Frying oils: selection, smoke points and potential deleterious effects for health

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Frying is a complex, high temperature process with many reactions of hydrolysis, oxidation and polymerisation occurring during the frying life of the oil with resultant effects on the fried food with respect to texture, taste, shelf-life and nutritional properties.

Deep fat frying and shallow pan frying are very common ways of cooking and dehydrating a wide range of foods at temperatures from 170-190 °C. Deep frying is generally carried out between 170-180°C and shallow pan frying tends to be uncontrolled with temperatures between 180-230°C.

Probably the most common fried snack products are potato and corn chips. Potatoes are cooked from a moisture of 80% down to 1.5 %. The fat contents of fried foods vary from around 35% in potato chips to 7-14% in French fries.

The control and disposal of over-used cooking oil presents a number of problems. Not only are there health issues to consider, the assessment of the degree of degradation also traditionally requires tedious and laborious chemical analysis procedures. Once the degree of degradation is established, the disposal or recycling of the used cooking oil presents another huge dilemma - to use in biodiesel or animal feed?

Choice of frying oil

With the global demise of trans-fat, many varieties of unhydrogenated vegetable oils have been proposed and used in both commercial and retail frying. Industrial and food service users have access to a wider range of suitable oils than consumers. Today's consumer seems to be driven by nutritional aspects, packaging, marketing hype and price. In the retail arena many people these days claim high smoke points without anybody really knowing what this means.

In terms of suitability and stability for frying, the fatty acid composition of the oil has a major effect, as does its refining. Oils with high linolenic acid (18:3>3%) are unsuitable, followed next by high linoleic acid oils (18:2>45%). France has had legislation since 1973 prohibiting the sale of frying fats with linolenic acid >2%.This is because of the susceptibility to oxidation and polymerisation of polyunsaturated oils. The high PUFA (polyunsaturated) oils were never really considered suitable for high heat and sustained use.

The most suitable are those oils high in monounsaturates with some content of linoleic acid (for flavour) and saturated fatty acids for stability. Examples are olive oil and the new high oleic acid canola and sunflower oils.

The relative rates of oxidation of the pure fatty acids, as a reference point are respectively oleic: linoleic: linolenic 1:45:100.

Refined, bleached and deodorised (RBD) tallow (52% saturated), virtually no PUFA, used to be the most common frying fat and is in fact still the most stable followed by palm. It has a smoke point specified at 220°C minimum. Its use has declined due to the reduction in animal fat consumption and concerns about oxidised cholesterol.

Of the industrial and commercial fats, palm olein (48% saturates) is probably the most economic and readily available globally. Palm has come under fire for its saturated fat content and environmental sustainability. It is also semi-solid in temperate climates and many users look for liquid oils. Those that are highly suitable may include high oleic varieties of sunflower oil, canola oil and safflower oil. High oleic acid canola is currently being grown in Canterbury by Pure Oil Ltd.

The specifications, functional requirements and supply conditions for the industrial food market are far more rigorous and demanding than for the retail market. Some specialty oils supplied to the industry are not available at retail.

Retail vegetable oils

There are many oils on the retail market and these include olive oil of various grades, rice bran oil, avocado oil, nut oils, canola oil and grape seed oil and oh yes the notorious coconut oil. Some selected smoke points of these oils are shown in the following table.

Smoke points of selected oils from literature

Frying oil/fat	%FFA	ºC
Beef dripping (tallow)	1.0	165
RBD tallow fats	<0.1	240
RBD standard canola	0.1	230
Olive oil NZ	<0.2	200
Olive oil imported	<0.8	165
RBD olive oil imported	?	190
Avocado oil	0.1	220
RBD coconut oil	0.1	170

The smoke point is a vital analytical measurement for any oil used for frying. The temperature is measured while observing a steady evolution of smoke from the oil in the vessel, the test being carried out under standard conditions (AOCS Cc 9a-48).

A higher smoke point is a desirable characteristic. Smaller, more volatile material, particularly fatty acids, lowers the smoke point and the reduction is maintained during the time of frying until the oil is no longer usable. The smoke point at this stage is <170°C.

