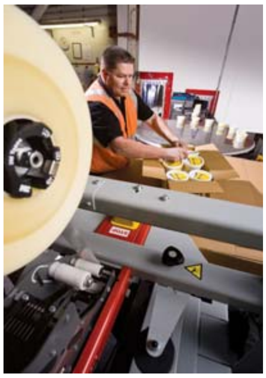
BAKELS Edible Oils

DEEP FRYING

'More of an Art Than a Science'



INTRODUCTION

The increasing patronage of fast food establishments and restaurants reflects the appeal of deep fried foods. In North America over 500 thousand tonnes of fat are used annually to produce potato crisps. The appeal for deep fried food arises from the colour, smell and flavour imparted to the food by this cooking process.

Consistent production of appetising fried foods appears straight-forward, but demands careful control of the frying operation itself. Problems of greasy, soggy food and poor frying fat life often arise when operators are unaware of good frying practice. The following paper discusses what happens as food is deep fried; how to select a good frying medium and maintain its quality in use, and typical problems and their causes arising in a fast food business.

WHY USE FATS?

When a Chef receives many food orders at short notice, the quickest way cooked items can be served is by deep frying. Cooking requires heat transfer from a heat source into the foodstuff. Heat conduction by air in an oven is relatively slow, total immersion of food in a liquid gives a rapid result if a suitably high temperature can be reached. Fats are capable of being heated to high temperatures, are reasonably stable and help improve the eating qualities of the food. Hence fats are ideal for deep frying.

DEEP FRIED FOOD

The popularity of deep fried food is due to the unique structural change imposed on the food by the technique.

The outer surface supplies the initial impact of colour and smell. The outside should be an even golden brown colour, which results from a Maillard reaction between sugars and proteins in the food on heating. The degree of browning is a function of the cooking temperature and the food surface composition. Too high a cooking temperature will burn the outer coating, and foods high in some sugars darken readily.

The crust or skin of the food is dehydrated by the heat of the frying fat to contain 3% or less moisture. Some of the moisture in the crust structure is replaced by fat which tenderises the crust, and gives flavour and good 'mouth feel' to the food. Because of absorption of the cooking medium, the customer can judge the quality of the fat used. Hence good management of the frying fat is important if customers are to place further orders. The amount of fat absorbed is related to the ratio of the food surface area to volume. French Fries contain 6 - 10% fat, potato crisps 30 - 40% fat.

Below the deep fried coating, the food should be cooked, moist and have a texture and flavour characteristic of heating the foodstuff alone.

WHAT IS A FAT?

Fats and oils are obtained from animal and vegetable sources and each has characteristics pertaining to its composition. Fats and oils consist of triglycerides which are esters of glycerol and fatty acids. The type and location of fatty acids as component triglycerides fingerprint the overall physical and chemical behaviour of the fat. When fats decompose, they release free fatty acids and produce other reactive chemicals. The main reactions of fat breakdown are oxidation and hydrolysis.

Some component fatty acids are unsaturated. Chemically this means they can potentially add hydrogen across a molecular double bond, and this amount of unsaturation is measured (and named for analytical reasons) as an Iodine Value. The more unsaturated the fatty acid, the higher the Iodine Value (IV).

Oils which contain significant amounts of polyunsaturated fatty acids are susceptible to oxidation at room temperature. This susceptibility increases significantly at elevated frying temperatures. These oils are unsuited for deep frying, ie Soyabean Oil. Fats with medium to low IV are more resistant to oxidation and better suited to frying purposes, ie High Oleic Sunflower, Palm Oil.

HOW TO SELECT A FRYING FAT

Selection of a frying fat requires consideration of its cost, whether the food is to be eaten hot or cold, whether the product will be stored, and how quickly the frying operation will use fat.

Oils high in polyunsaturated fatty acids are liquid at room temperature, drain well from foods, can be cheap, but will quickly oxidise. Use of polyunsaturated oil is not recommended - particularly for products to be stored, and also because of their rapid breakdown at frying temperature to form gums. Fryers charged with SBO quickly develop a varnish like polymer on surfaces which is difficult to clean, and catalyses further fat breakdown. A fishy, painty odour and other problems develop.

Partial hydrogenation of vegetable oils to medium IV provide low melting products with improved oxidative resistance. These are more suited for products to be stored or eaten cold.

