Chapter 10

FATS AND OILS

Fat is present naturally in many foods. This fat is often referred to as invisible fat. Examples of foods containing appreciable quantities of invisible fat include meat, poultry, fish, dairy products, eggs, nuts and seeds. Visible fats are made from these products. They are lard, cooking oils, salad oils, margarine and butter.

Fats play a variety of roles in both food preparation and nutrition.

In common usage, fats that have a relatively high melting point and are solid at room temperature are called fats, whereas those that have lower melting points and are liquid at room temperature are called oils.

Classification of fatty acids and occurrence is given in Table 10.1.

Table 10.1: The important natural fatty acids and their occurrence

Fatty acids		*Occurrence*
Saturated acids		
Short chain		
Butyric acid	$C_4 : 0$	Butter
Caproic acid	$C_6 : 0$	Butter, coconut oil
Caprylic acid	$C_8 : 0$	Butter, coconut oil
Medium chain		
Capric acid	$C_{10} : 0$	Butter, coconut oil
Lauric acid	$C_{12} : 0$	Butter, coconut oil
Myristic acid	$C_{14} : 0$	Butter, vegetable foods
Long chain		
Palmitic acid	$C_{16} : 0$	Most vegetable and animal fats.
Stearic acid	$C_{18} : 0$	Most vegetable and animal fats.
Arachidic acid	$C_{20} : 0$	Butter, lard, peanut oil
Behenic acid	$C_{22} : 0$	Vegetable oils
Monounsaturated acids		
Palmitoleic acid	$C_{16} : 1$	Olive oil, fish oil, beef fat
Oleic acid	$C_{18} : 1$	Olive oil, Canola oil
Erucic acid	$C_{22} : 1$	Rape seed oil, Canola oil
Polyunsaturated acids		
Linoleic acid	$C_{18} : 2$ (n–6)	Vegetable seed oils (Safflower, corn, soyabean, cotton seed)
Linolenic acid	$C_{18} : 3$ (n–3)	Vegetable seed oils (Soyabean oil)
Arachidonic acid	$C_{20} : 4$ (n–6)	Fat and phosphate fractions of animal tissues particularly liver, lard, meat
Eicosapentaenoic acid	(20:5) (n–3)	Fish oils and
Docosahexaenoic acid	(22:6) (n–3)	Shell fish

NUTRITIONAL IMPORTANCE

- They are concentrated source of energy. Weight for weight, they furnish 2.25 times more energy than proteins and carbohydrates. All oils and fats except butter give 900 kilocalories per hundred grams.
- They reduce bulk in the diet.
- They are excellent source of fat soluble vitamins A, D, E and K. Consumption is low because it is expensive. Butter contains 15,000 I.U. of vitamin A. Refined vegetable oil and hydrogenated shortenings contain little or no vitamin A but vegetable oils are good source of vitamin E.
- They play a part in the biosynthesis of several long chain fatty acids.
- They provide essential fatty acids, which are components of membranes of living cells.
- They are also used by the body to make prostaglandins involved in large variety of vital physiological functions. Fish is an excellent source of eicosapentaenoic acid (EPA) from which the body can make a hormone-like compound called a prostaglandin. This particular prostaglandin reduces the blood clotting rate and thus the likelihood of a clot blocking the coronary arteries.
- Fats are slow in leaving the stomach and hence retard digestion. This delays the pangs of hunger. There is no difference in the digestibility of different fats. They are utilised to the extent of 95-98%. Digestibility is related to melting point. Those which melt below 43°C are completely digested while those melting above 43°C are slowly digested and less completely absorbed.

PFA standards of edible oils is given in Table 10.2.

Table 10.2: PFA standards of edible oils

	Gingelly oil	Coconut oil	Groundnut oil	Sunflower oil	Palm-olein	Cotton seed oil
Butyro refractometer reading	58-61	34-35.5	54-57.1	57.1-65.0	43.7-52.5	55.6-60.2
Saponification value	188-193	< 250	188-196	181-194	195-205	190-198
Unsaponifiable matter Maximum	1.5	1.0	1.0	1.5	1.2	1.5
Iodine value	103-120	7.5-10	85-99	100-145	54-62	98-112
Acid value maximum	6	6	6	6	6	0.5

COMPOSITION

Fatty acid composition of oils

Table 10.3 gives fatty acid composition of different oils.

Table 10.3: Percentage fatty acid composition of commonly used oils

Oil	*Saturated*	*Mono Unsaturated*	*Poly Unsaturated*
Coconut	91	8	1
Cotton seed	34	26	40
Groundnut	20	54	26
Mustard	6	73	21
Niger	12	35	55
Palm	80	13	7
Safflower	11	13	76
Sesame	14	46	40
Soyabean	15	25	60
Sunflower	8	34	58

When fats contain a relatively high proportion of saturated fatty acids such as palmitic and stearic acids, they have relatively high melting points and are usually solid at room temperature. When fats contain a relatively high proportion of unsaturated fatty acids such as the monounsaturated oleic acid and polyunsaturated linoleic acid, they have relatively low melting point and are oils at room temperature.

As the number of carbon atoms in the fatty acids increases, thus making longer chain fatty acids, the melting point also increases. Butyric acid with four carbon atoms melts at a lower temperature than does stearic acid with eighteen carbon atoms. Both of these fatty acids are saturated. Butter contains a relatively large proportion of short-chain fatty acids and melts at a lower temperature than does beef fat or hydrogenated shortenings, which contain more long chain fatty acids.

19.2 Functions of Oil and Fats in Foods

In addition to their nutritional function, oils and fats have other uses which derive principally from their distinct physical properties. They contribute to the tenderness, flavour, colour and texture of food products. They also serve as the chief ingredients in preparing foods that form emulsions and as cooking media.

19.2.1 Tenderness

One of the most important functions of oils and fats is to tenderize baked products. Large quantities of them find use in the preparation of baked products, such as breads, cakes, biscuits, cookies, etc. Their function is particularly important in pastry and bread which have little or no sugar to contribute to tenderness. In the absence of oils and fats, the gluten strands will be held firmly together as a solid mass. Fats, being insoluble in water, interfere with gluten development during mixing. Thus, fats act as shortenings in the preparation of baked products. Fat absorbed on flour proteins interferes with hydration and thus the development of a cohesive gluten structure.

