

Processing, Manufacturing, Uses and Labelling of Fats in the Food Supply

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Processing of Fats and Oils

Small-Scale/Home Processing

Oils and fats occur naturally in a range of plant and animal sources. Whilst there are innumerable seeds and nuts that are a source of oils, globally approximately 30 vegetable oils and animal fats have been commercially exploited. Of these, roughly a dozen oils are of worldwide importance. Table 1 lists plant and animal sources of oils.

The 4 main oils commercially produced on a large scale are soy, palm, rapeseed and sunflower, which account for approximately 80% of the world production. The fat and protein content of oil seeds varies considerably (table 2). The major vegetable oils are pressed and/or extracted from seeds using solvents.

The contrasting ranges of saturated and unsaturated fatty acid composition of various oil seeds are presented in table 3.

Village level/small-scale processing of oil has a long history and shares common methodology irrespective of the country of production. The generalised process may be summarised as follows.

- (1) Raw material preparation. This includes the removal of husks, seed coats and separating the seeds from the chaff. It also removes stones and debris.
- (2) Extraction. This can be mechanical using an oil press, expeller or a pestle and mortar. Solvent extraction is rarely used in small-scale production of oil.

- (3) Clarification. Fine pulp, resins and water are removed at this stage. Allowing the oil to stand undisturbed for a few days promotes clarification, after which the upper layer is removed. If further clarification is required the oil can be filtered through a filter cloth. The oil may be heated to evaporate any remaining water.

- (4) Packaging and storage. In order to increase shelf life and prevent rancidity, the oils may be stored in clean, dry glass or plastic containers. The containers are tinted/coloured to prevent oxidation with sunlight. If stored correctly, the expected shelf life is 6–12 months.

Two contrasting village level/commercial processing methods from Africa (groundnut) and Asia (coconut) are shown in figures 1 and 2.

Lauric Oils: Coconut and Palm Kernel Oil

In the world of oils and fats, lauric oils stand apart due to the presence of medium-chain triglycerides. Of the 18 oils of major global importance, coconut oil (*Cocos nucifera*) and palm kernel oil are the only lauric oils.

Coconut oil is derived from copra, which is the dried kernel of coconut. It is the white 'meat' formed inside the coconut. Approximately 50% of the kernel is moisture, 35% oil, 7% carbohydrate, and 3–3.5% fibre and protein. Copra also has the highest oil content (65–70%) of all the oil-bearing crops. The extraction of coconut oil remains a village-level process in many developing countries.

Table 1. Plant and animal sources of oil

• Almond oil	• Babassu oil
• Avocado oil	• Blackcurrant oil
• Borraige oil	• Coconut oil
• Cocoa butter	• Cottonseed oil
• Corn oil	• Fish oils
• Evening primrose oil	• Groundnut
• Grapeseed oil	(<i>Arachis</i> or peanut oil)
• Hard butter – illipe butter (Borneo tallow), sal fat and shea butter	• Jojoba oil
• Hazelnut oil	• Linseed oil (flaxseed oil)
• Lard	• Macadamia oil
• Olive oil	• Palm kernel oil
• Palm oil	• Pistachio nut oil
• Mustard and rapeseed oil	• Rice bran
• Canola oil	• Sesame seed oil
• Safflower oil	• Soybean
• Sunflower oil	• Whale
• Tallow	• Walnut oil

Table 2. Typical oil and protein content of some oil seeds

Seed	Percentage oil	Percentage protein
Corn	4–5 (germ: 34)	9
Cottonseed	18–24	19–24
Linseed	40–46	22–26
Peanuts (groundnuts)	45–50	21–36
Canola	40–45	25–29
Safflower	30–35	14–17
Sesame	50–55	18–22
Soybean	19–23	36–44
Sunflower	35–45	14–19

Household Wet Processing of Coconut

In countries such as Indonesia, South India, Sri Lanka, Africa and Tanzania, fresh coconuts are used at household level for oil or milk extraction. The nuts are split in two so that the meat can be scraped out. Water is then added to the grated coconut. The mixture is kneaded and squeezed by hand to produce 'milk'. The 'milk' is then boiled in order to obtain the coconut oil. After boiling, a crispy residue known as latik (a confectionery item) is produced.

Pre-treatment of oilseeds with proteases and enzymes having cellulose and hemicellulase activities are reported to increase the extraction by 26% in cocoa beans [Tano-Debrah and Ohta, 1995] and 20% in shea (*Butyrospermum parkii*) kernel fat, mainly due to the degradation of

Table 3. Typical fatty acid composition (wt%) of selected vegetable oils and fats

Fats and oils	16:0	18:0	18:1	18:2	18:3
Canola	4	2	64	19	9
Cocoa butter	26	35	35	3	
Corn	12	2	28	57	1
Cottonseed	25	2	18	53	0.3
Groundnut	7–12	3	46–71	14	60
Linseed	5	5	20	16	53
Olive	14	3	71	10	0.6
Palm	44	5	39	12	
Palm olein	41	4	31	3–10	
Palm stearin	47–74	4–6	16–37	4–11	
Palm mid-fraction	41–55	5–7	32–41	32–36	
Peanut	12	3	25	15	
Rape (high erucic)	3	1	16	22	10
Rape (low erucic)	4	2	62	32	
Rice bran oil	17	2	43	34	1
Safflower (regular)	7	2	13	78	
Safflower (high oleic)	6	2	80	12	0.2
Sesame	10	5	41	43	0.2
Soybean	11	4	23	53	8
Sunflower	7	5	19	69	0.5

Adapted from White [2008].

the cellular structures [Tano-Debrah and Ohta, 1994; Tano-Debrah et al., 1996]. The process essentially consists of mixing the dehulled and finely ground samples with water in predetermined ratios, addition of the enzymes at 1% of the sample weight, mixing, incubation for about 6 h at 37°C, and then extraction by a water flotation technique. It is suggested that the enzyme-assisted aqueous fat extraction method could improve the efficiency of rural fat and oil technologies currently in use in many developing countries. This technique has also shown to be promising with other oil resources such as rice bran [Hanmoungjai et al., 2002].

Extraction of Animal Fats and Marine Oils

Animal fats and marine oils are removed from the tissues by a cooking process called rendering. Edible tallow and lard have been used extensively as a deep-fat frying oil for many years. There are 2 ways in which these types of oils and fats can be recovered: wet rendering and dry rendering.

The majority of the fat in an animal is stored in the subcutaneous adipose tissue and as visceral fat surrounding internal organs. Between 85 and 90% of fat in pigs,

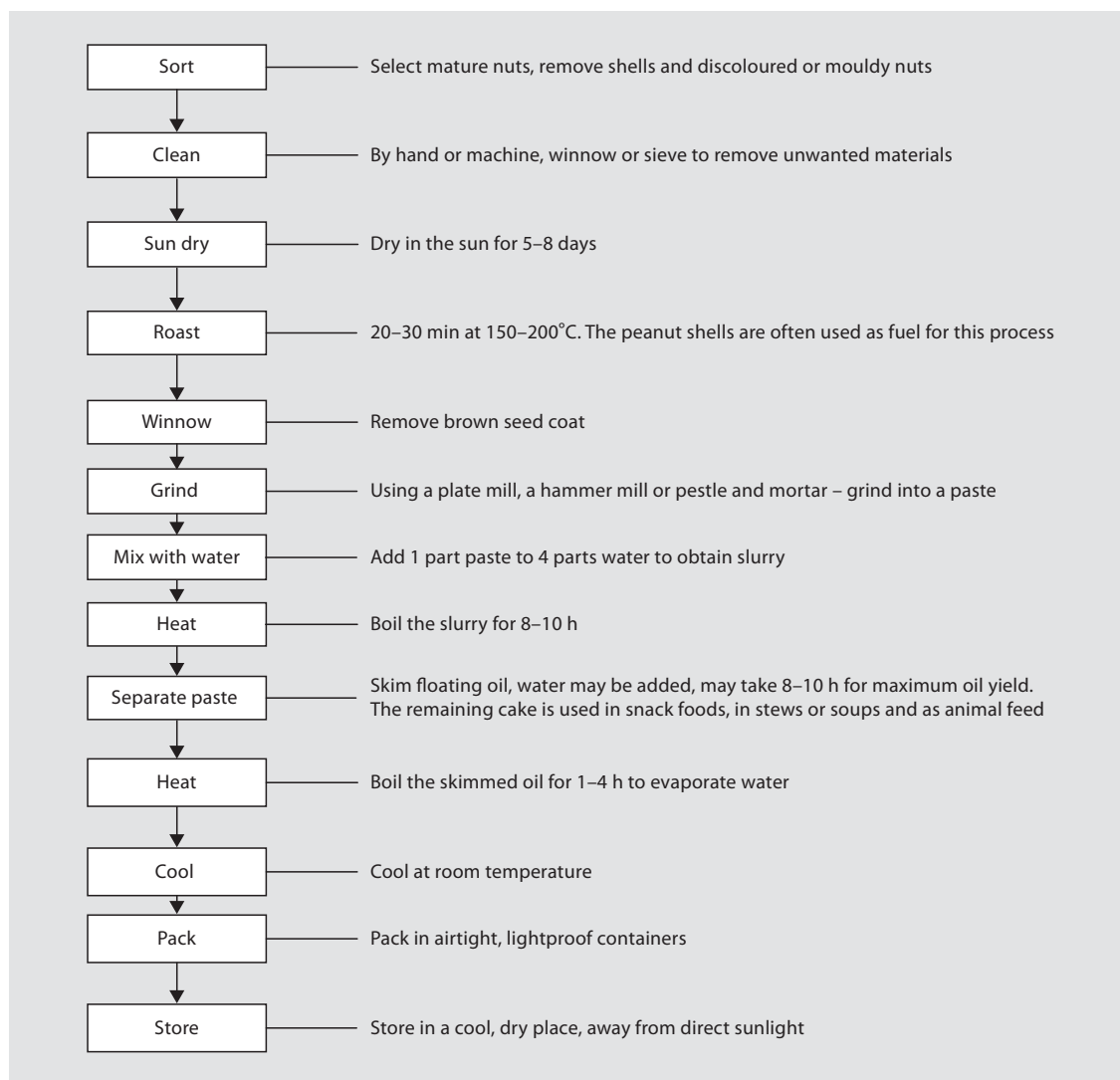


Fig. 1. Example of small-scale processing of groundnuts (peanuts).

sheep and cattle consists of palmitic, stearic and oleic acids (table 4).

Regardless of the process used, the first stage is to crush and break the tissue into small pieces. Using a batch or continuous cooker, the fats are released from the tissues during the rendering process.

Wet Rendering

This is the simplest and oldest method, which involves cooking the tissues in water. Using steam under pressure (temperature up to 140°C), for 2–3 h, the denatured protein and other substances settle at the bottom with the fat floating to the top.

