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Physico-chemical changes of fried products during oil and vacuum frying

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Abstract
With critical analysis of the available literature, this review article emphasizes upon physico-chemical changes of various fried food products during oil and vacuum frying processes. Physical characteristics involve texture and colour. On the other hand, chemical and nutritional parameters include moisture content, fat content, acrylamide, carotenoids, flavonoids, phenolics etc. Such investigation affirmed positive dependency of textural parameters such as hardness, firmness and stiffness with temperature and time during both oil and vacuum frying processes. Similarly, colour such as L*, a*, b* and ΔE enhances during the frying processes. On the other hand, nutritional parameters such as protein, fat, carotenoids, flavonoids and phenols reduced significantly with increase in temperature and time during oil and vacuum frying. On the other hand, such frying processes leads to a toxic compound known as acrylamide which is carcinogenic in nature. Thus, this article addresses the major parametric changes during oil and vacuum frying processes. This would facilitate product-process design for the said frying processes. Further, it would be beneficial to design a frying equipment and optimize the process condition. The main result of this study was the demonstration by Sothornvit R. that the use of two hydrocolloids (guar gum and xanthan gum) helped reduce the oil absorption of vacuum-fried banana chips, giving values of 8-9% oil absorption, hardness 27.32 N (Sothornvit R, 2011). Variation of Gulab Jamun balls with temperature. - 130oC and time - 10 minutes, activation energy, texture - 24.5-77.6 kJ/mol, color - 28.66-43.52 kJ/mol, lightness (L*) - 79.86 decreased to 23.48 - 29.25, overall color (ΔE) - 53.22 - 59.30, hardness - 0.168 N/mm - 3.935 N/mm, strength - 0.13 N/mm - 11.19 N/mm, stiffness - 0.19N/mm2 - 7.91N/mm2. This paper aims to study the combined effect of different baking methods on fruits and vegetables and some traditional sweets.

Keywords: Fried products, oil and vacuum frying

Introduction

Fried meals are immensely popular today all across the world, as evidenced by the rise in fast foods outlets over the past few decades. Due to their distinctive organoleptic and sensory qualities, deep-fat fried meals are incredibly popular (Al Faruq *et al*., 2022) [32]. Foods that are deep fried at high temperatures have more sensory qualities such as distinctive flavour, a golden-brown hue and a crispy texture. Submerge food in cooking oil or fat at temperatures well above the boiling point of water. The heat from the oil will cook and dehydrate the food. Some frying oil also transfers to the food and becomes a major part of the final product. (Moreno *et al*., 2010) [36] In the food system, chemical processes including oxidation, polymerization, hydrolysis etc. occur which ultimately change the physical and chemical properties of fat (Nayak *et al*., 2015) [31]. Indeed, fried meals are bad for your health because they are high in oil, calories, and acrylamide. To decrease oil absorption during the frying process and produce healthy fried goods with reduced oil content, it is essential to create revolutionary frying methods (Zhang *et al*., 2020) [33].

Foods high in oil content have been identified as a major dietary contributor to a number of chronic diseases such as cancer, hypertension, and cardio-vascular diseases (Sayon-Orea *et al*., 2015) [34]. As a result, low-fat – foods are becoming more popular on the market. Foods high in oil are typically fried goods where oil is absorbed as the item is being cooked (Ziaiifar *et al*., 2008) [35]. It has been determined that vacuum frying can replace conventional frying. It is also excellent for frying sugar-rich fruits, which is otherwise not possible to do in traditional frying because it results in the end product browning and making them unacceptable.

The widespread practice of deep frying in heated oil between 120 and 200 °C results in chemical and physical alteration. While the air released into the frying system will be oxidized to produce free radicals, the predominant chemical change is the hydrolysis of triacylglycerol's, which results in the creation of free fatty acids and diacylglycerols (Oke *et al*., 2018) [21].

Deep fat frying is the most commonly used frying process for various value-added products available on the market, such as Malpao, Pakora, Gulab jamun, Chenna jhili, French fries, and so on. Vacuum frying is the most commonly used frying process for a variety of value-added fruits and vegetables on the market, including pumpkin chips, banana chips, gold kiwi fruit, apricot, mushroom, apple slices, French fries, papaya chips, carrot chips, and so on.

One of the traditional and frequently used unit processes in the production of a variety of fried meals, such as potato chips, French fries, extruded snacks, fish sticks, doughnuts, and fried chicken products, is deep fat frying. Deep-fat frying is a quick procedure that involves simultaneous heat and mass transfer. The material also goes through physical and chemical changes while being fried at a high temperature of roughly 140–180oC. Fried meals are more palatable due to their soft and moist interior, crispy, porous exterior crust, and robust scent. Cooking is also dehydrated by frying, which similarly causes protein denaturation, starch gelatinization, aromatization, and colouring through Maillard reactions before absorbing oil (Lumanlan *et al*., 2020) [22].

