghee, now freed of ghee residue is allowed to cool to 40-42^{o}C and then packaged in individual packages. Clarification temperature is kept higher at about 120-140^{o}C in southern India.

This method of ghee-making from medium fat cream (~40%) yields a higher quantity of ghee residue and consumes more fuel and takes longer time. To avoid such problems, a high-fat cream (60-75% fat) may be used; cream may be washed with warm water to reduce the content of SNF, which will yield less ghee residue, enabling higher fat recovery in ghee.

Creamery butter method: Unsalted creamery butter (white butter) may initially be melted in a butter-melter, followed by pumping into a ghee boiler. In the ghee boiler, the moisture in butter is evaporated with constant stirring to reach a temperature somewhere between 110-120^{o}C. Other steps followed are the same as mentioned in the previous method.

Creamery butter with pre-stratification: A modification to the above method involves heating the melted butter to ~80^{o}C followed by quiescent storage at that temperature in a pre-stratification tank for several hours. Based on density difference, the scum, fat and serum gets separated in different strata in the same tank. The lower-most serum portion is allowed to drain out through an outlet at the bottom of the tank, by which about 74% of the water present in white butter is removed. Less water remains to be evaporated in the ghee-boiler, thereby economizing on the fuel. Thereafter, the mixture of scum, fat and curd is pumped to the ghee boiler for removal of the remaining moisture, wherein the colour and flavour of ghee is developed at 110-120^{o}C. Rest of the steps remains the same as discussed previously for creamery butter method.

Table 3. Comparison of ghee made by various methods

Ghee making method	Adaptability	Flavour and texture	Keeping quality	Fat recovery in ghee (%)
Desi method	Rural home industry	Characteristic fermented flavor, good body and texture	Poor	78.0
Creamery butter method	Large commercial scale	Flat flavor, ripened cream improves flavour	Good	92.0
Direct cream method	Large commercial scale	Flat flavor, ripened cream improves flavour	Excellent	88.0

Continuous ghee making

In a continuous method developed by National Dairy Development Board (NDDB), Anand, Gujarat, the concentration of fat and breaking of oil-in-water emulsion is done mechanically with the help of centrifugal forces in the clarifixator and concentrator and use of heat is limited to the development of flavour and removal of last traces of moisture. The crude oil coming from the fat concentrator goes to SSHE and then to vapour separator, filter/clarifier and then to the ghee cooler (see powerpoint). A continuous process developed by National Dairy Research Institute (NDRI), karnal consists of receiving-cum-heating vat for cream/white butter, gravity separator (not used when cream is the feed material), scraped surface heat exchanger (SSHE), coupled with vapour separators and positive displacement pumps to move the raw material through the different units. Final heating takes place at about 110-115°C in SSHE as is the case in batch method of ghee making. The NDRI equipment is a 3-stage pressurized, swept-surface separator. The design of such machine is sanitary.

Some plants in India are already utilizing this principle (Mother dairy, Gandhinagar, Gujarat; Panchamrut Dairy, Godhra, Gujarat; Nestle, Moga, Punjab, etc.) in producing ghee. The principle involved is concentration of fat in cream along with de-emulsification of fat (through use of clarifixator or centrifixator), followed by serum separation and finally heating the oil (95-99% fat) in a SSHE in order to develop the desirable cooked and caramelized flavour. Such continuous production preserves the fat soluble vitamins better than in conventional method of ghee manufacture.

Quality of ghee

The quality of ghee obtained is dependent on the following factors:

- Type of animal feed
- Use of raw material ï makkhan, cream, white butter
- Method of preparation
- Clarification temperature adopted
- Storage conditions of ghee

The ghee has a unique pleasing flavor and a granular texture (when solid).

Color of ghee: Cow milk fat has a dense yellow colour due to presence of carotenoids (ɓ-carotene), while that from buffalo milk is white, with a characteristic yellowish or greenish tinge. On souring of milk, the biliverdin pigment is dissociated and undergoes a rapid chemical reduction to a fat-soluble yellow pigment, bilirubin IX alpha. This pigment binds milk lipids and imparts the characteristic greenish-yellow appearance to ghee prepared by the traditional method (desi method).

Flavour of ghee: It has a pleasant cooked and rich flavour. The taste is usually characteristic of milk fat; slightly acidic flavour is sometimes preferred. The ódesiô ghee prepared from ó*makkhan*ô, contains many of the aromatic compounds formed during the fermentation of dahi and its subsequent fractionation into ó*makkhan*ô. These impart a distinctive characteristic flavor. Use of ripened cream butter helps in improving the flavor of resultant ghee.

Much of the typical flavor of ghee is due to very complex mixture of compounds including carbonyls, lactones, FFA, and esters generated during processing. The typical flavor of burnt nonfat milk solids combined with some component derived from oxidation of the milk fat is also involved. Lactones, which have a coconut-like flavor, seem important for the characteristic flavor of ghee. The levels of these are increased by increasing temperature during the production, and are often twice as high in ghee as in butter.

