

Oil Extraction and Oil Refining:

Large-scale production

Storage. Many steps in industrial processing find their origin in the traditional processes. In large-scale operations, oilseeds are dried to less than 10 percent moisture. They may be stored for prolonged time periods under suitable conditions of aeration with precautions against insect and rodent infestation. Such storage reduces mould infection and mycotoxin contamination and minimizes biological degradative processes which lead to the development of free fatty acids and color in the oil.

Oil-bearing fruits such as olive and palm are treated as quickly as possible. Palm is sterilized as a first step in processing. Adipose tissues and fish-based raw materials (that is, the body or liver) are rendered within a few hours by boiling to destroy enzymes and prevent oil deterioration.

Processing/ oil extraction: Oilseeds are generally cleaned of foreign matter before dehulling. The kernels are ground to reduce size and cooked with steam, and the oil is extracted in a screw or hydraulic press. The pressed cake is flaked for later extraction of residual fat with solvents such as "food grade" hexane. Oil can be directly extracted with solvent from products which are low in oil content, that is, soybean, ricebran and corn germ.

After sterilization, oil-bearing fruits are pulped (digested) before mechanical pressing often in a screw press. Palm kernels are removed from pressed cakes and further processed for oil. Animal tissues are reduced in size before rendering by wet or dry processes. After autoclaving, tissues of fish are pressed and the oil/water suspension is passed through centrifuges to separate the oil.

Oil Refining. Refining produces an edible oil with characteristics that consumers desire such as bland flavour and odour, clear appearance, light colour, stability to oxidation and suitability for frying. Two main refining routes are alkaline refining and physical refining (steam stripping, distillative neutralisation) which are used for removing the free fatty acids.

Alkaline refining:

The classical alkaline refining method usually comprises the following steps:

- Step** **1.**
Degumming with water to remove the easily hydratable phospholipids and metals.
- Step** **2.**
Addition of a small amount of phosphoric or citric acid to convert the remaining non-hydratable phospholipids (Ca, Mg salts) into hydratable phospholipids.
- Step** **3.**
Neutralising of the free fatty acids with a slight excess of sodium hydroxide solution, followed by the washing out of soaps and hydrated phospholipids.
- Step** **4.**
Bleaching with natural or acid-activated clay minerals to adsorb colouring components and to decompose hydroperoxides.
- Step** **5.**
Deodorising to remove volatile components, mainly aldehydes and ketones, with low threshold values for detection by taste or smell. Deodorisation is essentially a steam distillation process carried out at low pressures (2-6 mbar) and elevated temperatures (180-220°C).

For some oils, such as sunflower oil or rice bran oil, a clear table product is obtained by a dewaxing step or crystallization of the wax esters at low temperature, followed by filtration or centrifugation.

Drawbacks:

The alkaline neutralisation process has major drawbacks, the yield is relatively low and oil losses occur due to emulsification and saponification of neutral oil. Also, a considerable amount of liquid emulsion is generated. The soaps are generally split with sulphuric acid to recover free fatty acids along with sodium sulphate and some fat-containing acid water steam.

Physical refining:

In physical refining, the fatty acids are removed by a steam distillation (stripping) process similar to deodorisation. The low volatility of fatty acids (depending upon chain length) requires higher temperatures in physical refining than those required for only deodorisation. In practice, a maximum temperature of 240-250°C is sufficient to reduce the free fatty acid content to levels of about 0.05-0.1 percent. A prerequisite for physical refining is that phosphatides be removed to a level below 5 mg phosphorus/kg oil. In the classic refining process, this level is easily achieved during the neutralisation stage, but special degumming processes may be required for physical refining of high-phosphatide seed oils. These procedures rely on improved hydration of phospholipids by intimate contact of the oil with an aqueous solution of citric acid, phosphoric acid and or sodium hydroxide, followed by bleaching.

It is unlikely that the mild reaction conditions during degumming and neutralisation will induce any significant undesirable changes in the oil composition. On the contrary, several impurities including oxidised components, trace metals and colouring materials are partially removed by entrainment with the phospholipids and soapstock. These impurities are further reduced during bleaching. Neutralisation also contributes significantly to the removal of contaminants such as aflatoxin and organophosphorous pesticides. Organochlorine pesticides and polycyclic aromatic hydrocarbons, if present, must be removed during the deodorisation/stripping stage and by active carbon treatment. Some loss of tocopherols and sterols during alkaline neutralisation usually occurs, however, under well-controlled conditions (minimising air contact) this need not exceed 5-10 percent.

Potential side reactions during high-temperature processing

The possibility of negative effects of high temperatures during deodorisation and stripping has evoked concern. The German Society for Fat Research (DGF) defined upper limits for deodorisation conditions [240°C for 2hrs, 270°C for 30 min.]

Good manufacturing practice also implies the following: the use of stainless steel equipment; the careful deaeration at < 100°C before heating to the final stripping temperature; the use of oxygen-free steam; and strict feedstock specifications (typically: Fe 0.1, Cu 0.01, P S, bleaching earth 5 mg/kg oil max.).