Table 4. Fatty acid composition of animal fats

Fatty acid	Percentage of total fatty acids		
	pig	cattle	sheep
C16 palmitic	24–28	32	27
C18 stearic	8–16	20	27
C18:1 oleic	40–49	42	35
C18:2 linoleic	6–15	1–12	2

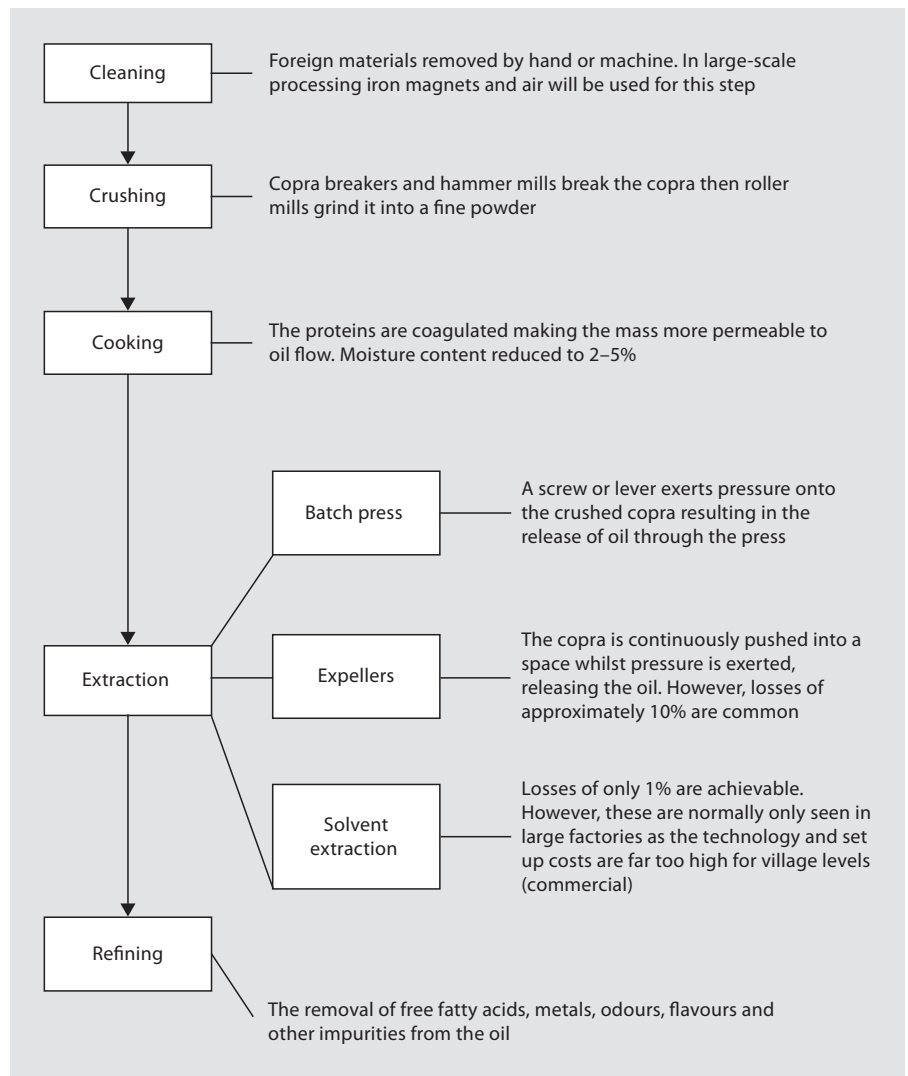


Fig. 2. Example of coconut oil processing.

Low temperature, wet rendering is currently replacing dry rendering. Edible tallow is often produced at 90°C using specialised processing equipment. It has been suggested that the transition from high-temperature rendering to low-temperature rendering may have contributed to the BSE crisis, as the process did not knock out prion proteins.

Dry Rendering

This is the most modern technique and involves cooking the tissues in their own fat at about 115–120°C in steam-jacketed vessels that are agitated. No water or steam is added in this process (hence it is called dry rendering). The cooking time can vary between 2 and 4 h.

The cooked material is then placed on a screen to drain off the free fat by pressing the high-protein solids, separating the remaining 6–10% residual fat. The accumulated fats are then centrifuged or filtered (table 5).

Large-Scale Processing

Large-scale extraction of oils from seeds is achieved through pressing and/or solvent extraction. Most industrial-level oil processing involves solvent extraction, with the refining steps including alkali neutralisation, bleaching and deodorising (fig. 3).

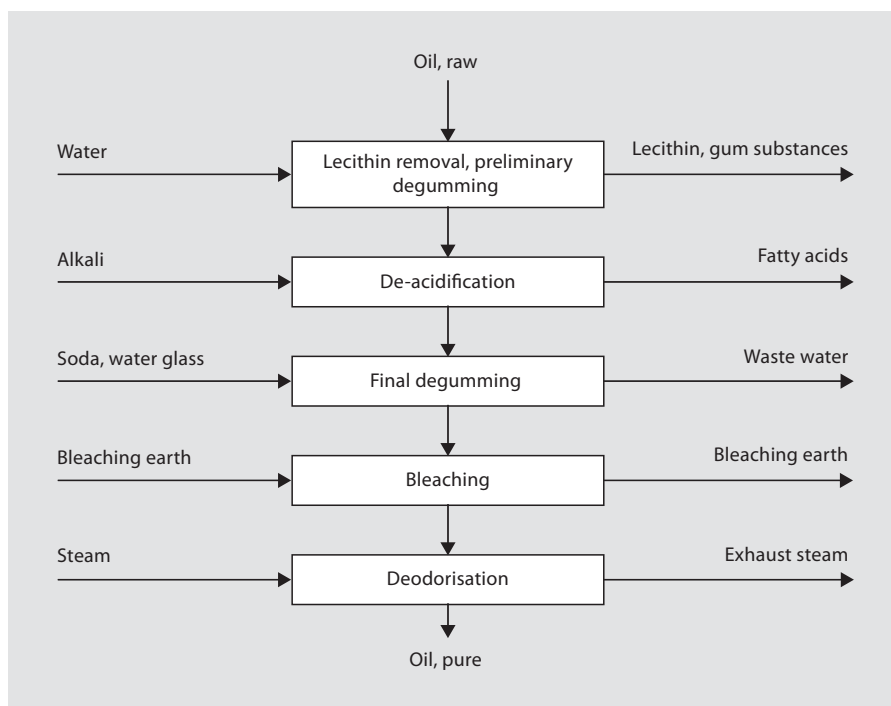


Fig. 3. Flow diagram of industrial oil refining process. Adapted from Belitz et al. [1987].

Table 5. Selected edible oils and fats and their methods of processing as illustrations of processing methods

Source	Method of processing
Canola	Pre-press solvent extraction
Coconut	Hard pressing
Corn (maize)	Wet or dry milling and pre-press solvent extraction
Cottonseed	Hard pressing, pre-pressing or direct solvent extraction
Lard	Wet or dry rendering
Palm	Hard pressing
Palm kernel	Hard pressing
Peanut	Hard pressing or pre-press solvent extraction
Rice bran	Pre-press solvent extraction
Rapeseed/mustard	Direct screw press or direct solvent or pre-press solvent
Sesame	Pre-press solvent extraction
Soybean	Direct solvent extraction
Sunflower	Pre-press solvent extraction
Tallow	Wet or dry rendering

Refining

With the exception of olive oils and a few other culinary oils, most oils undergo a process of refining. During the refining process a number of undesirable compounds are removed. These include undesirable flavours, colours, free fatty acids, waxes, sulphur-containing compounds and phenols. There are 2 forms of refining: chemical and physical.

Whilst the refining process is designed to remove undesirable materials, it can also remove valuable materials such as antioxidants, vitamins and minerals. Some of the valuable materials recovered include phospholipids, free acids, carotenes, sterols, tocopherols and squalene, which can be sold as a by-product. The refining process generally follows 5 steps, which are as follows.

- (1) Removal of lecithin. This step is critical for soybean, canola and rapeseed oils. The phospholipids in the crude oil/water interface are enriched by adding 2–3% water to the crude oil. The resulting emulsion is heated to 80°C and then separated or clarified by centrifugation. The crude lecithin is isolated from the aqueous phase and is recovered as crude vegetable lecithin after evaporating the water in a vacuum. Water degumming is also used to remove lecithin, which can be sold as a by-product.
- (2) Degumming. This is the process for removing phospholipids (gums), which cannot easily be hydrated in step 1. Phosphoric acid (0.1% of oil weight) or caustic soda (sodium hydroxide) is added to the oil to disperse the remaining protein and carbohydrate. The oil is then clarified with the addition of a filtering aid and subsequent filtering. Residual phospholipids are then removed by this processing step, usually by centrifugation.
- (3) De-acidification/neutralisation. This is the process for removing free fatty acids from the oils. The most frequently used method is the removal of free fatty acids by the addition of 15% sodium hydroxide (alkaline refining). However, the 15% sodium hydroxide is not a fixed quantity. The amount used will depend on the free fatty acid content of the raw oil. The oil is heated to 70°C or lower. The soaps precipitate and are then separated by centrifugation. The neutralised oil is then washed with more hot water to remove any remaining soaps. The remaining oil will contain 0.05% free fatty acids. Many modern processes will complete step 2 (degumming) and step 3 (de-acidification/neutralisation) together. The residual soap after caustic refining is neutralised with citric acid simultaneously with earth bleaching. Bleaching is known in industry as ‘adsorptive cleaning’ as it removes hydroperoxides, trace metals and residual gums as well as pigments. This is a very important step, and is a critical step in oil refining.
- (4) Bleaching. Bleaching eliminates the strong yellow, reddish pigment, which is considered undesirable in the oil. The fat or oil is heated to approximately 100°C and then stirred for 30 min in the presence of bleaching earths containing complex silicates in a vacuum at 90°C in order to remove the plant pigments and auto-oxidation products. For difficult oils, activated carbon can also be used. Silicate is added at 0.5–2% of the weight of the fat or oil and is often used together with 0.1–0.4% activated charcoal. The bleached oil is removed from the adsorbent by filtration.
- (5) Deodorisation. This takes place under high vacuum (3–5 mm Hg) with oxygen free steam. It is vitally important that the steam is oxygen free for the formation of bland and stable products. The oil is heated under vacuum to 200–260°C and steam is injected into the oil. Although the main purpose of deodorisation is to remove the unwanted odours, it also removes residual free fatty acids, partial glycerides and pigment decomposition products. The process usually takes 20 min to a maximum of 6 h depending on content of the volatile compounds, the type of fat or oil and the process being used. The process today usually takes approximately 1 h.

Manipulation of Physicochemical Properties of Oils and Fats

Three processes are used to manipulate the physicochemical properties of food lipids: hydrogenation, interesterification and fractionation.

Hydrogenation

This is basically the addition of hydrogen to a fat in the presence of a catalyst in order to obtain different degrees of hardness. Hydrogenation is used to reduce the level of unsaturation in oils and thereby increase the oil’s solid fat content as well as increase stability.

There are 2 processes, which occur during hydrogenation. The first is saturation, where a molecule of hydrogen is added directly across a double bond to give a saturated single bond. This process does not generate *trans* fatty acids. The second process (isomerisation) does generate *trans* fatty acids through the *cis* bond isomerising to give a *trans* bond.

Hydrogenation is particularly useful where it is important to maximise the use of oil. Processing conditions can be modified to create a range of fats and oils with different characteristics, such as melting points. One such example is that of soybean oil, where relatively unstable linolenic acid (C18:3) is converted to more stable fatty acids.

Hydrogenation has been implicated in the formation of *trans* fatty acids that have been linked to coronary heart disease. The principle advantage of interesterification over hydrogenation is from a nutritional perspective. Notably, no *trans* fats are formed during interesterification [Baldwin et al., 1992].

The formation of *trans* fatty acids during hydrogenation has compelled consumers, health authorities and manufacturers to reconsider the process as *trans* fatty acids are considered a health risk. For an increased cost to overall production, the formation of *trans* fatty acids can

be controlled and, to a certain extent, reduced by the use of new catalysts. Another solution is to completely hydrogenate the oil and thereafter interesterify the fully hardened oil with liquid oil.

Interesterification

Interesterification involves a re-arrangement or randomisation of acyl residues in triacylglycerols with the fats and oils taking on new properties. 'Tailored fats' (fats with specific properties) are easily obtained during this phase, as the raw materials and processing conditions can be controlled or manipulated to produce a fat that has specific desired characteristics.

Interesterification has become important for the processing of hardened oil as it minimises the content of *trans* fatty acids in the blend. Interesterification not only minimises *trans* fatty acid production but can also produce no *trans* fatty acids in the end product. Lipases have been developed to retain their activity up to a temperature of 80°C. However, the increased temperature may result in higher free fatty acid and diacylglycerol content, which can alter the end product and may require subsequent refining. The cost of this method of interesterification is high and therefore is currently predominately used for high-value fats and oils.

Lard is an example of how changing the properties of the fat may be achieved through interesterification. This improves the baking properties of lard. The improvements in volume and softness of the baked products are a result of the uniform distribution of palmitic acid in the triacylglycerols.

The most widely used class of interesterification in the food industry is transesterification. Here the ester bonds linking the fatty acids to the glycerol molecule are broken thus releasing the fatty acids. The liberated fatty acids are then randomly shuffled in a fatty acid pool and re-esterified in new positions, either in the same (intraesterification) or in a different (interesterification) glycerol molecule.

Microbial lipases are commonly used in interesterification.

Fractionation

Fat fractionation involves the separation of fat into different fractions depending on the melting point, molecular structure, size and solubility in different solvents. The simplest method used for fractionation is by controlled cooling. The melted fat is slowly cooled until the high melting point triacylglycerols selectively crystallise. The separated crystals are then removed by filtration. In

the processing step of 'Winterisation' of rapeseed (Canola), cottonseed or sunflower oil, small amounts of higher melting point triacylglycerols or waxes are removed, as they would cause turbidity during refrigeration.

