

# REVIEW: IMPACT OF CONVENTIONAL FRYING AND NOVEL FRYING METHOD ON THE QUALITY OF FRIED FOOD PRODUCTS

## Abstract

Starch is a functional element in food that serves as a vitally important source of energy. In fried foods like potato chips, French fries, instant noodles, and coating flour, starch is primary ingredient. Deep frying changes the structure of foods and adds extra oil to them. When it comes to cooking and processing food, deep-fat frying is by far the most popular technique employed by consumers, eateries, and factories around the globe. Most obviously, it slashed lead times and allowed for the innovation of novel cuisine with appealing sensory properties. After being ingested, the starch and fat found in deep-fried foods are digested by enzymes in the human body, yielding glucose and fatty acids as the primary source of energy. Overconsumption of these deep-fried starchy meals, however, has been linked to an increase in body fat, obesity, and the onset of several different degenerative and cancerous conditions. Pressure frying, microwave frying, vacuum frying, radiant frying, and air frying are only a few of the alternative frying technologies that can lower the amount of processing toxicants in fried foods. In this analysis, we look at how the new frying technique has influenced the industry.

**Keywords:** Starchy foods, deep frying, Alternative frying method, Food products.

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## I. INTRODUCTION

Frying is the extensively oldest and most structured cooking method as it is the outcome of intense heat and quick heat emission. Since ancient times, it has been used to prepare various kinds of food. Usually, starchy food is used. Frying enhances the sensory quality of food by forming aromatic compounds, tempting color, texture, and crust. Further, cooking ameliorate the healthful grade of food by immobilization of pathogenic microorganisms and enhancing the palatability of food and the bio-availability of nutrients in the gastrointestinal tract. Unacceptable alteration involved mitigate heat and oxidation of susceptible vitamins and water-soluble minerals [1]. Alteration of meal and oil depends on the quality of the food, kind of oil surface and volume ratio of the oil, rate of air incorporation into the oil, temperature, heating process, length of immersion, and the material of the frying container is made of. Prolonged exposure of oil to high temperatures and atmospheric air can give rise to highly oxidized, undesirable toxic products [2]. The frying process depends on the high temperature and can alter the structure of versatile nutrients like proteins, vitamins, and antioxidants. During water evaporation, some water-soluble molecules like ascorbic acids can be lost.

Bognar, A stated the most important frying methods are

- Deep frying - In this method, the food is submerged in extremely hot oil or fat.
- Shallow frying - Frying food in a small amount of fat or oil in a frying pan.
- Roasting - Mostly protein-containing food is used to fry with or without fat in an oven.

At atmospheric conditions, the deep frying process occurs the temperature of hot oil is 150-190°C at which food is immersed. Furthermore, during frying the high temperature causes the chemical degradation of some easily destroyed by heat food components. Frying has advantages and disadvantages both. Advantages like being a swift cooking method. Fried foods are attractive, tasty, and appetizing has a higher satiety value. In shallow frying, the amount of oil consumption can be controlled. On the other hand, the drawback of frying and fried foods are that it covered with layers of fat and becomes difficult to digest. Due to high temperatures, the nutrient loss is higher specifically of fat-soluble nutrients. Product disadvantages are related to the oil quality and oil content of the final product. Current studies have stated that often use of fried foods i.e., four or more times per week is related to a higher risk of forming obesity, type 2 diabetes, heart failure, and hypertension [3]. Nowadays people are more health conscious and they are becoming more aware of their diet and also about the health risk factors, so it becomes more important that the fried products they are demanding should be healthy. So in this chapter, we are discussing alternate frying technologies.

