

Nutritional and health aspects related to frying (II)

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Abstract

Current consumer requirements are directed towards improving the quality of foodstuffs expecting that certain processed foods and the ones prepared by frying will exhibit in addition to sensorial attributes nutritional qualities as well. Most of the processing and preparation methods of food are based on heat treatment, which also has less desirable effects on food such as: changing in color, taste, flavor and texture. In addition, during heat treatment by frying beside the aroma compounds formed which are very appreciated by consumers also other compounds which are not desirable get accumulated in the products; those compounds are formed by partial or total alteration of thermolabile nutrients present in food and in the frying oil. Tocopherols, essential amino acids, fatty acids present in food are degraded following hydrolysis, oxidation and polymerization reactions, etc. Therefore we are trying to review the nutritional and the risk factors associated to frying.

Keywords: food safety, food quality, frying process, oils

Introduction

There is a growing concern about the nutritional and safety aspects of consuming deteriorated frying fats and oils. Many experiments have been done on rats by feeding them with degrading frying oils [21]. It is well established that the heating of fats can result in the formation of compounds with non-nutritional properties. Compounds formed may be enzyme inhibitors, vitamin destroyers, lipid oxidation products, gastrointestinal irritants, and /or potential mutagens [10].

Early studies used extremely overheated fats that were toxic if fed to animals [5]. High mortality rates were observed in most of the cases. Growth of the liver and an increase in kidney volume were also reported, following the use of degraded oil [21]. Later fats and oils were heated in equipment for deep fat frying under the conditions of good catering practice. Such heated fats showed no detrimental effects even if fed in long-term feeding trials [5]. However, certain fractions of the heated fats, the so-called "Total Polar Compounds", caused the following clearly noticeable effects in the feeding studies: growth retardation, increased liver and kidney weights, and disorders of the enzyme system but, only if fed in high doses [5].

There are several classes of material in oxidized fat that have toxic effects: peroxidized fatty acids and their subsequent end products, polymeric material and oxidized sterols [1].

The toxic components are: i) Hydroperoxides, ii) Hydroxy fatty acids, iii) Carbonyl compounds, iv) Cyclic monomers, v) Dimers and Polymers, vi) Polycyclic aromatic hydrocarbons, vii) Oxidized sterols [23].

i) Hydroperoxides

The first step in the oxidation of fats and oils is the formation of hydroperoxides, which are unstable in hot oil, but which can be formed again in periods of cooling the oil and during storage of the fried food [5]. Peroxide formation is a major point of concern from a toxicological point of view [26]. Lipid hydroperoxides may activate or inhibit certain enzymes [23]. Linoleic acid hydroperoxides have been reported to inhibit *in vitro* the activity of ribonuclease, pepsin, trypsin, and pancreatic lipases [75]. Kanazawa and Ahida (1991) reported that the hepatic dysfunction caused by lipid peroxides may be due to decreased activity of hepatic enzymes such as glucose 6-phosphate dehydrogenase, glucokinase and coenzyme A [14]. Lipid hydroperoxides may lead to the oxidation of thiol groups in proteins leading to altered protein conformation [23]. Vitamin E is destroyed in the body membranes by peroxides or subsequent free radical reaction [26].

Hydroperoxides show very low absorption in the organisms, but are hydrolyzed by lipases as fast as the original triglycerides. All low molecular hydroperoxides are very toxic, if they are injected into the veins, but rather harmless if they are fed via the gastrointestinal lumen, where they are converted to hydroxy acids by enzymatic action of a peroxidase [5].

ii) Hydroxy fatty acids

The secondary lipid oxidation products are mainly responsible for the acute biological effects. Diarrhoea is considered to be a common symptom caused by the formation of fatty acids with hydroxy groups from fatty acid hydroperoxides [2].

