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Review on deep fat-fried food products safety and its implication for consumer healthiness

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Abstract

Edible oil is the most widely consumed food in worldwide. However, high-temperature cooking of fat results harmful compounds. This extended cooking times caused chemical and physical reactions at high temperatures. Additionally, heat-labile chemical compositions such as phenolic compounds, fatty acids, and essential amino acids gradually changed. High cooking temperatures have a real impact on the flavor quality and stability of the oil. But, applying antioxidants and inhibitors slows down the oxidation of frying oil at lower temperatures. The primary goal of this review process was to create awareness among the public and regulatory bodies about the extent to which oil based food processed at high temperatures for long time degrades food quality and endangers consumers. To address the problem of deep fat frying, the various earlier research works were well reviewed. The results of this study were thoroughly examined and concluded that cooking fat for a long period of time reduced its quality and increased the risk of non-communicable diseases. Thus, to lower the amount of free radicals in oils, frying them for a short period of time and using antioxidants. Also, it is critical to implement food quality control policies and educate community to safeguard the health of consumers.

Keywords: Chemical reactions, Chronic disease, Deep frying, Degradation, Edible oil, Food, Inhibitors, Physical reactions.

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Contribution of this paper to the literature

The review paper advances scientific awareness and encourages further research to address the issue of the negative effects of deep fat cooking on food quality and consumer health. Once more, it offers information on food quality control regulations and how consumers can avoid consuming excessive amounts of fat-fried food.

1. Introduction

Commercial deep-fat frying has been estimated to be worth £45 billion in the United States and at least twice this amount for the rest of the world [1]. Although oilseeds make up the bulk of Ethiopia's crop production, the country relies primarily on foreign products to meet its growing demand for edible oil. According to the Merchandise Wholesale Import and Trade Enterprise [2], the annual consumption of edible oil in Ethiopia is approximately 530,000 tons per year.

Cooking can be defined as the process of submerging food in hot oil to a temperature of 150 to 190 degrees Celsius while maintaining contact between the food, oil, and air. Cooking oil enhances the texture and flavor of food by serving as a medium for heat transmission. Food surface area, cooking duration, food wetness, breading or bashing techniques, and frying oil all affect how much oil is absorbed by food. Most of the time during cooking, the absorbed oil tends to collect on the surface of cooked food and seeps inside while chilling [2]. Foods that are fried below at a lower temperature or for a shorter amount of time than is ideal, but, have a white or light brown color. Foods that are under-fried lack interesting deep-fat cooked flavors, vibrant colors, and crisp textures. Foods that are overfried at temperatures higher and cooking times longer than ideal have surfaces that are hardened and blackened, and their texture is greasy due to the excessive absorption of oil [3].

Frying produces desirable or undesirable flavors, and changes flavor stability and quality, color, texture, unsaturated fatty acid, foaming, color, viscosity, density, heat, free fatty acid content, volume, polar materials, and composite materials increase. In particular, fatty foods such as potato chips, cookies, and other street food fast foods are made from a variety of plant and animal ingredients and are highly exposed to frying. Cooking temperature and time, frying oil, inhibitor, and product type influence oil hydrolysis, oxidation, and polymerization during frying [4]. Long-term consumption of processed foods, frying oil, cooked oil, and unconsumed oil can significantly impair a person's antioxidant defense network and cause diseases such as hypertension, diabetes, obesity, and fallopian tube inflammation [5].

The purpose of the research is to review the effects of edible frying on oil quality and health issues and to provide integrated data on oil/fat frying changes to customers and food processors. As a result of raising awareness through a review of this seminar, it became clear that the intensive and repeated frying of fats and oils has an impact on health and deteriorates the quality of products. In Ethiopia, food processing is local and industrial, causing health problems as there is no required method of control or safety awareness to deal with the problem.

2. Changes throughout Deep-Fat Cookery

2.1. Changes of Physical Characteristics

Frying is a process of cooking and drying in hot oil which is the process of heat and mass transfer. When heat is transferred from the oil to the food, the moisture in the food turns into gas, and the oil is absorbed by the food. In addition to the thermal and physical properties of food and oil, food shape and size, and oil temperature, several factors affect heat and mass transfer. Table 1 exhibits a series of changes in several physical parameters of oil/fat during frying and the reasons for these changes [6].

Table 1. Changes in some physical parameters of oils/Fat during deep-frying.

Physical parameter	Changes during frying deep	Caused by
UV	Increases	Conjugated fatty acids stored
Density	Increases	Polymerized triacylglycerol
Insulator constant	Decreases	Polar-oxidized parts
Color	Millard reaction	No
Conduction	Increases	Polar compounds physical action
Surface tension	Decreases	Polar compounds
Smolder point	Decreases	Volatile oxidized breakdown cpds.
Heat	Increases	Polar compounds
Viscosity	Increases	Polymerized triacylglycerol

Source: Choe and Min [6].

According to Table 1, deep-frying either increased or decreased the physical characteristics of oil such as density, color, conduction, surface tension, heat, and viscosity. Because certain chemicals changed into new forms and some volatilized. The oil's or fat's quality is altered to have an unwanted flavor or odor. To maintain food quality and the health of consumers, it is crucial to cook oils or fat at the ideal temperature and time.

2.2. Chemical Changes Characteristics

Cooking oils not only transfer heat to cooked foods, but they can also add unwanted off-flavors to fried foods due to damaged oil [7]. During frying, many harmful chemical processes (hydrolysis, oxidation, polymerization, etc.) occur, causing the oil to break down and form volatile products and non-volatile monomers and compounds. In addition, these chemical reactions Cross linked by hydrolysis, oxidation, and polymerization, free fatty acids, low molecular weight alcohols, aldehydes, ketones, acids, lactones and hydrocarbons, diglycerides and monoglycerides, cyclic and epoxy compounds, rumored trans isomers, triacylglycerol monomers and dimers, oligomers, etc. [8]. Likely Table 2 exhibits some chemical changes occurred during deep fat frying at high temperature for long time and shows the parameters prone to be changed due causes of oxidation and polymerization.

Table 2. Changes in some chemical parameters because of fat frying.

Chemical parameter	Changes during deep-frying	Caused by
Anisidine value	Rises	Secondary oxidation
Iodine value	Declines	Formation of oxidized fat products
Peroxide value	Rises /Declines	Primary oxidation products
Petrol ether	Rises	Oxidized polymerization products
Polar compounds	Rises	Oxidized and polymerized degradation of products
Polymerized triacylglycerol	Rises	Oxidized and polymerized Triacylglycerol
Acid value	Rises	Formation of products oxidation using free carboxyl groups

Table 2 lists the chemical parameters that changed when oil or fat was repeatedly and repeatedly deep-fried at a high temperature. Oil deep-frying causes a rise in parameters such as the anisidine value, peroxide value, petrol ether, polar compounds, and polymerized triacylglycerol, while a fall in iodine value is caused by the reaction of free fatty acids with oxygen. However, depending on the type of fat or oil, peroxide value can occasionally rise or fall. These are brought on by the oxidation of oil and the polymerization of compounds when cooking or frying in an environment where air is present.

2.2.1. Oil Hydrolysis

Cooking food in hot oil immediately generates steam, which evaporates in the form of bubbles and gradually reduces as the food is fried. Water, steam, and elements cause chemical reactions in cooking oils and foods. Water, a weak nucleophile, attacks the organic compound bonds of triacylglycerols, producing di- and monoacylglycerols, glycerol, and free fatty acids. The content of free fatty acids in frying oil increases with the amount of food being fried [9]. Thermochemical reactions mainly occur in the oil region and not at the water-oil interface.