Butter, margarine, a blend of vegetable and animal fats, and hydrogenated fats or oils, are used as shortening agents. Hydrogenated oils used as shortening agents are partially hydrogenated as complete hydrogenation would make them too hard. Super glycerinated shortenings are used for baking. These are fats to which some 2.5 per cent monoglycerides and diglycerides have been added, to promote the emulsification of fat in water and improve the baking properties.

Different shortening agents are used in the baking of different products. The usual fat used, if any, in yeast bread is butter or margarine. In biscuits, a hard fat must be used so that the fat can be distributed in small pieces to give the desired flakiness to the biscuits. Muffins require that the fat be fluid during mixing. Shortened cakes are made using a plastic fat which combines readily with the ingredients in the flour mixture. Chiffon cakes are formulated with the use of oil. Butter and commercial shortenings are used in the preparation of cookies. Thus, the type of fat used as shortening in making pastries depends on the type of product desired. Butter is usually used in puff pastry.

Fats also contribute to the incorporation and retention of air in the form of small bubbles in the batter. Carbon dioxide and steam diffuse into these air cells during baking. Thus, fats contribute to the grain and volume of the baked products.

19.2.2 Flavour

Some fats influence the flavour of the food. Fats that are used for seasonings, table use and salad dressings, possess distinctively pleasing flavours. Butter, margarine, pecan fat and olive oil are commonly used for salad dressings. Cottonseed oil, corn oil, groundnut oil and soyabean oil lack flavour and are used for salad dressing when a bland flavour is required. All fats, flavoured or bland, act as solvents for the flavour of the foods to which they are added. For example, the flavour of onions, celery, pepper and other flavoured foods, when cooked, is extracted by fats.

19.2.3 Texture

Fats have textural effects in foods. They affect the smoothness of crystalline candies and frozen desserts through the retardation of crystallization and the gelatinization of starch in starch-thickened mixtures. They contribute to the juiciness of meats and the foam structure of whipped cream.

19.2.4 Emulsion

Fats constitute one of the essential constituents in food emulsions. Prominent among the natural food emulsions are milk, cream and egg-yolk. In most food emulsions, oil is the dispersed or discontinuous phase and water is the dispersion medium or continuous phase. For the stabilization of the emulsion, an emulsifying agent is required. Various substances commonly used as emulsifiers are egg-yolk, whole egg, gelatin, starch paste, vegetable gum, casein and fine powders, such as those of paprika and mustard.

Salad dressings, such as mayonnaise, French dressings and cooked salad dressing are permanent or semi-permanent emulsions of oil-in-water. Occasionally a single food, such as vinegar or sour cream, may be used as salad dressing. They may also be a simple mixture of oil and vinegar.

Mayonnaise: This is semi-solid emulsion of vegetable oils (corn oil or cottonseed oil), egg-yolk or whole egg, vinegar and seasonings. Vinegar reduces the tendency of the oil to become rancid. Mustard is frequently used in making mayonnaise as a flavouring material (which also stabilizes the emulsion) and other spices are added for taste. The oil content of mayonnaise is as high as 75 per cent.

French dressing: French dressing is an emulsion of vinegar, vegetable oils, salts and spices. The emulsion is not as stable as mayonnaise and contains about 35 per cent oil. Commercial French dressings are stabilized by adding powdered paprika, eggs, tomato sauce and other materials.

Cooked salad dressings: They are made from fat (butter, margarine or cream) or salad oil, egg, vinegar, starch and seasonings. Fruit juice or milk may be used in place of vinegar. The liquid ingredients are thickened with egg and added to water and starch heated to boiling point. Cooked dressings contain less than 30 per cent oil.

19.3 Processing of Oil and Fats

Oils and fats do not occur free in nature. They occur in animal tissues, and in the seeds and fruits from which they are isolated, refined and processed for specific use. Fats are extracted from animal tissues chiefly by rendering and from other sources by pressing and solvent extraction.

19.3.1 Rendering

In this process, fat from animal tissues is extracted by heat. Chopped or minced tissues are heated with water (wet rendering) or in its absence (dry rendering). In the former method, it is more common to use steam which results in the good disintegration of cells and efficient separation of fat. In dry rendering, the tissue is heated with steam in vacuum containers. An improved technology involves the division of the fatty tissues into fine particle size after which flash heating is applied for 15 secs. The product is then pulverized and centrifuged. This method gives a high yield, and a bland and stable product.

19.3.2 Pressing

In India, oil has been obtained by processing oil seeds in village "ghanis" (made of pestle-and-mortar) driven by bullocks, from time immemorial. Power ghanis are now replacing non-power units. About 20 per cent of the total production of edible oil in the country is by the ghani sector. The predominance of this sector is because of the consumer's preferences for the natural flavour and taste in ghani pressed oils.

The modern method of oil extraction by pressing is by the use of high-pressure expellers. In this process, the oil-bearing material is cleaned, tempered and dehulled, crushed or flaked and then passed through the expeller, when the oil separates out. Deoiled cake is a good cattle feed. About 80 per cent of the oil in the country is produced by this method.

19.3.3 Solvent Extraction

Extraction of oil from expellers is not a very efficient method. Pressed cakes contain appreciable quantities of oil. Therefore, it is now common to extract oils by solvent extraction or by a combination of pressure and solvent extraction. With materials containing a low percentage of oil, solvent extraction is the only practical method of removing oil. Various organic solvents could be used, but the most commonly employed solvent is hexane. After extraction of the oil, the solvent is removed from the oil. The residue after solvent extraction (the protein-rich, deoiled meal) can be processed as edible flour. About one-tenth of the oil produced in the country is obtained from solvent extraction.

19.3.4 Refining

Oils extracted by the above methods are crude and contain many other constituents like free fatty acids, unsaponifiable matter, gums, waxes, mucilaginous matter, a variety of colouring matter, metallic contaminants, undesirable odoriferous constituents, etc. In refining, the suspended particles are removed by filtration or centrifugation. The free fatty acids are removed by alkali treatment. When the free fatty acid content is high as in palm oil (5 per cent), it is removed by blowing steam through hot oil under vacuum. This results in both deacidification and deodorization. Any remaining free fatty acids are removed by neutralization. Pigments are removed by bleaching using adsorbents like activated earth or carbon or, in special cases, chemical bleaching agents. Finally, the oil is deodorized by injecting steam through the heated fat kept under reduced pressure. Techniques for continuous bleaching and deodorizing are available.

