Frying

Frying is a unit operation which is mainly used to alter the eating quality of a food. A secondary consideration is the preservative effect that results from thermal destruction of micro-organisms and enzymes, and a reduction in water activity at the surface of the food (or throughout the food, if it is fried in thin slices). The shelf life of fried foods is mostly determined by the moisture content after frying: foods that retain a moist interior (for example doughnuts, fish and poultry products which may also be breaded or battered, have a relatively short shelf life, owing to moisture and oil migration during storage. These foods are important in catering applications and are produced on a commercial scale for distribution to retail stores, preserved by chilling and/or gas packing. Foods that are more thoroughly dried by frying, for example potato crisps (potato chips in the USA), maize and other potato snackfoods, have a shelf life of up to 12 months at ambient temperature. The quality is maintained by adequate barrier properties of packaging materials and correct storage conditions.

Theory of frying

When food is placed in hot oil, the surface temperature rises rapidly and water is vaporised as steam. The surface then begins to dry out in a similar way to that described during baking and roasting. The plane of evaporation moves inside the food, and a crust is formed. The surface temperature of the food then rises to that of the hot oil, and the internal temperature rises more slowly towards 100ºC. The rate of heat transfer is controlled by the temperature difference between the oil and the food and by the surface heat transfer coefficient. The rate of heat penetration into the food is controlled by the thermal conductivity of the food.

The time taken for food to be completely fried depends on:

- the type of food
- the temperature of the oil
- the method of frying (shallow or deep-fat frying)
- the thickness of the food
- the required change in eating quality.

Foods that retain a moist interior are fried until the thermal centre has received sufficient heat to destroy contaminating micro-organisms and to change the organoleptic properties to the desired extent. This is particularly important for comminuted meat products (for example sausages or burgers) or other foods that are able to support the growth of pathogenic bacteria.

The temperature used for frying is determined mostly by economic considerations and the requirements of the product. At high temperatures (180–200ºC), processing times are reduced and production rates are therefore increased. However, high temperatures also cause accelerated deterioration of the oil and formation of free fatty acids, which alter the viscosity, flavour and colour of the oil and promote foaming. This increases the frequency with which oil must be changed and hence increases costs. A second economic loss arises from the vigorous boiling of the food at high temperatures which causes loss of oil by aerosol formation and entrainment in the product. Acrelein is a breakdown product of oil, produced at high temperatures, which forms a blue haze above the oil and is a source of atmospheric pollution.

There are two main methods of commercial frying which are distinguished by the method of heat transfer involved: these are shallow frying and deep-fat frying.

Shallow (or contact) frying

This method is most suited to foods which have a large surface-area-to-volume ratio (for example bacon slices, eggs, burgers and other types of pattie). Heat is transferred to the food mostly by conduction from the hot surface of the pan through a thin layer of oil. The thickness of the layer of oil varies as a result of irregularities in the surface of the food. This, together with the action of bubbles of steam which lift the food off the hot surface, causes temperature variations as frying proceeds and produces the characteristic irregular browning of shallow fried foods. Shallow frying has a high surface heat transfer coefficient (200–450$Wm^{-2}K^{-1}$), although as explained above, this is not uniformly found across the entire surface of the food.

Deep-fat frying

Here heat transfer is a combination of convection within the hot oil and conduction to the interior of the food. All surfaces of the food receive a similar heat treatment, to produce a uniform colour and appearance. Deep-fat frying is suitable for foods of all shapes, but irregularly shaped food or pieces with a greater surface:mass ratio tend to absorb and entrain a greater volume of oil when it is removed from the frier. Heat transfer coefficients are 250–300$Wm^{-2}K^{-1}$ before evaporation of

moisture from the surface begins but subsequently increase to 800–1000$Wm^{-2}K^{-1}$ owing to the violent turbulence caused by steam escaping from the food.

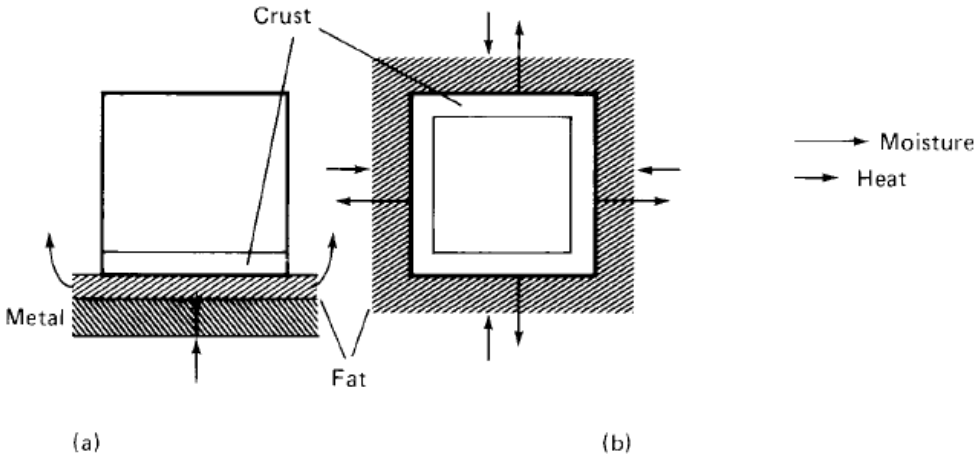

Fig. 17.1 Heat and mass transfer in (a) shallow frying and (b) deep fat frying.