Margarine Processing

Historically a mixture of milk or water with oil or fat (not butter) is churned to make margarine. The traditional processing method used milk and oil or fat. However, more recent methods use a mixture of water and oil or fat to produce the margarine. Therefore, today there is a large variety of margarine products available, which are milk free and are made using sophisticated flavours such as lactones. The fats or oils are emulsified with cultured cream, milk or skimmed milk and then chilled, separated from the liquid, washed and salted. Permitted compounds are added to the mixture to give margarine its distinct flavour. Preservatives are also added to stop microbial growth when the margarine is stored without refrigeration.

The oil used for margarine is selected based upon its cost, quality and desired properties of margarine, such as stability, melting point and plastic range. Approximately 16–18% of the margarine is an aqueous milk mixture, which is produced by subjecting pasteurised fresh milk or reconstituted dry milk to a ripening process. The ripening process is induced with the addition of *Streptococcus cremoris* and the milk is held in vats at 20–22°C and at a pH of 5.3–6.3.

The majority of margarine and shortening is manufactured in scraped-surface heat exchangers. Though these will vary in design, the underlying principals are the same. The inner tube has a heated shaft, which runs the length of the tube, on which are mounted floating scraper blades. As the shaft rotates, these blades scrape the internal surface of the tube.

Margarine manufacture is essentially 3 continuous steps:

- (1) emulsification of water within the continuous oil phase;
- (2) chilling and mechanical handling of the emulsion;
- (3) crystallisation, preserving the type of water/oil emulsion by efficient removal of released heat during crystallisation.

There are 5 types of margarines and spreads:

- (1) table margarine (fat content of at least 80% and a maximum of 16% water): there are a large number of specific types falling into this category, including soft, tub, diet, and high in polyunsaturated fatty acids; table margarines tend to be used for spreading, frying and baking;

Table 6. Application of SLs in human health

Application	Investigator	Year
Prevention of thrombosis	Kennedy	1991
Lipids in enteral/parenteral nutrition	Mascioli et al.	1988
Improved nitrogen balance	Mok et al.	1984
Reduced-calorie triacylglycerols	Finley et al.	1994
Enhanced absorption of other lipids	Ikeda et al.	1991
Enhanced immune function	Kennedy	1991
Reduced cholesterol and triacylglycerols	Ikeda et al.	1991

- (2) industrial margarines for baking;
- (3) reduced fat spreads: these contain 60–70% fat and are used for frying and baking, although they can also be used for spreading;
- (4) low-fat spreads: these contain a maximum of 40% fat and can be used for spreading only;
- (5) very low-fat spreads: these typically have a fat content of 3–25%; there are a growing number of these available on the market.

Modification Processes and Implications for Nutrition

There are many processes that can change the nutritional value of oils and fats. One such process is hydrogenation. Soybean and rapeseed oils undergo a light hydrogenation, which reduces linolenic acid in the oils and extends the shelf life of the product. Partial hydrogenation is applied to unsaturated liquid oils to produce semi-solid fats that can be used in spreads and margarines. Partial hydrogenation reduces levels of polyunsaturated fatty acids and causes a rise in monounsaturated acids, including some with *trans* configuration. The *trans* acids have a higher melting point than the *cis* configuration, therefore contributing the desired increase in solid acids.

Structured Lipids

Structured lipids (SLs) or structured triacylglycerols may be broadly defined as triacylglycerols that have been altered or restructured using natural oils and fats. The earliest example of a structured triacylglycerol is the development of medium-chain triglycerides. Using coconut and palm kernel oil, caprylic acid C8:0 and capric C10:0 are liberated. Medium-chain triglycerides are produced by esterification of these fatty acids with glycerol. The most widely available ones have a C8:0 to C10:0 ratio of 10:30. They are also known by the trade name Captrin.

As medium-chain triglycerides are metabolised more like carbohydrates, they do not enter the lymphatic system but enter the portal vein directly. They are widely used as a source of energy in hospital patient feeds. Their application in treating children suffering from protein energy malnutrition may also be considered.

Examples of Applications of Structured Lipids

Human milk is composed of 3–5% fat, with palmitic acid being the most abundant fatty acid. Fats used for infant formulas are usually vegetable oils where the palmitic acid is esterified at the sn-1 or sn-3 position. These fatty acids in the 1,3 position when hydrolysed by lipase tend to form insoluble soaps with calcium and are easily excreted by infants. In order to minimise the formation of calcium soaps and improve fat absorption, Benapol® has been developed to mimic human fat. Benapol is an enzymatically interesterified lipid. Tripalmitin is re-esterified with unsaturated fatty acids from vegetable oils to form triacylglycerols with up to 60% palmitic acid in the sn-2 position, thus resembling the structure of human milk fat.

These SLs offer additional advantages in calcium absorption and improved energy intake. Dietary lipids are an essential source of energy and essential fatty acids.

Application of Structured Lipids in Human Nutrition and Health

One of the earliest uses of SL was in enteral and parenteral nutrition followed by its application in a range of clinical settings (table 6).

SLs containing n-3 highly unsaturated fatty acids were produced with immobilised sn-1,3 specific and non-specific lipases as biocatalysts. Highly unsaturated fatty acids, such as eicosapentaenoic (EPA, 20:5n-3), docosahexaenoic (DHA, 22:6n-3), linolenic (18:3n-3) and gamma linolenic (18:3n-6) acids, are important in foods, nutrition, and pharmaceutical applications. SL containing these fatty acids and medium-chain fatty acids may be desirable as 'nutraceuticals' for supplementation in infant formula or as food supplement for adults to enhance overall health. For the most part, the position of the highly unsaturated fatty acid in the glycerol moiety is key to their functionality in foods and absorption when consumed. Perhaps, these designer lipids may replace conventional fats and oils in certain specialty applications because of their structure-health (nutraceutical or medical lipids) and structure-function (functional lipids) attributes. In most cases, insertion of the desired highly unsaturated fatty acid at the sn-2 position will provide maximum nutritional benefits [Akoh, 2001].

Table 7. Commercial SLs and their food and medical applications

Brand name	Fatty acid composition	Application	Sources
Benefat®	C18:0 (high content) and C2:0, C4:0 or C6:0	Incorporation in reduced-calorie baked products, chocolate coating and nutrition bars	Cultor Food Science Inc.
Betapol™	C16:0 (45%)	Infant food formulation	Loders Crokkan
Bohenin	C18:1 and C22:0	Tempering aid and anti-blooming agent in the manufacture of chocolate and chocolate coating	Fuji Oil Company Ltd.
Captex	C8:0/C10:0 (60%) and C12:0 (30%) or C8:0/C10:0 (40%) and C18:2 (40%)	Pharmaceuticals for parenteral and enteric hyperalimentation, and cosmetic industry	Abitc Corp.
Caprenin®	C8:0, C10:0 and C22:0	Confectionery coating fat	Procter & Gamble
Impact®	Interesterification with high lauric acid oil and high linoleic acid oil	Pharmaceuticals for patients suffering from trauma or surgery, sepsis or cancer	Novartis Nutrition Corp.
Laurical	C12:0 (40%) and unsaturated fat (C18:1, C18:2 and C18:3)	Medical nutrition and confectionery coating, coffee whiteners, whipped toppings and filling fats	Calgene Inc.
Neobee®	C8:0, C10:0 and LCFA (n-6 and n-3)	Nutritional or medical beverages	Stepan Corp.
Structolipid	LCT (63%) and MCT (37%) – caprylic (27%), capric (10%), palmitic (7%), oleic (13%), linoleic (33%) and α-linoleic acid (5%)	Intravenous fat emulsion as a rapid source of energy for patients and parenteral nutrition	Fresenius Kabi

Adapted from Lee and Lee [2006]. LCFA = Long-chain fatty acid; LCT = long-chain triglyceride; MCT = medium-chain triglyceride.

The design of SLs with selected fatty acids at specific locations of the triacylglycerol is also beneficial for medicinal applications. For instance, it is appropriate to develop an SL containing polyunsaturated fatty acids at the sn-2 positions with medium-chain fatty acids at the sn-1,3 positions for patients with maldigestion as well as cystic fibrosis. An SL containing a mixture of medium- and long-chain fatty acids is useful in alleviation of specific diseases and metabolic conditions. The n-3 fatty acids such as α-linolenic acid, EPA and DHA have health benefits related to cardiovascular disease, inflammation, allergies, cancer, immune response, diabetes, hypertension and renal disorders. Despite the health benefits of SLs containing polyunsaturated fatty acids, they are highly prone to oxidative deterioration and thus require adequate protection to deter their oxidation. Further research is necessary to optimise their stabilisation and storage by use of appropriate antioxidants and packaging technologies [Shahidi and Hamam, 2006].

Other Applications of Structured Lipids

There are several commercial products such as low-calorie oils and infant formulas that make use of SLs. In addition, SLs find applications in following foods:

- cocoa butter substitutes;
- confectionery;
- snack foods;
- low-calorie foods;
- baked products;
- frying oil;
- dairy products (melting points);
- margarines;
- spreads (improved melting point);
- candy.

Enzymotec produce a similar fat to that of Betapol called Infat™, which is made by enzymic esterification and is being promoted for infant formulae (table 7).

Conjugated Linoleic Acids

These are a group of fatty acids, which are positional, and geometric isomers of octadecadienoic acid (18:2) and more commonly referred to as conjugated linoleic acids (CLAs). The double bonds in the CLAs are not separated by a methylene group (-CH₂-) and are therefore conjugated. This is typical of the double bonds in polyunsaturated fatty acids, such as linoleic acid (LA or 18:2n-6) – an n-6 essential fatty acid. The main sources of CLA isomers are dairy and beef products (or products derived

from ruminant sources) since the process of bacterial biohydrogenation of polyunsaturated fatty acids in the rumen leads to their formation, however, many other foods contain CLAs as well.

Chemically prepared CLA mixtures or natural products containing octadecadienoic acids have been reported to contain conjugated double bonds at positions 7,9; 8,10; 9,11; 10,12; 11,13 and 12,14 along the alkyl chain (counting the carboxyl end of the molecule). There are potentially 24 possible isomers for the positional conjugated diene isomers of CLAs occurring in 1 or more of the following 4 geometric configurations: *cis,trans*; *trans,cis*; *cis,cis*; *trans,trans* ('c' and 't' can also be used to represent 'cis' and 'trans' respectively). Commercially available preparations of CLAs are produced under alkali conditions from vegetable oils containing high concentrations of LA. Commercially produced CLAs are generally comprised equally of 2 CLA isomers c9,t11 and t10,c12, with some smaller amounts of other isomers present depending upon the raw materials and manufacturing processes used. However, it should be noted that the composition of commercial CLAs and isomeric distribution can vary considerably between batches and manufacturers. Natural CLAs are formed through bacterial bio-hydration and contained mainly in the c9,t11 isomer, which accounts for approximately 80% of the total CLA isomers present in foodstuffs.

The most common CLA isomer present in meat from ruminant animals and bovine dairy food products is the octadeca-c9,t11-dienoic acid. Other minor components such as the t7,c9; t8,c10; t10,c12; t11,c13; c11,t13, and t12,t14 isomers, and their c,c and t,t isomers, can also be present.

It is thought that the CLA in ruminant meat and dairy products is formed by bacterial isomerization of LA and possibly of α -linolenic acid (18:3n-3) from grains and forages to the c9,t11-18:2 in the rumen of these animals. CLAs may also be formed during cooking and processing of foods.

Food Sources of CLA

Dairy products and the fat in the meats of lamb, veal calves and cattle contain the highest concentrations of CLA for food sources. Although a larger number of different isomers can be found in food, the main isomer of CLA in food is the c9,t11 isomer. A brief summary of these sources of CLA in common foodstuffs is presented in table 8.

Dietary intake of CLAs ranges from country to country but is estimated to be on average 0.36 g/day for wom-

en and 0.44 g/day for men. Many experts believe that this average intake is not adequate to elicit the biochemical, molecular and physiological effects against cancer, atherosclerosis, and obesity based on animal studies and models. These animal studies suggest that a reasonable intake to initiate these benefits would be 3.0 g per day, which is possible to achieve if existing food sources are enriched with CLAs.

CLA is also present in other non-ruminant animal products. Of these, turkey has the highest concentration with 2.5 mg/g fat, chicken contains 0.9 mg/g fat, pork 0.6 mg/g fat with c9,t11 being the main isomer at 84 and 82%, respectively, for the chicken and pork. The amount of CLA in chicken egg yolk ranges from 0 to 0.6 mg/g fat. Although these animal sources contain small amounts of CLA they too can be enriched with dietary manipulations and interventions.