19.3.5 Hydrogenation

Refined oil on storage can become rancid. The unsaturated fatty acid components of the oil undergo deteriorative changes with time. To overcome this and to obtain fats of desired properties, refined oils are hydrogenated. Hydrogenation is brought about by passing hydrogen under pressure through hot oil in presence of catalysts like nickel. The properties of the final product are affected by temperature, rate of mixing with hydrogen, nature of catalyst, and pressure of hydrogen. However, hydrogenation will bring about some isomerization of oleic acid to its *trans* isomer, eladic acid, which has some effect on the fluidity of cell membranes. The fat obtained will be neutral in flavour with a high enough smoking temperature to make it useful for frying and having shortening power. Hydrogenated fats used as shortenings may be mixed with mono- and diglycerides to improve their emulsification properties.

19.3.6 Vanaspati

Hydrogenated oil is known as vanaspati in India. It contains 95 per cent hydrogenated oil to which 5 per cent of a liquid oil is added. In earlier days, groundnut oil was used for hydrogenation and sesame oil as the liquid component. With the shortage of oil in the country, more and more non-traditional oils are being used in the vanaspati industry. In 1981, vanaspati production in India was of the order of 0.84 million tonnes.

19.4 Animal Fats

Oils and fats are essential ingredients of foods. Several animal and vegetable fats are used in food preparations. Their use depends upon the properties of the fats, their availability, and the culture of the area of its use. The animal fats used are butter and lard, and those of vegetable origin, are the oils obtained generally from oilseeds and other vegetable sources like cereal brans.

19.4.1 Butter

Butter, because of its pleasing flavour and good shortening qualities, has for a long time been an important fat component in food preparations. It is made from milk fats. For an account of butter see Chapter 21.

Table 19.3 Production of important oils in India (million tonnes)

Oil	1994–95	1995–96	1996–97	2004–05
Coconut *Cocus nucifera*	0.400	0.460	0.430	0.550
Groundnut *Arachis hypogaea*	1.680	1.420	1.710	1.616
Mustard *Brassica nigra*	1.730	1.970	1.980	2.590
Sunflower *Helianthus annus*	0.504	0.450	0.460	0.404
Sesame *Sesammumindicum*	0.229	0.370	0.290	0.220
Soyabean *Glycine max*	0.480	0.660	0.600	1.202

Source: www.fas.usda.gov/wap/circular/2006 oil.xls

19.6 Sources of Edible Oils

A brief account of the sources of edible oils in the country is the following:

19.6.1 Groundnut (*Arachis hypogaea*)

In developing countries, groundnut mostly goes into the production of oil and, to a certain extent, in the manufacture of confectionery. In India, about 50 per cent of the total edible oils produced is groundnut oil.

When groundnut is not properly stored it gets contaminated with the fungus *Aspergillus flavus*, resulting in the production of the toxic substance aflatoxin (see Chapter 27). Consumption of oil from fungal infected nuts is a health hazard and it is advisable to avoid its use. When moisture content of groundnut is more than 8 per cent, there is the danger of fungal infection. Groundnuts should be dried to the safe moisture level soon after harvest and stacked where the relative humidity may not exceed 70 per cent, as this will help maintain the moisture content of dried nuts.

Groundnut oil is a clear amber coloured liquid extensively used in cooking and as a salad oil. It is one of the most important fats used for making margarine. Large quantities of groundnut oil are used in the manufacture of vanaspati, though it is being replaced by some non-traditional oils of late. It is also used in preserving fish, as in the case of tinned sardines.

The residue left after the oil extraction of groundnuts is groundnut cake and this is used for the preparation of groundnut flour and for feeding cattle and other farm animals.

19.6.2 Rapeseed-Mustard

There are a large number of species of mustard, such as black mustard, rape, etc., cultivated in India and other countries of the world. The seeds closely resemble each other. The cultivated rapeseed-mustard in the country is a mixture of three species, *Brassica compestris*, *Brassica jincea* and *Brasicca nigra*. In 2005–06, the area under cultivation was 7.3 million hectares with a production of 0.93 million tonnes.

19.6.3 Sesame (*Sesamum indicum*)

Sesame or gingelly is one of the oldest oilseeds of the world. It is said to be native to India though its origin is sometimes traced to Central Africa and sometimes to Indonesia. Gingelly oil is one of the most important oils of domestic consumption in India.

India is the largest producer of sesame accounting for 36 per cent of the world's production. It was grown in about 1.8 million hectares and its annual production in 2004–05 was 680 thousand tonnes. It is grown in almost all parts of the country. The yield was 37.7 quintals per hectare.

The seeds are edible as such and are also fried and eaten. The decorticated seeds contain about 25 per cent oil and are used for extracting oil. The oil is extracted both by the old fashioned ghani and in modern mills. When clean oil is required, the seedcoat of gingelly seed is removed by soaking the seed in water and then rubbing off the seedcoat, which is loosened by steeping in water. Most of the oil produced in India is locally consumed.

19.6.4 Cottonseed (*Gos-sypium*)

Cottonseed is a by-product of ginning cotton (*Gos-sypium*). Generally, the proportion of cotton to cottenseed is 3 to 1. On account of the huge production of cotton in India, cottonseed is an important commercial product. The seeds are of two types; the fuzzy, i.e., consisting of outer fluff or fuzz, and the non-fuzzy. The fuzzy seeds have to be delinted (removal of fuzz) before the extraction of oil. Both types of seeds are dehulled before processing. Cottonseed oil is extracted by two different methods, decorticated and non-decorticated. The fuzzy seeds are considered to possess better properties for processing into edible oils. The decorticating and dehusking method of processing yields high-grade edible oils. The undecorticated method gives oil with poor bleachability and involves considerable loss of oil.

19.6.5 Coconut (*Cocos nucifera*)

Coconut is used for two important purposes, viz., for use as an edible product and for the preparation of oil. Coconut oil is made from dried coconut meal or copra. The copra is milled both in ordinary rotary mills and in modern machinery. Recovered oil percentage varies from 57 to 75. Unlike other oils, coconut oil is poor in unsaturated acids. Oleic and linoleic acids are present only to the extent of about 9 per cent. The remaining 91 per cent is saturated fatty acids, characterized by the presence of a high percentage of lauric (C_{12}) and myristic (C_{14}) acids. Coconut oil is more easily absorbed than other oils, and for this reason it is used extensively for edible purposes. The major industrial uses for coconut oil are in the manufacture of soap, vanaspati, margarine, pharmaceutical preparations, etc. Coconut cake obtained after extraction of the oil is a valuable foodstuff for cattle.