## II. CHANGES IN STARCHY FOOD BY DEEP FRYING

Starch is a vital part of the human diet because it provides a quick and steady supply of energy. More than 80% of the worldwide starch market [4] is currently supplied by grain starch, which is also utilised in the production of fried starchy dishes. Most of the oil is drawn to the surfaces of the starch granules, where it is absorbed [5]. As a result of mass transfer

and heat, starch's composition and physiochemical properties are varied during frying, affecting the ultimate quality of starch-based foods [6]. Many people today worry about their diet and how it affects their health. Oil is absorbed by the food during the frying process causing an increase in fat content of 30–50% [7]. Saturated and trans fats are employed in excessive amounts in industrial frying to prevent oxidation, but these fats have been linked to a variety of health problems, including obesity, cardiovascular disease, neurological disorders, and cancer [8]. Fried foods contain both starch and protein, and the high temperatures used to cook them create hazardous chemicals called process induced toxicants (Hydroxymethyl furfural, acrylamide etc.) [9]. The Maillard reaction between the amino acids (asparagine) and reducing sugars (mainly glucose) generates the poisonous chemical at high temperatures [10]. The variety of cooking oil, and for the most part its structure, is crucial to the standard of the finished product when deep-frying food. The absorption of acrylamide formed during frying stays on several element, involving the sort of food being cooked, its moisture content, and the frying conditions.

Unsaturated fats are more allowing to lipid oxidation during frying, which results in the generation of hazardous reaction products. During oxidation and heating, Extra Virgin Olive Oil (EVOO) is found to be more stable than other culinary oils [11]. Since EVOO is predominantly constituted of triglycerides with nearly immense concentrations of oleic acid, monounsaturated fatty acids (MUFA), and minimal levels of polyunsaturated fatty acids (PUFA), it is more safe at high temperatures apart from different cooking oils with elevated PUFA concentrations [12, 13]. According to Napolitano et al. [14], there is less acrylamide production when olive oil (which is rich in polyphenols) is used to fried potatoes. Friedman and Levin [15] stated that the antioxidant can degrade the level of acrylamide in cooked meals. Additional research has demonstrated that the amylose content of starch samples affects the oil absorption of starch-based frizzled meals, with more advanced amylose content starch samples resulting in less oil absorption in potatoes [16]. While soybean oil is very vulnerable to oxidation due to its high content of polyunsaturated fatty acids (PUFA), it is nonetheless broadly employed in starch-based fried meals as a result of cheap cost [17]. Liu et al. [18] hypothesised that prolonged frying can result in the formation of toxicants compound in fried foods. Furthermore, the type of oil influences the synthesis of acrylamide. Gertz and Klosterman [19] discovered that acrylamide levels are greater when French fries are fried in palm oil as opposed to rapeseed oil. According to Becalski [20], samples fried in olive oil contained a greater concentration of acrylamide than samples fried in corn oil.

**Table 1:** Advantages and Disadvantages of Edible Oils

Edible oils	Advantages	Disadvantages	Ref.
Soybean oil	<ul style="list-style-type: none"> <li>Rich in vitamin E</li> <li>Highly consumed by the world</li> <li>The price is cheap.</li> </ul>	<ul style="list-style-type: none"> <li>It has a high content of polyunsaturated fatty acids (PUFA) which easily makes it oxidize.</li> <li>Regarding rancidity, it smells like fishy beans</li> </ul>	[21]
Rapeseed oil	<ul style="list-style-type: none"> <li>The high content of Monounsaturated fatty acids(MUFA)</li> </ul>	<ul style="list-style-type: none"> <li>Highly expensive</li> </ul>	[22]

Sunflower oil	<ul style="list-style-type: none"> <li>The content of vitamin E and chlorogenic acid with antioxidant activity is high.</li> </ul>	<ul style="list-style-type: none"> <li>It contains high Polyunsaturated fatty acids (PUFA).</li> <li>Which easily get oxidized and degrade.</li> </ul>	[22]
Peanut oil	<ul style="list-style-type: none"> <li>Having a unique flavor of peanuts and is highly thermal stable.</li> <li>Can be fried for short period.</li> </ul>	<ul style="list-style-type: none"> <li>During the frying formation of foam is easy due to the small number of phospholipids</li> </ul>	[21, 23]