Chemical reactions are more pronounced in oils containing short chains and unsaturated fatty acids than in oils containing long chains and saturated fatty acids. This is because short chain and unsaturated fatty acids are more soluble in water than long chain and saturated fatty acids. Water from food does access short-chain fats and oils and cause chemical reactions. Large amounts of water transform oil rapidly [10]. Water hydrolyzes oil faster than steam. Heavy contact between the oil and food components increases the hydrolysis of the oil. Mono- and diacylglycerols are initially expanded in vegetable oil when cooking potato chips between 155°C and 195°C.

Frequently replacing the cooking oil with modern oil will slow down the chemical reaction of the frying oil. The hydroxides and alkaline substitutes used to wash poultry promote oil hydrolysis. Frying time did not affect oil hydrolysis [4]. Free fatty acids and their compounds produce off-flavors, making the oil unsuitable for frying. Diacylglycerols and monoacylglycerols, glycerol and free fatty acids promote strong hydrolysis reactions of oils [11]. Glycerol evaporates at 150 °C, and the glycerin left in the oil promotes the formation of free carboxylic acids through chemical reactions [4]. The free fatty acid content of edible oil is 0.05% to 0.08%. The basic reactions that occur during oil hydrolysis are shown in Figure 1. The content of free fatty acids in frying oil increases with the amount of food being fried (Figure 1). Free fatty acid values are used to determine the quality of frying oil. So, the Figure 1 illustrates how the triglycerides are decomposed to glycerol and free fatty acids as the oil cooked at high temperature in steam. Then the oils hydrolyzed to free fatty acids which are prone to oxidation and become piousness to human.

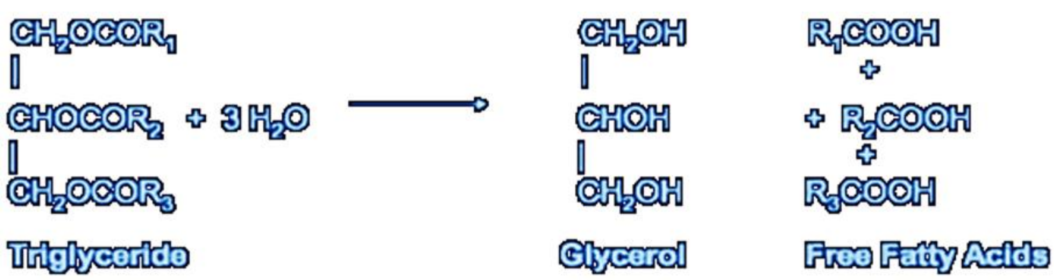

Figure 1. Chemical reactions in oil produce free fatty acids.

2.2.2. Oil Oxidization

When oil fried, elements react with oil [12]. The chemical process of thermal oxidation is essentially the same as the mechanism of autoxidation. Although thermal oxidation rates are faster than autoxidation, specific and detailed scientific data and comparisons of oxidation rates between thermal and autoxidation do not seem to be available. As shown in Figure 1, the mechanism of thermal oxidation includes initiation, progression, and termination of the reaction. Oil in its best non-radical state does not react with di-radical elements in its triplet state thanks to the spin barrier. Normal oxygen in the air is a radical compound. Radical oil is required for the oxidation of radical elements. The oil must be in a highly radical state so that it can react with radical oxygen for oil oxidation reactions. The chemical elements that have the weakest bond with the oil's carbon are removed and become radicals. According to rumors [12], the energy required to break the carbon-hydrogen bond at the 11th carbon atom of linoleic acid is 50 kcal/mol.

As shown in Figure 2, the double bond between carbon 9 and carbon 12 reduces the carbon-hydrogen bond of carbon 11 by withdrawing electrons. The carbon-hydrogen bond at carbon 8 or 11 is α to the covalent bond in oleic acid and is 75 kcal/mol. The carbon-hydrogen bond on a saturated carbon without double bonds is approximately 100 kcal/mol. Differences in the strength of the bonds between chemical elements and carbon in fatty acids represent differences in the oxidation rates of stearic, oleic, linoleic, and linoleic acids during thermal or autoxidation. The weakest carbon-hydrogen bond in linoleic acid is that carbon-11 is removed first, thus removing the hydrogen on carbon-11 and creating a radical on carbon-11.

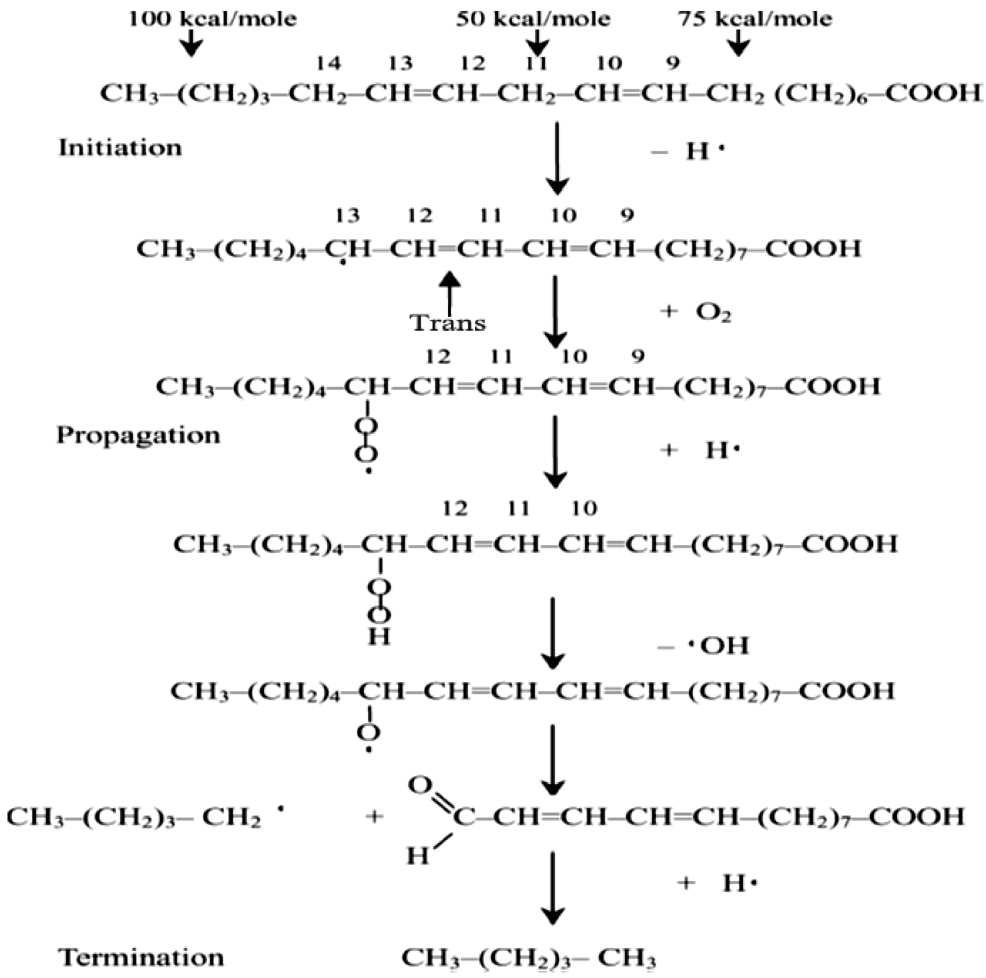

Figure 2. The initiation, propagation and termination of oil thermal oxidation.

