POTENTIAL APPLICATION OF OLEOGEL AND CITRUS PEEL FIBER IN OIL UPTAKE REDUCTION OF DEEP-FRIED SURIMI PRODUCTS: AN OVERVIEW

Joinul Islam and Reza Tahergorabi*

Food and Nutritional Sciences Program, NC A&T State University, Greensboro, NC 27411, USA
*Correspondence: rtahergo@ncat.edu; Tel.: +1-336-285-4865

Abstract:

Deep-fried foods are getting popular due to their unique flavor, taste, and texture. Surimi is deboned minced fish flesh which is prepared by washing out fat, blood, and impurities. Surimi is generally used as a functional ingredient in various surimi-based products. Although deep-fried surimi-based products are crunchier and more appealing to people, they absorb a large amount of oil during deep-frying. Thus, high consumption of deep-fried surimi may lead to non-communicable diseases such as obesity and heart diseases, which are the primary causes of death in the world. Therefore, oil uptake reduction in deep-fried surimi-based products is of great importance. However, citrus peel fiber (CPF) which is a by-product of juice production, has been gaining popularity among researchers for reducing oil uptake in deep-fried products as CPF has many health benefits as well as technical properties such as oil-binding ability. On the other hand, there is a growing interest in using oleogel for oil uptake reduction in deep-fried products as it has viscoelastic properties similar to solid fats and can improve the gelling property and reduce oil uptake in deep-fried products. Therefore, this paper reviews the potential of using CPF and oleogel for oil uptake reduction in deep-fried surimi-based products.

Key words: Citrus peel fiber, Deep frying, Oil uptake reduction, Oleogel, Surimi.

1. Introduction:

Deep-fat fried food constitutes a substantial portion of the American diet (Gadiraju et al., 2015). Commercially, deep-fried foods are estimated to have a value of $83 billion in the United States and at least twice that amount in the rest of the world. Deep-fat frying is a conventional cooking technique in which foods are immersed in edible oil and cooked to temperatures above 100°C. However, it has been demonstrated that foods fried in this manner contain a substantial amount of oil. Fried fish is one of the most popular processed foods around the world. The fat content of fish increased from 1.4% in raw fish to 18% in fried fish (García et al., 2008). Therefore, consumption of fried fish correlates favorably with various cardiometabolic risk factors, including low blood HDL cholesterol (good cholesterol), high LDL cholesterol (bad cholesterol), hypertension, and obesity (Gadiraju et al., 2015). Thus, food scientists have explored methods to limit the oil uptake during deep-frying.

Surimi is minced and deboned fish meat made by washing fish mince with water resulting in a product containing mainly myofibrillar proteins. It is the functional ingredient for various surimi-based seafood products, such as imitation crab legs. In the 1980s, surimi-based seafood products became popular in North America, and the popularity of surimi remains high and continues growing. The reason behind the popularity of surimi is its low-fat content, nutritional quality, and

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highly functional protein content. Surimi is mostly stabilized myofibrillar proteins and gelation or gel-forming ability is one of the significant functional properties of proteins. A gel is the intermediate state of a solid and liquid phase and has no steady-state flow. In surimi gels, myofibrillar proteins are the major contributor to the gelation of surimi gels (Tahergorabi & Jaczynski, 2012). However, the processing procedure negatively affects the gel-forming capacity of the surimi, which in turn affects the structural properties and texture of surimi products and affects consumer acceptability (Dong et al., 2019). This abrupt effect on the gel-forming capacity of the surimi weakens the gel strength, which is responsible for moisture loss and oil uptake during deep-frying. Therefore, reducing oil uptake in deep-fried surimi products is of great importance.

