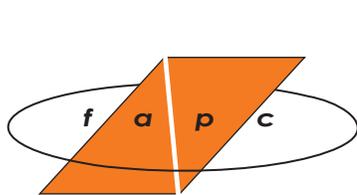


Robert M. Kerr Food & Agricultural Products Center



FOOD TECHNOLOGY FACT SHEET

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Industrial Deep Fat Frying

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Deep fat frying is a process during which food is cooked and dried through contact with hot oil. The oil not only serves as a heat transfer medium but also is absorbed by the food and contributes to flavor and texture of the product. Moisture in the food is heated above its boiling point and leaves the product as steam (vapor) during frying. Starch in the food starts to gelatinize immediately after the product is placed in hot oil. As the product dehydrates, a layer of crust is formed on the outer surface. This phenomenon is referred to as “case hardening.” After the product is removed from the fryer, it remains hot for a period of time and continues to cook.

Oil may be absorbed by the product at different stages of frying. The surface of the product is coated with oil as it enters the fryer. Although some of the surface oil is swept away by the vapor released from the product depending on surface characteristics of the product, some oil may be absorbed by capillary action. The product may absorb more oil after vapor evolution (moisture removal) subsides. Some oil may be carried out of the fryer by the product.

The amount of oil removed from the fryer depends on the shape of the product and design of the product take out conveyor. The residual moisture in the fried product (hot vapor) condenses as the product cools down and creates a slight vacuum, which pulls the surface oil into the product. If desired, oil absorption can be minimized by maintaining the finished product temperature, while blowing dry steam or high velocity inert gas over the product to sweep away the residual surface oil. Air blowing over the fried product to remove surface oil is not recommended since air accelerates the oxidation reactions as a result the shelf life of the finished product

is reduced. Today, dry steam blowing over the product in an oxygen free chamber or centrifugation has been commonly practiced to remove surface oil from the fried products.

Oil Turnover Rate

Oil turnover rate is defined as the number of hours required for make-up oil addition to maintain the amount of oil in the fryer during frying and calculated as:

$$\text{Theoretical Oil Turnover Rate (h)} = \frac{\text{Weight of initial oil in the fryer}}{\text{Weight of oil carried out by the product/h}} \text{ where, } \text{weight of oil carried out by the product/h} = [\text{Production throughput (weight/h)}] \times [\% \text{ (w/w) oil in the finished product}]$$

Oil turnover rate calculation shown above is based on a full capacity frying operation (100% design capacity). In practice, fryer start-up, shut down, product change-over and interruptions due to mechanical failures reduce fryer utilization to 80-90%. Hence, “actual oil turnover rate” would be equal to “theoretical oil turnover rate/0.8 (or 0.9).” Factors such as types of oil and product used, frying temperature, fryer design, oil heating system and operating conditions determine the oil turnover rate for a frying operation. For industrial fryers, oil turnover rate can vary from 5 to 10. Low oil turnover rates are desirable because oil degradation increases and product shelf life decreases at high oil turnover rates.

Types of Fryers

Industrial fryers are designed for either batch or continuous operations. Batch type fryers are suitable for

small operations and preferred for specialty products, i.e. kettle fried products. Oil in the fryer is heated directly or indirectly. In a direct heated fryer, oil is heated in the fryer by an internal heat transfer mechanism such as gas fired burner tubes, thermal fluid tubes/fins or electrical heating elements located right under the vessel holding oil. Oil is continuously taken out and returned to the indirectly heated fryers after it passes through an online filter and is heated in an external shell and tube type heat exchanger (oil passes through the tubes and heat transfer fluid flows through the shell side).

In batch operations, oil is heated to the desired frying temperature and then a batch of product is placed in the fryer. Temperature of the oil in the fryer drops rapidly following product addition and then recovers as the temperature of the product rises. The product in the fryer is stirred with an automatic stirrer. The fried product is taken out of the fryer with a take-out conveyor. The temperature and the amount of the oil in the fryer are maintained at desirable levels by automatic controllers.

Instead of batch frying, large producers use what are called continuous fryers. Unlike batch frying, the product is fed from one end of the fryer and taken out at the other end continuously. Similar to the batch type fryers, oil is heated directly or indirectly. Industrial fryers are equipped with paddle wheels to assist with uniform product distribution through the fryer, regulate flow and briefly submerge the product in hot oil. Oil level in the fryer and desired frying temperature are automatically maintained.

Vacuum fryers are preferred for products that require minimal color change or browning. As the name implies, these fryers operate under vacuum (< 100 mm Hg) and low temperature (about 250° F). Frying is carried out in a vacuum chamber. In general, vacuum fryers are operated in batch mode and tend to have small capacity and cost higher than a regular fryer.

Fryer Selection

Finished product attributes largely depend on the fryer design and operation conditions. The first step in fryer selection is to define the product to be fried. Every product has its own unique set of characteristics that need to be considered while selecting a fryer.

Fried foods can be broadly classified into two groups: coated (batter and breaded items) and uncoated (i.e. meat balls, dough enroled products etc.) products. A coating system applied to the product (batter, seasoned flour, bread crumbs etc.) has a significant effect on fryer selection and maintenance. Product buoyancy, color and texture are also key attributes affecting fryer selection. If the product is buoyant, a product conveyor that will hold-down or submerge the product in the oil is required. The products that sink in oil require a bottom conveyor to control their flow in the fryer. Buoyancy characteristics of some products may change during frying hence these types of products may require multi-stage conveyors.