Many suppliers and retailers of vegetable oils claim 'High smoke points" without measuring it. This should be done under the standard methods of the AOCS by a registered laboratory.

The lauric oils, such as coconut and palm kernel have the lowest smoke point in standard refined vegetable oils because of the content of the more volatile medium chain and short chain fatty acids. A higher

smoke point limit is often specified for frying oils since it indicates a long life in its use.

The use of antioxidants

Although the addition of the traditional phenolic antioxidants BHA and TBHQ increased the shelf life at ambient and under the conditions of the AOM test (accelerated shelf life test), they were not effective at frying temperatures as they are volatile. Some natural antioxidants such as tocopherols, rosemary extracts and polyphenols can assist in extending frying life. A most effective antioxidant is the addition of 1ppm silicone oil. Some oils contain antioxidants even after processing and these include rice bran oil (oryzanol), palm oil (tocotrienols) and sesame oil (sesamol).

A patented blend known as Good Fry™ contained a blend of rice bran oil, high oleic sunflower and sesame oil.

Evaluation and testing of oils

During frying many complex chemical processes occur. Hydrolysis happens by reaction with moisture producing free fatty acids. Oxidation and bond cleavage also yields material which analyses as acidic. Polymerisation, conjugation and isomerisation all happen, producing a multi component mixture of breakdown products which lead to a degrading of colour and an increase in viscosity. Many test methods have been used to evaluate the stability of oils for frying and their resultant shelf life. The most relevant measure after years of research seems to be the amount of total polar material in the oil (TPM).

The Testo 270 monitor now seems to be the most suitable, quick and easy to use piece of hand held instrumentation which is suitable for the measure of TPM in the field or in the laboratory.

Potential deleterious effects of used frying oils

The products of degradation from oils, especially PUFA oils heated to high temperatures, have been shown to be toxic. A recent article in *Inform* magazine (2014) reported the presence of toxic lipid hydroperoxides and their breakdown compounds using NMR. These included acrylamide, trans alkenals and aldehyde fragments.

These authors recommend that anyone promoting the use of PUFA oils for nutritional purposes, caution the consumer about the potential toxicity from overheating and abusing PUFA oils.

Some countries in Europe have strict legislation covering the use of frying oils. Most of them specify a TPM content $<25\%$, smoke point $>170^{\circ}C$, and polymers $<15\%$. The topic was discussed in full at a symposium on deep fat frying in 2005 where "A frying fat or oil is considered to be deteriorated if odour and taste are objectionable or if the total polar material exceeds 24% and polymerized triglycerides exceed 12% (Drummond, 2007).

In Europe, to be suitable for human consumption, the law requires adherence to certain limits for selective compounds, among them polar components (TPM) and polymerized triglycerides (PTG). It states that the level of TPM should not be more than 25%, while the limit for PTG is 16%. A survey done in 1997 by the Department of Biotechnology and Food Technology in the Pretoria Metropole showed severe abuse of cooking oil in some fast food outlets with the worst sample drawn having 63% TPM and 56% PTG . These results are much higher than those found in similar surveys conducted in other countries such as Australia and Saudi Arabia, with their highest TPM recorded in oil being 29% and 33% respectively.

Used cooking oil (UCO)

A random analysis of a take away bar using canola oil showed a TPM level of 17% using the Testo meter. There is growing uncertainty around the issue of feeding used cooking oil of undetermined polar material to animals such as pigs and chickens. Any toxic materials could find their way into the meat or the eggs.

References and further reading

Supplier of suitable vegetable oils, Bakels Edible Oils www.beobakels.co.nz

Smoke point testing Flinders Cook www.flinderscook.co.nz, AOCS Cc 9a-48

Testo analytical monitor 270, www.eurotec.co.nz

Drummond, L. review in Handbook of Australasian edible Oils, (2007), pages 271-294

Healthy frying, NZ Heart Foundation http://www.heartfoundation.org.nz/healthy-living

Toxic material in frying oils and their detection, Inform magazine, (2014), Vol. 25, p614

Deep Frying: Chemistry, Nutrition and Practical Applications AOCS Press (2007)