19.6.6 Sunflower (*Helianthus annuus*)

Sunflower is an important oilseed crop in temperate countries like Russia, Canada, and elsewhere. It is an important non-traditional crop which has been recently introduced to India. It was cultivated in an area of 2.4 million hectares, and in 2004–05, the production of sunflower seeds was 1.42 million tonnes.

Some important advantages of sunflower as a commercial oilseed crop are that it is a short duration crop, it can be cropped at any time of the year, oil yield is high per unit area, crushing and extraction of oil are easy, and the quality of oil for edible purposes is high.

19.6.7 Soyabean (*Glycine max* Merr) (See 17.7.14)

It is the most important oilseed crop of the world, though it has only a minor role in India. Soyabean oil is the world's leading vegetable oil in terms of both production and consumption. It is obtained from the raw bean by solvent extraction and is processed to a refined product that has a number of uses. It is used in vanaspati, salad oil, mayonnaise, sandwich spreads, baby food, cake mixes, and non-dairy creamers.

Soyabean oil has considerable nutritional importance. It has a high polyunsaturated fatty acid composition next only to sunflower oil. It has both n-6 and n-3 fatty acids and hence has a considerable plasma cholesterol lowering effect. Being a vegetable oil, it has no dietary cholesterol content and a low plant sterol content. It is also reported to have anti-tumourogenic and blood sugar lowering effects. It is a good source of vitamin E.

19.6.8 Niger (*Guizotia abyssinica*)

Niger is grown in most parts of India, but it is an oilseed of minor importance. The seeds contain about 40 per cent oil. Niger seed oil is a clean pale yellow oil which is edible and is used largely as a substitute for gingelly oil.

19.6.9 Flaxseeds (Linum usitatissimum)

Flaxseeds are known as *Linum usitatissimum* with its species name meaning "most useful." That would definitely describe the versatility and nutritional value of this tiny little seed. Flax seeds are slightly larger than sesame seeds and have a hard shell that is smooth and shiny. Their colour ranges from deep amber to reddish brown, depending upon whether the flax is of the golden or brown variety. While whole flaxseeds feature a soft crunch, the nutrients in ground seeds are more easily absorbed. The warm, earthy and subtly nutty flavor of flax seeds combined with an abundance of omega-3 fatty acids makes them an increasingly popular addition to the diets of many a health conscious consumer. Whole and ground seeds and oil are available throughout the year.

Flaxseed oil is rich in *alpha linolenic acid*, an omega-3 fat that is a precursor to the form of omega-3 found in fish oils called *eicosapentaenoic* acid or EPA. Alpha linolenic acid or ALA, in addition to providing several beneficial effects of its own, can be converted in the body to EPA, thus providing EPA's beneficial effects. For this conversion to readily take place, however, depends on the presence and activity of an enzyme called *delta-6-destauras*e, which, in some individuals, is less available or less active than in others. In addition, the *delta-6-desaturase* function is inhibited in diabetes and by the consumption of saturated fat and alcohol. For these reasons, higher amounts of ALA-rich flaxseed oil must be consumed to provide the same benefits as the omega-3 fats found in the oil of cold-water fish.

The following table 19.6 shows the nutrients for which flaxseed is either an excellent, very good or good source. Next to the nutrient name is found the following information: the amount of the nutrient that is included in the noted serving of this food; the %Daily Value (DV) and, the food's World's Healthiest Foods Rating

19.6.10 Oil from Other Sources

The gap between the supply and demand of vegetable oils in India is widening. As there are limitations for increased production of oil from traditional sources, alternative sources have to be developed. Of these, rice bran and oil palm are of great importance.

Table 19.6 Nutritional profile of flax seeds:

Nutrient	Amount	DV (%)	World's Helthiest FoodsRating
Omega-3 fatty acids	3.51g	140.4	excellent
Manganese	0.64mg	32.0	very good
dietary fibre	5.41g	21.6	very good
Magnesium	70.14mg	17.5	good
Folate	53.86mcg	13.5	good
Copper	0.20mg	10.0	good
Phosphorus	96.49mg	9.6	good
Vitamin B-6 (pyridoxine)	0.18	9.0	good

Source: http: // www.whfoods.com.

Rice bran: Rice bran has not yet been exploited in the country to the fullest-possible extent as a source of vegetable oil. In 2004–05, the country produced 6,00,000 tonnes of rice bran oil of technical non-edible grade. Though a lot of work has been done in the country to develop the production of rice bran oil, we have yet to develop designs which could be widely used in the rice mill for a total exploitation of bran oil.

Oil palm: Red oil palm is an important new source of edible oil and can narrow the gap in our requirements. At present oil palm is cultivated on about 90,000 hectares. In 2005 India produced 70,000 tonnes of oil palm. The great attraction of oil palm is the fantastic yields of oil per unit area, nearly 4 tonnes per hectare. Palm oil accounts for nearly 40 per cent of Indian oil imports and it has found consumer acceptability as a substitute for traditional edible oils.

There are about 25 varieties of oil seeds of tree origin in the country capable of producing about 3 million tonnes of edible oil; 40 per cent of this is from sal, a forest tree (*Shorea robusta*). Hardly 5 per cent of the available seeds from tree sources are collected at present. The minor and tree origin oil seed potential has not been fully exploited in our country. These sources could provide a sizable quantity of edible oils and reduce the gap between demand and supply.

ing, with a final drying process. This is followed by bleaching and deodourising to remove colour pigments and further purify the oil.