Hydrogenation to a solid gives good oxidative resistance. The mouthfeel of the product will depend on the melting point of the fat. A lower melting point has a better mouthfeel since it melts quickly at body temperature. For hydrogenated oils, melting point increases as IV drops.

Beef fats and some vegetable oils such as Palm Oil comprise largely saturated and mono-unsaturated fatty acids. They have little tendency to form gums, good oxidative stability and good flavours, and are ideal general frying shortenings (Table 1).

Some fats contain totally saturated fatty acids, eg Coconut Oil and fully hydrogenated oils. Despite excellent oxidative resistance, the latter are unsuited for products to be eaten cold because of their very high melting point, and poor mouthfeel or palate cling. Short chain lauric fats such as Coconut Oil are used to spray coat snack foods because of their good mouthfeel and excellent shelf life. Coconut Oil must not be used for deep-frying because it promotes foaming.

Some shortenings are designed specifically for pan frying or grilling and contain emulsifiers which help prevent spattering of fat when cooking wet foods. Although they perform well in low temperature, shallow fry situations, at deep frying temperatures, emulsifiers promote foaming and darkening.

Some deep frying shortenings contain antifoam agents notably methyl silicone which can extend a frying fats life but are not absolutely essential in a well run operation. Silicones can cause excessive absorption in the frying of certain foods such as donuts.

A good quality fat will perform better and longer than one of lesser standards. Initial fat quality is the responsibility of the edible oil producer. A specification for a frying fat should show that it has light colour, bland flavour and odour and if food is to be eaten cold, a suitable melting point. Most important is FFA or free fatty acid level. An FFA <0.1% shows the fat is properly refined. PV or Peroxide Value measures initial oxidation products, and if PV <1.0 meq/kg the sample is fresh. A smoke point >200°C should be specified so that the oil doesn't smoke when first used. Moisture <0.1% indicates the product is pure fat, and no spattering will occur when first used. Another test commonly quoted in the technical trade is the Rancimat Stability, which gives an indication of the stability of a fat.

Having selected a suitable quality frying shortening, responsibility for maintenance of a quality frying medium in use rests with the fast food operator.

Table 1 - Properties of Some Fats and Oils

Iodine Value	Example	High Temperature Oxidative Stability	M Pt	% Fatty Acid Composotion			
				Saturated	Monounsaturated	Polyunsaturated	
0	Coconut Oil	Excellent	25°C	100	0	0	
0	Fully Hydrogenated Soyabean Oil	Excellent	68°C	100	0	0	
40 - 45	Beef Fat	Very Good	46°C	50	48	2	Good Frying Fats
48 - 50	Beef Oleo	Very Good	38 - 40°C	48	50	2	
80 - 85	High Oleic Sunflower	Very Good	<10 °C	12	85	3	
51 - 56	Palm	Good	38 - 40°C	49	41	10	
52 - 58	Palm Olein	Good	25°C	45	43	12	
110 - 135	Maize Oil	Poor	<0 °C	15	31	54	
110 - 135	Rapeseed Oil	Poor	<0 °C	7	61	32	
110 - 135	Peanut Oil	Poor	<0 °C	22	39	39	
110 - 135	Sunflowerseed Oil	Very Poor	<0 °C	11	17	68	
110 - 135	Soyabean Oil	Very Poor	<0 °C	15	22	61	
110 - 135	Safflower Oil	Very Poor	<0 °C	11	15	74	

WHAT HAPPENS TO THE FAT WHEN FOOD IS DEEP FRIED?

Throughout the running of a fast food operation, frying fat is exposed to elevated temperatures and the effects of air and moisture. These conditions lead to eventual thermal decomposition of the fat, largely by oxidation, and also by hydrolysis. These reactions alter the chemical and physical nature of the fat. The rate at which these changes occur can be controlled if the operator is aware of factors encouraging these adverse reactions.

MOISTURE REMOVAL OF VOLATILE SPECIES

Initially when food is placed in a fryer, moisture present is transformed into steam by heat absorption from the fat. The steam removes some volatile odorous compounds produced by the fat or dissolved into the fat from previous foodstuffs, also some antioxidants both naturally present and added. Antioxidants are added to frying fats to retard oxidative breakdown of the fat while heating it up to frying temperatures and will not be permanently present. Some fat soluble vitamins and spices in foodstuffs serve as antioxidants too.

