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Mini Review

The Chemistry in Re-Frying of Foods

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Abstract

Frying is a process of immersing food in hot oil at a high temperature of 150˚C- 190˚C. On the other hand, re-frying is repeated use of left-over frying oil which has already been consumed for frying a particular food. There are various chemical reactions involved during frying and re-frying of foods which generates some hazardous chemical compounds which are not beneficial for health. Therefore, in this review paper, drawbacks of re-frying of oil during preparation of fried food has been explained. Also, if re-fried food has been consumed in excess amounts, there are some precautions mentioned in the paper which can be followed.

Keywords: Chemical Reactions; Hazardous Compounds; Frying and Re-Frying

Introduction

Frying is a process of immersing food in hot oil at a high temperature of 150˚C-190˚C. There is a simultaneous heat and mass transfer of oil, food and air during frying which produces desirable and unique quality of fried foods with good texture and flavour. On the other hand, re-frying is repeated use of left-over frying oil which has already been consumed for frying a particular food.

Composition of oils

Oils are fats which are liquid at room temperature. Oils belong to a group of biological substances called lipids. Lipids are biological chemicals that do not dissolve in water [1].

Function of lipids [1,2]:

- Act as regulatory messangers (hormones).
- Forms the basis for structural components of cell membranes.
- Act as store- house of energy.
- Insulate body organs.
- Transport fat- soluble vitamins through blood.

Molecular structure of oils- Oils are composed of three fatty acids and a glycerol molecule [1] and is shown in Figure 1.

Figure 1: Molecular structure of oils.

Thus, these fats are also called tri-glycerides or tri-acyl glycerol. When, the fatty acids contain single bond in between each C- atom, then the fats are called saturated fats and when C-atoms are bonded by certain double bonds in a chain of fatty acid molecule, then the fats are called unsaturated fats. If, in a carbon chain, one double bond is present, then the oil is said to be mono-unsaturated and if in a carbon-chain, more than one double bond is present, then the oil is said to be poly-unsaturated [1].

Kinds of oils used for frying food

The types of oil used for cooking and the percent of total fatty acids present are shown in Table 1 below [3].

Chemical changes in oil during frying

When the frying takes place, the following changes occur in the composition of oil

- Hydrolysis of oil- Hydrolysis means breakdown of oil into free fatty acids and glycerol. This process increases with increase in frying.4 Permissible free fatty acid content in oil- Max- 0.08%- 1.00% [5].
- Oxidation of oil- When the fried oil (frying temperature) comes in contact with oxygen in air, it gives rancid flavor. The rancid flavor is because of the reaction of free fatty acid in the oil with oxygen, which is known as oxidative rancidity. This reaction produces various compounds like including aldehydes, ketones or other volatile products like sterol oxides. These products are responsible for rancid odours and flavours [6].

		Percent of total fatty acids		
S. No.	**Kinds of oil**	**Saturated**	**Mono-unsaturated**	**Poly-unsaturated**
1.	Safflower oil	9	12	75
2.	Sunflower oil	10	20	66
3.	Corn oil	13	24	59
4.	Olive oil	13	74	8
5.	Soybean oil	14	23	58
6.	Peanut oil	17	46	32
8.	Cotton seed oil	26	18	52
9.	Lard	40	45	11
10.	Palm-oil	49	37	9
11.	Palm-kernel oil	81	11	2
12.	Coconut oil	86	6	2

Table 1: Percentage of total fatty acids in cooking oil.

Oil (During frying) + Oxygen (Air) $\rightarrow$ dehydes, Ketones
Frying temperature (Rancid flavor)

Polymerization of oil- Frying of oil, leads to decomposition of oil with generation of products like dimers and non- polar polymers, cyclic monomers, trans isomers and position isomers [6].

Polymers are acyclic or cyclic compounds depending on the kinds of fatty acids forming an oil. The acyclic polymers are formed when fatty acids like oleic acid are present in oil. Also, oils rich in linoleic acid is more easily polymerized than oleic acid [6]. Linoleic acid content of various oils is presented in Table 2.

S. No.	Name	Linoleic acid (%)†
1.	Safflower oil	78
2	Grape-seed oil	73
3	Poppy seed oil	70
4	Sunflower oil	68
5	Hemp oil	60
6	Corn oil	59
7	Wheatgerm oil	55
8	Cotton seed oil	54
9	Soybean oil	51
10	Walnut oil	51
11	Sesame oil	45
12	Rice bran oil	39
13	Peanut oil	32
15	Canola oil	21
16	Egg Yolk	16
17	Linseed oil	15
18	Lard	10
19	Olive oil	10
20	Palm oil	10
21	Butter	2
22	Coconut oil	2
†Average value		

Table 2: Percentage of linoleic acid in oils.