Construction material for the surfaces that will come into contact with oil and food should be T-304 or better stainless steel. Brass and copper should be avoided as the fryer construction material because they catalyze oil oxidation. Welded joints should be smooth and polished. A CIP (Clean-In-Place) system should be included in the frying system.

Fryer dimensions

Fryers operating at full capacity and in continuous mode produce high quality products. The dimensions of a fryer are determined by the production rate, frying time and product loading (product weight/area, product weight/length or product pieces/length) also referred to as “belt loading.” The cook area (effective cooking area available in a fryer) and fryer length can be calculated as follows:

$$\text{Cook area required} = [\text{Production rate (product weight/time)} \times \text{frying time}] / [\text{product loading (product weight/area)}]$$

$$\text{Fryer length} = \text{Cook area required} / \text{fryer width}$$



Photo 1. Donuts after the frying process.



Photo 2. Chicken before the frying process.

Operations outside fryer design capacity alter the temperature profile in the fryer and may lead to excessive heat load, which trigger premature equipment breakdowns and unacceptable product flavor and quality. The fryer operations below the design capacity also may have adverse effects on frying oil and final product quality such as low oil turnover, increased oxidative stress and reduced finished product shelf life.

Heat Load

Frying system should be designed to deliver the heat load required to cook the product. The mass and heat transfer calculations have to include losses from fryer vessel, pipes, filters, exhausts, and the thermal efficiency of the product and the heat exchange system. Delta-T along the fryer, which is defined as the temperature difference between feed and discharge end of the fryer, is a very important factor in heat balance calculations and affects the rate and total amount of moisture removed from the product and color and texture development. A Delta-T of 12-18°F is common for industrial fryers.

As mentioned, oil temperature drops rapidly as the product is loaded into the fryer and then recovers as the temperature of the product rises. Heat load calculations have to take into account the temperature recovery time and minimize temperature fluctuations during frying. The temperature fluctuations are the largest for the direct heated gas fired fryers, 10-15°F. The heat exchange systems that use thermal fluids are more reliable and have a lower temperature fluctuations range, 7-10°F than the gas fired systems. Indirect heated systems have the lowest temperature fluctuations, $\pm 2^\circ\text{F}$, which can be further reduced by precise control of the oil flow.

Particulate Removal

Crumb removal screens placed before the oil circulation pump remove relatively large particles to avoid plugging of the heat exchanger tubes. Fines falling off the product during frying should be removed from the fryer otherwise they will burn and carbonize and accelerate oil degradation reactions and develop burnt flavor in the product. The selection of a fines removal/filtration system is based on the particle size, amount, hardness and buoyancy (floating or sinking) characteristics of the fines. Paper, dual basket, motorized catch box, and rotary drum filters and centrifugal system are some of the fine removal equipment used in industrial frying operations (see first reference).

Paper filters may cause high oil loss and oil degradation because of the exposure of oil to air due to low filtration rates. Settling particles in the fryer can be removed via a sludge conveyor or pan wiper system. Floating fines require a weir or skimmer type removal system. Continuous in-line systems filter about 5% of the oil and return the filtered oil to the fryer. Properly designed systems drive the fines through the filter system and do not allow formation of dead spots due to slow or non-uniform flow in the fryer.

Fryer Maintenance and Safety

Oil loading, circulation and heating should be initiated right before the production starts to avoid running the fryer idle for extended time. Fryer start-up and shut-down cause more damage to oil and product quality than continuous frying operation. Hence, it is imperative that a comprehensive operation and oil and fryer management program is developed and followed to minimize inter-

ruptions. In the case of an unexpected interruption or fryer shutdown, make-up oil addition should be stopped and the oil heater should be turned off. Oil circulation may continue.

Heat in the fryer can sustain minimum frying temperature for several minutes after the heat is turned off. Hence, towards the end of production make-up oil addition and heating should be stopped to save oil and speed-up oil cool down. The time to stop make-up oil addition and turn the heat off should be chosen so that oil reaches to the minimum frying temperature as the last product leaves the fryer. Oil circulation should be continued until the oil temperature drops to the level specified by the fryer manufacturer. The oil needs to be cooled down rapidly. This can easily be achieved by using heat exchangers. If the production is going to resume within 24 hours, oil can be left in the fryer after filtration. Otherwise, the oil needs to be transferred into an oil storage tank.

The fryer should be sanitized by a CIP system after the shut-down. Many countries require installation of a wet scrubber on the fryer exhaust line to control steam, odor and volatile compound emissions. A proper ventilation system is essential to prevent grease or con-

densation collecting on walls and ceilings. Although the United States Food and Drug Administration has not established specific regulations to control the quality of fried foods and frying oils, they are subject to the general provisions of the Federal Food, Drug and Cosmetic Act and the specific food safety programs such as proposed Hazard Analysis and Critical Control Points (HACCP) and Good Manufacturing Practice (GMP) required for food manufacturing.

References

- Perkins, E.G. and Erickson, M.D. 1996. Deep Frying. AOCS Press, Champaign, IL.
- Gupta, M.K., Warner, K. and White, P.J. 2004. Frying Technology and Practices. AOCS Press, Champaign, IL.

More Information

If you would like more information, please call the Robert M. Kerr Food & Agricultural Products Center at 405-744-6071 or email fapc@okstate.edu to request assistance.