A chain reaction between free alkyl radicals and peroxyl radicals promotes thermal oxidation of oil. The oxygen-oxygen bond strength of R-O-O-H is approximately 44 kcal/mol. This is a relatively weak chemical bond. Hydroperoxides usually seem to become unstable during the frying process. Hydroperoxides are degraded into alkoxy radicals and group radicals by peroxide-bound hemolysis [13]. The hydro peroxide is decomposed to supply oxy- and hydroxy radicals. Known mono-oxygenated product love 9-keto-10, 12- and 13- keto-9-, 11-octadecadienoate and hydroxyl group derivatives such as 9- hydroxy-10, 12- and 13-hydroxy-9- and 11-octadecadienoate from hydro peroxides of thermally change alkyl group linoleate at a 150°C. The alkoxy radical reacts with other alkoxy radicals or is decomposed to form non radical products. The formation of non-radical volatile and non-volatilizable compounds at the tip of oxidization is named the termination step. Most volatiles are aloof from cookery oil by steam throughout deep fat frying [13].

As stated, adding water to the frying system reduces volatile compounds in the oil [14]. The number of volatile compounds found in oils varies widely and depends on the type of oil, food, and frying conditions. Volatile compounds greatly affect the taste quality of frying oils and cooked foods. The rate of aerobic decomposition reactions increases as the concentration of elements and free radicals increases [15]. Refined oils may contain less than 1 ppm of alkaline substances, such as atomic number 11 or atomic number 19 fatty acid salts. Modern cooking oils should contain less than 10 ppm of alkaline substances [3].

2.2.3. Oil Polymerization

Labile compounds are very important to the flavor properties of edible oils and frying products, but volatile components are present in the total degradation products of frying oils at concentrations of 1:500,000. The main decomposition products of frying oil are non-volatile polar compounds and triacylglycerol dimers and polymers. The number of cyclic compounds is relatively small compared to non-volatile polar compounds, dimers, and polymers [16]. Dimers and polymers are large molecules with molecular weights between 692 and 1600 Daltons that are formed by a mixture of -C-C, -C-O-C, and -C-O-O-C bonds. Dehydroxydimer, ketodehydrodimer, monohydrodimer, dehydrodimer of linoleic acid, and dehydrodimer of oleic acid are dimers that occur in vegetable oils upon cooking at 195 °C [17].

Dimers and polymers have hydroperoxy, epoxy, hydroxyl, and carbonyl groups, as well as -C-O-C and -C-O-O-C bonds. Dimers or polymers can be either acyclic or cyclic, depending on the reaction method and the form of fatty acids present in the oil [18]. Dimerization and chemical action during frying are radical reactions. The group radical is ideally formed on the group carbon at the alpha position of the double bond. Dimers are formed by reaction of allyl radicals with C-C bonds. The formation of acyclic polymers from monounsaturated fatty acids during heating is shown in Figure 3. Triacylglycerols react with atomic number 8 to form alkyl radical hydroperoxides (ROOH) or dialkyl peroxides (ROOR). These are immediately converted to alkoxy and peroxy radicals by RO-OH or ROO-R cleavage. Alkoxy radicals extract chemical elements from oil molecules to provide group compounds or mix with various alkyl radicals to produce oxydimers [18].

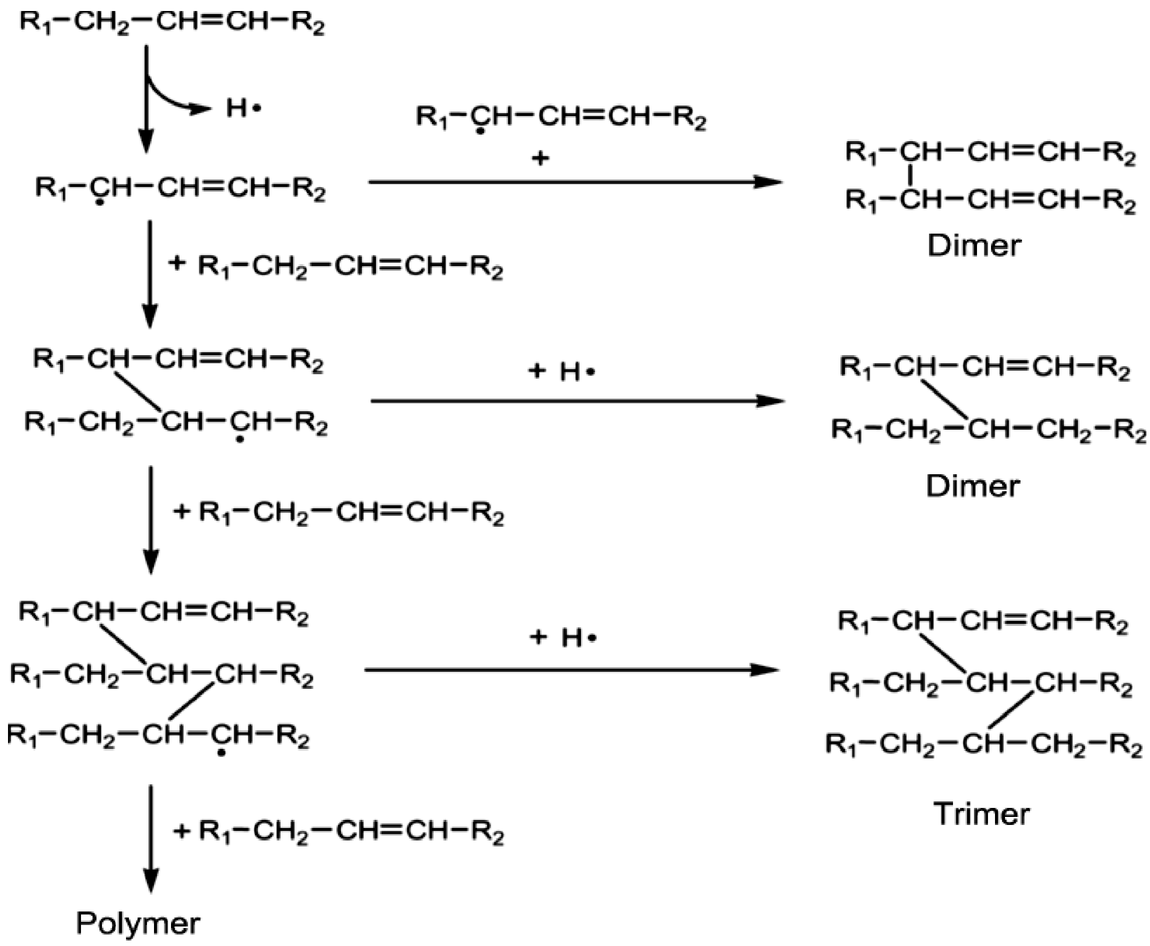

Figure 3. Acyclic compound formation from monounsaturated fatty acid throughout deep-fat cooking.

Peroxy radicals mix with alkyl radicals to form peroxy dimers. The formation of dimers and polymers depends on the type of oil, frying temperature, and frying range, with the amount of polymer increasing as the number of frying steps and frying temperature increases. Oils rich in polyunsaturated fatty acids polymerize much more easily during frying than oils rich in oleic acid [19]. Cyclic polymers are prepared between or among triacylglycerols by radical reactions, namely Diels-Alder reactions. The formation of cyclic compounds in edible oils depends on the degree of unsaturation and frying temperature. The formation of cyclic monomers and polymers accrued because the quantity of omega-6 fatty acid increased [18]. The formation of cyclic monomers was negligible till the linolenic acid content exceeds 20%. Cyclic compounds don`t seem to be shaped to a big extent until the oil temperature reaches 200°C to 300°C.