Several research studies have been conducted and are continuing to identify novel strategies to reduce oil absorption during frying (Adrah et al., 2021). One of the strategies that are growing popular among researchers for oil absorption reduction is oleogel technology. Generally, oil is converted into oleogel by using one or more organic gelators. Oleogels are classified into different categories depending on their compositions and building blocks. Some of the most promising food-grade oleogel systems are monoacylglycerides, wax esters, long-chain fatty acids, and phytosterols and oryzanol (Edmund Daniel Co & Marangoni, 2012). These oleogels are promising as they are edible and can form stable gels. However, researchers have been using different strategies for oleogel application in order to reduce oil uptake in deep-fried products (Adrah et al., 2022). Some studies converted liquid oil into oleogel and used as a frying medium, while others directly incorporated oleogel in the product to reduce oi absorption. However, apart from the oleogel technology, another strategy that is gaining popularity among researchers for oil uptake reduction is the use of dietary fiber as a functional ingredient in deep-fried products as it has hydrocolloid properties. Due to the oil-binding and water-binding ability, dietary fiber from citrus fruits, also known as citrus peel fiber (CPF), has been found to be effective for improving the physical properties of surimi gels (Sharaf Eddin et al., 2020). Therefore, the purpose of this review is to provide an overview of using oleogel and CPF for oil uptake reduction in deep-fried surimi products.

2. Deep-fat frying

Deep-fat frying is a cooking process where foods are submerged in edible oil at high temperatures (150-200°C) to induce fast cooking (Moreno et al., 2010). During deep-fat frying, both heat and mass transfer occurs. Heat transfer occurs from the frying medium to the submerged food using conduction and convection. The high temperature frying oil penetrates the foods and transfers heat by convection. This frying oil remains inside the food products and is responsible for the change of quality during frying. The absorbed oil is mainly retained in the crust region and saturates during cooling periods and increases the saturated and trans-fat content of the deep-fried food. Due to the high temperatures used in deep-frying, lipids undergo a variety of physical and chemical changes and convert the monounsaturated fatty acids (MUFA) and polyunsaturated fatty acids (PUFA) into saturated fatty acids (SFA). Moreover, during deep frying, fat/oil is converted into trans fatty acid (TFA) due to partial hydrogenation (Chen et al., 2014). The presence of TFA in food items adversely affects human health. Different metabolic studies showed that TFA increases the risk of cardiovascular diseases (CVDs), insulin resistance, and type 2 diabetes (Bhardwaj et al., 2011).

3. Using hydrocolloids in batter formulations for oil uptake reduction

In deep-fried products, the batter is applied on the surface of the product as a coating before frying. Batter generally consists of flour, liquid, and additional ingredients such as starch, salt, and leavening agents. Food engineers and scientists have conducted significant studies on the use of batter and breading coatings to limit the oil absorbed in fried foods. For instance, (Adrah et al., 2021) used sweet potato starch (SPS) in the batter formulation to reduce the oil-uptake in deep-fried chicken products. Moreover, using hydrocolloids in batter formulation can reduce oil absorption (Al-Asmar et al., 2018). Hydrocolloids are basically important in the production of fried foods for two reasons. First, hydrocolloids build a thin film surface coating that might reduce oil absorption before and after frying (Bajaj & Singhal, 2007). Second, hydrocolloids are combined with other ingredients to enhance other quality features, such as coating pick-up and adherence, viscosity, and crispiness. However, dietary fibers which are protective against chronic diseases, possesses hydrocolloid properties and have technological implication in food product development. Previous studies used hydrocolloid properties of dietary fiber for reducing oil uptake in fish and meat products. For instance, Zeng et al., (2016) used bamboo shot dietary fiber (BSDF) in battered and breaded fish balls and reported that 6% BSDF in batter reduced fat content from 25.5% to 17.7% in crust and 2.4% to 1.3% in core without affecting the textural and sensory properties of the product. Generally, dietary fibers are extracted from soy, pear, citrus fruits, gum, etc. CPF which is the by-product of juice production, possesses functional, nutritional, and technical properties and applied as ingredients to enhance the quality of fish and meat products (Song et al., 2016).

Citrus fruits are mostly used for juice production, producing a huge amount of by-products that mostly contain peels of citrus fruits and are generally discarded or used as fertilizers. However, CPF produced from these by-products of juice production which possesses functional and technical properties. Different studies reported the hydrocolloid properties of CPF in meat and fish products. Sharaf Eddin et al., (2020) reported that the incorporation of smaller particle size CPF in surimi gels can potentially enhance the physical properties of surimi gels without affecting the structural properties. On the other hand, de Moraes Crizel et al., (2013) used fiber from orange by-products as a fat replacer in ice-cream and reduced 70% fat without causing significant changes in the product's quality characteristics. However, although CPF showed hydrocolloid properties in different studies, it has been rarely used in the batter formulation for deep-fried products such as surimi. Due to fat-binding and water-binding abilities and hydrocolloid properties, CPF can be used in the batter formulation to reduce the oil uptake in deep-fried surimi fish products.