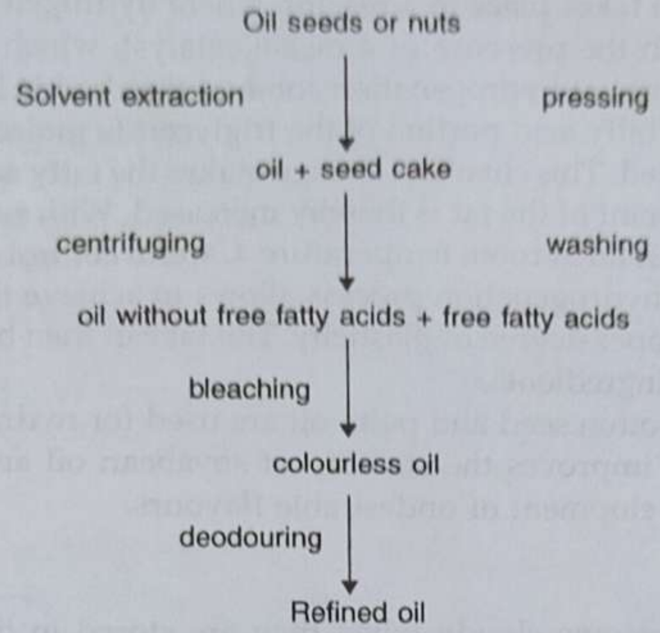


Figure 10-a: Steps involved in making refined oil

Soyabean oil is the major component of vegetable shortening and margarine.

Canola oil is rapeseed oil and the name is derived from canadian and oil.

Cotton seed oil is consumed as a salad or cooking oil while some is used as shortening. It has a neutral flavour that does not mask the flavour of other products.

Coconut oil contains a high proportion of saturated fatty acids, about 92%. Many of these are short chain fatty acids, particularly lauric acid. Coconut oil has a sharp melting point, similar to the fat found in chocolate and is therefore useful in confectionery and cookie fillings.

Sunflower oil has good flavour stability. Safflower oil has 75-80% linoleic acid. Peanut oil has excellent oxidative stability. Corn oil is used primarily in margarine.

Plasticity

Most fats that appear to be solid at room temperature actually contain both solid fat crystals and liquid oil. The liquid part is held in a network of small crystals. Because of this unique combination of liquid and solid, the fat can be moulded or pressed into various shapes without breaking. This property of fat is called plasticity. The type and size of the crystals in a plastic fat influence the performance of the fat in baked products and pastry. Plastic fats can be creamed that is, mixed with the incorporation of air.

Hydrogenation

The process of hydrogenation changes liquid oils into more solid plastic shortenings and to increase the stability of the oils to prevent spoilage from oxidation, which results in undesirable rancid flavour and odours.

Hydrogenation takes place in a reactor, where hydrogen gas is bubbled through the liquid in the presence of a nickel catalyst, which speeds up the reaction. In the process of hydrogenation some of the double bonds between carbon atoms of the fatty acid portion of the triglyceride molecule are broken and hydrogen is added. This chemical change makes the fatty acids more saturated. The melting point of the fat is thereby increased. With sufficient hydrogenation it becomes solid at room temperature. Careful control of temperature and pressure in the hydrogenation process allows to achieve the desired end result, that is, the proper degree of plasticity. The fat can then be creamed and blended with other ingredients.

Soyabean oil, cotton seed and palm oil are used for hydrogenation. Hydrogenation greatly improves the stability of soyabean oil and therefore its resistance to the development of undesirable flavours.

Winterisation

Some cooking oils become cloudy when they are stored in the refrigerator. This occurs because some of the triglyceride molecules in the oil have higher melting points than other molecules in the mixture and crystallise or become solid at the low temperature.

In manufacturing oils intended to be used primarily for the making of salad dressings, a winterising process is applied. In this process, the temperature of the oil is lowered to a point at which the higher-melting triglycerides crystallise. Then the oil is filtered to remove these crystals. The remaining oil has a lower melting point and does not crystallise at refrigerator temperatures. It is referred to as salad oil.

SPECIFIC FATS

Lard

To make lard, fatty tissues of the hog are chopped into small pieces and heated, with or without the addition of water, to remove fat from the cells, a so-called rendering process. The quality of the lard depends on the location of the fatty tissue in the animal and on the method of heating. An antioxidant is added to delay the onset of rancidity. Sometimes lard is modified to improve its baking performance. It may be bleached, hydrogenated, deodourised and an emulsifier added. In addition, the arrangement of some of the fatty acids within the fat molecules may be changed by a process known as inter esterification. This change results in a product of improved plasticity and creaming qualities.

Butter

The cream is pasteurised to inactivate the enzyme lipase and to destroy microorganisms. Sometimes a culture of bacteria called a "starter" is added to the cream to produce lactic acid and alter the flavour. The cultured cream is allowed to ripen a few hours and is then churned.

are quite resistant to this type of

RANCIDITY

Spoilage of fats may occur or storage, particularly if the fats are highly unsaturated and the conditions of storage are conducive to chemical change in the fats. Rancidity is of two types—hydrolytic and oxidative.

Hydrolysis

Hydrolysis is brought about by enzymes that decompose fats into free fatty acids and glycerol. Butyric and caproic acids which are the volatile fatty acids predominating in butter are largely responsible for the odour and flavour of rancid butter. These acids may render butter inedible even when they are present in low concentrations.

Long chain fatty acids such as stearic, palmitic and oleic acids do not usually produce a disagreeable flavour unless other changes such as oxidation also occur.

Heating thoroughly to destroy the lipase enzyme that catalyses the hydrolysis of triglycerides should prevent hydrolytic rancidity. Contaminating microorganisms may also produce lipase and these can similarly be destroyed with sufficient heating.

Oxidation

Only unsaturated fats and foods which have lipoxygenase are susceptible to oxidative changes. Highly hydrogenated and saturated fatty acids are relatively resistant to oxidation. Hydroperoxides that are formed, break readily producing smaller volatile substances that give the characteristic odours of rancid fat. The reaction is a chain reaction that is self-perpetuating.

The development of rancidity is objectionable not only because of the undesirable changes in odour, flavour, colour and consistency of fat but because, it is accompanied by the inactivation of vitamin A and E. Oxidative rancidity may be a problem in dry foods containing only small quantities of fat, such as prepared cereals.

Prevention of rancidity

Fats can be protected against the rapid development of rancidity by controlling the conditions of storage.