Vegetable oil formed a dimer of antidepressants and a cyclic dimer of linoleic acid, similar to the cyclic monomers in fried foods. The polymers formed during frying are rich in oxygen. Polymers further accelerate oil degradation, increase oil viscosity [20], reduce heat transfer, form foam during frying, and cause undesirable discoloration of foods. Polymers also cause high oil absorption into foods. The polymer is a highly conjugated diene, and when the oil or metal comes into contact with the atomic number 8 in the air, it forms a brown, resinous residue on the edges of the fryer. Resinous residues are typically formed when oil does not release water but retains water while absorbing air [3].

3. Causes of Repeated Fat Cooking

Even today, the cuisine of the day is consistent with society's preferred methods of preparing more delicious meals. There is a high demand for ready-to-eat foods in developing countries. Cooking forms compounds with rich flavors, attractive colors, skins, and textures that improve the sensory quality of foods and are highly appreciated by consumers. Cooking fat is the main component of these fried foods [21]. Therefore, oil prices are the most important economic factor. Therefore, to ensure economy, vegetable oil is usually repeatedly heated. In order to reduce the cost of frying and save a lot of money, several household users and most food processors in Ethiopia repeatedly use the same vegetable oil for frying until the oil completely turns an undesirable color. I am. The oil is repeatedly reused and is discarded and replaced with fresh oil only when it becomes foamy, very viscous, emits dangerous odors, and darkens in color [22]. Often, they are not replaced at all. Rather, fresh oil is different from already heated thick and viscous oil [23].

3.1. Oil Recooking Alterations

Eating limited amounts of fried foods does not cause any degree of health problems in conventional people. The problem begins when you heat and use the same oil over and over again. When frying food at temperatures between 170°C and 200°C, the oil used undergoes various changes. 1. Hydrolysis – The water from the food being fried evaporates and the triglycerides (TG) in the cooking oil are hydrolyzed to glycerin. Free fatty acids (FFA), monoglycerides (MG), diglycerides (DG). 2. Oxidation – Lipid molecules in frying oil undergo primary oxidation to form unstable lipid species called "hydroperoxides." This is cleaved to produce secondary oxidation products containing non-volatile and volatile compounds [24].

Some of these byproducts polymerize (tertiary oxidation), increasing the viscosity of the oil and causing surface browning and darkening of the oil. Thermal polymerization at high temperatures during the cooking process, high molecular weight cyclic carboxylic acid monomers (FA) and TG dimers and oligomers are formed [24]. Fried foods may absorb some aerobic products such as hydroperoxides and aldehydes produced by this method of increasing the amount of oil [25].

Table 3. Peroxide value (POV) for ethyl radical Linolenate throughout heating at completely different temperature.

70 ºC		180ºC		250ºC	
Cooking time (h)	**POV (Meq/Kg)**	**Heating time (h)**	**POV (Meq/Kg)**	**Heating time (h)**	**POV (Meq/Kg)**
6	1777	5	237	3	44
24	1058	10	251	5	77
45	505	20	119	10	198
69	283	30	80	20	67

Source: Nawar [26].

Table 3 displays the precise chemical change parameter for variations in peroxide value at various heating times. Oils that are cooked or reheated can become oxidized due to the reaction of oxygen with free fatty acids. When oil is cooked repeatedly at different temperatures, it completely changes its peroxide value. As a result, the table provided a clear explanation of the POV changes in Meq/Kg for ethyl radical lenolenate during heating and cooking.

4. Deeply Fried Oil and Foods Quality

Food flavors that are created by high temperature oil cooking include fruity, grassy, burned, nutty, and gloomy. However, the frying temperature has no effect on the flavor of the oil; it relies on the oil and quantity of frying. When frying potatoes at 160°C, 180°C, and 200°C, the oil's flavor quality was superior than that of vegetable or colza oil. According to Wu and Chen [14] the main volatile chemicals in vegetable oil at 200°C were reported to be 2-heptenal, 2-octenal, 1-octen-3-ol, 2, 4-heptadienal, and 2, 4-decadienal. At the ideal concentration of atomic number 8, a typical intriguing deep-fried flavor is produced. High oxygen levels result in an odd flavor, whereas low oxygen levels yield a weak and bad flavor [27].

Flavor compounds in fried foods are volatile compounds from polyunsaturated fatty acids and are dienals, alkenes, lactones, hydrocarbons and many cyclic compounds [27]. 4-hydroxy-2-nonenoic acid and its lactone, 4-hydroxy-3-nonenoic acid and its lactone, trans, trans-2, 4-decadienal, trans, trans-2, 4-nonadienal, trans, trans-2, 4-octadienal, trans-2-heptenal, trans-2-octenal, trans-7-octenal, nonenlactone and trienals are attractive flavor compounds found in cooking oil and are made by oxidation of linolenic and it is polyunsaturated fatty acids. Polyunsaturated fatty acids are responsible for the desirable flavor of frying. Completely different oils give different flavors when frying due to the difference in the quality and quantity of fatty acids in the frying oil. Butanal, pentanal, hexanal, heptane, pentanol, 2-hexenal, heptanal, 1-octen-5-ol, 2-pentylfuran and 2-decenal give unpleasant results when frying [28].

Carbonyl compounds formed during deep- fat frying will reply with amino acids, amines, and proteins and turn out fascinating and nutty pyrazines. A number of unpredictable composites shaped in deep- fat cuisine, 1, 4- dioxane, benzene, toluene, and hexylbenzene, do not contribute to desirable flavor and are noxious compounds [28].