4. Using oleogel as a frying medium for oil uptake reduction

During deep-fat frying, the absorption of oil is influenced by the quality of the frying medium. Modification of frying medium is a potential strategy to enhance the quality of the frying medium. Oleogel, which has viscoelastic properties similar to solid fat, has been used in different studies as a modified frying medium to reduce oil uptake in deep-fried products (Adrah et al., 2022). Nonetheless, as a relatively new fat replacement, oleogels can provide the nutritional benefits of oil while enhancing the sensory and technical properties of food products (Zetzl et al., 2012). Generally, oleogel is prepared by combining edible oil with one or more organic gelators. Oleogel consists of 3D network structures that enclose liquid oil (Wang et al., 2016). Numerous structurants, including plant waxes, monoglycerides, and phytosterols, have been authorized for use in foods. However, several gelation techniques have been investigated which can be categorized as direct dispersion, biphasic template, and solvent exchange techniques (Martins et al., 2018). (Adrah et al., 2022) prepared oleogel by using direct dispersion methods with canola oil and carnauba wax and used it as a frying medium in deep-fried chicken breast samples and significantly decreased the oil uptake and lipid oxidation. Another study created oleogels from soy oil and carnauba wax for evaluation as a deep-frying medium for instant fried noodles (Lim et al., 2017). At temperatures below 80°C, the study found that oleogels have a higher viscosity than ordinary soybean oil and palm oil. Due to the higher viscosity, the oleogel fried noodles were expected to have higher oil content as oil with high viscosity adheres more readily to the food surface. However, the study found that oleogel frying reduced oil absorption in fried noodles by 16% compared to palm oil and soybean oil. These contradictory results happened because of the surface characteristics of the oleogel-fried sample. It is well known that oil absorption in deep-fried products is related to the surface characteristics of fried foods (Ziaiifar et al., 2008). Oleogel fried noodles exhibited a smooth and continuous surface, while palm and soybean oil fried noodles had rough and coarse surfaces, which is the reason behind the reduced oil uptake. Additionally, the fatty acid composition of oleogel fried noodles revealed significant levels of unsaturated fats (about 81g/100g) and low levels of saturated fats (19g/100g).

5. Mechanisms of oil uptake

In deep frying, the oil uptake of a food is defined as the ratio of the product's oil uptake to its dry weight. The mechanism of oil uptake is complex and depends on the product's initial structure, the heating medium, and the product and oil characteristics. During deep-frying, heat and mass transfer occur, altering the product's structure and core-to-crust temperature during deep-frying. These processes lead to the absorption of oil by fried foods (Liberty et al., 2019). There are numerous theories that explain the mechanisms of oil absorption during frying. Water replacement, the cooling phase effect, and the surfactant theory are prevalent among these mechanisms.

The water replacement mechanism is based on the loss of water during frying and its subsequent replacement with oil. During frying, the product's surface moisture evaporates due to high heat. As a result, the surface dries out and leads to the case hardening. However, due to the high heat, the moisture present in the core of the product is transformed into steam and tends to escape but cannot go out due to case hardening. On the other hand, heat and mass transfer decreased due to the low thermal conductivity of the surface and created a pressure gradient on the continuously dehydrated surface. This leads the steam to escape through cracks and open capillaries in the food's cellular structure and membrane by creating pores. As the process continues, fat attaches to the surfaces of the product and eventually flows freely inside the products through these pores due to the lack of resistance and size of the pores (Ananey-Obiri et al., 2018). On the other hand, the cooling-phase effect mechanism explains the absorption of oil after removal from the frying medium. When the fried foods are removed from the oil, the vapor pressure of the capillaries on the surface of the crust falls, resulting in rapid oil absorption into the pores. This process is dependent on the microstructure and quality of the product surface. However, the surface quality of deep-fried products can be enriched by incorporating hydrocolloids in the batter formulation. Different studies reported the hydrocolloid properties of citrus peel fiber (CPF) in meat and fish products (Sharaf Eddin et al., 2020). Therefore, CPF addition in the batter formulation could be a potential strategy to improve the surface quality and reduce moisture loss and oil absorption.