1. Storage at refrigerator temperature prevents rancidity.
2. Rays of light catalyse the oxidation of fats. By the use of coloured glass containers that absorb the active rays, fats can be protected against spoilage. Certain shades of green bottles and wrappers and yellow transparent cellophane wrappers are effective in preventing rancidity.
3. Vacuum packaging also helps to retard the development of rancidity by excluding oxygen.
4. Antioxidants naturally present in the food such as vitamin C, beta carotene and vitamin E protect against rancidity.
5. Antioxidants can also be added like butylated hydroxy anisole (BHA) butylated hydroxytoluene (BHT), tertiary butyr hydroquinone (TBHQ) and propyl gallate.
6. Substances like citric acid may be used along with antioxidants in foods as synergists. A synergist increases the effectiveness of an antioxidant but is not as effective an agent when used alone. Some synergists may be effective because of their ability to bind or chelate the metals and prevent them catalysing the oxidation process. Chelating agents are sometimes called sequestering agents.

SMOKING POINT

Smoke point of a fat is the temperature at which smoke comes continuously from the surface of the fat. Because fats differ in their smoke points, fats to be used for frying should be chosen on the basis of their resistance to smoking at the temperature used.

Factors that lower smoking point

- The development of free fatty acids by some hydrolysis of the fat during frying causes a decrease in the smoke point.
- A fat that has had repeated or prolonged use will begin to smoke at a temperature too low for frying.
- Suspended matter such as flour or batter particles also lower the smoke point. And the greater the surface of the fat exposed, the lower is the smoke point.
- Fats heated in shallow wide pans with slightly sloping sides begin to smoke at lower temperatures than do those heated in smaller pans with vertical sides.

Table 10.4: Smoking temperatures of fats

Fat Oil	*Smoking Temperature (°C)*
Butter fat	208
Cotton seed oil	230
Coconut oil	138
Ground nut oil	149-162
Hydrogenated fat	221-232
Lard	194
Olive oil crude	176
Olive oil refined	234
Soyabean oil	230

The smoke point of a fat is partly a matter of its natural composition and partly a matter of the processing it has received. Soyabean, cotton seed, peanut and corn have smoke points of about 230°C (446°F). Hydrogenated fats smoke at 221° to 232°C. Shortenings containing monoglyceride as an emulsifier smoke at a lower temperature about 176°C. First, smoke is given off by the emulsifier and later the smoke point may raise from 190° to 193°C (375° to 380°F).

Changes in fat on heating

There are four main ways in which the oil decomposes and all of these pathways lead to a diminution of smoke point and operating temperature. Cooking oil is chemically decomposed in the cooking process and this decomposition leads to a deterioration in cooking quality if the oil is kept in use for a long time. Figure 10c gives changes in decomposition of fat.

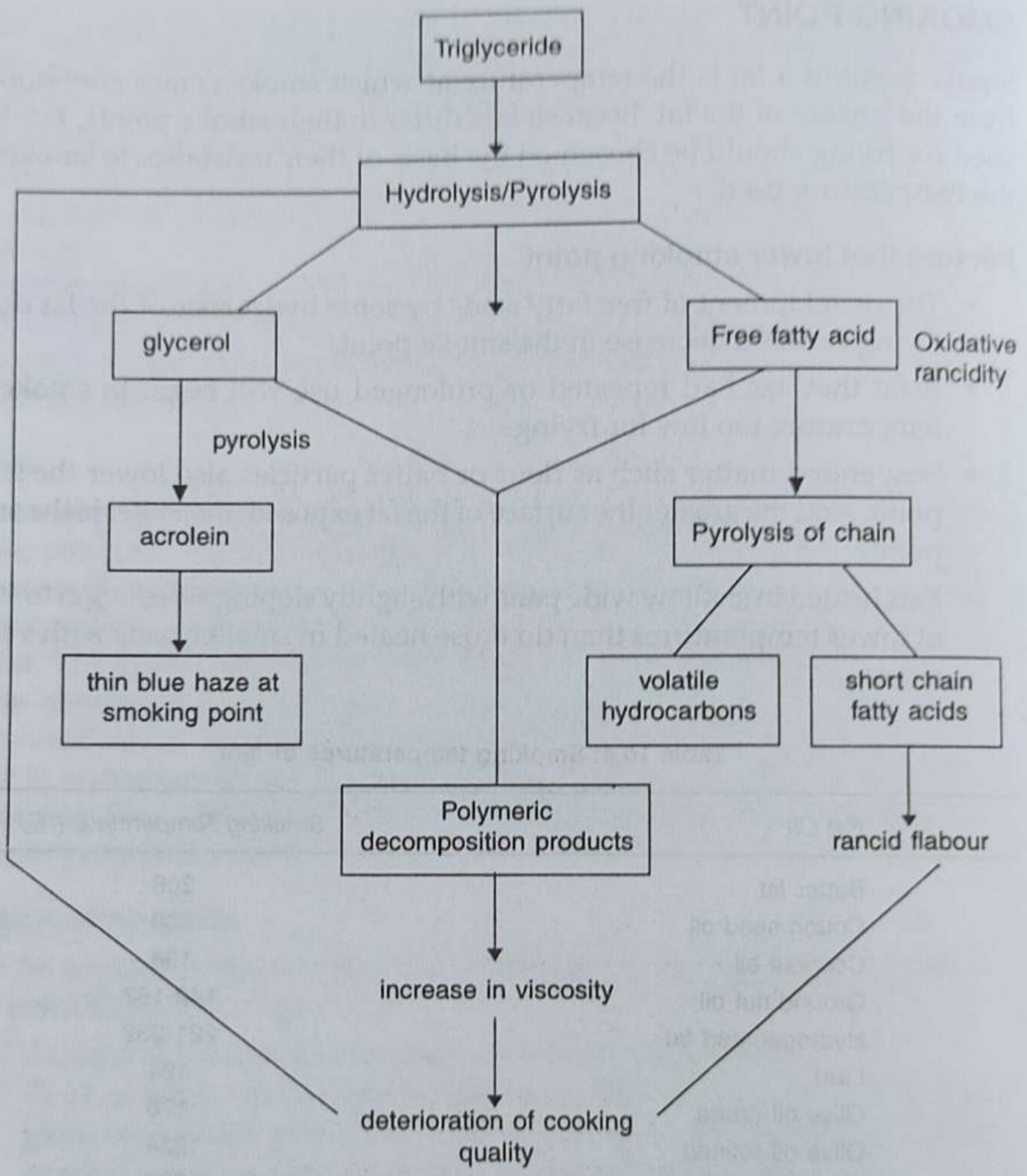
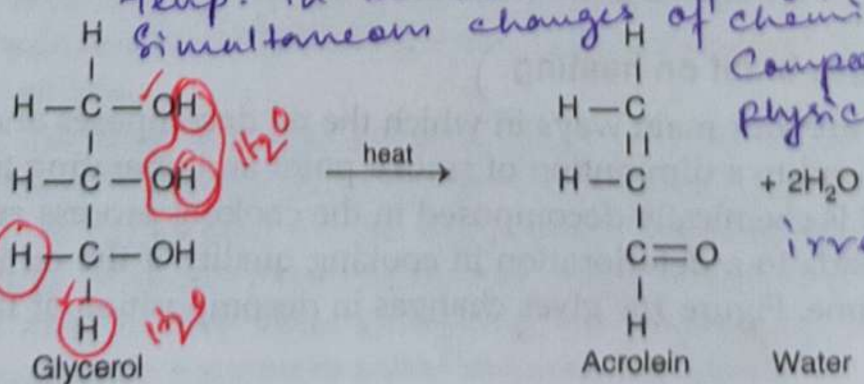