Of the eleven carbonyls in most ghee produced, six have been identified as propanone, butanone-2, pentanone-2, heptanone-2, octanone-2 and nonanone-2. About 95% of carbonyls in ghee are non-volatile. Cow ghee contains more volatile carbonyls than buffalo ghee. The total carbonyl of buffalo ghee is higher than that of cow ghee, irrespective of the method of preparation and the clarification temperature adopted.

Most of the flavor components are concentrated in very low melting point fat fractions.

Granulation of ghee

Ghee should have a soft and granular texture, with a large proportion of crystalline fat suspended in sufficient liquid fat, so the product can be poured at room temperature. Such a texture could be promoted by slow cooling under constant stirring, but textural changes might occur during storage depending on the temperature. On cooling of ghee, there is development of fat crystals which leads to granulation in ghee. Sometimes, seeding with previously granulated ghee can induce good grain formation in ghee.

The partly granular form of ghee appears to be primarily due to presence of high melting triglycerides (HMT). On storage at 29^{o}C, granulation was found to be complete in three days, for both cow and buffalo ghee. The grain size on 3rd day for cow and buffalo ghee was 108 and 420 µm respectively. Commercial ghee having poor granularity had a lower level of saturated fatty acids, while those with bigger grains had a higher level of palmitic acid (> 35%).

The texture of ghee is better due to the bigger grain size, which, in turn, may be due to the higher proportions (9.0ï 12.0%) of HMT compared to only 5.0% in cowøs milk fat.

Physico-chemical characteristics of ghee

Chemical characteristics

Chemically, ghee is a complex lipid of glycerides (usually mixed), free fatty acids, phospholipids, sterols, sterol esters, fat soluble vitamins, carbonyls, hydrocarbons, carotenoids (in cow ghee only), small amount of charred casein and traces of calcium, phosphorus, iron, etc. Glycerides constitute 98% of the total material. Of the remaining constituents (i.e. 2%), sterols (mostly cholesterol) occur to the extent of about 0.5%. The phospholipid content of buffalo milk, butter and ghee per unit weight of fat is much lower than in cow milk fat. Winter ghee and the solid fraction obtained at 29°C are rich in phospholipids. On heating ghee (milk fat), thermal oxidation of cholesterol occurs, resulting in a lowered cholesterol level.

Phospholipid content of ghee: Ghee prepared from butter by heating at 120°C contains trace amount (10 mg/100g ghee) of phospholipids; increasing the period of heating increases the phospholipid content of ghee. Maximum transfer of phospholipid (i.e. 132 mg/100 g ghee) amounting to 57.7% of total phospholipids took place at 40 minutes of heating. These phospholipids serve as antioxidant in ghee, especially in moisture-free conditions; it exerts synergistic antioxidant function with α-tocopherols.

Physical characteristics

Ghee has a melting range of 28 to 44°C. Its Butyro-refractometer (BR) reading is 40 to 45 at 40°C. The saponification number is not less than 220. The iodine value varies from 26 to 38 (i.e. less of unsaturation). The Reichert Meissl (RM) value of cow ghee varies from 26 to 26, while that of buffalo ghee is about 32. However, ghee made from milk of animals fed cottonseed has much lower RM value (i.e. 20). The Polenske value (PV) of cow ghee (2.0-3.0) is higher than for buffalo ghee (1.0-1.5). The physico-chemical characteristics of ghee have been shown in Table 4 and Table 5.

Table 4. Physico-chemical characteristics of cow and buffalo ghee

Ghee method	Moisture (%)		B.R. values		Liquid portion (%)		Grain size (μm)	
	Cow	Buffalo	Cow	Buffalo	Cow	Buffalo	Cow	Buffalo
Control	0.24	0.21	42.48	41.56	64.1	33.4	223.0	291.3
CBM	0.26	0.22	42.40	41.58	65.0	39.0	241.6	323.0
RCM	0.24	0.21	42.29	41.43	56.6	55.9	162.1	239.1
UCM	0.23	0.23	42.14	41.44	59.2	52.1	173.3	243.3

Control ï from fresh milk, CBM ï ghee from continuously made butter, RCM ï ghee from ripened cream, UCM ï ghee from unripened cream
Source: Changade *et al.* (2006)

Table 5. Physico-chemical characteristics of cow ghee

Physico-chemical parameters	Value
Specific gravity (g/cc)	0.939
Melting range (°C)	37.2-37.4
Acid value (number of mg of KOH required to neutralize the free acids in 1.0 g of substance)	0.374
Iodine value	16.44
Saponification value	224.5
Solidification temperature (°C)	21.0-22.2
Unsaponifiable matter (%)	0.923

Anisidine value	10.14
Peroxide value	8.1

Melting point: Cow ghee has lower melting point than buffalo ghee; the melting point of cow and buffalo ghee ranges from 32.7-35.8°C and 33.4-38.8°C respectively.