Steam generated by cooking food not only helps remove some thermal breakdown material, but effectively blankets the surface of the oil from the oxidative action of air. Any unprotected fat heated to frying temperatures in the presence of air will suffer quickly. Ideally fryers should be used with a continuous throughput of food, or when not in demand, cooled down to a standby temperatures of 90 -120°C. Antifoam agents can help prevent air oxidation during standby by forming a monolayer on the fat surface.

A good ventilation system should remove excess steam and volatiles. If the fume cover is too close to the fat, condensation of the steam will drop moisture and condensed volatiles back into the fat, promoting hydrolysis of the fat and production of FFA, and other polar compounds. For this same reason, foods to be cooked should be dried as much as possible, unless pre-prepared and frozen.

NON-VOLATILE BREAKDOWN PRODUCTS DISSOLVED IN USED FAT

When a fat is heated for a considerable time, oxidised and polymerised species form, largely from unsaturated fatty acids present in the fat. These species account for the chemical and physical changes seen in used fat. The oxidation rate is proportional to the amount of unsaturation and particularly polyunsaturation of the fat. When a fat deteriorates with high temperature use, the main changes seen concern colour, viscosity, FFA and IV, foaming, smoking and polymer formation.

COLOUR DARKENING OF FAT AND FOOD

Some coloured species are formed on heating and can be dissolved from the food into the fat. Colour can develop from secondary reactions of fat breakdown products. Certain fats if overheated on initial melting will develop dark colours within a few days use. Excess colour can be due to fine deposits of burnt food dispersed in the fat, and this will give the cooked food a speckled appearance. Patchy colouration on the food surface occurs when foaming has begun.

CHANGE IN FFA AND IV

As oxidation of the fat sets in, the IV of the oil will drop as unsaturated fatty acids undergo oxidative reactions, and FFA (one of the breakdown products) will increase. If fresh fat can be regularly added to the fryer the FFA of fat in the fryer can be maintained at workable levels. Generally fat with an FFA >1.5% should be discarded as there will be sufficient breakdown material present to rapidly catalyse further oxidation. Foaming becomes a severe problem when FFA >2.0%.

VISCOSITY INCREASE

As a fat progressively oxidises, its viscosity increases, due to a high content of high molecular weight polymer and gum. The ability of a fat to serve as a heat transfer agent decreases as viscosity increases, and food will be greasy, as if it had been cooked at too low a temperature.

SMOKING AND FOAMING

When a fat has deteriorated to the extent that it foams or smokes it should be totally discarded, as this indicates the presence of material capable of wrecking the best fresh fat. Working with smoking or foaming fat is potentially dangerous, and produces food with poor flavour, colour and little appeal.

ECONOMIC AND EFFICIENT USE OF DEEP FRYING FAT

Realising that frying fat is a cooking medium, is expendable and part of the finished product, it is sensible to manage an operation so that the frying fat is kept in the best possible condition.

HEAT BALANCE AND FRYER DESIGN

Continued output of appetising fried food can largely be arranged by choice of good fryer design and size. The fryer capacity should allow required throughput of food for a minimum amount of fat.

Normally one part of food is fried in six parts of fat. Use of too large a vat means excess fat is being kept hot and slowly deteriorating for no return in sales.

When food is placed in hot fat, there is a sudden heat drop as moisture is converted into steam. If the fat temperature is not regained, food is effectively cooked at too low a temperature and becomes greasy and soggy. The fryer should have a heating element capable of rapidly returning the temperature of the fat. The fryer capacity is hence limited by its ability to maintain heat.

Overloading, by placing too much food to be cooked in the fryer, causes the fryer temperature to drop beyond the capacity of the heating element. This is often wrongly compensated for by increasing the initial fryer temperature. This only serves to prematurely oxidise the fat. To cope with fluctuating demand it is best to have a series of fryers with one in operation over quiet periods, and the others on standby at 90 - 120°C. During peak demand the additional fryers can be brought into use.

A related problem of heat balance comes when frying food from a freezer. A greater heat drop is experienced by the fat, and less frozen food should be cooked at one time than food at room temperature. The amount depends on the fryer heat capacity. The same fat temperature should be used.

To assist the heat balance in the fryer, food to be cooked should be of uniform size - large pieces cooked in fryer, small pieces (eg chips) in a separate fryer. Large food items should be cooked at slightly lower temperatures as the larger mass requires more heat input to cook, and yet the outer skin or coating should not be burnt.