Figure 10-c: Decomposition mechanisms in triglycerides

Source: Robins, G.V., 1982, Food science in catering, Heinemann, London

Pyrolysis (thermal breakdown)

The action of heating the oil, whether or not it is in contact with food, causes a breakdown in its molecular structure.



When fat begins to smoke, its chemical breakdown begins and free fatty acids and acrolein are formed from glycerol.

If the fat is allowed to smoke for any period of time, the acrolein causes irritation of the eyes and nostrils.

Oxidation

Reaction of the hot oil surface with oxygen in the air causes molecular breakdown and ultimately the development of rancidity. This change will occur whenever the oil is heated.

Hydrolysis

As water is boiled in large quantities from food during frying, some of this water will tend to decompose the oil.

Reaction with food residues

Any food fragments left in the oil after cooking will undergo chemical reaction, particularly if the oil is heated again without the residues being removed. Straining the oil after use can help to prevent this type of decomposition.

ROLE OF FAT/OIL IN COOKERY

In addition to their nutritional function oils and fats have their uses in cookery which are derived principally from their distinct physical properties.

Fat oil used as medium of cooking

Fat is used in shallow and deep fat frying. Cooking oil is a better heat transfer medium than air or water in that it heats up very quickly because of its greater specific heat, and its operating temperature of about 200°C is considerably higher than that of water.

Pan frying is used to cook dosas, chapatis, omelettes, cutlets and tikkis. Moderate temperatures are used as smoking of fat is a definite indication that decomposition is occurring and should never be permitted. In pan frying, the amount of fat used can be limited.

Deep fat frying method is used in preparing pooris, vadas, cutlets, bajjis and pakodas.

In deep fat frying, there is a direct transfer of heat from the hot fat to the cold food that continues until the food is cooked. Water is lost from the exterior surface of the food as it is converted to steam. The steam carries off energy from the surface of the food and prevents charring or burning. Water then migrates from the central portion of the food outward to the edges to replace that loss by evaporation. Finally the interior of the food is cooked. Sufficient heat must be transferred to gelatinise starch and coagulate proteins that may be present in the food. Most foods are fried at 117°C to 196°C.

Most oils and fats are suitable for use in frying but there are some exceptions like butter because the water content restricts the cooking temperature and the presence of short chain esters leads to rapid breakdown and discolouration on heating. Longer chain fatty acids in margarine is less vulnerable to thermal decomposition.

A satisfactory fat is one that has high decomposition point, a high smoking temperature with no undesirable odour.

Suspended matter, such as flour or batter particles also lowers the smoke point. The greater the surface of the fat exposed to air, the more rapidly the smoke point is lowered.

Heated oils and their degradation products interact with the food being fried. Some materials are leached from the food into the frying fat and some of the fat itself is gradually broken down or degraded. Oxygen from the air may react with the fat as the fryer at the oil-air interface. This creates many different chemical compounds in the frying fat in addition to the basic triglyceride molecules that originally made up the fat. Some of the chemicals produced the surfactants, that is, molecules that interact at the air-oil or oil-food interfaces and lower the surface or interfacial tension.

A surfactant theory of frying suggests that the lowered surface tension allows oxygen to be drawn in, producing some oxidised compounds that aid in heat transfer. Also, the contact time between the hot oil and the aqueous food surfaces is increased and more heat is transferred to cook the food. If surfactant levels become too high, however, degradation of the fat is enhanced, polymers are formed, increased viscosity results from the gun formation and foaming becomes excessive.

There is an optimum level of surfactants in the frying fat that results in a quality fried product that is golden-brown in colour, crisp with rigid surfaces, and has delicious odours, fully cooked centres and optimal oil absorption. As frying fat is used, darkening occurs. As the fat darkens, the foods fried in it darken more rapidly and may be uneven in colour. The ingredients in the product being fried influence the colour changes of the frying fat. Potatoes form little colour in the frying fat, whereas chicken, egg yolk increases darkening of the fat.

Fat absorption

From the standpoint of both palatability and ease or rapidity of digestion, it is desirable to hold fat absorption by fried food to a minimum. Generally some 10% oil or fat is absorbed but larger amounts are absorbed in some conditions where the products becomes soggy and undesirable. Among the factors that affect the amount of fat absorbed are:

The character and composition of the food

- Diamond cuts containing a high percentage of sugar and fat absorb more fat while frying than do diamond cuts containing lesser amounts of sugar and/or fat.
- The addition of egg to fritter type batter that contains no additional shortening significantly increases fat absorption. Egg yolk contains phospholipids.

- Doughnuts made from soft wheat flours absorb more fat than made from strong flours. The development of gluten by the extensive manipulation of the dough decreases fat absorption as compared with doughs in which gluten has not been developed.
- Porous surfaces like bread or fermented foods absorb fat. Surfaces with more cracks, due to under manipulation, absorb more fat.
- Addition of sodium bicarbonate to bajji batter causes porousness in the food which absorbs oil.
- Greater the surface area more absorption of fat takes place.
- If the moisture content of the material is higher, the fat absorption is also greater than the control in preparation like pooris and vadas.