The Importance of CLA in Human Nutrition

The effects of CLA isomers on human health have been investigated, including their effects on body weight, lipid metabolism, insulin resistance, diabetes and immune function. However, at present, the results are equivocal and therefore no recommendations have been made. The reason for some of the differences in findings can be explained by the differences in isomers given as supplements, age, gender and health status of the subjects and duration of the studies.

Weight Loss

Many studies have investigated the effect of CLAs on weight loss and control. Animal studies have provided conclusive evidence that CLAs reduce body fat, weight and increase lean mass in pigs [Dugan et al., 1997], mice [Park et al., 1997; DeLany et al., 1999; Pariza et al., 2000], rats and chicks [Martin et al., 2000; Pariza et al., 2000; Wang et al., 2003]. However, human studies have been less convincing. Some studies have described a positive effect of CLA in reducing body fat, particularly abdominal fat, change in serum total lipids and a decrease in whole body glucose uptake [Blankson et al., 2000; Smedeman and Vessby, 2001; Thom et al., 2001]. However, other studies have failed to show any marked changes [West et al., 1998; Blankson et al., 2000; Riserus et al., 2001; Smedeman and Vessby, 2001; Thom et al., 2001]. Zambell et al. [2000] found that CLA supplementation (3 g/day) had no effect on body composition or energy expenditure in 17 healthy females studied for 64 days following a baseline period of 30 days.

Table 8. Food content and isomeric distribution of CLA in commercial and natural food products

Product	CLA content mg/g fat	C9,t11 %	CLA isomers
Natural cheeses			
Blue	0.55–7.96	15–100	c9,t11; t9,c11; c10,t12; t10,c12; c9,c11; c10,c12; c11,c13; t9,t11; t10,t12
Cheddar	1.36–5.86	18–100	c9,t11; t9,c11; c10,t12; t10,c12; c9,c11; c10,c12; c11,c13; t9,t11; t10,t12
Cottage	4.5–5.9	83–100	c9,t11
Mozzarella	4.31–4.96	84–100	c9,t11
Processed cheeses			
Processed Kraft	1.81–6.2 3.19	18–100 58	c9,t11; t9,c11; c10,t12; t10,c12; c9,c11; c10,c12; c11,c13; t9,t11; t10,t12 c9,t11
Butter and milk			
Cow's milk	0.7–10.1	59–100	c9,t11; t9,c11; c10,t12; t10,c12; t7,c9; c9,c11; c10,c12; c11,c13; t9,t11; t10,t12
Butter	4.7–8.11	78–90	c9,t11
Fermented dairy products			
Buttermilk	4.66–5.4	89–100	c9,t11
Sour cream	4.14–7.49	78–100	c9,t11
Yoghurt	1.7–9.01	71–100	c9,t11
Ice cream			
	3.6–4.95	76–86	c9,t11
Beef			
Uncooked beef products	1.2–8.5	21–61	c9,t11; t9,c11; c10,t12; t10,c12; c9,c11; c10,c12; c11,c13; t9,t11; t10,t12
Cooked beef	3.3–9.9	19–84	c9,t11; t9,c11; c10,t12; t10,c12; c9,c11; c10,c12; c11,c13; t9,t11; t10,t12

Adapted from Watkins and Li [2006].

Role of Nutrition in Developing New Fat-Based Food Products

Development of Products Based on Nutritional Advances

Global concern about obesity, cardiovascular disease and cancer has prompted the food industry to formulate and develop a range of new foods. These foods have the following characteristics:

- reduced fat content;
- increase in polyunsaturated fatty acids notably EPA and DHA;
- reduced saturated fats;
- reduced *trans* fatty acids;
- fortified with phytosterols and other functional ingredients.

Reduced Fat Content

A large segment of the adult population in Western countries consume low-fat reduced-calorie products. Examples of this include the consumption of low-fat margarine and spreads, fat substitutes, and functional foods

that contain bioactive molecules that provide specific health benefits [Gershoff, 1995].

Fat-Based Foods Developed to Enhance Satiety

Satiety is the feeling of fullness felt between meals and usually inhibits resumption of feeding. A fat emulsion, Fabuless® (formerly known as Olibra®) developed from a palm oil and oat oil fraction has been shown to increase satiety and reduce overall food intake in human subjects [Burns et al., 2000, 2002]. Fabuless is now incorporated into a range of products including yoghurt and other dairy-based foods.

Development of Low-Energy Density Foods

Global concerns about obesity have stimulated food companies to develop a range of low-energy density foods. These low energy density foods have been shown to decrease energy intake and may lead to changes in body weight [Kral et al., 2002]. The use of fat replacers and fat mimetics has the potential to lower the energy density of foods thereby enabling consumers to be in negative energy balance [Astrup et al., 2000].

Diacylglycerols

An alternative to cooking oil was developed in Japan in 1999 and are commonly called diacylglycerols (DAG). These cooking oils are usually of 1,3 configuration. Whilst the DAG cooking oil tastes, smells and feels like oil, it is metabolised differently. Feeding trials have shown that the ingestion of these cooking oils not only reduced postprandial lipidemia but also reduces fat accumulation due to increased fatty acid oxidation [Flickinger and Matsuo, 2003].

More recently, clinical studies in humans have suggested that the consumption of DAGs compared to triacylglycerols suppressed body weight, altered the composition of fat deposition and reduced postprandial lipidemia [Kunio, 2001; Yamamoto, 2001].

Both animal and clinical studies have indicated DAGs lower postprandial serum triglyceride levels (up to 23% as compared to triglycerides) and serve as a dietary component that affects body weight and body fat levels. DAG has also been reported to enhance the activity of enzymes involved in β -oxidation, suppress the activity of enzymes involved in fatty acid synthesis [Murat et al., 1997], and also stimulate expression of genes involved in lipid metabolism [Murase et al., 2002a, b]. DAG has been shown to promote the formation of ketone bodies both in humans and animals. The limited human evidence does not support a thermogenic effect, but the increased fat oxidation may suppress appetite [Kamphuis et al., 2003]. The mechanisms of action of DAG are suggested to decrease the resynthesis of chylomicrons as well as shunting them directly to the liver through the portal vein, where they are oxidised. This increased fat oxidation may influence control of food intake by increasing satiety. Further study into the precise mechanism is required to understand its effects. Safety studies show no risks in consuming a diet rich in DAG oil. Overall, consumption of oils with higher amounts of DAG, specifically 1,3-DAG, may be useful in the battle against obesity [Rudkowska et al., 2005].

Relatively large doses (>10 g/day) are necessary in humans for modest reductions of postprandial triglyceridemia after 4–6 h, although long-term use at the same level modestly reduces weight. Dose-effect relationships are required to indicate the exact dose required. DAG oil has been commercially available in Japan since 1999 and its nutritional properties have been recognised through approval from that country's Foods for Specified Health Use (FOSHU) regulatory system. In the US, DAG oil has been introduced to American consumers.

Fat Replacers: What Are They?

Consumer demand for reduced-fat food products with appearance, textures and flavours similar to full-fat counterparts has generated considerable interest in the development of fat replacers. Approaches to reduce the high-energy properties of fats in foods are based on one or more of the following principles:

- replace fats with combinations of water and surface-active lipids or non-lipid additives with lower-energy contributions such as proteins and/or polysaccharides;
- utilise compounds such as cetoglycerols and medium-chain triacylglycerols that contribute less energy per gram;
- replace fats with compounds that significantly differ in structure of triacylglycerols;
- replace fats with compounds having fat-like functionality and structures similar to common lipids with modified ester linkages, including such compounds as glycerol ethers, pseudo fats and carbohydrate fatty acid esters.

From a practical viewpoint, fat replacers are broadly classified as 'fat mimetics' and 'fat substitutes'.

Fat Mimetics

These are products that mimic or imitate the organoleptic or physical properties of triacylglycerols, and are labelled as stabiliser or humectant ingredients. They generally absorb a substantial amount of water, and are based on natural or modified polysaccharides such as gums, starches, pectins or cellulose. Micro-particulation of proteins is another approach that provides the creamy feeling in the mouth from fats and oils in foods. These mimetics cannot deliver thermal stability or heat transfer during high-temperature cooking due to either caramelisation (in the case of polysaccharides) or denaturation (in the case of proteins), although products that could withstand baking and retorting have been developed. Another problem associated with these mimetics is their inability to carry lipid-soluble flavouring compounds, although water-soluble flavours are not a problem. These cannot be substituted on a gram-to-gram basis, and contribute 0–4 kcal/g depending on concentration, digestion and absorption.

Fat mimetics are classified by their micronutrient base as follows:

- polydextrose, a poorly digested, randomly bonded polymer of glucose, sorbitol and citric or phosphoric acid;
- protein-based mimetics blended with selected gums from gels that provide structure and functionality similar to the structure and mouth feel of fats;

- fat 'barriers' that inhibit oil absorption in foods by altering the surface tension, structure or area.

Commercial examples of fat mimetics are available under the brand names Kelcogel® and Simplese®. Simplese is a microparticulated protein that has been approved by the US Food and Drug Administration. It is principally derived from egg and milk proteins and provides a fat-like creamy feel in the mouth. It is widely used in low-calorie foods such as soup, yoghurt, cake and mayonnaise. It has the benefit of providing only 2 kcal/g and can be used to replace animal fat in a food product. It cannot be used in any food system that requires heat treatment.

Fat Substitutes

These are macromolecules that physically and chemically resemble triacylglycerols and can replace oils and fats on a gram-to-gram basis. Basic strategies for developing this group of fat replacers are essentially based on one of the following approaches:

- replacement of glycerol moiety of triacylglycerols with alternative alcohols such as carbohydrates, sugar alcohols, polyols or neopentyl alcohol – examples of this group which have been approved by FDA are sucrose fatty acid esters, sucrose polyesters and sorbitol fatty acid polyesters;
- replacement of long-chain fatty acids with alternative acids such as branched carboxylic acid esters of glycerols, and structured lipids containing short-, medium- and long-chain fatty acids esterified to glycerol;
- development of microcapsules that will replace the discontinuous lipid droplets in emulsified foods.

Sucrose Polyesters. This is a mixture of hexa-, hepta-, and octaesters of sucrose with long-chain fatty acids isolated from edible fats and oils, and is now recognised as Olestra® or Olean®. Originally developed by Procter & Gamble in 1971, the functionality, physical properties and potential applications depend on the chain lengths and saturation of the fatty acids used in the synthesis of sucrose polyesters. It can be used as 100% replacement for frying of savoury snacks. The lipases in the human body are unable to metabolise sucrose polyesters and hence they provide zero calories [Kinsella, 1988; Gerstoff et al., 1995]. The FDA have given the following conclusions with respect to Olestra: (i) it is not toxic, carcinogenic, genotoxic or teratogenic; (ii) all safety issues have been addressed, and (iii) there is reasonable certainty that no harm will result from the use of Olestra in savoury snacks.

However, Olestra may need to be used in small amounts as excessive consumption may lead to diarrhoea and the leaching of certain fat-soluble vitamins from the body.

Structured Medium-Chain Triacylglycerols. This is available under the brand name Salatrim® developed by the Nabisco Foods Group. Caprenin® was developed by Procter & Gamble.

Salatrim is an acronym for 'short- and long-chain acid triacylglycerols molecules'. This is a structured triacylglycerol exhibiting the physical properties of fat but providing only a fraction of its energy content (5 calories/g). Unlike polyol esters, it can be included in low-moisture foods. The principles behind the properties of Salatrim are that stearic acid is only partially absorbed in the body and short-chain fatty acids provide relatively few calories. It is produced by replacing the long-chain fatty acids in hydrogenated oils with short chains (acetic, butyric, propionic) and redistribution of fatty acids in the glycerol molecule.

Carpenin is made up of behenic, caprylic and capric acids. It is recommended for use as a cocoa butter substitute. Similar to Salatrim, the behenic acid in Carpenin is only partially absorbed by the body whilst the medium-chain fatty acids are metabolised in a similar manner to carbohydrates.

Salatrim and Carpenin cannot be used for frying due to the generation of intense off flavours.

Other Approaches (Multiple Emulsions)

This involves replacing some of the fat inside fat globules (in an oil/fat emulsion) with water droplets. As a result, the fat content and the subsequent energy density is reduced. The physio-chemical properties of a multiple emulsion are expected to be similar to that of a normal oil-in-water emulsion. However, maintaining the stability of multiple emulsions over long periods of time has proven difficult and therefore is not widely used (table 9).