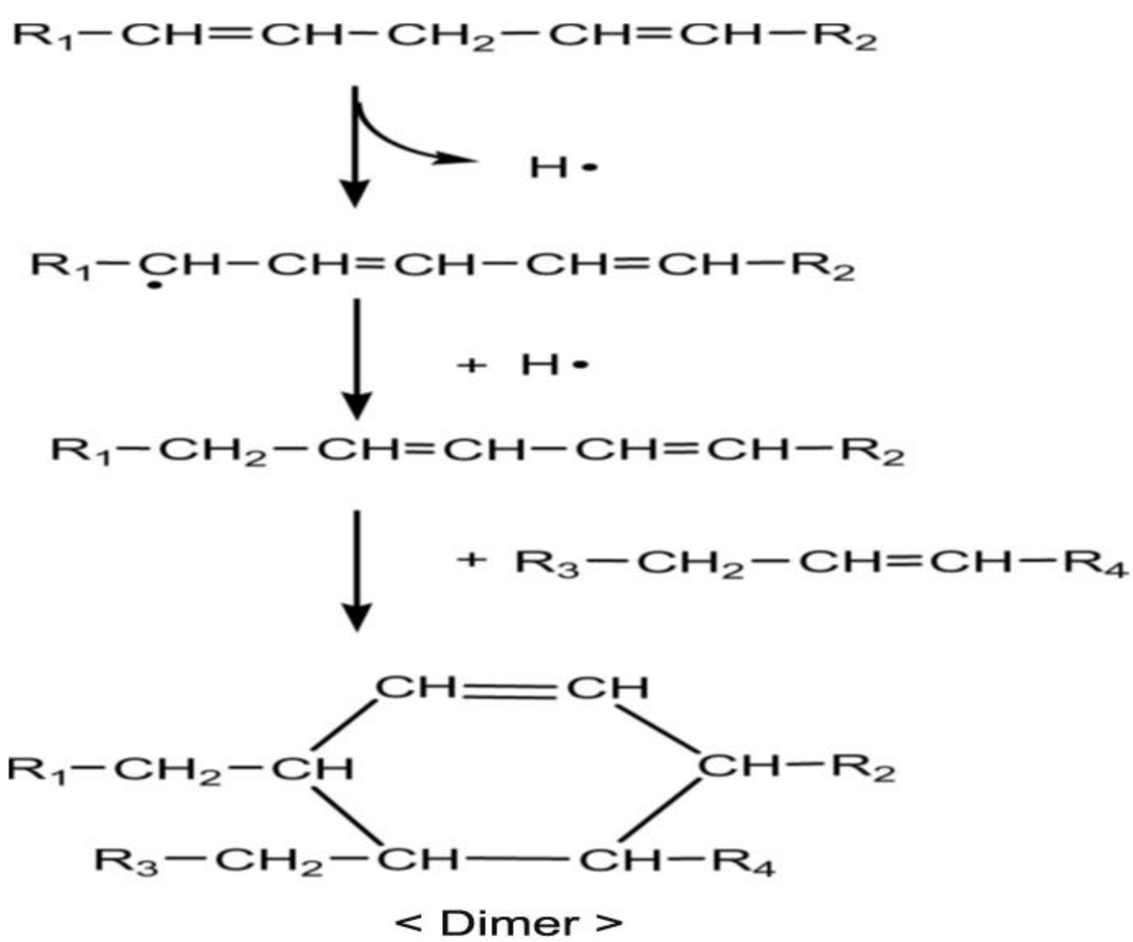

Figure 4. Cyclic compound formation from polyunsaturated fatty acid by Diels-Alder reaction throughout deep-fat frying.

Figure 4 illustrates the formation of cyclic compounds from polyunsaturated fatty acids through chemical reactions during deep fat frying at high temperature for a longer period of processing. Polyunsaturated fatty acids are liquid oils which can be easily oxidized as exposed to high temperature and oxygen. When the polyunsaturated oils treated at high temperatures free radicals occurred and immediately reacted with oxygen, as a result the oil become oxidized and deteriorate. Finally, the rest chemical structures become cyclic compounds by reacting each other instead of migrated hydrogen.

5. High Temperature Oil Cooking Factors

The ratio of oil, frying time and temperature, type of heating, frying oil composition, initial oil, composition of food to be fried, type of fryer, antioxidants and oxygen content material have an effect at the deterioration of oil throughout deep-fats cooking. The consequences of frying factors on the usual of frying oil are normally rumored in any other case or oppositely, due to the utilization of diverse analytical ways for high-quality determination and different experimental situations [29].

5.1. Fresh Oil Replecement

A high quantitative relation of clean oil to total oil presents higher frying oil exceptional. Frequent replenishment of clean oil decreases the formation of polar compounds, diacylglycerols, and loose fatty acids will boom the frying existence and first-rate of oils [30]. Again, rumored that refilling with recent oil improved the usual of cooking oil completely 1/30 frying. Also [31] mentioned that common turnover of oil prompted quite a few aerophilous response than hydrolytic reaction in the course of deep-fat frying of potatoes. A suggested every day turnover is 15% to twenty-five% of the capability of the pullet and therefore the high turnover will decrease the usage of antifoaming agent akin to silicones.

5.2. Cooking Conditions

Cooking time will increase the contents of loose fatty acids, polar compounds consisting of triacylglycerol dimers and exchange triacylglycerols, dimers and polymers. the primary 20 cooking's boom the formation of polar compounds unexpectedly. there has been no essential growth of polar compounds 1/30 frying [18].

Excessive frying temperature quickens thermal oxidization and chemical action of oils. Vegetable oil showed three.09% and 1. sixty-eight% of conjugated dienes and trans-acids, respectively, after 70-m frying of potato chips at 170oC. but soybean oil that performed equal cooking at 190oC showed 4.39% and 2.60% of the several values. excessive frying temperature shrunken polymers with peroxide linkage and amassed the polymers with ether linkage or carbon to carbon linkage [32]. The intermittent heating and cooling of oils causes' higher deterioration of oils than continuous heating because of the atomic number eight solubility growth within the oil as soon as the oil cools down from the frying temperature [29]. The 25% of polyunsaturated fatty acid of the flower oil became destroyed in the intermittent frying, while totally the five% become destroyed in non-stop cooking.

5.3. Quality of Cooking Oil

Unfastened fatty acids boom the thermal oxidization of oils and their unsaturation in place of chain length light-emitting diode to vital effects on thermo oxidative degeneration; the addition of 0.53 mmol of tridecanoic, palmitic and oleic acids to virgin oil confirmed 15.zero, 14.3 and 10.1 h of induction amount with a Rancimat (Metrohm) [11]. Chemical technique and genetic change are two of the methods to decrease the unsaturated fatty acids of cooking oil. Chemical procedures will grow the frying balance of oil. However, hydrogenation produces trans-carboxylic acid or aluminous taste, and it does not in addition improve the usual of oil with low omega-6 fatty acid. Modified vegetable oil with zero.1% linoleinic acid had a variety of hydrolytic degradation, but lower p-anisidine values and compound formation, than the soybean oil with 2. 3% linoleinic acid [18]. Genetically modified high oleic vegetable oil improved frying stability over conventional corn oil.

Consequently, low linoleinic acid oil through genetic amendment changed into advised to be a likely diverse to alter cooking oil. Mixing of many oils can change the carboxylic acid compositions of oils and might decrease the oxidization of oils at some point of deep-fats frying. The esterified glyceryl ester doesn't display any pro-oxidant activity in the oil oxidation during deep-fat frying. Loose fatty acids in frying oil improved thermal oxidation of the oil [33].

The remedy of shortening with bleaching clay, charcoal, chelate, or MgO advanced the oil exceptional for fries. Every day addition of ascorbyl palmitate to current oil shrunken loose carboxylic acid formation, however gathered stuff consistent and coloration modifications. Oils with beneath 0.05% unfastened fatty acids and 1.0 milliequivalent peroxides in 1 kilogram of oil are fascinating for deep-fats cooking [18].

Table 4. Common indicators for deep-fat frying fats and oils.

Parameter	Levels in unused fat and oil
Free fatty acids	0.05–0.08%
Peroxide value	1.0 meq/kg oil
Smoke point	200 °C
Moisture	0.10%
Flavor and odor	Bland

Source: Christopoulou and Perkins [17].

Before any physical or chemical alterations take place, the fresh oil parameters value is displayed in Table 4. These parameters vary according to the temperature and frying time as the oil deep-fries. However, when deep fat frying, it was thought that using mixed types of oil would be more stable than using monotype oil. The table indicates that the parameters that are most likely to alter while frying are free fatty acids, peroxide values, smoke point, moisture, flavor, and odor.

5.4. Food Compositions

Moist conditions in meals create steam insurance over the pullet and decrease contact with air [34]. Fantastic deal of moisture in foods will increase the oil reaction during deep-fat cookery. Lots of the moisture contents in meals, the maximum the hydrolysis of oils. Emulsifier from frying foods triggered foam formation at the initial stage of deep-fat frying. Phosphatidylcholine attenuate the oxidization of animal oil at 180oC for 3hr. Starch increases the degradation of oil and amino acids guard the oil from degradation at some point of deep-fats cookery [35].

5.5. Types of Fryers

Transition metals just like iron, that are present in meat, had been gathered in the oil in the course of frying and this inflated the fees of oxidization and thermal degradation of oil. Even and fast heat transfer to the oil can save you hot spots and the scorch of oil. Polymerized fats deposited at the fryer causes gum formation, the formation of froth, color darkening and in addition deterioration of frying oil. A small floor-to-volume ratio of fryer for a minimum touch of oil with air is suggested for deep-fat frying. Negishi, et al. [36] reported that oil oxidation become slowed down by means of editing a fryer to have a ratio of oil intensity (D) to grease vicinity (A) with D/A1/2 = 0.93. Copper or iron fryer hastens the oxidation of frying oil.