Flavour Quality of frying oil- During frying, certain compounds are formed from linoleic acid. Volatile compounds like dienals, alkenals, lactones, hydrocarbons and various cyclic compounds produces off- odours and flavours. Hence, sensory quality of the fried food decreases [6].

Changes in nutrients in food- As mentioned above, during oxidation of oil, the aldehydes and ketones which are formed, react with amines, amino acids and proteins in fried foods. This causes nutrient loss and browning in fried foods [6].

The overall changes in the composition of food is mentioned below in Table 3 [6].

Ill- Effects of re-frying of oil

Once the oil has been utilized for frying in a batch, and the remaining oil when kept for longer time without any use, to be used again, has certain disadvantages which should be noted;

- Increase in fatty acid content- As seen above, hydrolysis of oil leads to development of free fatty acid content which increases with re- frying of oil. If an oil has free fatty acid content greater than the permissible limit, then the oil becomes unsuitable to be used, since free fatty acids are insoluble in water and they have tendency to get maximum oxidized [6].
- Increase in rancidity- Free fatty acids and their oxidized compounds produce rancid (off- flavors) and makes the oil less acceptable for re-frying.Rancidity leads to loss of freshness in food, affects the shelf- life of food adds an objectionable flavours and odours [7]. Increased rancidity due to re-frying of oil produces certain toxic compounds like acrylamide which is a probable human carcinogen [6].
- Increase in polymerization- With re-frying, the polymerization of oil increases, which accelerates the degradation of oil, which increases oil viscocity, reduces heat transfer, produce foam during frying and develops undesirable colour in food. Polymers also cause high oil absorption in foods [6].
- Generation of toxic compounds- With re-frying, certain cyclic compounds are formed from linoleic acid like 1,4- dioxane, benzene, toluene and hexyl benzene which do not contribute to desirable flavor and are toxic in nature. Re-frying also increases the formation of trans-fatty acids (depending on oil used). These trans-fatty acids cause the risk of cardiovascular diseases [6].
- Nutrient loss in fried foods- When the oil is used for re- frying, the intensity of browning of food increases which also leads to loss of essential amino acids like lysine in fried food. There is also loss of vitamins like Vitamin C (ascorbic acid), Vitamin B (thiamine, riboflavin, niacin and B6), Vitamin A and Vitamin E which changes the favour and colour of oil.6 Due to the destruction of these nutrients, adverse health effects could occur like mutations or gastro-intestinal irritations [7].

Component	Changes during frying
Fat	Increased concentration and change in composition
Water	Significant loss
Sugars	Browning
Proteins	Alteration of the composition
Amino acids	Formation of undesirable flavouring substances
Vitamins	Moderate loss
Minerals	Small loss
Antioxidants	Moderate loss

Table 3: Changes in composition of food during frying.

Conclusion

Fried foods are the major attractions for each and every person. Everyone like to have some or the other kind of fried food for a mouth change. But, there are certain drawbacks which should be avoided before consuming a fried food, as mentioned above. It is obvious that the hawkers on streets have to look at their economy and save the oil for re-use. Thus, in that case, it is our duty to consume those foods in limited quantity. At homes, after preparation of a batch of food, it should be kept in mind that the remaining oil has to be discarded and not kept for re-frying. If possible, the left-over oil should be collected and sent to an oil-refinery which utilizes the cooking oil for re-cycling. In this way, the left- over oil will not be wasted and also help oil- refineries, which is a kind of contribution in oil industry. Also, the oils which are rich in high percent of linoleic acid can be avoided. Some oils have "smoke point" at a specific temperature. "Smoke point" is the point at which oils begin to break- down and can have a foul odour or taste. Therefore, the oils which have high smoke point are less susceptible to break during deep- frying or re- frying and can be utilized. Some of the oils with their high smoke point are mentioned in Table 4 below. At last, the main focus has to be on- "Eat healthy, live happy".

Type of oil	Approximate smoke point
Peanut, Safflower, Soybean	450°F
Grapeseed	445°F
Canola	435°F
Corn, Olive, Sesame seed, Sunflower	410°F

Table 4: Smoke point of oils [8].

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