### III. FRYING PROCESS

The deep-frying process involves four stages, they are Heat-up, Surface boiling, Falling rate, and Bubble endpoint [24]. The warm-up interval starts when the foodstuffs are set down in the oil and the surface extends the boiling point of the surface water. This beginning heating stage is active for only a few seconds with minor moisture loss. In the surface boiling stage, there is a quick rise of the heat transfer coefficient by free convective (heat transfer from the oil to the food surface) and conductive (heat transfer within food) heating. In this stage of frying, there is the formation of crust and explosion of bubbles as seen in the early stage of the frying processes [25]. The falling rate is the longest frying stage which comprises food core heating, thickening of crust layer, loss of moisture, and other reactions that also involve starch gelatinization, and protein denaturation. Water vaporization ends when the food enters this last stage of frying which is the bubble endpoint stage. The bubble endpoint stage is caused by many factors such as a reduction in heat transfer to the crust/core interface or complete removal of all liquid water in the sample [25]. Synchronous heat transfer and mass by hot oil alter the food surface, forming a crust that maintains flavors and absorbs part of the juiciness of the food although it is cooked, making chewing easy to digest [26]. On average the deep-fat frying oil reaches 175°C, ranging from 150 to 200°C [27]. In frying the temperature is heterogeneous, a higher temperature which is closer to the oil temperature is observed in the peripheral region of the food although the core of the food is rich in water which shows the temperature around 100°C (mostly between 101 and 103°C). Accordingly, in the peripheral region, there is a high rate of nutrient degradation than in the center [28]. The composition of the food and its qualities of heat and mass transfer together with thermal conductivity, thermal diffusivity, specific heat, and density affects the rate of heat transfer. Frying can be attained in batches and continuous fryers. Batch fryer is mainly compact and frequently used in catering services whereas continuous fryers can hold a large amount of frying oil and foods. They are mainly used in industrial zone and include mass production. Fryers feasibly work under atmospheric, high, or low pressure and even under vacuum [29].

By figuring out the procedure of frying such as the quality of the product, oil uptake has aided in regulating different methods to overcome the limitations of deep frying. In recent circumstances, the main challenges for fried food industries are reducing the oil content and maintaining the oil quality to reach proportionally safe and healthy products. Overcoming these limitations current procedures are discussed in the following sections:

- 1. Reducing the Oil Uptake:** Oil uptake during deep frying is unavoidable and has been broadly studied. According to D Dana and IS, Saguy [30] proposed the mechanisms of a complex process of oil uptake during deep fat frying. In a nutshell, the water replacement mechanism explains when water evaporated in the fried foods the oil uptake is created in voids whereas the cooling phase effect describes the oil uptake after food is removed from the fryer, and the surfactant effect contributes a limited description for the rising oil uptake during deep frying. U Mehta and B Swinburn [31] explained the various factors affecting the oil uptake by food products. The current researches on pre-frying approaches for reducing oil uptake are focused on the alteration of product formulations and the advancement of new batter and coatings for various products. F Yuksel et al. [32] stated that notable oil reduction is observed when 10% barley flour is added to wheat chips without any change in product sensory properties. Dueik et al. [33] stated that adding wheat bran to the food matrix point can result in up to 70% oil reduction. The ongoing style prefers more whole flours, and high-fiber components in various products to reduce oil uptake at the same time increase the dietary fiber intake. Another way of oil reduction uptake is the formation of oil barriers using different batter and coating systems. Current researchers on various coating systems like low-methoxyl pectin [34], hydroxypropyl methylcellulose [35], almond gum [36], basil seed gum [37], and whey proteins [38] have shown good outcomes of oil reduction uptake without disturbing the product sensory properties.
- 2. Raising the Stability of Frying Oil Quality:** Deep frying is a traditional method that results in unacceptable changes and deterioration of the frying medium. During frying many chemical reactions occurs like hydrolysis, oxidation, isomerization, and polymerization reactions which tend to form free fatty acids, trans isomers, cyclic and epoxy compounds, alcohol, aldehyde, ketone, and acids that show alteration of off-flavor, changing colors, foaming, and reduction of shelf life [39]. Many researchers is been a focus on the formation of high-stability oils for frying. Delfanian M et al. stated that the extract of Jujube fruit has shown better oil stability than synthetic antioxidants in soybean oil [40]. Another researcher stated that Roselle extract helps to increase the oil stability in bulk frying oil [41]. In brief, Antioxidants have shown good results for the stability of frying oil.
- 3. Physical and Chemical Changes in Fried Foods:** Physical and chemical changes occur during frying. These changes depend on the composition of the food and the temperature of the oil, which affects the development of color, flavor, taste, and texture. Bordin K. stated that changes in the food surface are mainly caused by Caramelization and the Maillard reaction (non-enzymatic browning) both of them are liable for the development of gold to brown hues, in addition, evaporation of surface water is also responsible for the texture of the fried food [42]. For example, color development in potato chips is proportional to the quantity of reducing sugars in the potato, since both browning and Maillard reactions have properties of heme pigments and are stimulated by the level of oxidation of the food [42]. At the time of frying, the Maillard reaction is the main reaction impacting the sugars which contain free amino groups of amino acids, peptides, protein, and carbonyl groups or other aldehydes and ketones of sugars [42]. At frying some intermediate products called Amadori products or pre-melanoidins get swiftly polymerized, forming dark color molecules (melanoidins). Above 150°C temperature browning is faster [43].