Improved Intake of EPA/DHA

Polyunsaturated fatty acids are broadly divided into 2 categories: the n-6 and n-3. The n-3 long-chain polyunsaturated fatty acids, notably EPA and DHA, have recently drawn considerable interest due to their extensive health benefits. Whilst fish oil and fish are rich sources of DHA and EPA, their consumption is both limited and poor. The provision of preformed EPA and DHA from marine oils has profound implications for health and disease. Their role as precursors for the synthesis of eicosanoids and docosanoids explains many of the multi-systemic effects observed when they are administered. Furthermore, under some physiological conditions (such as preterm birth), there is evidence to suggest that C18 n-3 fatty acids are not sufficiently converted to DHA to allow

Table 9. Synthetic fat substitutes and their regulatory status

Fat substitute	Chemical composition	FDA approval	Potential applications
Polydextrose	modified glucose polymer	GRAS	bulking agent, humectant, texturiser
Caprenin	structured medium-chain triacylglycerol	GRAS	cocoa butter equivalent
Salatrim, Benefat	two medium-chain fatty acids and one long-chain fatty acid in a triacylglycerol	GRAS	cocoa butter equivalent
Olestra, Olean	sucrose fatty acid polyester	approved January 1996, July 2004	savory snacks, prepackaged ready-to-eat popcorn
Sucrose fatty acid esters		approved	emulsifier
Sorbestrin	cyclic sorbitol fatty acid polyesters	no approval	frying or baking oil, salad dressings
Polyglycerol	polyglycerol fatty acid esters	no approval	shortenings, margarines, confectionaries
Retrofat	trialkoxyltricarballylate	no approval	shortenings, mayonnaise
Trialkoxy citrate	ester bonds reversed from triacylglycerol	no approval	similar to corn oil
Trialkoxy glycerol ethers	dialkyl glycerol ethers, glycerol monoester diethers	no approval	vegetable oils
Dialkyl dihexadecylmalonate	fatty alcohol dicarboxylic acid esters of malonic acid and alkylmalonic acid	no approval	mayonnaise, margarine, salad dressing
Polysiloxane, phenylmethyl polysiloxane, and phenyl-dimethyl polysiloxane	organic derivatives of silica	no approval	functionality similar to soybean oil
Esterified propoxylated glycerol	polyether polyol fatty acids	no approval	vegetable oils
Joboba oil	linear esters of C20:1 and C22:1	toxic?	edible oils
Membrane lipids	extracts of <i>Halobacterium halobium</i>	expensive?	fat-like materials

From Swanson [2006]. GRAS = Generally Recognized as Safe notice.

for biochemical and functional normalcy; thus DHA may be considered a conditionally essential nutrient for normal eye and brain development. Under disease conditions, EPA plays a major role in modifying the balance between n-6- and n-3-derived eicosanoids, thus modulating related functions.

The use of marine oils has some potential risks that can be circumvented by careful processing, storing and preserving the unsaturated fatty acids. Technological procedures based on chemical and physical separation of the unsaturated fatty acids have permitted the elaboration of concentrated EPA and DHA for clinical testing. The development of structured lipids has allowed the synthesis of novel forms of EPA and DHA delivery [Uauy-Dagach and Valenzuela, 1992].

Fortification of foods regularly consumed with EPA/DHA appears to be an alternative strategy. The fortification of foods with EPA/DHA poses several technical problems. First, these fatty acids are highly susceptible to oxidation and are prone to rancidity. Second, they also impart a fishy flavour. In order to maximise stability and minimise off-flavour, food manufacturers observe the following processes:

- minimise access to oxygen;
- minimise contact with heavy metals and light.

Foods rich in fats, such as spreads, margarines and salad dressings, are good media for the addition of EPA/DHA. Recent advances in micro-encapsulation of EPA/DHA have allowed a range of foods to be fortified with these polyunsaturated fatty acids. The foods include

snacks, juices and soft drinks, pasta, margarine, bread and bakery products.

Micro-encapsulation is the process by which individual particles of an active compound (in this case EPA/DHA) is surrounded by a coating to produce a microcapsule in the micrometer range. The commonly used coatings include gelatine, starch and waxes.

Reduced Trans Fatty Acids

In 1993, Walter Willet from Harvard University produced a paper that drew critical attention to the negative nutritional effect of consuming *trans* fatty acids [Willet, 1993]. In the intervening years, numerous fat-containing foods have been developed called ‘virtually *trans* free’, suggesting a level of *trans* fatty acid of less than 1% in the lipid phase.

Hydrogenated vegetable oils remain the most important source of *trans* fatty acids in our diet. Hydrogenated vegetable oils and fats from ruminant animals may contain up to 20 *trans* and *cis* positional isomers.

Manufacture of Trans-Free Lipids

Many of the *trans*-free lipids are made into spreads, margarine, shortening and frying oils. There are numerous ways of producing these *trans*-free lipids. Table 10 summarises some of these methods.

Processing Losses

Oils from nuts and seeds are a very concentrated form of energy, high in calories and very nutritious. Nuts and seeds also contain a substantial amount of protein. The nutritional value of the oil is directly related to the fatty acid content of the oil. High LA content decreases the shelf life of oils. From a nutritional viewpoint, high LA content is desirable due to this being an essential fatty acid. There is currently no evidence to demonstrate that the degree of roasting of the seeds has any effect on the oil’s nutritional value. However, the amount of heat applied when roasting has a substantial effect on the oil’s antioxidant content. Heat reduces the antioxidant content in the roasted seeds and nuts by up to 25%. Whilst oils are usually not recognised as an important source of vitamins and minerals in the diet, the exceptions are that they are rich sources of tocopherol and carotene. The blending of vegetable oils to provide higher thermal stability has now been recognised. The concept is based on using naturally occurring antioxidants in oils to minimise fat oxidation.

In recent years the nonglyceride components of vegetable oils have received considerable attention as they

Table 10. Methods to manufacture *trans*-free/low-*trans* fatty acid products

Food system	Method
Frying oil	interesterification and fractionation to obtain olein fraction
Margarine	<i>trans</i> -esterification of stearic fats with vegetable oils using lipase
Margarine – hard stocks	interesterification of palm fats with high palmitic acid with hard lauric fats
Spread	blend of interesterified hard stock and vegetable oil
Shortening products	mixture of vegetable oils rich in stearine fraction combined with diglycerides
Confectionery fat	fractionation of high stearic soy oil

contribute to shelf life and thermal stability at frying temperatures and have cholesterol lowering and/or antioxidant effects.

The contribution of phytosterols from natural food fats and vegetable oils (corn oil, ricebran oil), sesamin (sesame seed and oil), oryzanol (rice bran oil) in lowering serum cholesterol has been well documented. Sesame ligands, oryzanol, phenolic compounds (olive oil) contribute to increasing the antioxidant potential of food or the diet [Hemalatha and Ghafoorunissa, 2007].

Uses of Processed Fats and Oils

In the Home and Processed Food Industry

Oil is used for cooking in its natural, unprocessed form or after processing, depending on the customs and beliefs of the consumers. The most important feature of margarine for the consumer is the spreadability, which goes hand in hand with oiliness and melting properties.

The properties of fat that make it an important component in foods include the following:

- it forms emulsions with water and air, air may be trapped as an emulsion in fat, as observed in whipped cream;
- it acts as a lubricant in foods;
- it acts as a shortening, interacts with both protein and starch structures to minimise the elongation of the protein structure;
- it contributes to both flavour and aroma of foods;

- fats impart mouthfeel and facilitates ease of swallowing of foods;
- fats and oils are excellent frying media.

Table Margarines. These contain a fat blend, which is designed to be spreadable at room temperature and straight from the fridge. Therefore, table margarine usually contains a high proportion of liquid oil and solid fats, which melt in the mouth, but they must also provide sufficient body to the margarine over the desired temperature range.

Soybean oil is commonly used in spreadable margarines, although palm oil, lauric fat, and partially hydrogenated marine oils are also used. Dairy products, emulsifiers, preservatives, flavours, vitamins and colours are ingredients also added to margarines to enhance properties such as colour and flavour.

Reduced-Fat and Low-Fat Spreads. These contain less than the legally required limit of fat for a margarine or butter and therefore cannot be called either, although the public will often still refer to them as this. They generally contain a higher percentage of water than butters or margarines and as such are usually not suitable for anything other than spreading.

Cake Margarine. Table margarine is acceptable for home cake baking but commercial units use a special margarine that has a wide plastic range, high creaming power and an ability to impact shortness to baked goods. Cake margarine has moisture content of 16% if it is classified as margarine. However, they may also be dry shortenings with no moisture. Therefore, a high melting point fat and liquid oil are blended together in its production.

Mayonnaise and Salad Dressings. Mayonnaise is a semi-solid food prepared from no less than 65% vegetable oil, egg yolk and vinegar. Salad dressings were developed to complement mayonnaise, with the standard of a salad dressing not to be less than 30% vegetable oil, vinegar, not less than 4% egg yolk and thickened by starch. The egg yolk phospholipids stabilise the emulsion, whereas products containing less than 50% oil contain a thickening agent instead. A salad oil or dressing must display oxidative stability and clarity in appearance.

Dairy Fats

Butter. The raw material for butter is milk fat, which is separated from milk to form cream that contains 30–40% fat. The cream is churned whereby the emulsion is disrupted and butter granules are formed. Spreadable butter is made using a similar process to that of margarine by utilising continuous scraped-surface heat exchangers. A

cream and anhydrous milk fat or milk fractions are used to initiate the process.

Dairy Spreads. Products with high EPA are often a blend of vegetable oil and cow's butter or cream. These usually have less than 80% fat and therefore may not be described as a butter or margarine. Dairy spreads have a similar taste to butter but can be spread straight from the fridge.

Ghee. Ghee is clarified butter from cow's or buffalo milk. It is extensively consumed in India and other south Asian countries, including parts of east Africa. Ghee manufacture is still a village-level process in most parts of India. Heat is applied either to the butter or cream to remove almost all the moisture from butter. This process of heating imparts a characteristic flavour and aroma.

Vanaspati. Vanaspati or vegetable ghee is a substitute for natural ghee and is principally based on hydrogenated vegetable oils. Vanaspati still remains a major oil consumed in many parts of India and South Asia. The common oils used in the manufacture of Vanaspati include palm, maize, sunflower, mustard, and cottonseed and rice bran oil. Vanaspati has a similar texture and colour to natural ghee. Vitamin A is added along with refined sesame.

Confectionary Fats

These fats must melt over a narrow temperature range and therefore are characterised by their high levels of symmetrical triacylglycerols obtained by fractionation. Oils rich in C14 fatty acids form the basis of cocoa butter substitutes. As the C14 fatty acids are incompatible with the C18-rich fats in crystallised form, care must be taken to exclude the lauric oils from cocoa butter equivalents.

Fats for Chocolate and Sugar Confectionery

The traditional fat component in chocolate and chocolate-based confectionery is cocoa butter, milk fat and a selection of vegetable oils. Cocoa butter is the fat extracted from the seeds of the *Theobroma cacao* tree. The cocoa beans consist of approximately 55–60% fat. Top quality cocoa butter is produced by hydraulic pressing of the cocoa beans followed by solvent extraction of the residual cake. A unique property of cocoa butter is its very narrow melting point, between 30 and 40°C. The melting point of cocoa butter falls within the human body temperature, making it a fat that provides a unique gustatory experience. Cocoa butter melts in the mouth with a pleasant soothing sensation. The major fatty acids in cocoa butter are palmitic, oleic and stearic acids. In recent years a series of cocoa butter substitutes have been developed that are composed of a variety of oils extracted from the plant sources listed in table 11.

Puff Pastry Fats

These fats need to be tough and elastic in order to produce a good lift of the layers of dough and fat. Relatively high solid glyceride contents are used in order to gain the right consistency for the fat that is preferred for this type of cooking. Lard containing 12–15% fully hydrogenated lard is often used to produce a good puff pastry. Vegetable-based fats utilise palm stearin and hydrogenated palm oil together with other hydrogenated vegetable oils. After chilling, the fat is left to crystallise before being plasticised and extruded. Table 12 shows typical fat blends for bakery fats.

The functions of fat in bakery products include:

- shortening power and lubricity;
- batter aeration;
- emulsifying properties;
- provision of impervious layer;
- improvements in keep properties;
- provision of flavour.