Lang *et al.* (1963) studied extensively the hydroxylated fatty acids. They fed rats for 8 weeks with diets containing up to 20% of the fatty acids formed by hydrolysis of epoxidized soybean oil. The hydroxylated oil was well absorbed, except at the highest level of hydroxylation, where decreased feed efficiency and high mortality appeared. The hydroxylated oils caused an impairment of liver function, an increase in blood lipids and cholesterol and an impairment of spermatogenesis, but no other histological changes [15]. Hydroxy acids isolated from oxidized corn oil are absorbed into the lymph and deposited in the body tissues [3].

iii) Carbonyl Compounds

Carbonyl compounds are secondary oxidation products formed by the degradation of hydroperoxides [12]. Carbonyls have been shown to be weakly mutagenic in the Ames assay [25]. Malonaldehyde, which results from lipid peroxidation, is both mutagenic and carcinogenic [23]. Malonaldehyde can cross-link with lipids and proteins, inactivate ribonuclease, and bind covalently to nucleic acids. In cultured mammalian cells, it induces chromosomal aberrations [16].

Malonaldehyde concentrations have been used as a measure of lipid peroxidation in foods during cooking (thiobarbituric acid assay). Boiling or microwave cooking leads to the lowest increments in malonaldehyde concentrations, whereas frying or baking leads to increased figure [20].

iv) Cyclic Monomers

The formation of cyclic monomers is considered proportional to the degree of unsaturation of the fat and the time of exposure to high frying temperatures [21]. Monomeric cyclic fatty acids are formed, mainly from linoleic and linolenic acids, during the heating of vegetable oils at temperatures of 200 °C and above. Such temperatures are reached during the frying of foods and during the refining of oils, especially in the deodorization step [9].

After ingestion with the food, fatty acids of this kind can be absorbed from the intestines and metabolized [9].

Artman *et al.* (1972) heated various oils under normal conditions and isolated a certain fraction, the distillable part of those fatty acids that could not be adducted by urea. This fraction contained cyclic monomers. The fraction proved to be toxic when fed to animals in high doses. This result was a matter of concern since the fraction was isolated from normally heated fats and oils.

The used frying fats contained only very small quantities of toxic substances. They are toxic only when administered in large doses to rats, and the fats themselves produce no appreciable ill effects on animals consuming them [4].

By administrating a mixture of 6-membered ring compounds (cyclohexadienoic compounds) containing approximately 10% aromatic compounds, the toxicity of cyclic monomers was examined. These cyclic monomers were given in amounts of 0.0075–0.15% in diets with different levels of proteins (8–15%). At the same protein levels, there was no difference in weight, food efficiency, or organ weight of the test animals. Only the lipid content in the rat livers receiving the 0.15% dose was increased. In these experiments, the cyclic monomers showed an unexpected low toxicity. This was attributed to the addition of proteins to the diet that alleviated the toxic symptoms [13].

Cyclic monomer amounts in used frying oils depend on the source and heating procedures. In experimentally heated and even somewhat overheated oils no more than 0.6% were found (Table 1) [5].

Table 1. Cyclic fatty acids in simulated frying tests [5]

Oil	Goods	Time	Amount %
Soybean	Potatoes	100 hours	0.33-0.57
Corn	None	216 hours	<0.2
Soybean	Various	80 hours	0.07-0.18

In ill-treated oils from snack bars in various countries, no more than 0.7 % were found [5]. Although the concentrations of cyclic fatty acids in heated oils are low, they were long believed to have potent biological effects. However, recent nutritional studies with highly purified preparations of cyclic fatty acids have cast doubt on these findings that there might be some toxic properties [9].

v) Dimers and Polymers

The use of polymeric fractions from heated fats in nutritional studies is popular due to their relative ease of isolation. The limited absorption of heated fat polymers appears to be largely responsible for the lack of dramatic symptoms in animals after ingestion of such materials [17].

Unsaturated fatty acids polymerize at frying temperatures. New bonds are formed between the fat molecules leading to dimeric, trimeric, and higher polymeric triglycerides. The intact fatty acids of the new molecules are well metabolized and only the higher polymers withstand enzymatic cleavage [5].

Unsaturated oils such as linseed, soy, cottonseed, rapeseed, corn, and peanut oil heated to 250-300 °C for 6-24 hours contain polymeric material corresponding to cyclic monomeric, dimeric, oligomeric, and higher polymers [10].