4. **Changes in the Fried Food Products Caused by the Maillard Reaction:** Many harmful compounds are produced by the Maillard reaction among them Acrylamide is the most toxic compound. It has been known to be a Carcinogenic, neurotoxic, and genotoxic compound in animals and humans categorized as a likely human carcinogen [44]. The formation of acrylamide has not been explained yet, but it is confirmed that when asparagine and reducing sugars are heated at high temperatures acrylamide is formed along the Maillard reaction [45, 46]. As stated by Miao et al. [47] Acrylamide contents increased simultaneously with the increasing treatment time and temperature in potato chips. This formation of a compound is affected by the water activity, the formation of acrylamide increases with decreasing the water activity [47]. Apart from Maillard reaction and caramelization. Frying oil also involve in the non-enzymatic browning process by the reaction of lipid oxidation products with amines, amino acids, and proteins [48, 49].
5. **Nutritional Change:** Rising energy intake is found on average in 42% of French fries and 53% of hamburgers, it is caused by increases in fat content in food due to the absorption and retention of oil [42]. The Dietary Guidelines for Americans recommend that less than 35% of daily calories are contributed from fat, however, in fried foods, up to 75% of calories are from fat [50].

Using reused oil/fat affects the digestibility of the fat. The toxic compound can appear in oil if frying oil is initiated, limiting polar compounds to 25% and polymer content to 12% [50]. The frying process produces trans fatty acids(TFAs) which are unsaturated fatty acids that contain non-conjugated carbon-carbon double bonds in the trans configuration. According to epidemiology studies, there is a linkage between the level of these compounds intake and the risk of cardiovascular disease [51, 52]. During the frying formation of TFAs in the oil has been investigated [52, 53, 54, 55]. Accordant with these studies, frying degrees of TFAs formation depend on three main factors: Frying condition, frying materials, and the methods of TFAs measurement [52]. In the beginning, the quality and type of oil/fat used during frying affect the incorporation or absorption of oil [56]. Accordance to Paul and Mittal [53] the penetration of oil into the food is affected by many factors such as the oil viscosity, geometric shape, oil temperature, food type, and length of frying. Heat treatments degrade the amount of protein and demolish some amino acids, changing the quality of protein composition in food [57]. During frying lysine is lost because it is the first amino acid involved in the Maillard reaction.

According to the studies it is found that during frying at high temperatures of 165°C - 185°C and short cooking time minerals are preserved [57]. Starch is the most prevalent polysaccharide in food. Starch gelatinization occurs when amylose and amylopectin dissolve in water and form a polymer network [58]. At high-temperature denaturation of globular proteins occur which causes gelatinization and contains carbohydrates, proteins, lipids, and water [58]. During the frying process composition of food gets changes, and there is a moderate loss of vitamins and antioxidants. Different alternative technologies have been discussed below. Vacuum frying is one of the alternative frying methods which prevents oil deterioration due to low-temperature processing and the absence of oxygen in the frying environment. This frying method has been discussed below in detail it is the most effective alternative frying method. Various

alternative frying methods have been discussed below like Pressure frying, Microwave frying, vacuum frying, radiant frying, and Air frying.