Traditional frying can be substituted by vacuum frying. By generating desired quality products, this technique has the ability to replace conventional frying. Three separate components make up the vacuum frying system: the vacuum frying chamber, the vapour cooling condenser, and the high intensity vacuum pump. According to definitions, vacuum frying is a closed-loop process. It is connected to decreased pressure, preferably below 7 kPa, which lowers the boiling point of liquids, including water and oil. By reducing the pressure inside the chamber, vacuum frying systems generate airtight conditions, which lower liquid boiling points. Reduced frying medium (fat/oil) boiling points and higher food moisture content are made possible by low pressure, which helps to prevent the development of hazardous chemicals. Foods that were vacuum-fried retained minerals such phenolics, flavonoids, carotenoids, and vitamins while maintaining nice colour and flavour.

Shallow frying is a popular cooking method due to its ease of use and ability to enhance the flavour of foods with the addition of spices, herbs, and salt. The amount of oil used in shallow frying processes is comparatively lower, i.e. the oil-to-food ratio is considerably lower than in deep fat frying, which would be beneficial in terms of both health and cost (Chiou *et al*., 2012) [37].

Because vacuum frying has advantages over conventional frying, it has become more and more popular over time. Studies have shown that vacuum frying produces low-fat goods compared to conventional frying, while also reducing nutritional loss and the production of hazardous chemicals. Fruit and vegetable items that are vacuum-fried maintain their original qualities, such as colour, flavour, and improved texture. Vacuum frying also involves the essential step of starch gelatinization. Vacuum frying has given people the chance to make high-quality snacks from a variety of fruits and vegetables, whereas traditional deep-fat frying is only capable of processing a small number of fruits and vegetables.

Physico-chemical changes during oil and vaccum frying

Texture

Texture is an important in fried products. Researchers reported that after frying the texture of various products such as fruits and vegetables is majorly related to internal properties likewise, size of cell, its surface area, specific gravity and starch content, pectin content and total solids. The ideal papaya chip vacuum frying conditions were determined to be 100 °C, 28 minutes, and 3.1 mm slice thickness has firmness 39.89 N and overall acceptability 8.3 (Pandey and Chauhan, 2019) [4]. Ren *et al*. discovered that changing the pre-treatments, did not significantly alter the texture of vacuum-fried mushroom chips and overall acceptability is 4 (Ren *et al*., 2018) [5]. According to Maity *et al*., vacuum-fried jackfruit chips had more breaking power after being pre-treated with hydrocolloids in this oil uptake is 35.24% (Maity *et al*., 2015) [6]. Sothornvit

R. confirmed that the use of both hydrocolloids (guar and xanthan gum) helped in reducing the oil absorption of vacuum-fried banana chips and the values obtained are oil uptake 8–9%, hardness 27.32 N (Sothornvit R., 2011) [7].

Colour

Colour is a parameter which shows its effect when a food is present in dry state. When atmospherically fried potatoes, Troncoso *et al*. found that vacuum-fried potatoes had greater L* values and lower a*, b*, and c* values (Troncoso *et al*., 2009) [10]. Mariscal and Bouchon studied apple slices were fried in both vacuum and air conditions, and the colour value changes are from an initial value of 76.4 to a final value of 32, L* decreased (much darker), the colour values varied significantly (p 0.05) (Mariscal *et al*., 2008) [11]. According to Ravli *et al*., increasing the temperature of vacuum-fried sweet potato chips from 120 to 140 °C had no appreciable impact on their b* value. Under the single-stage conditions, the b*value (blue-yellow chromaticity) fell from 26.81 (120 C) to 25.48 when the frying temperature was raised (140 C). The b*value for the two-stage frying was 29.73, which was higher than it was for the single- stage method of frying the chips (Ravli *et al*., 2013) [12].

Moisture Content

The first minute of frying, which might be regarded as the first falling rate period (constant drying rate might not exist due to high starting solid content), saw a rapid loss of moisture, which was subsequently followed by a second falling rate period (due to change in the slope). The doughnuts' final MC ranged from 32 to 35% db (or 24 to 26% wb). According to Sothornvit R. moisture content for vacuum fried banana chips is 5–6% (Sothornvit R., 2011) [7]. According to Diamante *et al*., Moisture content of gold kiwi fruit is 2.11–3.80% (db) The moisture content of the product from the 80°C for 50 minutes treatment and the 90 °C for 35 minutes treatment was unaffected by the pretreatment process (soaked or unsoaked) (Diamante *et al*., 2011) [7]. Moisture 8.7% (db) was observed in apricot during vacuum frying when it is treated with Maltodextrin (PT) with temperature of 100 °C and time is 72.5 min by keeping the pressure at 2.3 kPa (Diamante *et al*., 2012).