TEMPERATURE

Too low a cooking temperature results in excess fat absorption by the food. The correct temperature to use is the lowest possible which gives a product of the desired quality.

Thermostat settings on fryers can be wrongly set by operators, and can read incorrectly. The temperature of the fat should be checked weekly with a stainless steel dial thermometer (not mercury in glass because of danger of breakage).

FAT TURNOVER

Problems due to gradual deterioration of fat quality are minimal if the fat turnover is less than two days. Because fat is absorbed by the cooked food, the level of fat in the fryer will drop. This creates a greater ratio of fat surface area to volume, hence effects of oxidation by air are greater. Slow business periods cannot be catered for by running fryers only half filled with fat. The fryer should be maintained at the correct level by addition of fresh fat.

Regular addition of fresh fat hinders build up of problem-causing oxidation material. Many experiments show that fat kept in continuous use will be of better quality than that kept standing, unused at frying temperature. Continuous use also necessitates addition of further fat and fat is not used long enough to breakdown. A high turnover means fat never has to be discarded.

If turnover time is greater than two days, the business output is not sufficient to be trouble free. Particularly when turnover extends to five or eight days, fat will deteriorate faster than it can be replaced. In such a situation, smaller frying kettles should be used, and some fat removed each day to allow addition of 15 - 25% fresh makeup fat.

CLEANING FAT AND FRYER

To promote the useful life of a fat and avoid colour problems with fried food, any crumbs or food particles breaking off into the fat should be removed before they char to carbon and catalyse colour forming reactions.

Some vats are equipped with a self filter device through which fat can be circulated. Filtering daily or more regularly is recommended to remove fines of broken food.

Some filter aids are advertised which claim to remove fat colour and decrease FFA level. There is some debate reported over the benefits of such treatments, and they should be used with caution.

Any deposits of gum or polymer around the fryer hood or utensils, eg baskets, should be removed when noticed because of their oxidative potential, and difficulty to remove if left for long periods.

It is important when fryers are cleaned to remove all trace of soap or detergent, and thoroughly dry the surfaces. Detergents and water at trace level will cause foaming, aeration and deterioration of the next fresh fat added.

When recharging a fryer with fresh solid fat, melted fat should be added to cover the elements which can then be turned on to 100°C to slowly melt the bulk of the fat. Solid fat is a poor heat conductor, liquid fat can superheat and burn before solid fat melts.

SUITABILITY OF FOOD FOR DEEP FRYING

While many foods gain appeal when deep fried, if incorrectly prepared they can cause problems for the fast food operator.

Crumbed Food	Should have a firm, well adhered coating that won't leave many bread particles in the fat.
Egg	Containing coatings tend to release lecithin into the fat. Lecithin is a natural emulsifier, which darkens at frying temperatures and promotes foaming.
Wet Foods	Should be dried as much as possible. If very wet, a good fried result is not possible. Potatoes at some times of the year have a very high moisture content and produce soggy chips in the best fat conditions.
Excess Flour	Should not be on the surface of prepared uncooked foods.
Salt	Should not be added to the fat.

High Fat Foods eg, meats leach these into the frying fat. These fats are unrefined and can diminish the overall frying fat quality.

Sodium Metabisulphite Is a cause of many fat colour problems. This chemical is used to whiten potatoes and is restricted in level of use by the Health Department. At frying temperatures the metabisulphite decomposes to sulphur compounds and will turn fat black long before many other causes of colour development. For a good lifetime from the fat, potatoes blanched in metabisulphite should be avoided. Alternative chemicals used for potatoe treatment include sodium and pyrophosphate which do not adversely affect frying fat life.

OTHER PROBLEMS

Aeration of fat should be avoided at all costs, since this accelerates oxidation of the fat. Aeration can be brought about by splashing fat when charging a fryer, leaking filter pumps and foaming.

Metals such as nickel, aluminium and especially iron and copper are severe antagonists for fat. Stainless steel fryers and utensils are recommended. Very often operational problems arise because of a brass or bronze fitting present in the system. Care should be taken to inspect repairs - welds can contain copper, and if present in the fryer, filter pump, fry baskets or utensils, will ruin good fat within a day.