#### IV. ALTERNATIVE FRYING TECHNOLOGIES

**Table 2:** A Brief Explanation of Alternative Frying Technologies

Frying techniques	Characteristics	Applications	Ref.
<b>1. Microwave Frying</b>			
i. Vacuum frying (VF)	<ul style="list-style-type: none"> <li>➤ The frying period is longer</li> <li>➤ Low-fat content</li> <li>➤ Smooth and uniform microstructure.</li> </ul>	The capability of vacuum frying machine is not high, so therefore microwave and ultrasonic frying technologies supported frying which can improve the capability in commercial production. Though the appliance is costly and the operation and assembly are more complicated so it is challenging to implement in global mass production.	[59]
i. Microwave vacuum frying (MVF)	<ul style="list-style-type: none"> <li>➤ Moisture is low</li> <li>➤ Having a similar taste to ordinary French fries</li> <li>➤ Damage to food nutrients gets reduced.</li> </ul>		[60–62]
ii. Ultrasound combined microwave frying (UMVF)	<ul style="list-style-type: none"> <li>➤ As compared to VF and MVF evaporation rate is high</li> <li>➤ Reducing the frying period, and improving the crispiness, texture, and color.</li> </ul>		[63-64]
<b>2. Air frying (AF)</b>	<ul style="list-style-type: none"> <li>➤ The processing time is lengthy</li> <li>➤ Helps to reduce the amount of acrylamide and polar compounds.</li> <li>➤ The degree of starch gelatinization is low.</li> <li>➤ Very low in fat.</li> <li>➤ The taste is bad as compared to traditionally fried products.</li> </ul>	No extra oil is needed when frying. It is very low in fat. Good for adult people and aged people with cardiovascular and cerebrovascular diseases like hypertension or hyperlipidemia. Price is cheap and used by many households. Due to its low frying productivity not suitable for industrial production.	[65,66]
<b>3. Oil water mixed frying (OWF)</b>	<ul style="list-style-type: none"> <li>➤ Deterioration of oil</li> <li>➤ Detaining of oxidation and polymerization.</li> <li>➤ There is no change in water content as compared to conventional frying.</li> <li>➤ Identical color, smell, and flavor as to conventional frying.</li> </ul>	It has minor deterioration in smell, color, and flavor due to which it is the healthier and best frying method for meat products. it is recommended that future measures should be taken to delay the hydrolysis of oil in the course of oil water frying technique.	[67]
<b>1. Spray frying</b>	<ul style="list-style-type: none"> <li>➤ Fat content is low</li> <li>➤ The color of the products is good i.e.</li> </ul>	For better spray frying different guidelines need to be enhanced.	[68]

	lighter.		
2. Radiant frying	<ul style="list-style-type: none"> <li>➤ The Colour is light.</li> <li>➤ Results in less oil and high moisture as compared to deep frying.</li> </ul>	According to the sensory test no different taste is found as compared to ordinary products, it can be used alternative to the deep frying method.	[69]
3. Electric field frying (EFF)	<ul style="list-style-type: none"> <li>➤ During frying oil deterioration is been delayed.</li> <li>➤ Moisture content is low.</li> <li>➤ Minute structural damage.</li> </ul>	This technique can bring down the price of commercial production and the forthcoming main focus will be on the electric field of fried products to upgrade the equipment.	[70]
4. Pressure frying	<ul style="list-style-type: none"> <li>➤ Time saving cooking</li> <li>➤ Uses less oil and energy than deep frying.</li> </ul>	Pressure frying works when the pressure inside a contained fryer is increased. When the atmospheric pressure is increased, it causes the boiling point of water continued in food being prepared to rise.	[71]

**1. Pressure Frying:** Pressure frying is the altered form of the deep frying technique. When the moisture is released from the food the pressure is generated inside the fryer. Pressure frying turned out to be efficacious in reducing the cooking time and so result in better-textured products [71]. D.P Pawar, et al. stated that oil degradation was less in pressure frying compared to conventional frying [72]. Researchers have studied that using nitrogen gas in pressure frying gives better quality fried products of moisture retention, texture, and juiciness. The moisture content and pressed juice inside the fried foods together with oil uptake are influenced by the magnitude of applied frying pressure [73]. On the Industrial scale, the use of pressure frying was found to be limited, however, on the commercial scale, the use of pressure frying has been broadly used such as in convenience stores, restaurants, supermarkets, schools, hospitals, and other industrial and commercial food service operation [72].