On the other hand, according to the surfactant mechanism of oil absorption, a sequence of chemical reactions takes place during deep frying, which degrades the oil's quality and makes the polar molecules more abundant. These polar molecules (surfactants) act as wetting agents to reduce the surface tension between liquids and increase the interaction among the food and the frying oil, resulting in excessive oil absorption. However, low levels of surfactants in a frying medium inhibit the heat transfer between two immiscible media (i.e., the frying medium and the water from the food) due to the absence of surfactants that facilitate this process. Surfactants, which are formed because of the hydrolytic degradation of oils, influence the viscosity of the oil. It is well known that oil viscosity impacts oil absorption during and after frying. Therefore, oleogel, which has viscoelastic properties similar to solid fat, has the potential to be used as a frying medium to reduce oil uptake in deep-fried products. For instance, Adrah et al., (2022) modified the frying medium by structuring canola oil into oleogels by using carnauba wax and successfully reduced oil-uptake in deep-fried chicken breast samples compared to the canola oil-fried samples.

6. Application of CPF and oleogel for oil uptake reduction in deep-fried surimi

Due to high functional protein, nutritional quality, and low-fat content, surimi-based seafood products are getting popular in the United States. However, deep-fried surimi-based products absorb large amounts of oil during frying. Therefore, high consumption of deep-fried surimi leads to non-communicable diseases. Nonetheless, oil and batter quality play important roles in oil absorption. Using hydrocolloids in batter formulation is an effective strategy to improve the batter quality. Additionally, previous studies reported the hydrocolloid properties of CPF, which is the by-product of juice production. Although CPF showed hydrocolloid properties in different studies, it has not been used in the batter formulation yet for oil uptake reduction in deep-fried surimi-based products. However, our preliminary results showed that the addition of different concentrations of CPF (0.5%, 1.5%, 2.5%) in batter formulation significantly reduced the oil uptake in deep-fried surimi fish balls. On the other hand, another popular strategy for oil uptake reduction is to modify frying the medium into oleogel, which was applied in several previous studies (Adrah et al., 2022). Therefore, using oleogel as a frying medium in combination with the CPF in the batter formulation could be a potential strategy to reduce the oil uptake in deep-fried food products. However, sensory evaluation is needed to understand the impact of oleogel frying in the sensory qualities of fried food products.

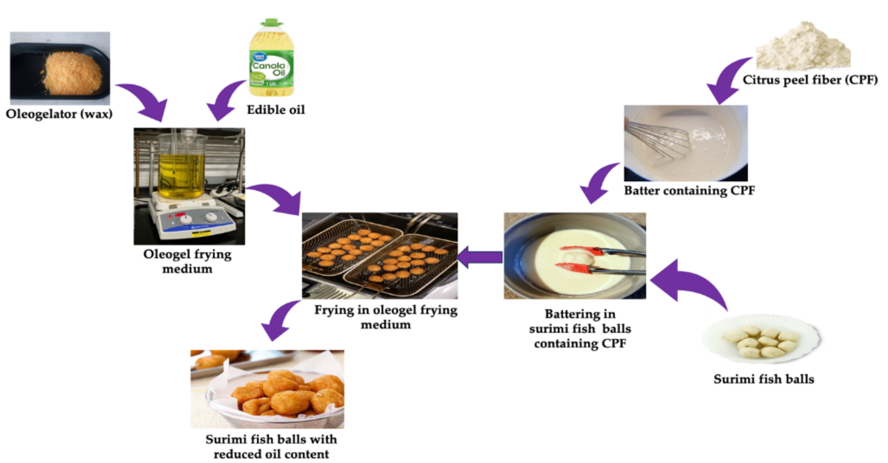

Figure 1: Oil uptake reduction in deep-fried surimi using oleogel frying medium and citrus peel fiber.

7. Conclusion

In addition to health benefits, CPF has shown hydrocolloid properties in meat and fish products such as surimi. Due to the hydrocolloid properties, CPF can improve the viscosity of batter by binding with other ingredients and can reduce the oil uptake in deep-fried surimi products. On the other hand, using oleogel as a frying medium helps to reduce oil uptake in deep-fried products. Therefore, this review supports the concept of using oleogel as a novel frying medium in combination with CPF in the batter formulation to reduce the oil uptake of deep-fried surimi.

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