The condition of the frying fat, including the level of surfactants present: An optimum level of surfactants in the frying fat produces optimal fat absorption. With excessive amounts of surfactants, more oil is drawn into the food.

The temperature of fat and the length of time of heating: Foods cooked at a lower temperature need to be cooked for a longer period. The longer the food remains in the fat, the greater the absorption. When oils are used again and again, the smoking point decreases, free fatty acid content increases and consequently oil absorption increases. The presence of finely divided material in the fat, often accumulates during repeated frying, lowers its smoking point.

The frying life of fats can be improved by filtering after use, storing in a refrigerator. The smoke point is lower if a surface of fat is exposed, indicating the importance of using a deep rather than a shallow pan for frying in deep fat.

Effect on the food fried in deep fat frying

1. Food absorbs oil when it is used for frying since oils are high energy foods, the energy value of the food is increased enormously.
2. Appearance, taste and colour of the food is altered. Browning reactions like Maillard reaction, dextrinisation and caramelisation may take place.
3. There is considerable weight loss in the food being cooked. The weight loss is primarily due to water evaporated at the temperature of frying.
4. Air expands in poori layers. Texture develops in badushah.
5. Protein gets coagulated.

Fat turnover

By turnover is meant the amount of fat in the frying kadai that is replaced by fresh fat in a given period. As fat is absorbed by the foods that are fried, the amount of fat in the kadai continuously decreases as frying proceeds unless fresh fat is added periodically. When turnover is slow, it is necessary to periodically discard the fat in the kadai and start again with fresh fat.

Choosing the frying fat

A number of factors affect the choice of a frying medium

1. It should be a fat that, during use, develops flavour that enhances the quality and acceptability of the fried product. The flavour should also be stable enough that it remains appetizing throughout the shelf life of the product. Minute amounts of methyl silicone are often added to fats during processing to help retard foaming and deterioration during frying. A certain amount of hydrogenation of the frying oil is needed to provide good flavour stability and to increase the frying life of the fat before too much degradation occurs.
2. The resistance of a fat to smoking at high temperatures is also important in choosing a frying medium. The smoke point of a fat is partly a result of its natural composition and partly a result of the processing it has received.
3. Other desirable factors to look for in choosing a fat are light colour, resistance to foaming and gum formation, uniformity in quality, stability for long term use, and ease of use, considering both form and packaging.

Fat improves the texture of foods

Fat plays an important role in the proper development of texture in cakes, biscuits and cookies. Its function is particularly important in pastries where there is no sugar to contribute to tenderness.

a. Fats help in leavening

In making cake, leavening occurs by incorporating air into the fat during the leavening process. When the butter is heated in the oven, the small air bubbles expand and fill with steam. The greater percentage of leavening in cake comes from the steam that collects in the tiny air bubbles rather than from the air itself. Gluten in the flour forms the walls around each little bubble and during baking they act to a fairly rigid structure. When the cake is removed from the oven and is cooled, the air in the small bubbles contracts and the steam condenses. In a well balanced recipe the walls are sufficiently strong to hold up and the cake does not fall. The role of fat in the leavening process is its ability to trap air during the mixing process. So the fat is indirectly responsible for the tenderness of the cake. The walls around each bubble are made of gluten and starch which can be very tough and hard. Fat is streaked through and serves as a lubricant so that when the cake is beaten, particles of gluten and starch slide on one another and the walls crumble. Thus fat contributes to the grain and volume of baked products. Though all baked products use fat, amounts used are different.

Fat forms part of the foam structure of whipped cream.

b. Fat as a shortening agent

One of the most important function of fat is to shorten baked products which otherwise are solid masses firmly held together by strands of gluten. Being insoluble in water, fat interferes the hydration of gluten and cohesion of gluten strands during mixing, thus literally shortening them and making the product tender.

For products like pastry and biscuits, intimate mixture of the fat with the other ingredients is purposely avoided so that the fat will form layers between the strands of gluten. These products are likely to be flaky as well as tender. As flour and fat are mixed more thoroughly, the products may become more tender but less flaky. In making recipes like puffs and pastries too much mixing is avoided.

Manipulation, temperature, ingredients like flour and fat and their concentration affect the shortening power of fat.

Lard has a very high shortening value and butter, a lower value with hydrogenated shortenings intermediate. This is true in pastry made from water, flour and fat.

Different shortening agents are used in baking of different products. The usual fat used, if any, in yeast bread is butter or margarine. In biscuits, a hard fat must be used so that the fat can be distributed in small pieces to give the desired flakiness to the biscuits. Shortened cakes are made using a plastic fat which combines readily with the ingredients in the flour mixture. Butter is used in puff pastry.

c. Fats for smoothness

(i) Fats have textural effects in ice-creams and frozen desserts. They limit the size of water crystals and help in maintaining smooth texture.

(ii) They affect the smoothness of crystalline candies through the retardation of crystallisation and the gelatinisation of starch in starch thickened mixtures.

(iii) Fat interferes with crystallisation of sugar, e.g. in halwa.

(iv) Fat prevents lump formation and brings smoothness. When grains are fried initially while making pulao or upma they get coated with oil or fat and this helps in reducing lump formation and excess gelatinisation and grains remain separated after completion of cooking.

(v) Fats form emulsion in mayonnaise and give smooth texture.

Fats improve palatability

Fat gives taste and flavour to the food. Some fats like ghee is used at the table to improve the flavour and to reduce pungency. Ghee and butter when used in the recipe improve the flavour. Butter is spread on bread to improve the palatability.

The ability of fats to take up or dissolve certain aromatic flavour substances is frequently used in food preparation. Onion, ginger, garlic, peppers and other flavourful foods are cooked in oil so initially flavour can be incorporated into other foods. Aromatic fruits and other flavours are also dissolved by fat.

Unconventional oils

Unconventional oils such as oils from mango kernel, cleome viscoss, mesta, Terminelia bellerica, neem, rice bran, kapok and mahua have been investigated in NIN, Hyderabad for their safety and nutritional evaluation. Of these, mango kernel oil, cleome viscosa oil and rice bran oil have a very promising future as edible oils. Mango kernel oil can be used as substitute for cocoa butter fat.

A butter substitute was developed at National Dairy Research Institute, Karnal. A butter flavoured low fat soya spread was developed based on soya concentrate and vegetable fat. The product is highly acceptable as a bread spread and it costs half the cost of butter.