**2. Microwave Frying:** Presently microwaves are being used on both domestic and commercial scales for various functions like baking, thawing, cooking, and drying. It is the configuration of electromagnetic radiation frequency ranging from 0.3 GHz to 300 GHz with wavelengths from 1mm- 1m [74]. Compare to conventional deep fryers microwaves are more beneficial in oil uptake and reduced processing time [75]. Both the authors, A Parikh and PS Takhar [62] compared the quality and sensory characteristics of French fries in microwave fryers and conventional fryers. They stated that the French fries which were fried in the microwave were lighter and more yellow and had a similar moisture content as conventional fryer French fries. And they also reported that no remarkable difference in the overall liking or flavor liking was noticed in the consumer test. The main challenge of microwave fryers is the degradation of oil at high temperatures and non-uniform heating. E Aydinkaptan, et al. [76] have reported that a microwave fryer shows a considerably more elevated change in the oil quality than a deep



fryer and is dependent on the microwave power level. This has limited the use of microwave fryers as a discrete technology. Presently researchers are trying to merge microwaves with vacuum fryers to produce better-quality products in less time and reduce oil uptake [60, 77].

**3. Vacuum Frying:** Vacuum frying is an advanced food processing technology that evolved in the late 1960s and early 1970s that is carried out below atmospheric pressure (6.65 kPa) vacuum frying uses pressure; this reduces the frying temperature of the oil and boiling point of water. According to the present studies vacuum fryers have shown many advantages in vegetables, fruits, and meat products [78-81]. The Food industries had already begun the use of vacuum fryers for commercial higher-quality products chiefly vegetables and fruits. Vacuum frying has various benefits they are:

- The absorption of oil is been deducted [82].
- Due to lower temperatures and pressures, the formation of acrylamide during frying is been deducted [83].
- The nutritional quality of the food is been conserved [84].

Due to this reason vacuum frying is also used in the baked and drying of fruits and vegetables [85]. Vacuum frying has a broad range of applications such as fruits like strawberries, apples, and bananas; vegetables like onions, carrots, potatoes, and tomatoes; dried fruits and nuts like peanuts and dates. Vacuum frying had shown a remarkable reduction in the deterioration of frying medium compare to deep frying, because of the low-temperature requirement for frying [80]. Researchers stated that vacuum frying results in less deterioration of nutritional compounds preserves the natural color, and flavor, and decreases acrylamide formation. In deep frying at high temperature, the oil comes in contact with air and water and form many complex reactions like polymerization, hydrolysis, and oxidation which results in the production of harmful substances. For example, many other harmful substances are produced like epoxy propionamide, acrylamide, furan, polycyclic aromatic hydrocarbons (PAH), and Trans fatty acids. A possible benefit of using vacuum frying is that these harmful substances get deducted because of the lower temperature. By Lozano-Catellon et al. [86] differentiated the changes of olive oil in deep frying and vacuum frying and outcomes show that vacuum frying conserved the phytochemical features of EVOO and deep frying produced more oxidation products like hydroxyl-derivatives of lipids. Acrylamide is broadly determined in fried foods containing high starch by the cause of the Maillard reaction [68]. According to the reports, these harmful substances show carcinogenicity, neurotoxicity, and gene toxicity [87]. During frying, the formation of acrylamide is caused by the hydrolysis of acrylonitrile. Williams et al. [88] reported that the formation of acrylamide in potato chips is mainly controlled by the reducing sugar level instead of the asparagine level. The formation of acrylamide in fried products is caused by the composition of the raw materials like asparagine, water contents, and glucose also frying conditions used like time, temperature, and pH value [89]. Low temperature during vacuum frying promotes the reduction of acrylamide formation and other potentially toxic reaction products. Also, the reduced oxygen level utilized in vacuum frying hinders the formation of harmful substances caused by the oxidation of oils and proteins [90, 91]. Granda and Moreira [92] stated that the formation of acrylamide is found less in vacuum-

fried potato chips as compared to conventional fried, which may be an advantage to healthier products. Further studies, stated that in vacuum-fried potato chips the acrylamide content was reduced by 94% than conventionally fried [93].