Dough Fats

In order to avoid bloom development during the life of the biscuit, biscuit dough fats must be β -prime stable. Palm or hydrogenated palm oils are used to achieve the β -prime polymorph in vegetable blends. The following criteria are required for dough fats:

- the melting profile must be sharper than that for other shortenings; at 35°C there must be less than 5% solid triacylglycerols and a maximum of 0.5% at 40°C;
- at 100°C the oxidative stability needs to be high (a minimum of 40 h) for a long shelf life, therefore liquid oils are normally excluded from blends, except for some specialised 'health' biscuits.

Cream Fats

These require medium to high solid triacylglycerols at ambient temperatures, alongside a rapid melting point and zero solid triacylglycerols at body temperature. The fat must set quickly and give a good coherence to the bis-

Table 11. Raw materials/oils used for producing cocoa butter alternative

Raw material (botanical name)	Origin
Palm oil	Indonesia, Malaysia
Shea butter (<i>Butyrospermum parkii</i>)	West Africa (dry tropics)
Illipe butter (<i>Madhuca longifolia</i>)	Borneo
Sal fat	India
Mango kernel	India

Adapted from Stewart and Ralph [2002].

Table 12. Typical fat blends for bakery fats

Product	All-vegetable blend	%	Not all-vegetable blend	%
Sweet paste	Hyd. palm oil (mpt 50°C)	10	Hyd. marine oil (mpt 35°C)	50
	Hyd. rapeseed oil (mpt 35°C)	35	Tallow	25
	Palm oil	20	Rapeseed oil	25
	Rapeseed oil	35		
Boiled pie paste	Hyd. palm oil (mpt 44°C)	15	Tallow	90
	Hyd. soybean oil (mpt 35°C)	55	Rapeseed oil	10
	Rapeseed oil	30		
Puff pastry	Hyd. palm oil (mpt 45°C)	65	Hyd. fish oil (mpt 46°C)	40
	Palm oil	25	Palm stearin	35
	Rapeseed oil	10	Rapeseed oil	25
	Plastic blend		Fluid blend	
Bread dough	Palm stearin	45	Hyd. rapeseed stearin	8
	Hyd. rapeseed oil (mpt 35°C)	35	Rapeseed oil	92
	Rapeseed oil	20		

Hyd = Hydrogenated; mpt = melting point. Adapted from Stewart and Ralph [2002].

cuit on the production line. Coconut and palm kernel oil (the lauric oils) make ideal starting oils for these blends. Hydrogenated rapeseed and soybean can be used singularly or in combination with the lauric oils.

Shortenings

The term 'shortening' describes the use of fat to impart shortening of the protein and carbohydrate fractions of the flour used in bakery products. Shortened fats contain little or no moisture. Most shortening blends have air or nitrogen added (between 8 and 15% by volume) prior to chilling to give a white appearance.

Shortening contains 100% animal or vegetable fat and is commonly used in baking, frying, cooking and confectionery items. The large number of air bubbles incorporated into the shortening improves the leavening of baked products.

Shortening Blends

Manufacturers aim to have a large range of shortening blends available so that there is always a low-cost option. Products containing shortening blends without middle melting triacylglycerols, produce baked goods of a satisfactory quality but with some loss of eating quality due to the increased level of high-melting triacylglycerols. The product is chilled above its melting point throughout the processing procedure, including tempering and annealing. An advantage of this type of blend is an extended plastic range. During the summer months, most manufacturers increase the solid triacylglycerols in their products by 2–4%. Shortening blends based upon hydrogenated marine oils have good cake-making properties, but an increased trend for all-vegetable shortenings has seen a decline in the demand for marine-based products.

Frying Oils

These oils need to be stable under high temperatures, have a high smoke point and a minimum tendency to form foam during use; this is achieved by using oils with a low level of un-saturation concomitant with good eating quality and very low traces metal content. Suitable oils include lightly hydrogenated soybean or rapeseed oil, with linolenic acid levels reduced below 3%, and blends of palm and vegetable oil. Suitable oils for foods that are blast-frozen (such as French fries) are palm or hydrogenated palm oil.

Deep fat frying is normally carried out at high temperatures (between 160 and 180°C) in the presence of air and moisture. The most important reaction is the forma-

tion of steam generated by contact of hot oil with the water present in food. Steam hydrolyses triacylglycerols of frying oil. Consequently, the physical and chemical properties of the oil change considerably because of hydrolysis, oxidation, and thermal alteration, which directly influence the functional, sensory and nutritional quality of the oil. The kinetics of these degradation reactions is influenced by several factors such as food composition, food-to-oil ratio, frying temperature, and oil composition [Ramadan, 2007].

Migration of the food components into the oil during frying due to leaching from the food can significantly alter the quality and the composition of the oil. Six main groups have been identified to influence the oil quality significantly [Segall and Artz, 2006]:

- phospholipids and oxidation products with emulsion functionality that can cause foaming;
- maillard browning pigments and other pigments;
- phenolic compounds present naturally in foods;
- off-flavour compounds derived from the foods;
- cholesterol and its oxidation products;
- trace metals (e.g. iron) that can accelerate the oxidation process.

In the case of fatty foods, fat is released from fried food into frying oil. Proteins inhibit oxidation reactions, with formation of lipid-protein complexes, but excessive temperatures may cause formation of heterocyclic mutagens, mainly isoquinolines and isoquinoxalines. The oxidation of frying oil is inhibited by various other components of fried food, such as tocopherols, carotenoids, phenolics or certain sterols, mainly avenasterols. On the contrary, heavy metals, chlorophylls and other pro-oxidants are released into oil, enhancing its oxidation. Fried food contributes to the formation of flavour substances, such as pyrazines, pyrroles or sulphides, which modify the typical fried flavour [Pokorny and Reblova, 1999].

Losses from the Frying Oil

The changes in oil quality characteristics and fatty acid composition of soybean oil under frying conditions was investigated by Tyagi and Vasishtha [1996]. Changes in fatty acid profile during frying were notably among the unsaturated fatty acids. In contrast, the saturated fatty acids (myristic, palmitic and stearic) remained constant. After 70 h of frying, oleic acid (C18:1) showed gradual decrease from 26.7 to 20.7%. In comparison, after 70 h LA (C18:2) deteriorated much faster, with a loss of 52%. Losses in linolenic acid (C18:3) were even higher and amounted to about 72%. During frying, a progressive decrease in iodine value was observed, confirming the loss of unsat-

urated fatty acids. This decrease could be attributed to the destruction of double bonds by oxidation and polymerisation.

Total Polar Compounds and Triacylglycerol Oligomer Content

In industrial frying, it is very important to ascertain the stage at which the frying oils should be discarded. This is particularly so in batch frying with no oil replenishment. Different analytical parameters have been proposed for determining the status of the frying oil, among which are the levels of total polar compounds (TPC) and triacylglycerol oligomer content (TOC) [Xu, 2003].

These determinations constitute the basis of legislation for oil discarding in some European countries. Most of them have set a maximum level of 25% TPC while others have established a TPC cut-point between 20 and 27%. In some jurisdictions the maximum TOC has been set at 10% while other countries permit 16%. The relationship between TPC and TOC has been investigated and the preference of TPC or TOC for oil discarding assessment has been made. Monounsaturated oils (olive oil, extra virgin olive oil, high oleic acid sunflower oil), polyunsaturated oils (sunflower oils and a blend of olive oil and sunflower oil), and saturated oils (palm olein) used in frying of different foods under domestic controlled conditions were employed. Although TPC and TOC were always very highly correlated ($p < 0.001$), the 25% TPC corresponds to a 10% TOC in palm olein but to 15% in sunflower oil. These findings suggest the need to unify criteria for oil discarding. Taking into account the potential toxicity of oligomers and also that some compounds defined as polar components are not necessarily altered (e.g. DAGs, free fatty acid), TOC has been suggested to give more precise information about the alteration of the oil and its potential toxicity than the TPC [Sanchez-Muniz and Bastida, 2003].

Fat Powders

These are manufactured from natural or hardened plant fats, sometimes with the addition of emulsifiers and protein carriers. They have a better stability against autoxidation than fats and oils in a natural state. In a cold-spray process, the melted fat is sprayed under high pressure into a cooled (-35°C) air blast crystallisation chamber, where the fat particles solidify. The particles are coated after re-crystallisation in order to avoid clumping (fig. 4).

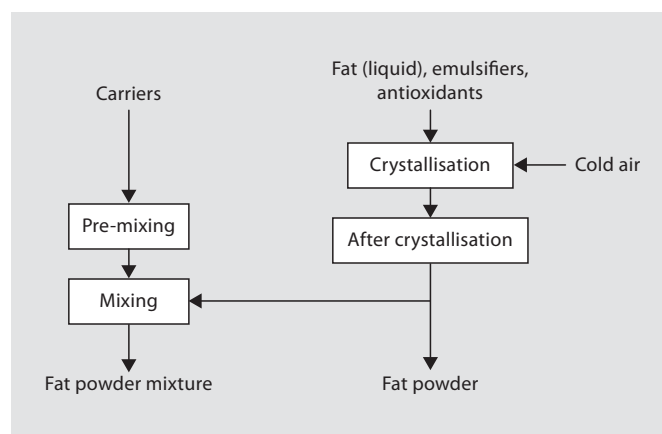


Fig. 4. Flow diagram to show cold-spray process (fat powder production). Adapted from Belitz et al. [1987].

Fast Food/Street Food

The terms 'street foods' and 'fast foods' describe an extensive range of ready-to-eat foods. Whilst street foods, as the term implies, are prepared on the streets, fast foods may also be manufactured in large-scale commercial factories. The growing street food sector in low-income countries offers easy access to inexpensive food as well as new job opportunities for urban residents. While this development is positive in many ways, it also presents new public health challenges for the urban population. Safe food hygiene is difficult to practice at street level, and outbreaks of diarrhoeal diseases have been linked to street food. A recent study from Ghana indicated 4 main food selection criteria among consumers of street food: (i) aesthetic appearance of food and food stand; (ii) appearance of the food vendor; (iii) interpersonal trust in the vendor, and (iv) price and accessibility of food – consumers often prioritised this over food safety [Rheinländer et al., 2008]. Fried foods and salads in Harare, Zimbabwe, have been shown to be heavily contaminated with *Staphylococcus aureus* and *Bacillus cereus* [Gadaga et al., 2008].

Most street foods and fast foods are characterised by the use of local ingredients and culinary practices. Inevitably, there is considerable diversity and variety in these foods. Vanaspati reportedly contains up to 40% *trans* fatty acids, and is used in Indian cooking and in the preparation of commercially fried, processed, bakery, ready-to-eat and street foods. *Trans* fatty acids in biscuits range from 30 to 40% and in sweets from 6 to 26% of total fatty acids [Ghafoorunissa, 2008]. Potato

Table 13. Snack food/fast food categories and examples of products

Category	Product
Hot snacks	mini pizzas, pizza baguettes, toasts au gratin, cup noodles, spring rolls, filled croissants
Cold snacks	
Milk and dairy products	yoghurt (plain or with fruit), mini cheese cubes
Bakery products	cake bars, mini tarts, biscuits
Bars	granola or muesli bars, chocolate bars, mini break bars, energy bars
Dry fruits	mango, banana, apricot, apple and mixtures
Savoury products	chips (crisps), sticks, crackers, pretzels, salt sticks
Other products	popcorn, puffed cereals, rice snacks, fruit sticks, dip sticks, tortilla crisps, fruit snack bar
Confectionery	plain cookies, deposit cookies, macaroons, wire-cut cookies
Extruded snacks	potato sticks, cereal-based tubes with cheese filling, corn pellets and chips
Low-pressure extruded fried snacks	sev, omumbadi, murukku
Nut-based snacks	roasted/fried/coated and fried/toasted/salted peanuts, roasted and salted almonds, sugared and spiced nuts, flavoured nuts and nut mixes
Legume-based Indian snacks	fried green peas, chick peas, lentils, dhals, fried products from bengal gram meal
Meat-based snacks	expanded pork rinds or skin, jerky

Adapted from Tettweiler [1991].

chips (crisps) remain one of the most popular fast foods worldwide. Typically the energy and fat content of potato chips is 2,189 kJ (525 kcal) and 33% fat per 100 g. Most fast foods have a high-energy density and fat content. Numerous processes have been developed to reduce both the energy and fat content of snack foods [Gould, 1985]. These include the use of olestra as a frying media in new product development using reduced fat formulations.

