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Deep fat frying of food: A review

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Abstract
Deep fat frying is one of the most commonly used procedure for the food industry as well as household culinary practice. Due to high temperature, the changes may occur in the frying fat/oils with formation of free fatty acids, peroxides, alcohol, cyclic compounds, dimmers and polymers are produced as byproducts. It is a common habit in the household and also in commercial frying to use the same batch of oil for food on a number of occasions spread over some days, which may cause deterioration of oil this become injurious to health. The purpose of this study was to review literature findings on physico-chemical changes in food during deep fat frying.

Keywords: Deep fat, frying, free- fatty acid, oxidation, hydrolysis

Introduction

Deep fat frying is one of the most commonly used procedures, both in the food industry and household culinary practice. The fat serves as a heat transfer medium and as an important ingredient of the fried food. In India and also in the whole of the world's diet and the deep-fried foods are one of the major items. A Major portion of edible oils and fats are consumed yearly in deep fried food. The popularity of deep fried products was due to in the past to the basic structure imposed on them by the way in which they are cooked. In deep frying, the food is totally immersed in hot fat. The fat acts as the medium of heat transfer. Cooking in this way is more efficient than the dry heat of an oven and more rapid than boiling in water, since the high temperature of deep frying fat results in more rapid penetration of heat into the product to be cooked (Stevenson *et al*. 1984) [15].

In India, oils and fats are extensively used for the preparation of deep fat fried products. A substantial part of dietary fat is derived from such products. During deep fat frying when the period of heating is short as encountered in household practices, the changes are considered favorable as this improves the organoleptic quality of the products through removal of raw odor of oil and providing desirable aroma and flavor to the products. During such short period, character and concentration of undesirable compound originating as a result of heating do not pose any problem. But when fats and oils are heated for a considerable time as encountered in commercial practice, there is an excessive accumulation of oxidized, polymerized and cyclic compounds as a result of hydrolytic and oxidative reactions and these are considerable harmful to human health (Sultana and Sen, 1979) [16].

Changes in fats during deep frying

During deep frying, the fat is exposed continuously or repeatedly to elevate temperature in the presence of air and moisture. As seen in Figure 1, a number of chemical reactions, including oxidation, hydrolysis and polymerization occurs during this time as make changes due to thermal decomposition. As these reactions proceed, the functional, sensory and nutritional quality of the fat changes and many eventually, reach a point where it is no longer possible to prepare high quality fried products and the frying fat will have to be discarded. The rate of formation of decomposition products and indeed the product themselves vary with the food being fried, the fat being used, the choice of fryer design and nature of the operating conditions. It is this sensitivity to variations which makes it very difficult to recommend one particular method as ideal for quality control monitoring in all deep frying operations. Like many food processing operations, frying of food involves simultaneous heat and mass transfer (Mittelman *et al*. 1983) [10]. Apart from physico-chemical changes, the loss of moisture from the product and entrance of oil into the product. (Gamble and Rice, 1987) [7] are of importance during frying, as these determine the product quality, process standardization and energy expenditure (Bllumenthal, 1991) [2].

Process parameters of importance, during frying, include a temperature of frying, initial moisture content of the raw material and time of frying (Mittelman *et al*. 1983) [10].

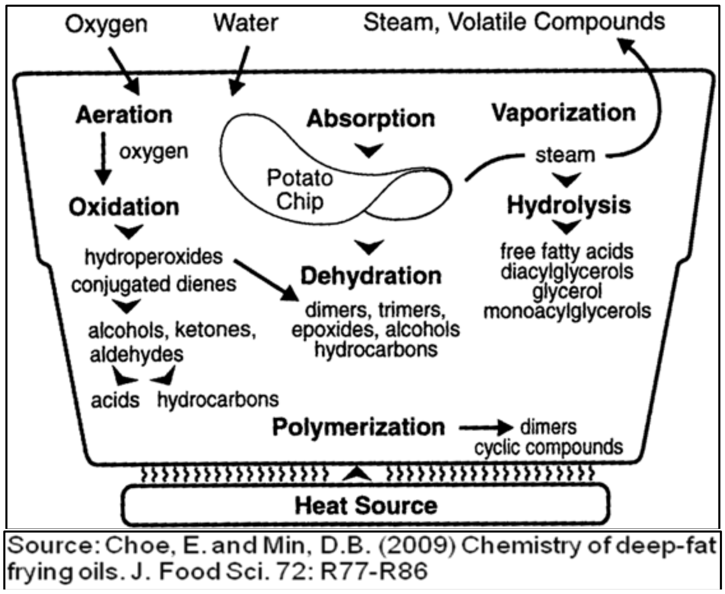

Fig 1: Changes occurring during deep fat frying

CH_2OCOR_1	CH_2OH	R_1COOH
|	|	+
$HOCOR_2$ + 3 H_2O ⟶	CHOH	+ R_2COOH
|	|	+
CH_2OCOR_3	CH_2OH	R_3COOH
Triglyceride	Glycerol	Free Fatty Acids