It is also reported that the acrylamide content in the final product is influenced by time and temperature. WHO stated furan give rise to detrimental substance during high temperatures is listed among 2B carcinogens. The formation of Funan in food products is mainly caused by the thermal degradation and rearrangement of sugars and amino acids and the thermal oxidation of polyunsaturated fatty acids (PUFA) and ascorbic acids [94]. According to the Garayo and Moreira et al. [95] stated that the microstructure in potato chips was different as compared to conventional fried ones. The major difference is in the number and size of the stomata which are present on the surface of the potato chips, which helps in the lower absorption of oil in a vacuum- fried potato chips. Juvvi et al. stated that low oil uptake has been observed in vacuum-fried as compared to conventional fried pear slices [96] and banana slices [97]. . Conclusion is that vacuum fryer has shown remarkable advantages in product quality and usable alternative to deep frying for premium products.

4. **Radiant Frying:** During deep fat frying, radiant frying is attained by applying high-temperature radiant emitters that imitate the heat flux profile. Nelson et al [98] stated that radiant fried chicken patties had 16% less fat and 19% more water than those produced by deep-fat frying. But the brittleness and appearance of the products produced by radiant frying were not fulfilling. By sensory analysis, the color of the radiant-fried samples was 11% deeper compared to deep-fried ones and they were not crispy too.
5. **Air Frying:** Air frying involves hot air comprised of oil droplets around raw food materials. The chief purpose of air frying is to encourage constant contact between the food and the oil droplets within the hot air stream, which decreases the total amount of oil required for productive cooking. This frying method promotes healthy cooking which involves low fat and calorie contents. This technique also promotes the environment such as decreasing fuel consumption and emission. The limitation of physical form may affect the texture, color, flavor, and moisture content of the final product [99]. Products fried in the air fryer were found to be healthy with less fat and likely harmful substances. By Basuny et al. [100] the toxic substances like Maillard and lipid oxidation reaction found during frying from fried foods products are higher in conventional frying than air frying. During frying or baking when the temperature of the food extends 120°C there is a formation of acrylamide which is the product of Maillard structured by the reaction of amino acids (asparagine) and reducing sugars (mainly glucose and fructose). Acrylamide is generally produced when high starch-containing food is fried. According to Basuny et al. [101] stated that Air-fried potatoes have a low level of acrylamide formation as compared to deep-fat fried potatoes. The formation of acrylamide content was reduced by 73.11% in air-fried potatoes as compared to traditional fried samples. Due to the lower frying temperature, the formation of acrylamide is less as compared to the traditional fried temperature. Kim et al. stated that the formation of polycyclic aromatic hydrocarbons (PAH) formed at the degree of unsaturation of the added lipids rises [102]. This occurrence was credited to unsaturated fatty acids which is being more susceptible to oxidation during heating [103]. Hence, the outcomes show that the unsaturated fatty acids that exist in the frying oil elevated the PAH formation. Due to this reason, the air-fried

samples show lower acrylamide formation and total PAH contents than deep-fat-fried samples and hence cause low oil content used [104]. Accordance with Basuny et al. [101] stated that polymer content in foods formed by air frying and conventional frying were around 0.07 and 0.20%, respectively. Furthermore, the concentration of oxidized fatty acids that exist after cooking rises to 0.13 and 0.06% for conventional and air frying, respectively. Eventually, the free fatty acids content rises from 0.09 to 0.22% in foods produced by conventional frying, although it only rises from 0.09 to 0.22% in foods produced by air frying. Free fatty acids are also used to control changes in oil quality during frying [105]. According to Feng et al. [106] stated that the depletion of fat content in foods produced by air frying converts into low postprandial triglyceride (ppTG) responses, which is good for wellness with many healthcare benefits.