Reichert Meissl value: The RM value of cow ghee is usually lower than that of buffalo ghee.

Polenske value: The PV of cow ghee ranged from 1.02 to 2.00, while that of buffalo ghee ranged from 0.35 to 1.85.

Saponification value: The SV of cow and buffalo ghee was reported to be 234.12 and 236.60 respectively.

Iodine value: The iodine value of cow and buffalo ghee ranged from 27.4 to 40.5, averaging 34.4.

Ghee residue and fat loss in ghee making

The total fat loss incurred in ghee making and the yield and phospholipids content of ghee residue are furnished in Table 6. On an average, the particle diameter of ghee residue is ~ 115 μ and density is 1.14 g/cm^3.

Table 6. Some particulars of ghee and ghee residue obtained using different methods.

Method of ghee making	Ghee residue		Total fat loss (%)
	Yield(%)	Phospholipid(%)	
Desi ghee	4.3	-	17.0
Direct cream	12.0	0.86-1.48	12.0
Creamery butter	3.7	2.78-7.89	8.5

Uses of ghee

Ghee is primarily used for cooking and frying and as dressing or toppings for various foods. It is used in the manufacture of snacks and sweets often mixed with vegetables, cereals, fruits, and nuts. Its main advantage over butter, from which it is traditionally prepared is its superior keeping quality derived from the almost complete removal of water during its preparation. Ghee is considered as a sacred product and is used in religious rites. Ghee is used in Ayurveda, which is a system of traditional medicine developed in India.

Packaging of ghee

Ghee is normally packed in metal cans and containers of various sizes internally lined with a nontoxic lacquer. Cardboard boxes with an inner liner of plastic foil are also used. Usually lacquered tins or cans and Polyvinyl Chloride (PVC) containers are ideal to prevent permeability, oxidation, rancidity and tempering. Introduction of anti-oxidants and inert gases such as nitrogen injected into the container before packaging to create an air-tight lid may prevent air induced oxidation and may therefore improve the ghee quality.

Detect adulteration of ghee

The adulterants used by unscrupulous traders include hydrogenated vegetable oils, mineral oils, waxes, vegetable oils and even cheap animal fats (tallow, suet, lard, etc.). Baudouin test which is specifically useful to detect dalda (hydrogenated vegetable fat) as an adulterant is already included in FSSAI specifications. Some of the recent findings recommend use of Holdeôs test for mineral oils (adulterated sample shows turbidity on saponification of ghee), Thin Layer Chromatography (TLC) for detection of adulteration with vanaspati or groundnut oil (formation of several bands on TLC plate in adulterated sample), use of certain ratios of specific fatty acids (C_{16}/C_{18}) in milk fat.

Shelf life of ghee and its extension

Ghee normally has a shelf life of 6ï 8 months at ambient temperature, but considerably longer storage stability has been experienced probably because of the anti-oxidative effect created during processing. However, ghee eventually deteriorates during storage; the limiting factor is normally the development of oxidized flavor.

Keeping quality of ghee is governed by factors such as the ripening of cream, method of manufacture, clarification temperature, and permeability of packaging materials to air and moisture, and type of animal feed.

The oxidative stability of buffalo ghee is poor compared to cow ghee because the amounts of tocopherol and phospholipids present are low in the former fat. Some of the promising natural source antioxidants are Mango seed kernel (MSK) or extracted phenolic constituents from MSK, aonla juice, dried berries of *Crataegus oxyacantha*, lecithin, tocopherol and so on.

Advances in ghee making

Microwave technology was found suitable in the production of ghee from high fat cream (72% fat) or cooking butter (80% fat) using microwave energy (2450 mHz, high H-setting of 700 W) for 26-27 minutes. The yield (52.7%), and scores for color and appearance as well as flavour were significantly greater for ghee made from buffalo cream compared to the one made from cow cream using microwave method; such parameters were also superior for ghee made by microwave method compared to óDirect cream (DC) heatingô method. However, the body and texture score was of ghee prepared by DC method was superior over that made using microwave method, irrespective of the type of cream (cow or buffalo) used. The flavour score of ghee was higher for the one prepared from cultured cream (*L. diacetylactis* or mixed culture of *S. lactis* and *L. diacetylactis* (1:1)) than from uncultured cream.

Recent studies have revealed the anticancerous and other healthful aspects exerted by conjugated linoleic acid (CLA) content, among other constituents of ghee. Conjugated linoleic acid (CLA) is a mixture of positional and geometric isomers of linoleic acid (c-9, c-12 $C_{18:2}$ octadecadienoic acid) with two conjugated unsaturated double bonds at various carbon positions. CLA are primarily in positions 9 and 11, and 10 and 12 along the carbon chain.

There has been some headway in removal of cholesterol from animal fats to produce ócholesterol-freeô dairy products including ghee. Some of the techniques so far used includes: steam stripping, ß-cyclodextrin method, Super-critical CO_2 method and biological methods (use of enzyme such as cholesterol reductase).