WHEN SHOULD FAT BE DISCARED

Operators can be trained to assess the physical attributes of a fat in use and decide when to discard the fryer contents. This judgement is often subjectively made on colour, but this can be misleading as some useful oils have a natural darkening tendency.

FFA is useful measure for anyone with laboratory facilities and chemical expertise, but is an impractical test for most food enterprises.

Odour is an important test, but the senses can be blocked if one works in a frying area for a length of time; odour needs to be compared with a very recent dose of fresh air.

Smoking and foaming are sure signs an oil should be abandoned, but the situation shouldn't be allowed to reach this dangerous state.

Many tests have been trialled for use by fryer operators to indicate FFA buildup, but few are genuinely successful.

A conductivity probe called a 'Testo Analyser' is available which responds to electrical conduction of polar oxidised material present in fat. It compares the ration of polar to non-polar material. Since it reacts differently to various species and response alters in various oils, its usefulness is limited since a suitable cut-off point cannot be assigned for all oils in any situation. It is suitable where only one fat is used and time is the only variable.

There have been various nutritional studies aimed at assessing toxicological dangers of eating food cooked in poor frying fat. Conclusions as to the direct effect of ingesting individual fat breakdown products vary but the consensus is that oxidative products formed in fats used for very extended times are harmful. Many experiments indicate that an oil left heated at cooking temperature but not used for cooking food, will deteriorate more than one in near constant use. In a recent study, conducted in a restaurant situation, changes in the fat and cooked food were monitored from a nutritional viewpoint, for fat used intermittently over a 100 hour frying time. This study suggested that overnight cooking of the oil or intermittent heating at lower temperatures is no more harmful than continued use of the oil. From a nutritional standpoint, oxidation products would not be present in cooked food at levels of toxicological danger if fat in the fryer is replaced by $^1/_3$ with fresh fat every 16.5 hours or sooner after cooking an equivalent of 25kg of potatoes. Ultimately the nutritional problem is not of concern if the fat turnover for the business is high.

All the above tests are designed to suggest whether food continued to be cooked in a fat will be of suitable quality. The only reliable test is to actually smell and taste fried food, and then judge whether the quality is desirable. If not, replace some or all of the fat, and review the whole operation and see that good management of the frying fat is being practised.

COMMON PROBLEMS AND THEIR CAUSES

Greasy Food	Effectively cooked at too low a temperature, from eg wrong fryer size or overloading food in the fryer or cooking in oxidised, viscous fat.
Speckled Food Surface	Burnt carbon in fat from broken food coatings of previous fries.
Patchy Coloured Food	Fat is foaming and should be discarded.
Dark Coloured Food	Food high in sugar content (if from cooking in severely degraded fat - fat would be viscous, burnt smelling, smoking, foaming).
Rapid Darkening of Fat	Metal source (eg copper). Check for brass fittings or welds. Charred foodstuff in fat, emulsifier or lipid colour reacting species leached from food. Residual soap from cleaning fryer. Fat temperature too high.

Smoking, Poor Odour

Fat temperature too high. Fat melted at high temperature and burnt on initial use. Severe oxidation of fat.

SUMMARY

The costs of any frying operation will increase if fat has to be prematurely discarded, or food produced of improper quality.

The following is a checklist to ensure good efficient operation to the quality standard desired.

Fat Fryers

Choose the best quality suited for your purpose, select a size and design to balance your heat requirement and food output. Use several fryers rather than one oversized fryer.

Charging Fryer

Melt solid fat at low temperatures. Solid fat absorbs heat slowly; melted fat will burn if present in small amounts on large heating elements.

Temperature

Check thermostats are at desired settings. Check temperature of fat in fryer. Cook at lowest possible temperature that provides the desired result. Don't leave unneeded fryers heating fat at high temperatures - in slack periods turn all but one fryer to 90 - 120°C.

Prevent Oxidation

Try to keep fat cooking continuously. Don't aerate the fat. Don't use fats which foam. Remove gums on fryer, baskets and utensils. Don't heat fat needlessly or use fryers bigger than your requirements. Manage the operation so that fat turnover is two days or less.

Cleanliness

Filter fat daily. Remove broken food particles. Clean fryers, baskets and utensils correctly and leave no trace of detergent or water.

Food

Cook suitable food. Do not overload the fryer capacity. Cook equivalent sized food items together. Use separate fryers for food of various sizes.

Taste

Check your food looks and tastes good. If it doesn't even your customer will know something is wrong.