One of the main disadvantages of air-frying technology is the food products produced from this have degradation in their sensory characteristics like drier mouth feel and modification in their flavor profile as compared to conventional deep-fat frying. The conventional frying of foods generally includes counterbalancing mass transport processes:-

- The movement of water from the food into the surrounding hot oil.
- The movement of oil from the surrounding hot oil into the food product [107].

The comparative rates of these two actions regulate the total amount of oil present in the final fried product. Teruel et al. stated that the deduction of humidity in foods has been slower during air-frying as compared to conventional frying [108]. Carla et al. [109] study the effects of different vegetable oil they are sunflower oil, olive oil canola oil, and soybean oil, on the quality of potatoes. They used these oil in both frying methods which are air frying and traditional frying method. He found that the fat content of air-fried potatoes decreased by an average of 70%, mainly in olive oil, and fat content was found to be low in potatoes. Teruel et al. [108] studied the effects on the quality of French fries fried on both methods i.e. conventional frying and air frying. He identified that the oil content of air fries (0.4 to 0.11 g/100g sample) was notably less than that of traditional fries (5.6 to 13.8 g/100g sample). Alike outcomes were attained by Carla et al. [109]. By Teruel et al. [108] the differences in the final oil content of foods are due to the frying medium which had been fried in air frying and conventional frying method. Textural characters are found to be different in fried food produced by air-frying as an outcome of the differences in the rate and extent of oil uptake and also the kinetics of heat and water transport processes. The frying time, temperature, and microstructure also play a very crucial role [110]. The appearance and color was not notably different between air-fried and deep-fat-fried. Although, the deep-fat fried gives an oil mouth coating and oily touch while the air-fried sample gives a puffed and dry appearance. The “mealiness” sensation stated that air-fried potatoes are linked with increases in the volume of gelatinized starch in their cells [111]. During cooling, there is higher crust shrinkage was demonstrated on hot air-fried samples [112]. Although, high vitamins level were found to be retained in hot-air fried samples and boost oil quality whereas chemical reactions are for bided [113]. The consequences of hot-air and deep-fat frying on the microstructure, starch, gelatinization, and digestibility of potato strips have been explored [114]. A low amount

of starch gelatinization and more starch digestibility was found in the hot-air fried samples as compared to deep-fat fried samples.

- 6. Electric Field Frying (EFF):** Electric field frying uses high-frequency, low-tension electric fields to enhance the air drying of foods during frying (EFF). Electric field frying instantly act on the frying oil without directly acting on the food but slightly damaging the food tissue. According to the recent studies when electric field was applied the acid value, total polar compound content, viscosity and color deepening rate of frying oil increased more gradually.

## V. CONCLUSION

In this review, the effect of frying on the quality of food, and the advantage, and disadvantage of frying has been discussed. Frying the structure and physiochemical properties of starch are influenced by mass transfer and heat, consequently changing the final quality of starch-based foods [6]. And also frying process, reducing the oil uptake, rising the stability of frying oil quality where antioxidant have shown the good results, physical and chemical changes in fried foods, changes in the fried food products caused by the Maillard reaction and nutritional change had been discussed. On the other hand, the overconsumption of these deep-fried starchy foods can aid in overweight, obesity, chronic diseases, and some other carcinogenic effect. Nowadays many people are health conscious and concerned about food and nutrition-related issues so, their focus is to find out alternative frying techniques such as Microwave frying, Vacuum frying, Microwave vacuum frying, Ultrasound combined microwave frying, Air frying, Oil water mixed frying, Spray frying, Radiant frying and Electric field frying. Traditionally the use of a vacuum fryer is common and most effective and had been used as an alternative technique to deep frying. Air frying technique promotes healthy cooking and promotes the environment such as decreasing fuel consumption and emission. Microwave frying is most common and used on both domestic and commercial scales for baking, cooking, thawing, and drying. And pressure frying is broadly used on a commercial scale.

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