5.6. Antioxidants

The evident gift or added antioxidants in oils and foods have an impact on oil exceptional during deep-fat frying. Tocopherols, butylated hydroxyanisole (BHA), butylated hydroxytoluene (BHT), propyl gallate (PG), and tert-butylhydroquinone (TBHQ) sluggish down the oxidation of oil at room temperature. But they end up less effective at frying temperatures because of losses through volatilization or decomposition [37].

The addition of spinach powder at five%, 15%, or 25% in flour dough attenuates the formation of polar compounds in oil [38]. The addition of crimson ginseng extracts to the flour dough at 1% and 3% accelerated the formation of loose fatty acids, conjugated dienoic acids, and aldehydes in oil all through the deep-fat cookery of the dough at 160°C. Beef nuggets battered with glandless oilseed flour attenuate unfastened fatty acids, conjugated diene compounds, and thiobarbituric acid-reactive substances. The addition of carrot powder to the dough at 10%, 20%, or 30% increased the aerophilic balance of oil at P < 0 xss=removed> zero.05 [39]. Propane and carbonyls fashioned throughout deep-fats frying aren't the maximum precursors of amide [40].

Many nutrients are touchy to higher temperatures and oxidization, however high temperatures are reached solely in floor layers of deep-fried food, wherever their loss is surely terribly excessive. Total losses depend mostly on internal temperature that every so often varies among seventy and 900C. Throughout this variety, diet retention depends alternatively extra at the inner temperature than on the temperature of the cookery oil [41]. Tocopherol is misplaced at the aspect of the oxidation of unsaturated fatty acids throughout heating.

Cookery oil is absorbed by means of the meals at some point of cooking and additionally the absorbed amount relies upon on the usual of the cooking oil, which impacts the net intake of tocopherol [42]. A stimulating resistance has been incontestable for tocopherol homologues for the duration of home cookery simulation with virgin olive oil, sunflower-seed oil or vegetable shortening oil for 8 sequential frying operations. Vegetable frying oils are a remarkable deliver of diet E. All vegetable oils used for frying comprise nutrition E quantity of between 15 and forty-nine mg/a hundred g. Deep-fried ingredients, because of oil uptake are enriched with respectable amounts of the vitamin. as an instance, a touch of a hundred g gives up to 50% of the Recommended Dietary Allowance (RDA) of tocopherol [43]. Tocopherol (tocopherols) from the frying oil participates in radical reactions.

Table 5. Effects of (Rosemary and sage) extract antioxidants on the quality of refined, bleached, and deodorized palm olein during frying of potato chips.

Characteristics	Heating time (d)	Control	Rosemary (0.4%)	Sage (0.4%)
Anisidine value	0	0.96	0.95	0.96
	2	36.0	30.6	29.3
	4	51.4	42.1	42.0
	6	62.0	50.2	50.8
Free fatty acid (%)	0	0.05	0.05	0.05
	2	0.19	0.15	0.16
	4	0.42	0.26	0.25
	6	0.59	0.42	0.44
Polymer content (%)	0	0.01	0.01	0.01
	2	1.00	0.73	0.70
	4	1.55	1.30	1.35
	6	2.65	1.82	1.90
C18:2/C16:0 ratio	0	0.29	0.29	0.29
	2	0.26	0.27	0.28
	4	0.21	0.25	0.24
	6	0.17	0.20	0.21

Table 5 shows how antioxidant sources like sage and rosemary affect refined, bleached, and deodorized palm oil when it's being fried. With an increase in oil frying time, the values of the characteristics exhibit rising trends. However, as more antioxidants are added to the oil during frying, the values tend to drop. For this reason, adding antioxidants like sage and rosemary to the oil helps to stabilize it a little bit when deep-frying it.

6. Foods Nutrient Changes during Deep-Fat Frying

The fee of nutrient decomposition in the course of deep-fats frying is contingent upon the frying length and the sort of oil applied. The decomposition price of γ-tocopherol for the duration of the deep-fat frying of potatoes in an aggregate of soybean and rapeseed oil at a hundred and eighty °C became located to be the maximum speedy, followed by means of δ- and α-tocopherol. Lipid oxidation effects within the formation of aldehydes, epoxides, hydroxyketones, and dicarboxylic compounds, which react with amines, amino acids, and proteins in fried meals [44].

Millard reaction happens during food frying, leading to nutrient loss and browning. The degree of browning is frequently associated with the losses of lysine, histidine, and methionine. The reaction among epoxyalkenals and proteins generates polypyrrolic polymers and volatile heterocyclic compounds [45]. Carbonyl compounds produced throughout lipid oxidation react with amino acids, mainly asparagines, resulting inside the formation of acrylamide and a lower in the dietary cost and safety of meals. Acrolein, shaped from oil, reacts with asparagines, generating acrylamide throughout deep-fat frying. Acrylamide formation requires a heating temperature above a hundred °C and increases because the temperature rises [1]. The styles of oil and addition of silicone had no influence at the acrylamide concentration in ingredients. Acrolein and carbonyls formed for the duration of deep-fat frying aren't the primary precursors of acrylamide [40].

6.1. Vitamins

Various nutrients are liable to degradation from excessive temperatures and oxidation, with the surface layers of fried meals being the number one region for such losses. but, the whole loss of nutrients is more often than not depending on the internal temperature, which typically tiers among 70 and 900C. On this variety, the retention of vitamins is more heavily motivated by using the inner temperature than the temperature of the frying oil [41].

Vitamin E is especially vulnerable to degradation due to the oxidation of unsaturated fatty acids for the duration of heating. the quantity of frying oil absorbed by using the food at some point of cooking is depending on the great of the cooking oil, which could affect the internet intake of vitamin E. but, tocopherol homologues have validated tremendous resistance at some stage in home frying simulations with virgin olive oil, sunflower oil, or vegetable shortening oil for up to 8 successive frying operations. Depending on the oil kind, as much as 50% of nutrition E can be retained after four to 5 consecutive frying sessions [42].

Vitamin E is particularly vulnerable to degradation due to the oxidation of unsaturated fatty acids during heating. The amount of frying oil absorbed by the food during cooking is dependent on the quality of the cooking oil, which can impact the net intake of vitamin E. However, tocopherol homologues have demonstrated remarkable resistance during domestic frying simulations with virgin olive oil, sunflower oil, or vegetable shortening oil for up to eight successive frying operations. Depending on the oil type, up to 50% of Vitamin E can be retained after four to five consecutive frying sessions [42].

Even as vitamin E from frying oil can take part in free radical reactions, it could also lower their fee, therefore having dietary and health advantages [41]. Apparently, no widespread exchange within the vitamin E content of French fries was found in the course of 4 days of commercial frying, because the growth in fat intake of the fries compensated for the diet E reduction due to frying the oil. Additionally, studies have shown a boom in overall diet E content material in chook nuggets and breaded shrimp after frying in soybean and corn oils [46]. Earlier than frying, the vitamin E content material became 4.6 mg/a hundred g in chicken nuggets and 0.6 mg/a hundred g in breaded shrimp, which multiplied to four.9 mg/100 g and five.1 mg/100 g, respectively, after frying.