Fat Content - Comparing vacuum frying to the conventional method, the oil stability exhibited a notable improvement. When oil is exposed to high temperatures, the addition of synthetic antioxidants plays a significant role in reducing the breakdown of the oil through improved oxidative stability. Tertiary-butyl-hydroquinone (TBHQ) fortification of oils prior to frying was found to be an effective treatment to reduce oil degradation. Vacuum frying had a substantially lower oil content than typical deep-fat frying, which had a higher temperature (180 C) and de-oiling in atmospheric conditions. The difference was 27.67 g/100 g db vs 46.83 g/100 g db (Fang *et al*., 2021). After 1 minute of vacuum frying donuts at 150 °C and 9 kPa vacuum, the oil uptake reached a maximum value of 20.3% db (Tan *et al*., 2006) [29]. Donuts with higher IMC saw a 46% dry basis resulted in a 13.1% dry basis oil uptake, which was less than the 17.9% dry basis oil uptake experienced by donuts with low IMC (Tan *et al*., 2006) [29]. The lower the oil content, the higher the frying temperature-average values of 0.39, 0.35, and 0.30 g/g dry basis for 120, 150, and 180 degrees Celsius, respectively.

Acrylamide formation - Another significant issue with conventional frying is the production of acrylamide. When food rich in carbohydrates is exposed to high temperatures during frying through the Maillard reaction pathway, acrylamide, which is naturally carcinogenic, is produced. When traditionally fried, potato crisps are more likely to generate acrylamide than in other fruits and vegetables. In model systems, a reduction in acrylamide production with temperature was observed (Mottram *et al*. 2002) [41]. According to Taubert *et al*. (2004) [42] and Biedermann *et al*. (2002) [43], this drop in acrylamide content could be the result of the compound degrading over time and after reaching a particular temperature.

Nutritional value

The most significant parameters affecting the quality of fried items during frying are the timing and temperature combination. Vacuum frying uses low pressure, considerably below atmospheric pressure, which slows down oil absorption, browning and vitamin and other phytochemical loss. To maintain nutritious qualities in fried food, processing parameter optimization is crucial. Ascorbic acid content of vacuum-fried pineapple chips was found to decrease with increasing frying temperature (106.3-117.7 °C) and time (6.3-7.7 min) at constant pressure (24 2 kPa) (Perez-Tinoco *et al*., 2008) [25].

Phytochemical properties

Content of Carotenoids

Trans b-carotene, which accounts for roughly 60% of the total carotenoid content, was the carotenoid that was present in the highest concentration in raw and fried carrot samples. Trans-a-carotene came in second place with a concentration of around 40%.

All-trans-carotenes may be lost during thermal processing, and cis isomers may be produced instead. In reality, during processing, there was a decrease in the amount of all-trans b-carotene and a simultaneous rise in 13-cis and 9-cis isomers (Chandler & Schwartz, 1988) [44].

Phenolics

The hydroxybenzoic and hydroxycinnamic structures are two distinctive constitutive carbon frameworks found in naturally occurring phenolic acids. Nearly all plants include the acids caffeine, coumaric, vanillic, ferulic, and protocatechuic; other acids are only present in food products or crops (e.g. gentisic, syringic). The hydrolytic degradation of phenolic acids (including enzymatic browning), the release of free acids from conjugate forms, and the formation of complex phenolic structures from related compounds like proteins, tannins, and anthocyanin are thought to be the main causes of the changes in phenolic acids during cooking.

Flavonoids

The most prevalent class of plant polyphenols are flavonoids, which are a major source of the pigments and flavours that give fruits and vegetables their colour and flavour. They are phenolic and pyrane ring-based benzo-pyrone derivatives that are grouped according to substitutions. The flavones, flavonols, flavanones, catechins, anthocyanidins, and isoflavones are the six main subclasses of flavonoids. Due to their complexity and the enormous number of distinct individual molecules that have been identified, flavonoids are primarily found in nature as glycosides and other conjugates.

Conclusion

The two processes of atmospheric frying are frying and cooling, with the majority of the oil being soaked during the cooling phase. The quantity of oil absorbed by the chips and the length of time it requires for the vessel to attain the vacuum pressure are both impacted by the pressurization process and vacuum pressure in vacuum frying, respectively. During the pressurization phase, the majority of the oil that is sticking to the surface of the product will be absorbed. Therefore, vacuum frying procedures need a way to remove the layer oil just before vacuum is broken. When frying vulnerable fruits and vegetables, pre-treatment methods like osmotic dehydration are frequently utilized to enhance the sample texture. Before vacuum frying, air-frying potato chips enhance the texture and starch gelatinization. The quality of vacuum-fried foods can be further improved by having a better grasp of the structural changes that take place in items during frying at both pressures. In comparison to atmospheric frying, the majority of the advancements in vacuum frying have focused on the kinetics of moisture loss and oil absorption. By adding the steps of evacuation, pressurization, and cooling in the fundamental modeling, the simulation Programme of the vacuum frying process can be improved; nevertheless, more work is required.

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