In order to produce a reduced-fat fried fast food, manufacturers have changed the dough structure. The dough contains 50–70% flour (preferably potato flour), 20–40% water; at least 3% hydrolysed starches and 1–10% calcium carbonate. The dough is formed into sheets from which snack pieces are cut and then fried. The resulting snack pieces contain only 18–38% fat due to the dough being of 10–14% larger in volume when fried compared to non-fat fried snacks.

As an alternative to modifying the dough for frying, many manufacturers are oven baking instead. This requires less oil for cooking and therefore absorbs less fat overall.

Table 13 shows examples of snack and fast foods.

Fast food (snacks) can be described as a small portion of a food that requires little or no preparation, is easy to handle and can take the form of a hot or cold meal. Fast foods can be savoury or sweet. They are however, not designed to replace our regular meals. Fast foods are frequently linked to the epidemic of obesity, but there has

been very little scientific appraisal of a possible causal role. A series of studies demonstrate that the energy density of foods is a key determinant of energy intake. These studies show that humans have a weak innate ability to recognise foods with a high-energy density and to appropriately down-regulate the bulk of food eaten in order to maintain energy balance. This induces so-called 'passive over-consumption'. Composition data from leading fast food company websites have illustrated most fast foods to have an extremely high-energy density. At some typical outlets the average energy density of the entire menu is approximately 1,100 kJ per 100 g. This is 65% higher than the average British diet (670 kJ per 100 g) and more than twice the energy density of recommended healthy diets (approx. 25 kJ per 100 g). It is 145% higher than traditional African diets (approx. 450 kJ per 100 g) that probably represent the levels against which human weight regulatory mechanisms have evolved. The high-energy densities of many fast foods challenge human appetite control systems with conditions for which they were never designed. Among regular consumers they are likely to result in the accidental consumption of excess energy and hence to promote weight gain and obesity [Prentice and Jebb, 2003].

Snacks form a significant proportion of the food industry and the leading snack is potato chips (crisps) followed by extruded snacks and corn chips.

Studies have found that 'healthy options' offered by fast food outlets such as burger and pizza chains are not as healthy as claimed, often being high in salt and fat.

Seventeen out of 20 products from traditional UK chain fast food outlets were high in salt and fat. While 5 out of 8 (63%) of the salads offered were also high in salt and/or fat. A study on determination of cholesterol oxides in samples of beef dripping used for deep frying in retail fast food outlets in Christchurch, New Zealand, has been reported. Based on the amount of fat in a typical deep-fried 'fish and chips' meal, the amounts of individual cholesterol oxides consumed would range from 0.05–0.7 mg. This is 3–9 times less than reported in a test meal experiment with humans but could still be expected to cause detectable increases in plasma cholesterol oxide levels [Lake and Scholes, 1997].

Snack foods can play an important role in our diet, depending on the snacks we choose. Therefore, fortification of some of these products has recently been discussed. Often snack foods – particularly those which are processed – are high in sodium and fat. They should be consumed in moderation.

Fat-Protein and Fat-Carbohydrate Interactions in Food Systems

Protein-Lipid Interactions

It has long been recognised that the level of calorie intake influences protein utilisation, notably nitrogen balance [Swanson, 1951]. The advantage of feeding carbohydrate calories over fat calories in maintaining nitrogen balance was first demonstrated by Munro [1951]. More recently, however, it has been reported that the use of structured lipids (notably medium-chain triglycerides) leads to a protein sparing effect and improved nitrogen balance.

Starch-Lipid Interactions

It is well recognised that the amylopectin fraction of starch is largely involved in swelling and hydration, leading to the thickening properties of cooked starch. The presence of fats and oils inhibits hydration, leading to a reduced viscosity and improved mouthfeel. Short-chain fatty acids are also known to inhibit retrogradation thereby leading to a slowing down of staling of bread and bakery products [Miles et al., 1984].

The glycaemic index measures the effect of a carbohydrate-based food on blood sugar. A high glycaemic index food will raise blood sugar quickly and to a greater extent than a low glycaemic index food. Moreover, the blood sugar value is likely to fall to or below baseline much faster in subjects consuming a high glycaemic index food. Complexes formed between amylose and long-

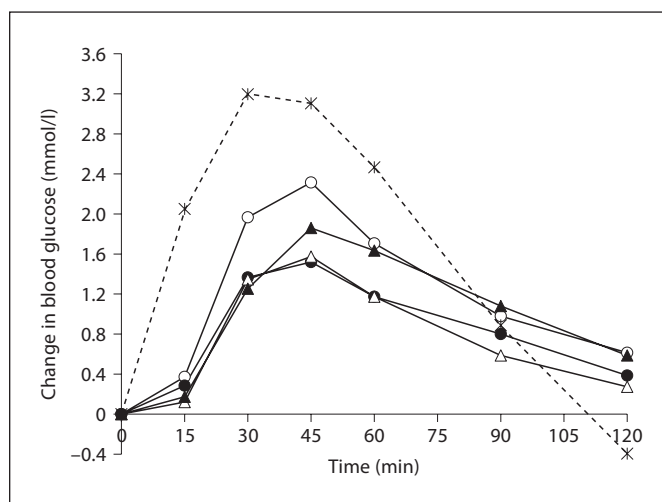


Fig. 5. iAUC for reference glucose (---) and for bread alone (○), bread + butter (●), bread + olive oil (△) and bread + grapeseed oil (▲). Each point represents the average change in blood glucose for 15 subjects. Henry et al. [2008].

chain saturated monoglycerides are generally more resistant to *in vitro* digestion than complexes with shorter chains or more unsaturated monoglycerides [Guraya et al., 1997].

Co-ingestion of lipids with starchy foods is known to lower glycaemic response. This is attributed to several factors, including slower gastric emptying, higher insulinemic response, decreased glucose absorption through the upper small intestine, and poor accessibility of starch to α -amylase. Studies carried out with 3 wheat-based products – wheat starch, white wheat bread, and 5-mm spaghetti strands – with oil, incubated with salivary amylase showed limited action of α -amylase [Fardet et al., 1999]. Extending this study, Henry et al. [2008] reported the effect of co-ingesting fats with white bread. Results of their study are presented in figure 5. The study observed that the addition of fat lowered the glycaemic response to bread and the results suggest that the glycaemic response to bread can be lowered using any type of fat. In order to obtain additional benefits on lipid profiles, the use of unsaturated fat is recommended.

Role of Fats and Oils in Infant Feeding

In many developing countries, weaning foods are starch based and are characterised by a low-energy density and an unpalatable viscosity. Oils and fats can play a critical role in reducing the viscosity and improving the energy density of weaning foods.

Table 14. Effects of added oil on energy, protein and iron density of maize

	Traditional maize pap	Oil-fortified maize pap
Amount of cereal (g/100 g)	8	8
Amount of oil (g/100 g)	0	5
Energy density (kcal _{th} /g)	0.32	0.77
Protein density (% energy)	9.0	3.4

Table 15. Dietary recommendations for *trans* fatty acids

Organisation/authority	<i>Trans</i> fatty acids
US	
American Heart Association	<1% energy (population)
Adult Treatment Panel III of the National Cholesterol Education Program	keep intake low
Health and Human Services/US Department of Agriculture	as low as possible
Institute of Medicine of the National Academy of Sciences	as low as possible
Non-US	
Health Council of the Netherlands	low as possible
Health Canada	upper limit 1% energy
Ministries of Agriculture of Austria, Germany, Switzerland and Japan	<2% energy
WHO/Food and Agriculture Organization of the United Nations	<1% energy

Adapted from Hunter [2008].

Human milk contains 40–55% of its energy in the form of fat. Weaning foods should have a comparable nutritional characteristic. Firstly, enough fat should be consumed to obtain the necessary essential fatty acids; secondly, an adequate amount of fat should be included in the diet so that it has a desirable energy density range. Energy density may be defined as the amount of energy stored in a specific food per unit volume or mass (usually 100 g). Due to fat having a relatively low viscosity, it can be easily added to food systems in order to increase energy density without contributing to an overly thick mixture.

A standard recommendation is that fat should supply 30–45% energy intake in children less than 2 years of age. Many experts have concluded that for children under the age of 2 years, fat intake should not be restricted.

Viscosity

One way to increase energy density without increasing viscosity is to add non-gelatinous carbohydrates such as simple sugars or fats to the diet. The addition of 1 tablespoon of vegetable oil to a typical weaning food (100 g)

would increase the energy density from 0.30 to 0.70 kcal_{th}/g, but decrease the percentage as protein by 5% (table 14). If this weaning food (pap) were consumed at sufficient levels to satisfy the children's energy requirements, it would not meet the children's protein requirements. The table 14 below provides an example of how the energy density and protein density is altered by the simple addition of oil.

Labelling

Labelling Considerations: Implications of Changes to Previous FAO/WHO Recommendations

Principles in the Codex Guidelines on Nutritional Labelling 1985 are summarised as follows.

Nutrient Declaration

'Information supplied should be for the purpose of providing consumers with a suitable profile of nutrients contained in the food and considered to be of nutritional

importance. The information should not lead consumers to believe that there is exact quantitative knowledge of what individuals should eat in order to maintain health, but rather to convey an understanding of the quantity of nutrients contained in the product. A more exact quantitative delineation for individuals is not valid because there is no meaningful way in which knowledge about individual requirements can be used in labelling.

Supplementary Nutritional Information

The content of supplementary nutrition information will vary from one country to another and within any country from one target population to another according to the educational policy of the country and the needs of the target groups.

Nutritional Labelling

Nutritional labelling should not deliberately imply that a food which carries such labelling has necessarily any nutritional advantage over a food which is not so labelled.'

Since the publication of the Food and Agriculture Organization document 'Fats and Oils in Human Nutrition' (1994) no significant changes in the recommendations surrounding labelling have emerged, except for those on the labelling of *trans* fatty acids. National legislation on *trans* fatty acids declarations vary considerably, as shown in table 15.

National variations in labelling and regulations for *trans* fatty acids are clearly illustrated by comparing those of the US FDA with those of Denmark. The US FDA requires that the amount of *trans* fat in a serving is listed on a separate line under saturated fats on the nutritional facts panel. However, *trans* fats do not have to be listed if the total fat in the food is less than 0.5 g per serving. In contrast, in Denmark from 2003 the content of *trans* fatty acids should not exceed 2 g per 100 g of oil or fat. In products that claim 'free of *trans* fatty acids' the content of *trans* fatty acids should be less than 1 g per 100 g of oil or fat.

General Conclusions

Public concerns about obesity and cardiovascular disease have increased our interest in minimising the consumption of saturated fats and *trans* fats. These concerns have been a driving force for the lipid industry to develop fats and fat-based ingredients that have improved nutritional properties. New processing technologies along with the creative use of newly discovered

functional properties of triglycerides have been the hallmark of innovation during the past decade. Using techniques such as interesterification, hydrogenation and fractionation, new and novel fat and sugar-based ingredients have been developed. These include zero-calorie olestra, low-calorie salatrim and DAGs that have a lower net energy.

Future areas of research include the role that fats and fatty acids may play in carbohydrate metabolism, notably glucose homeostasis. There is mounting evidence that the lipid-starch complex may play a significant role in reducing the glycaemic response of carbohydrate foods. The greatest global challenge is to find methods to reduce fat intake in peoples living in the Western hemisphere with the concomitant drive to modestly increase fat consumption in the developing world. Weaning foods consumed by children living in Asia, Africa and South America are of very low energy density. Finding innovative methods to increase their energy density with the use of fats and oils remains a challenging area for research.

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Disclosure Statement

Prof. Henry has nothing to disclose.

Appendix 1

Codex Standard for Butter: Codex-Stan A-1-1991, rev. 1-1999 (amended in 2003 and 2006)

Description: 'Butter is a fatty product derived exclusively from milk and/or products obtained from milk, principally in the form of an emulsion of the type of water-in-oil.'

If it is felt that if the consumer would be misled by the omission of the declaration of milk fat content then the manufacturer must declare it. The milk fat content must then be displayed in a manner acceptable to the country in which the product will be sold, either as a percentage of the mass or in grams per serving quantified by the label (provided that the number of servings is stated).

Raw materials: Milk and/or products obtained from milk.

Permitted ingredients:

- sodium chloride and food-grade salt;
- starter cultures of harmless lactic acid and/or flavour producing bacteria;
- portable water.