Table 6. Retention of tocopherol in a mixture of soybean and rapeseed oils during frying of potatoes at 180 °C

Tocopherol retention (%)			
Number of frying	**α**	**γ**	**δ**
0	100	100	100
4	86.2	82.1	91.0
8	85.9	74.0	87.1
12	83.1	67.6	80.3
16	75.9	59.3	74.3
20	71.9	49.6	67.8
24	64.5	41.6	63.7
28	60.9	33.5	51.5

Source: Hidalgo and Zamora [45].

Table 6 illustrates the retention of tocopherol at frying frequencies ranging from 0 to 28 minutes. We all know that high temperatures during cooking and frying cause vitamins to be lost. Thus, research on the amount of tocopherol vitamin retained during deep fat frying is summarized in the table. It makes clear that the concentration of vitamin drops as frying time increases. Thus, extended oil-frying times result in the loss of vital nutrients, especially tocopherol and other vitamins.

Plant source food incorporates active carotenes, along with vitamin A, which can be lost for the duration of the frying process. However, if the frying technique is short, losses of beta-carotene, the most critical consultant of this organization of pro-nutrients, can be stored low. In evaluation, deep fried greens enjoy losses of beta-carotene which are two times as excessive as the ones in shallow-fried foods, with some beta-carotene probably migrating into the frying oil. studies have proven that in the frying of cabbage, 29% of beta-carotene turned into destroyed, and common losses of vitamin-A interest were discovered to be 14% for boiling, 24% for frying, 29% for fermenting, 44% for sun-drying, and 60% for solar-drying observed through boiling.

Even as a few carotenoids are misplaced in cooking water, losses all through frying are more due to leaching into frying oil.

In terms of other vitamins, research has shown that vitamins B1, B2, B6, and C are better retained in frying than in boiling, steaming, or stewing. Thiamin, and vital vitamin of the B group, stories decrease losses for the duration of frying than when food is prepared the use of other strategies. The largest lack of thiamin happens during boiling, followed by steaming, parching, and frying, which can be attributed to the water-soluble nature of the diet being leached out into the water.

Riboflavin, any other crucial vitamin B, is often poor in human diets and is better retained when frying bird meat than thiamin is when frying darkish meat. Niacin is exceptionally stable, but nevertheless reports losses all through frying pork muscle, beef, and cook meat. Vitamin C retention in green greens is higher whilst stir-frying than when cooking with numerous waters or the usage of a microwave.

Table 7. Vitamin C retention of broccoli and green beans cooked using four methods.

Cooking method	Vitamin C % retention in broccoli	Vitamin C % retention in green beans
Stir-frying	76.6	57.5
Microwave	56.8	58.9
Much water	44.8	59.6
Little water	72.2	76.0

Source: Fillion and Henry [47].

Table 7 provides an overview of the vitamin C retention for various frying methods and meal types. When broccoli is stir-fried, the vitamin C retention is improved. However, the nature of the product makes stir-frying green beans less suitable. Cooking green beans with minimal water likely results in the best retention; this also applies to broccoli. Therefore, the length of time that vitamin C remains stable in various food products varies depending on the method of cooking and amount of water used.

6.2. Mineral Components

Because mineral additives dissolve in water, they undergo significant changes during cooking, especially when boiling. On the other hand, since mineral additives are best soluble in small amounts of frying oil, cooking has little effect on them. However, the weight of fried foods is reduced because of water loss. Although the majority of mineral components are non-volatile, it is anticipated that their content material on moist weight will increase. Even so, the frying oil absorbs simultaneously, resulting in a boom in the weight of the fried fabric. A small decrease in mineral content may be found if the metallic content is expressed on a dry weight basis. Deep-fried foods lose a significant amount of minerals, ranging from 1% in potatoes to 26% in beef. Mineral losses from deep-frying range from 2 to 8% in breaded meat and fish; which is significantly less than in deep-fried meat and fish fillets without coating. This is because the minerals dissolved in the meat gravy are absorbed by the breadcrumbs [41, 48].

6.3. Mineral Metabolism

The effects of frying and non-frying consumption of olive, sunflower, and palm oil on the bioavailability of calcium, phosphorus, and magnesium in growing rats were investigated by the researchers [49]. The results demonstrated that the type of oil consumed had no effect on magnesium's bioavailability. However, the body's ability to retain magnesium remained unaffected by any of the three frying oils; instead, they all increased the amount of magnesium absorbed and urined. Calcium absorption efficiency was higher in animals fed both kinds of sunflower oil—unused and used for frying—but there was no appreciable difference in calcium retention, urine, serum, or carcass calcium. The consumption of frying oils did not significantly change the bioavailability of calcium.

6.4. Protein

Fry food does not change the digestibility of protein when no other ingredients are added. However, the addition of substances that reduce—such as the flour-based meatballs and fishballs—can result in a slight but discernible decrease in the protein's digestibility. According to Bognar [48] research, cooked foods can retain anywhere from 90% of their protein when meat is boiled to 96%–100% when meat, fish, and potatoes are deep-fried. The study looked at how different cooking techniques affected the amount of protein. These findings lend credence to the theory that frying has no impact on protein digestibility.

Table 8. Protein digestibility coefficient of raw and fried foods

State	Hake	Beef	Pork	Swordfish	Meat balls	Fish balls
Raw	0.92	0.93	0.92	0.94	0.90	0.92
Fried	0.91	0.93	0.92	0.96	0.88	0.89

Source: Fillion and Henry [47].

The protein digestibility coefficients for foods containing raw and fried protein sources are explained in Table 8 of the research report. The findings show that, aside from some typical structural changes, very few appreciable differences exist between the raw and fried products during oil deep-frying. This indicates that protein digestibility is the foods most stable during cooking and frying. Some slight alterations are noted, though, as a result of the products containing a combination of meat and flour.

6.5. Carbohydrate

Studies on the impact of frying on the carbohydrate content of potatoes, potato products, and breaded meat and fish have been carried out. The findings indicated that, depending on the kind of food, carbohydrate retention varied from 95% to 100%, indicating that the frying process had no discernible impact. Deep-frying considerably raised the resistant starch content while cooking frozen French fries had no effect on the starch composition when compared to raw samples. Amylose-lipid complex formation might have a role in this. After being fried, potatoes' digestible starch content decreased, but their fiber content increased. According to Fillion and Henry [47] fiber is essential for preventing diseases like diabetes, heart disease, and colon cancer.

7. Deep-Fat Frying Consumption Unhealthiness

Tasty food is made edible through deep-frying. Foods fit for human consumption are deep-fried using copious amounts of oil. It is not thought that increasing oil consumption is good for human health. Fried foods are generally regarded as safe, even though deep-frying generates some unquestionably toxic products (such as polar compounds or polymers) [50]. When cooking oil is used frequently and turns toxic for ingestion by humans, it works best. Cooking oil's plant antioxidant content decreases and hazardous reactive oxygen species are produced when oil is heated repeatedly, hastening the oxidative breakdown of lipids. It is anticipated that eating meals that contain heated oil for an extended period of time will negatively affect the antioxidant defense system, which is a major contributor to the development of diseases like vasculitis, diabetes, hypertension, and obesity [51].

Foods originating from plants fully absorb food originating from animals. Fried veggies, whole eggplants, tomatoes, onions, mushrooms, and pineapple pulp are better sources of fat absorption for them. Large amounts of fat are consumed by vital people collectively. Cooking meats like beef, pork, lamb, or sausages reduces their fat content. Cooking fats and oils enter our diets through absorption from hard foods. Depending on the food and consequently the type of frying medium, the percentage of oil absorbed in food varies from 4% to 14% of the total weight. The absorption of cooking oil is influenced by its quality. The surface tension between the potatoes' surface and the frying oil is high when using fresh oil. Frequent frying causes an increase in oil polarization and interfacial tension decreases. So, oil consumption increases with regular cooking of potatoes [52].