A strong effect of temperature on the formation of trans fatty acids and polymeric compounds occurs. Time also has a significant effect. At 280-300°C, there was evidence for appreciable inter- or intra-esterification (increase in the content of saturated fatty acids at the 2-position of the triacylglycerols); substantial amounts of conjugated fatty acids were formed as well.

Cis-trans isomerisation. One of the most sensitive parameters used to detect chemical changes resulting from severe processing conditions is cis-trans isomerisation, especially of linolenic acid. The most complete study in this area was made by Eder (1982), who investigated the formation of geometric isomers in various oils on the laboratory, pilot plant and production scales. On a laboratory scale, with unbleached soyabean oil at 240°C, the formation of C₁₈:3 isomers (determined by GLC)

was insignificant (less than 1 percent, even after 5 h, against 3 percent at 260°C). The total trans contents (determined by infrared spectroscopy) for several types of oils deodorised in stainless steel equipment on the pilot plant scale is depicted in Figure 5.2. The data show a strong effect of temperature, especially between 240 and 270°C, and confirm the general trend. That is, even for highly unsaturated oils containing linolenic acid, the formation of trans isomers is slow under the conditions recommended for industrial deodorisation/physical refining (for example, 250°C max.). In conclusion, in the temperature range of 240-250°C, the amount of trans fatty acids formed from unsaturated oils is about 1 percent or less per hour.

Physical losses

During deodorisation or physical refining, volatile components are removed from the oil by the combination of high temperature, low pressure and stripping action of inert gas (steam). The degree of removal depends on the physical properties of the components (especially vapour pressure) and on the temperature and volume of steam passed through the oil. Some physical losses are highly desirable, for example, the removal of off- flavours, pesticides and polycyclic aromatic hydrocarbons, if present. Other losses of nutritionally valuable components, such as tocopherols and sterols, are potentially undesirable.

Quantitative data on the composition of deodoriser distillates and the removal of various types of contaminants from oils during deodorisation were reported. During high temperature deodorisation or physical refining, especially, the concentrations of organochlorine pesticides (lindane, DDT etc.), if present in the bleaching oil, are reduced to very low levels.

Polycyclic aromatic hydrocarbons (PAM) have also been removed at high temperature.

Some loss of tocopherols and sterols by evaporation during high temperature deodorisation and physical refining is inevitable. However, they have higher molecular masses and lower volatilities than free fatty acids and light polycyclic aromatic hydrocarbons. Consequently, the losses of tocopherols and sterols need not be severe if the processing conditions are well-chosen.

Fat modification processes

Hydrogenation. Hydrogenation of edible oils and fats has been applied on a large scale since the beginning of this century. The process is carried out in a three-phase system (hydrogen gas, liquid oil and solid catalyst) at temperatures ranging from about 120°C to about 220°C max. in the final stages of the reaction. The catalyst consists of small nickel crystallites supported by an inorganic oxide, usually silica or alumina. After the reaction, the catalyst is filtered off and any traces of residual nickel are removed in post-refining to a level of about 0.1 mg/kg or below.

Apart from reduction of unsaturation, isomerisation of double bonds also takes place during hydrogenation: geometric isomerisation (cis-trans) and positional isomerisation. The mechanisms of hydrogenation and isomerisation are strongly interrelated.

Storage, transport and packaging of oils. Oils and fats must be protected against oxidative deterioration, contamination with water, dirt, or other fats, absorption of foreign odours and tastes, thermal deterioration, and entry of foreign substances from packaging and lining materials. Temperature, oxygen pressure, oxidation products, trace metals, oxidative and lipolytic enzymes, reduction in natural antioxidants and visible and ultraviolet light are all factors in such deterioration. The use of low storage temperatures, nitrogen or vacuum packaging; the avoidance of copper, copper alloys and iron as construction material of storage vessels; and the use of synthetic or natural antioxidants and metal sequestrants as additives, work to prevent deterioration of oil during storage.

Conclusions

Rural refining of oil-bearing plants can produce fats and oils of good quality which provide needed energy and fat soluble vitamins. Commercial refining produces fats and oils that can be of high quality and have the characteristics of bland taste, clear colour, good keeping quality and frying stability. Commercially-refined fats and oils are free from known contaminants extracted from the raw agricultural products. Refining may remove nutritionally valuable carotenoids to yield oils of low colour, but retains substantial proportions of tocopherols, and does not change fatty acid nor triacylglycerol compositions. Temperature, time and pressure must be carefully controlled during industrial refining. Oil products should be properly stored, transported and packaged to maintain quality and consumers must assume responsibility for not abusing oils and fats within households.

Industry can design almost any fat or oil for a specific application by the use of various modification processes, such as hydrogenation, interesterification, fractionation or blending. Hydrogenation typically reduces essential fatty acid content and creates various fatty acid isomers, both cis and trans. The wide flexibility available to industry through the selection of raw materials and different modification processes allows for the production of oils at the lowest cost possible, an important aspect of food production.