The toxicity of dimers isolated from cottonseed oil that have been heated in air has been attributed to the fact that dimers contain carbonyl groups, hydroxyl groups and unsaturation that is difficult to remove by hydrogenation. Dimers isolated from oxidized sunflower oil proved toxic and growth depressing when given to rats in doses of 100mg/rat/day for 12-14 weeks [3].

Billek (1974) and Perkins (1978) isolated dimers from heated oil and fed them to rats. Only 1% (Billek) and 6% (Perkins), respectively, of the substance was metabolized to CO₂, and most of the radioactivity (80% Billek and 85% Perkins) was excreted with feces or found in the gastrointestinal tract. A very small part of the dimers was metabolized [5,22].

Polymeric material is poorly digested, but may interact with gut contents and affect the absorption of fat-soluble vitamins [23].

The polar material isolated from thermally oxidized oils, the complex glycerides, was hydrolyzed *in vitro* under the action of pancreatic lipase. The triglycerides in the heated oil disappeared after 2 min, but the polymer material remained practically untouched. Dimeric triglycerides were partly hydrolyzed, as well as trimeric triglycerides, but to a smaller degree. Hydrolysis with pancreas lipase is more difficult as the molecular weight increases [18].

Monomaeric, dimeric, and trimeric acids are classified as non toxic by ingestion. In addition, they are considered neither primary skin irritants nor eye irritants, as these terms are defined by the federal regulations dealing with toxic substances [8].

vi) Polycyclic Aromatic Hydrocarbons

Polycyclic aromatic hydrocarbons are potential toxic materials that are known as carcinogens [23].

The quantity of polycyclic aromatic hydrocarbons in oils after frying is lower than in fresh oils. 3,4-benzpyrene exhibit the greatest reduction and could not be detected in lard even after heating. With regard to the formation of carcinogenic hydrocarbons, the heating of fats at temperatures used in cooking may be considered safe [10].

vii) Oxidized Sterols

There is an increasing interest in the oxidation products of sterols because of the possible adverse effect on human health. Cholesterol oxidation products have been investigated for possible mutagenic, cytotoxic and carcinogenic activity [7].

Oxysterols have gained increasing attention with the recognition of their many biological activities. While many oxysterols have toxic properties, others are intermediates in bile acid formation, affect cholesterol transport or regulate gene expression. As they may be generated by enzymatic or autoxidative mechanisms, cholesterol-containing foodstuffs may contain oxysterols, at much lower concentrations than those of cholesterol [6].

Although fresh cholesterol containing foods are virtually oxysterol free, processing can significantly increase the concentration of these compounds in foodstuffs. Humans absorb oxysterols from food into the blood stream [11].

Oxidized sterols, particularly cholesterol may possess hormone-like activity [23]; they exhibit cytotoxicity to smooth muscle cells, fibroblasts and endothelial cells, and they alter membrane fluidity, permeability and interfere with gap junction communication and the modulation of intracellular calcium [24].

Conclusions

Frying is an extremely complex process. Research has revealed a variety of compounds namely hydrocarbons, aldehydes, cyclic monomers, dimers, trimers, and polymers that are formed during the oxidation, polymerization and hydrolysis of frying oils. Nevertheless the resulting products of heated fats from frying foodstuff are not always detrimental to the metabolic processes in the human body especially at the concentrations normally encountered in food. Furthermore the polymeric compounds are absorbed at a very low rate in the intestine, and thus will have practically no influence upon metabolic processes. Usually the amount of oxidation products used in animal tests is several fold greater than the

concentrations that are normally encountered in fried foods, hence the results are unfortunately misleading in most cases.

The final nutrient compounds of the fried food are dependent on: the time/temperature of frying, the frying method (deep-fat frying or shallow-frying), the type of oil, and the type of food fried (including size and form).

The high temperature and short transit time of the frying process largely contributes to the retention of heat-labile vitamins. Moreover, frying has little or no impact on the protein or mineral content of fried food.

The quality of oil or fat used for frying is of great importance with regard to the quality of the fried food. The particular frying oil should be selected taking into account the oxidative stability of the oils.

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