Composition:

- 80% m/m minimum fat content;
- 16% maximum water content;
- 2% maximum milk solids non-fat content.

The butter must also comply with the maximum limits for heavy metals and pesticide residues.

Name of the food: 'The name of the food shall be 'butter'. The name 'butter' with a suitable qualification shall be used for butter with more than 95% fat.'

Butter may be labelled to indicate whether it is salted or unsalted according to national legislation.

Appendix 2

Codex Standard for Named Vegetable Oils: Codex-Stan 210 (amended in 2003 and 2006)

Edible vegetable oils are defined as 'foodstuffs which are composed primarily of glycerides of fatty acid obtained only from vegetable sources. They may contain small amounts of other lipids such as phosphatides, of unsaponifiable constituents and of free fatty acids naturally present in the fat or oil.'

Cold-pressed oils are defined as 'being obtained without altering the oil, by mechanical procedures only (i.e. expelling or pressing), and the application of heat. Washing with water, settling, filtering and centrifuging only, may have purified them'.

- low erucic rapeseed oil must contain a maximum of 2% erucic acid (as a percentage of total fatty acids);
- high oleic safflower oil must contain a minimum of 70% oleic acid (as a percentage of total fatty acids);
- high oleic sunflower oil must contain a minimum of 75% oleic acid (as a percentage of total fatty acids).

Slip point:

- palm olein, not more than 24°C;
- palm stearin, not more than 44°C;
- palm superolein, not more than 19.5°C.

Food additives: no food additives are allowed to be added to virgin or cold-pressed oils.

Flavours: natural flavours and their identical synthetic equivalents and other synthetic flavours, except those which are known to represent a toxic hazard (table A1).

Contaminants (maximum limits allowed in the product, set by the Codex Guidelines):

- lead (Pb) maximum concentration of 0.1 mg/kg;
- arsenic (As) maximum concentration of 0.1 mg/kg.

Appendix 3

Codex Standard for Named Animal Fats: Codex-Stan 211-1999

Colours are allowed for the purpose of restoring natural colour that has been lost in processing. However, the added colour(s) may not mislead the customer by seeming to conceal damaged or inferior products (table A2).

Contaminants (maximum limits allowed in the product, set by the Codex Guidelines):

- lead (Pb) maximum concentration of 0.1 mg/kg;
- arsenic (As) maximum concentration of 0.1 mg/kg.

These recommendations should enable food manufactures worldwide to formulate methods to decrease or eliminate *trans* fatty acids in their foods.

The most significant legislation on *trans* fatty acids are from Denmark.

Manufacturers aim to develop a 'healthy' fat product. A 'zero saturate' claim requires 3.5% saturated fatty acids in the oil and a 'low saturates' claim must have no more than 7% saturated fatty acids.

The source or origin of oils from nuts and seeds must be indicated. The labelling must also indicate the degree of saturation of the fatty acids as 'saturated', 'monounsaturated' or 'polyunsaturated'. Many modern oils are so interchangeable in their use that they can be labelled as 'vegetable oils'. These oils tend to be used for deep-fat frying, roasting nuts, home cooking and industrial purposes.

Any claims that the company wishes to make must be substantiated claims that have been previously accepted by a food safety authority before they can be accepted or used.

Appendix 4

Codex General Standard for the Labelling of Pre-Packed Foods: Labelling for Non-Retail Containers

Storage instructions should appear on the packaging or in accompanying documents. The name of the product, lot identification and the name and address of the manufacturer must appear on the container, unless an identification mark is present which collates this information on a document provided with the containers and products.

Pre-packaged food shall not be described or presented on any label or in any labelling by words, pictorial or other devices which refer to or are suggestive, either directly or indirectly, of any other product with which such food might be confused, or in such a manner as to lead the purchaser or consumer to suppose that the food is connected with such other product.

Mandatory Labelling: The Name of the Food

The name given to the product should indicate the nature of the food, being specific and not generic:

- where a name exists in Codex guidelines, at least 1 of these names should be used;
- if a name does not exist in Codex guidelines, a name prescribed by national legislation is used;
- if a name does not exist in Codex guidelines of national legislation, then a name existing by common usage as an appropriate descriptive term should be used;
- a brand name or trade mark may appear alongside of any subsequent name;
- words such as 'smoked' or 'concentrated' may also appear in close proximity to the name as not to mislead the consumer to the true nature of the product.

List of Ingredients

All ingredients will be listed appearing in descending order of their weight. The only exception to this is single-ingredient food, as these do not require an ingredients list.

Table A1. Additives and colours permitted under Codex standard for named vegetable oils

Number	Name	Maximum level
Antioxidants		
304	ascorbyl palmitate	500 mg/kg individually or in combination
305	ascorbyl stearate	500 mg/kg individually or in combination
306	mixed tocopherols concentrate	GMP
307	α -tocopherol	GMP
308	synthetic γ -tocopherol	GMP
309	synthetic δ -tocopherol	GMP
310	propyl gallate	100 mg/kg
319	TBHQ	120 mg/kg
320	BHA	175 mg/kg
321	BHT	75 mg/kg
	any combination of gallates, BHA and BHT and/or TBHQ	200 mg/kg but above limits not to be exceeded
389	dilauryl thiodipropionate	200 mg/kg
Antioxidant synergists		
330	citric acid	GMP
331	sodium citrates	GMP
384	isopropyl citrates	100 mg/kg individually or in combination
	monoglyceride citrate	100 mg/kg individually or in combination
Anti-foaming agents (oils for deep frying)		
900a	polydimethylsiloxane	100 mg/kg

BHA = Butylated hydroxyanisole; BHT = butylated hydroxytoluene; GMP = good manufacturing practice; TBHQ = tertiary butyl hydroquinone.

Table A2. Additives and colours permitted under Codex standard for named animal fats

Number	Name	Maximum level
Colours		
100	curcumin or turmeric	5 mg/kg (calculated as total curcumin)
160a	β -carotene	25 mg/kg
160b	annatto extracts	10 mg/kg (calculated as total bixin or norbixin)
Antioxidants		
304	ascorbyl palmitate	500 mg/kg individually or in combination
305	ascorbyl stearate	500 mg/kg individually or in combination
306	mixed tocopherols concentrate	GMP
307	α -tocopherol	GMP
308	synthetic γ -tocopherol	GMP
309	synthetic δ -tocopherol	GMP
310	propyl gallate	100 mg/kg
319	TBHQ	120 mg/kg
320	BHA	175 mg/kg
321	BHT	75 mg/kg
	any combination of gallates, BHA and BHT and/or TBHQ	200 mg/kg but above limits not be to exceeded
Antioxidant synergists		
330	citric acid	GMP
331	sodium citrates	GMP
384	isopropyl citrates	100 mg/kg individually or in combination
	monoglyceride citrate	100 mg/kg individually or in combination

BHA = Butylated hydroxyanisole; BHT = butylated hydroxytoluene; GMP = good manufacturing practice; TBHQ = tertiary butyl hydroquinone.

Where an ingredient is a compound ingredient (a product of 2 or more ingredients), the compound ingredient is declared in the ingredient list followed in brackets by its ingredients, again in descending order of weight.

If an ingredient(s) is known to cause hypersensitivity it will always be declared. These ingredients include the following:

- cereals containing gluten (wheat, rye, barley and oats);
- crustacea and products of these;
- eggs and egg products;
- fish and fish products;
- peanuts, soybeans and products of these;
- milk and milk products (including lactose);
- tree nuts and nut products;
- sulphite in concentrations of 10 mg/kg or more.

Added water should be declared in the ingredient list unless it is part of another ingredient used in a compound food. Water or other volatile ingredients evaporated during the course of production do not need to be declared.

As an alternative to the general provisions of this section, in dehydrated or condensed foods which are reconstituted by the addition of water only, the ingredients may be listed in order or proportion (m/m) in the reconstituted product provided with a statement such as 'ingredients of the product when prepared in accordance with the directions of the label' is included.

Any names used for ingredients must comply with Codex guidelines or be named in national legislation, with the exception of some general classes:

- refined oils other than olive oil: 'oil' together with the term 'vegetable' or 'animal', qualified by the term 'hydrogenated' or 'partially hydrogenated';
- refined fats: 'fat' together with either the term 'vegetable' or 'animal';
- other: fat, lard and beef fat should always be labelled with their specific names.

For food additives permitted for use in foods, certain classes of terms must be used, followed by the specific name or recognised numerical identification of national legislation (table A3).

The term flavour or flavours maybe qualified by using terms such as natural, nature identical, artificial or a combination of these words.

Net Content

This is to be stated by volume for liquids, by weight for solid foods and by weight or volume for semi-solid or viscous fats or oils.

Other Information

The name of the manufacturer, packer, distributor, importer, exporter or vendor of the food should be clearly stated on the packaging and label. The country of origin should also be added if the consumer might be misled by its omission. However, when a product undergoes secondary processing in another country, for the purposes of labelling the second country of processing shall be stated. A permanent mark of a lot number or clear marking must be present to identify the producing factory.

The date markings should consist of:

- for products with a shelf life of 3 months or less, a day and month are required;
- for products with a shelf life greater than 3 months a month and year are required.

Table A3. Class terms for permitted food additives

• Acidity regulator	• Acids
• Anticaking agent	• Antifoaming agent
• Antioxidant	• Bulking agent
• Colour	• Colour retention agent
• Emulsifier	• Emulsifying salt
• Firming agent	• Flour treatment agent
• Flavour(s) and flavouring(s)	• Flavour enhancer
• Foaming agent	• Gelling agent
• Glazing agent	• Humectant
• Modified starch(es)	• Preservative
• Propellant	• Raising agent
• Stabiliser	• Sweetener
• Thickener	

All date markings should be declared with the terms 'Best before ...' where the day is indicated and 'Best before end ...' in all other cases followed by the date or a reference to where the date can be found. All dates must be given in numerical format so that consumers are clear about the information. If the best before date is dependant upon correct storage conditions then these conditions must also be clearly stated upon the labelling.

When a fat or oil specifies that 1 or more nutrients/ingredients are present in a low or high concentration, the percentage of the nutrient/ingredient must be stated.

Presentation of Mandatory Labelling Information

- Labels must be applied in a manner in which they will not become separated from the container.
- All information presented on the label must be legible to the consumer at the time and under the conditions of purchase.
- Where external packaging covers the container, the external packaging must present all the necessary information, or the external packing must not obscure the internal label.
- The name and net contents of the fat or oil will be presented in a prominent position and in the same field of vision.
- The language of the packaging must be acceptable and appropriate for the intended consumer. If this is not the case then a supplementary label containing the mandatory information may be provided. If this is the case then this supplementary label must present the same essential information as the original label.

Specifics for Labelling of Fats

- Any refined fat or oil in a food needs to be declared in the ingredients. With the exception of olive oil, it should be preceded with either 'animal' or 'vegetable' as appropriate, or it can be listed as a specific oil or fat, for example 'cocoa butter'.
- If the fat or oil has undergone hydrogenation, this too must be declared on the ingredients list, stated as, for example 'hydrogenated palm oil'. This must be declared irrespective of whether or not the oil or fat has been partially or fully hydrogenated.

- Nutritional labelling falls into 2 basic groups:
 - first group: the big 4: energy, protein, carbohydrates and fats are declared;
 - second group: the big 4 plus the little 4: energy, protein, carbohydrates, sugars, fats, saturates, fibre and sodium are declared;
 - if any claim is made on the 'little 4' then the listing must follow this second grouping.
- It is not necessary to declare other types of fatty acids unless a nutritional claim is made about them and included in the group 2 declaration.
- Manufactures can also label other fatty acids without making a claim about them.
- Sometimes a label will include total fat, saturates, monounsaturates, and polyunsaturates. If the fat component is partially hydrogenated, then the sum of the 3 types of fatty acids will not be the same as the total fat. The difference is the level of *trans* fatty acid present.

- Fat declaration therefore could take the following form:

Fat (x g) of which:

- saturates	a g
- monounsaturates	b g
- polyunsaturates	c g
- cholesterol	d mg

x, a, b, c and d are all expressed per 100 g or 100 ml but may also be given as per portion or serving or pack size.

- Polyunsaturated fatty acid is defined as a fatty acid with a *cis*-*cis* methylene interrupted double bond.
- *Trans* fatty acids are defined as all the geometrical isomers of monounsaturated and polyunsaturated fatty acids having non-conjugated, interrupted by at least 1 methylene group, carbon-carbon double bonds in the *trans* configuration.

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