Equipment of frying:

Shallow-frying equipment consists of a heated metal surface, covered in a thin layer of oil. Commercially, continuous deep-fat friers are more important. In batch operation the food is suspended in a bath of hot oil and retained for the required degree of frying, often assessed by changes in surface colour. Continuous deep-fat friers consist of a stainless steel mesh conveyor which is submerged in a thermostatically controlled oil tank (Fig. 17.2). They are heated by electricity, gas, fuel oil or steam. Food is metered into the oil by slow-moving paddles and either sinks to a submerged conveyor or, if the food floats, is held below the surface by a second conveyor (Fig. 17.3). The size of pieces, conveyor speed and oil temperature control the frying time. An inclined conveyor then removes the food and allows excess oil to drain back into the tank. The equipment operates automatically at production rates of up to 15 t of fried product per hour.

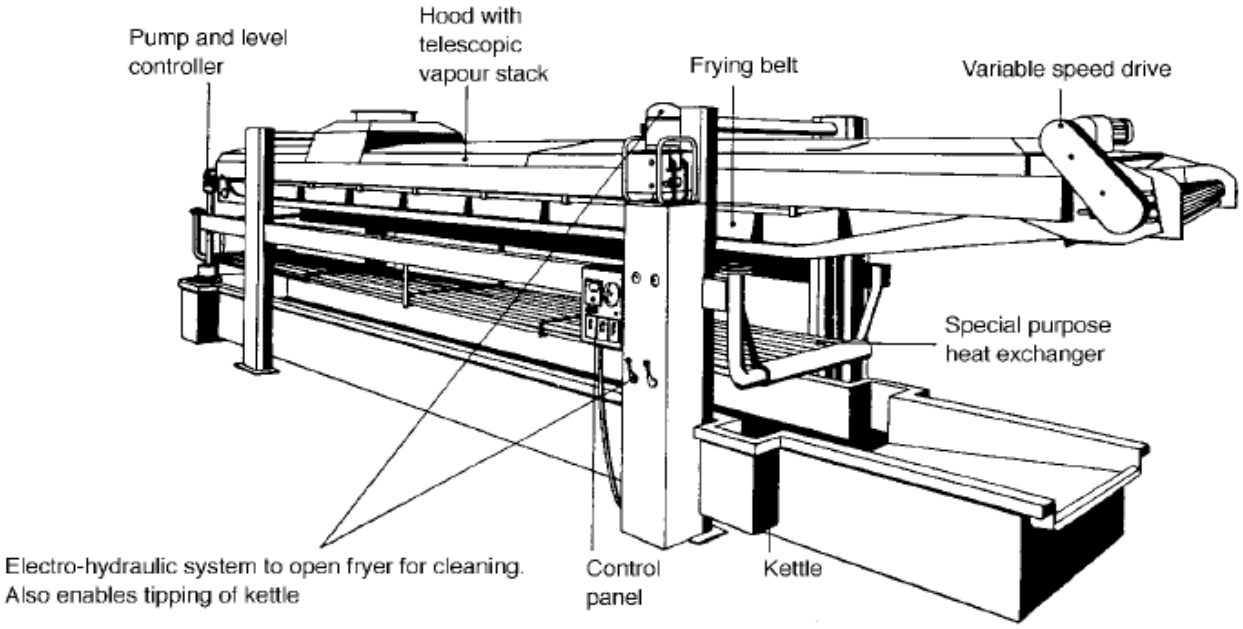

Fig. 17.2 Continuous deep-fat frier.
(Courtesy of Coat and Fry Ltd.)

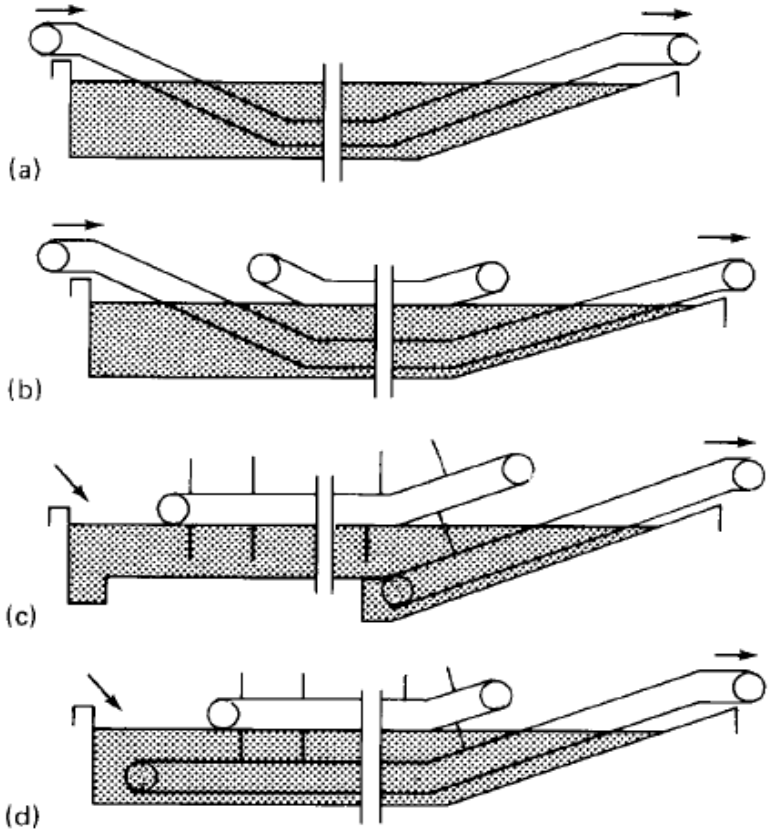

Fig. 17.3 Different conveyor arrangements: (a) delicate non-buoyant products (for example fish sticks); (b) breadcrumb-coated products; (c) dry buoyant bulk products (for example half-product snacks); (d) dual purpose (for example nuts and snacks).
(Courtesy of Coat and Fry Ltd.)