Heating causes thermal and aerophilous breakdown, which produces changed, polymerized compounds with more polarity. This consequently modifies the properties of deep-fried food and dietary fat in the organic process. The World Health Organization (WHO) recommends limiting one's consumption of sugar, salt, and saturated and trans-fats (hydrogenated fats). Snacks, processed foods, and drinks frequently contain these ingredients [53].

7.1. Cardiovascular Disease (CVD)

According to Mozaffarian, et al. [54], CVD is the leading cause of death globally and is expected to be linked to over 23.6 million deaths by 2030. As early as the 1970s, it was proposed that people who consume a diet high in fat, primarily from olive oil, would have lower rates of coronary heart disease (CHD). However, eating deep-fried food is also linked to an increased risk of cardiovascular disease. On the other hand, there is limited and inconsistent evidence supporting the link between consumption of fried foods and the risk of coronary artery disease (CAD) food [55].

These null results contradict the positive associations reported in alternative studies. It is possible that Mediterranean diets emphasizing fruits and vegetables, meat and whole grain coffee intake [56], and/or the types of oils used for coaching in Spain (particularly vegetable and flower oil) could contribute to the distinction determined by research. It has been demonstrated that using extra virgin olive oil when frying some foods decreases the depth of macromolecule oxidation [57].

A study conducted in Costa Rica using a case-control sample of 485 individuals who had survived a major acute myocardial infarct and 508 controls found no correlation between nonlethal acute myocardial infarct and an increase in the frequency of deep-fried food consumption (from 4.57 to 9.75 servings/day; $p < 0.05$) [58]. The most important oils used for instruction on this population are palm oil, vegetable oil derivatives, and oil. In a case-control study conducted in India in 2003, involving 199 matched controls and 160 five patients with coronary cardiovascular disease, the patients with coronary heart disease reported consuming more deep-fried and shallow-fried food than the controls did.

7.2. Heart Failure

According to a study, eating deep-fried fish has also been linked to lower glide, a lower ejection fraction, and a higher resistance to the trendy tube-shaped shape in older adults. Belin, et al. [55] found that consuming more than one serving of fried fish per week at baseline was linked to a 48 % increased risk of Heart Failure (HF) and Heart Rate (HR) is 1.48 with 9.5 % confidence interval: 1.19–1.84. Additionally, compared to subjects who reported consuming fried food, there was a positive and significant correlation between the consumption of fried meals and the incidence of heart failure in a prospective cohort study [55].

7.3. Hypertension

Changes in unhealthy cooking habits from boiling to cooking have been found to be beneficial for dominant pressure according to unit location and fat in the general population. When it comes to cooked food intake and elevated blood pressure, there may be limited and inconsistent treatment evidence at the same time. A cross-sectional study conducted in Spain found that eating more fried food was linked to a higher prevalence of hypertension [59]. The solar (Seguimiento Universidad de Navarra) Mediterranean cohort study found that a baseline common intake of fried foods was linked to the following risk of high blood pressure (adjusted hazards ratios = 1.18 (95 percent confidence interval: 1.03–1.36) and 1.21 (95 percent confidence interval: 1.04–1.41) for those who consumed excessive amounts of cooked meals twice or more per week, respectively [59].

7.4. Type Two Diabetic Disease (T2D)

The risk of T2D has been directly linked to the consumption of potatoes, red meat, and opportunity processed meats [60]. Restaurant cooked meals and dietary consumption had certainly been linked to T2D. Information from the nurses' fitness assessment and the medical professionals' adherence to: Further investigation revealed a strong correlation between the frequency of fried food consumption and, in turn, the risk of type 2 diabetes (T2D), with adjusted RRs (95 percent confidence intervals) for those who consumed fried foods [61].

7.5. Obesity

According to several studies, eating deep-fried food is positively correlated with obesity, a larger waist circumference, or weight gain in pregnant women [62]. Additionally, two large potential studies have suggested a link between a higher incidence of incident obesity/weight problems and the consumption of fried foods. According to Tiwari, et al. [63] the prospective study revealed a strong correlation between the consumption of fried food and both general and vital obesity (adjusted odds ratios for general obesity in the highest quintile versus the lowest quintile of fried meal consumption: 1.26 (ninety five% CI: 1.09–1.Forty five, p for fashion four times/week).

8. Ways to Solve the Harmful Effects of Deep Fat Cooking

Since the oil will be made safe for human consumption, there will be a reduction in the harm that comes from using heated oil continuously in a number of ways. Vegetable oil can be made safe by using natural antioxidants as adsorbents to delay the production of products that cause oil deterioration. Numerous studies have made it clear that antioxidants such as propylgallate (PG), tert-butyl hydroquinone (TBHQ), butylated hydroxylanisole (BHA), propylated hydroxyl toluene (BHT), and tocopherols reduce the reaction of oil at temperature. Nevertheless, due to losses from volatilization or breakdown, their effectiveness decreased at cooking temperature [37].

It has been observed that adding different absorbents during frying, such as sugarcane bagasse, rosemary, and antioxidants from turmeric extract, reduces the detrimental effects of the deterioration products. The addition of curcumin, a naturally occurring inhibitor found in turmeric (olantof zingiberaceae) family, is said to lessen the negative effects of products that cause oil deterioration. When turmeric extract was added to the cooked food at a concentration of 0.03%, the amount of trans-carboxylic acid decreased. This relates to curcumin, which inhibits the rate of auto-oxidation by converting lipoid radicals into a highly stable form, which typically inhibits the fat reaction [64].

Antioxidant supplements added to vegetable oil that is frequently used can slow down the rate at which the oil oxidizes during cooking and improve the way that cooked food is perceived by the senses. The findings of this study are corroborated by the claim made by Abriana and Johannes [65] that the addition of an inhibitor to vegetable oil verifies the integrity of the reaction during cooking and that curcumin is a useful antioxidant due to its ability to scavenge radicals by donating a H atom from synthetic resin as its active group. Other than this, a number of adsorbents like ash, magnesol XL, and sugarcane bagasse can also be used to reduce the formation of the decay product produced by continuous frying [66].

9. Conclusion

Edible oils are widely consumed and popular food worldwide but the high temperature cooking of oils causes deterioration of food and health problems. This oil long time and high temperature cooking oils problems occurred because of the chemical and physical changes upon cooking. Reactions in oils increase the number of free fatty acids, mono and diacylglycerols and glycerols. These compounds with free radical hydrogen react with oxygen in the air and causes great health problems on the consumers. But using fresh oil, temperature of cooking, time of cooking, food materials, fryer and antioxidants have an effect on the quality and safety of oil during cooking. Also using artificial antioxidants like turmeric and natural antioxidants like tocopherols, BHA, BHT, PG, and TBHQ can decrease oil oxidations, even if they diminished normally at cooking temperature. But using lignin compounds instead of using antioxidants are more effective to stabilize oil during cooking. Therefore, the consumption of fried fat/oil at high temperature for long time becomes dangerous for human causing chronic diseases like CVD diseases, Heart failure, hypertension, polygenic disorder and fatness. So, the review warns us to take care with oil cooking and consumption so as not expose to chronic diseases.

10. Conflict of Interest Declaration

The authors declare that there are no potential competing financial interests or personal relationships that could have appeared to influence the work reported in this review paper. The authors mentioned in this paper are the only owner of the research paper work both in finance and technical works.

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