Fig 2: Hydrolysis of oil

Hydrolysis of oil: When food is fried in heated oil, hydrolysis of fat and oil takes place. Food contains water and moisture forms steam, which evaporates with a bubbling action and oil absorption of fried food gradually start. Water, a weak nucleophile, attacks the ester linkage of triacylglycerols and produces di- and mono-acylglycerols, glycerol, and free fatty acids (Chung *et al*. 2004) [4]. In deep fat frying free fatty acids are produced by hydrolysis to form free fatty acids, di and mono-glycerides and glycerine. Some of the factors which affect the rate of hydrolysis are unknown, oil, which has higher initial free fatty acids, on hydrolysis, will produce a greater amount of free fatty acids. Free fatty acid contents in frying oil increase with the number of fryings. Hydrolysis occurs more in oil with short and unsaturated fatty acids than oil with long and saturated fatty acids. Water from foods is easily accessible to short-chain fats and oils for hydrolysis. Glycerol evaporates at 150°C and the remaining glycerol in oil promotes the production of free fatty acids by hydrolysis. The maximum free fatty acid content of frying oil should be around 0.05% to 0.08%.The free fatty was formed by hydrolysis of triglycerides, which was promoted by the presence of food, moisture and by oxidation or by the reaction of oil with moisture formed during other deterioration reactions (Oke *et al*. 2018) [14].

Oxidation of oil: The oxygen in deep-fat frying reacts with the oil called oxidation. During deep fat frying three types of oxidation take place such as auto-oxidation, thermal oxidation and photo-sensitized oxidation. In auto-oxidation, oxygen reacts with oil at ordinary temperature. It results in the rancidity of oil. Oxidative rancidity involves oxygen attack of glycerides and occurs in all kinds of unsaturated fats (Sangle and Daptare, 2014) [13]. The chemical mechanism of thermal oxidation is principally the same as the autoxidation mechanism. The thermal oxidation rate is faster than the autoxidation. Unstable primary oxidation products (hydroperoxides) decompose rapidly into secondary oxidation products such as aldehydes, alcohols and ketones. Secondary oxidation products that are volatile can significantly contribute to the odor of the oil and flavor of fried foods. The rate of oxidation increases geometrically with the number of double bonds, temperature, light and heavy metals like iron and copper, which accelerate the reaction (Arumughan *et al* 1984) [1]. Photo-oxidation occurs when normal triple oxygen is converted to a singlet oxygen by the exposure to ultra-violet radiations and this convert polyunsaturated fatty acids to hydroxyl peroxide which initiate the oxidation process (Nayak *et al*. 2015) [12].

Polymerization of oil: The major decomposition products of frying oil are nonvolatile polar compounds and triacylglycerol dimers and polymers. The amounts of cyclic compounds are relatively small compared to the nonvolatile polar compounds, dimers, and polymers. Dimers and polymers are large molecules with a molecular weight range of 692 to 1600 Daltons and formed by a combination of -C-C-, -C-O-C-, and

-C-O-O-C- bonds. Dimmers or polymers are either acyclic or cyclic depending on the reaction process and kinds of fatty acids. The potentially hazardous non-volatile compounds gradually build-up in the fried oil. The majority of these products are called “polar compounds” (PC) formed as secondary oxidation products- eg. epoxides, polar dimmers, oxidized polymers, ketones and aldehydes (carbonyls), as well as hydrolysis products of triglycerides such as free fatty acids, monoglycerides and diglycerides (Dobarganes *et al* 2000, Tompkins and Perkins 2000) [17, 6]. The oxidation rate of oil increased as the content of unsaturated fatty acids of frying oil increased. This explains why groundnut oil with less unsaturated fatty acid is a better frying oil than soybean or rice bran oil. Oils with more unsaturated fatty acids The content of linolenic acid is critical to the frying performance, the stability of oil, and the flavor quality of fried food. Low linolenic acid oil produces less free fatty acids and less polar compounds. (Agrawal 1998).

Nutritional and organoleptic changes: Deep fat frying produces numerous decomposition products. As these reaction proceeds, the functional, sensory and nutritional quality of frying fats are changed and may reach a point where high quality foods can no longer be prepared. Although taste evaluation in many food operations is the most important quality measurement, taste evaluations are unreliable for routine quality control testing. It is always preferred to have a quantitative method for which the rejection points to be established using formal sensory evaluation. (Varela *et al* 1998) [18]. Quality evaluation in some foods is conducted, meaningfully when the flavor impact components are chemically analyzed (Fross 1981). Rancid flavor in oil is well known to occur due to oxidation and no single compound is responsible for it, but a sensory evaluation perceived rancidity is clear and gives a direct indication of quality (Gray, 1978) [8]. These sensory techniques have been recognized and continued to be found essentially in odor evaluation in oil (Jackson 1981) [9]. High peroxide value, usually means a poor flavor score, but low peroxide value and odor does not necessarily means high flavor score, indicating low correlations. In study the relationship between peroxide value and odor as well as the flavor was found to be significant. (Narsimhan *et al*. 1986) [11]. During deep fat frying of pakoda in the same batch of oil, after 6th days of friyng in soybean oil and double filtered groundnut oil after 7th day frying should be discarded as there was a development of rancid flavor in the fried products (Agrawal 1998).

Conclusions
The continuous deep fat frying for a long time results in destruction of oil quality due to oxidative degradation, as odour and taste of the fried products become unacceptable. Thermal decomposition of fat deteriorate the functional, sensory and nutritional quality of fat. Its decomposition products are injurious to human health.

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