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Application of fat substitutes in meat products

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Abstract. In the human body, fat plays a key role. In addition to providing the body with the necessary energy, it also has a decisive influence on the structure and overall quality of food. However, frequent intake of high-fat food will have adverse effects on human health. With the increase in people's health awareness, the production of low-fat or fat-free food is an important way to improve people's dietary habits and improve their health levels. Therefore, it is hoped that by adding fat substitutes, we can reduce the harmful effects of excessive fat intake on the human body while maintaining the original flavor of food as much as possible. In this paper, the research reviews the basic concepts and classification of fat substitutes and their application in meat products, the current status of their application in sausage, pork, beef, and other products is elaborated, and the problems of fat substitutes such as intolerance to high-temperature frying are analyzed, and countermeasures for the research and development of fat substitutes with high thermal stability, high water absorption, low calorie content, and nutritional safety are proposed, providing provide a theoretical basis for the further development and utilization of fat substitutes in meat products.

Keywords: Fat substitutes, meat products, application, progress

1. Introduction

Fats, together with sugars and proteins, are known as the three major nutrients and are one of the important nutrients in food, inseparable from our lives. Meat products contain human essential fatty acids such as linoleic acid and linolenic acid, which are also high-quality solvents of fat-soluble vitamins, and likewise give food a smooth and delicate texture, good flavor, and fluffy texture [1]. However, with the economic and social development and the improvement of people's living standards, people began to consume too much fat, which led to the problem of being overweight and obesity in urban and rural residents continue to highlight. Some studies have shown that excessive fat intake, especially animal fat contains a large amount of saturated fatty acids and cholesterol, which can greatly increase the risk of developing obesity, hypertension, cardiovascular disease, and coronary heart disease [2]. Nowadays, research results have shown that adding fat substitutes to meat products can effectively reduce the calorie intake of food. Adding low-calorie fat substitutes to reduce fat in food has been gradually adopted by the food industry and has been a hot research direction for food researchers in recent years.

However, if the fat in the original food is simply removed, it will lead to a decrease in the color, aroma, and taste of the food to varying degrees, as well as a decrease in the storage stability, which will lead to a decrease in the acceptance of the food by consumers. In this case, to simulate the sensory and functional properties of fat, people will carry out appropriate processing and treatment of other substances, to achieve the purpose of "replacing" fat, so that it has the same or similar sensory effects as the same kind of full-fat food. Therefore, in this case, reducing the fat content of meat products while retaining their original flavor has become the focus of current research. Based on the current development of low-fat meat products at home and abroad in recent years, this paper summarizes the research progress and development trend of the use of fat substitutes in different products, makes predictions for future development, and puts forward countermeasures to solve the problems of heat stability and safety.

2. Fat substitutes

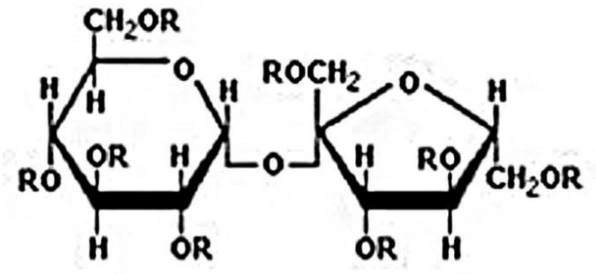

Figure 1. Chemical equation of Fat replacers [2]

Fat replacers are a class of substances that partially or completely replace the use of fats and oils in the manufacture of food products and can mimic the physicochemical and sensory characteristics of fats found in certain foods, providing a taste and texture similar to that of fats, as well as a large number of dietary polysaccharides and proteins [3]. Since their ester bonds resist the catalytic decomposition by lipase and do not participate in energy metabolism, they can effectively reduce food calorie intake. Pintado et al [4] used olive oil and chia seed oil in different ratios to prepare oleogels and emulsion gels, respectively, and replaced fats in dry-fermented sausages with oleogels and emulsion gels, respectively, to prepare four types of dry fermented sausages. The color characteristics and good oxidative and microbiological status of the products were maintained under storage conditions under frozen. Gómez-Estaca et al [5] prepared ethylcellulose oleogel and beeswax oleogel using lipid mixtures of olive oil, flaxseed oil, and fish oil, respectively, which were two types of oleogels with solid lipid functionality, and used them to fully or partially replace the fat in the porcine liver patties, so that the resulting porcine liver patties had an optimal Fatty acid distribution.

The main fat-based fat substitutes available are sucrose polyester, Salatrim, jojoba oil, trialkoxypropyl tricarboxylate, carboxylic acid esters, propoxyglycerol esters, dibasic acid esters, and polysiloxanes.

Among them, Olestra is one of the most representative fat substitutes, also known as sucrose polyester, which is the esterification product of sucrose and long-chain fatty acids (⩾C16) in edible fats and oils, and mainly consists of mixtures of hexyl, heptyl, and octyl esters [6], and its chemical structural formula and structural schematic diagram are shown in Fig. 1. Olestra has a large molecular structure, with 6-8 fatty acid chains attached to sucrose molecules Olestra has a large molecular structure with six to eight fatty acid chains attached to the sucrose molecule, which is different from the triglyceride structure of ordinary fats, and therefore pancreatic lipase is unable to hydrolyze it in the intestines, which means that esters containing six fatty acids are almost impossible to be absorbed by the human body and cannot provide energy [7]. It is for this reason that sucrose polyesters, although having similar chemical properties to fats, differ from ordinary fats in their physiological functions and are therefore suitable for fat replacement in a variety of high-fat foods. In addition, sucrose polyesters, like conventional fats, are also lipophilic, which can help reduce the absorption of cholesterol in the body, partially dissolve and assist in the elimination of cholesterol from the body, and reduce the efficiency of intestinal absorption of cholesterol [8].

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Nonetheless, studies have shown that high intake of sucrose polyesters can lead to significant weight loss and may cause constipation, diarrhea, loss of fat-soluble vitamins, intestinal cramps, and other physiological problems. Although the U.S. Food and Drug Administration has agreed to the use of sucralose polyester as a generally recognized safe ingredient in quick-serve products such as French fries, it requires that fat-soluble vitamins must be added to sucralose polyester and that it must be labeled as a problem that may lead to gastrointestinal discomfort if consumed in excess. To date, research organizations in Canada and the United Kingdom have not included sucrose polyesters in their lists of food additives [9]. Therefore, more in-depth research is needed on the use of sucrose polyester as a fat replacement for food safety toxicity purposes.

3. Fat mimics

Fat simulants are broadly based on the use of proteins or carbohydrates to achieve the replication of some of the properties of fat in food products. Protein-based fat mimics are mainly based on the application of physical and chemical means to treat raw proteins to mimic fats by altering their properties such as particle size, emulsifying ability, and moisturizing ability. However, proteins tend to denature under high-temperature conditions, which limits their application in high-temperature fried foods; secondly, proteins may combine with certain flavor components, further reducing or altering the taste of the food. Therefore, the use of protein-based fat mimics requires a higher degree of system specificity, not only concerning the source of the protein used but also concerning other components in the food formulation. Carbohydrate-based fat mimics form a gel when used and provide a fat-like flow and lubricity to food products by absorbing large amounts of water, thereby optimizing the aqueous phase structural properties. However, there are challenges with the use of carbohydrate-based fat mimetics in high-temperature manufactured products, where their high water retention capacity may allow for increased water activity within the product, thereby reducing the shelf life of the product [10].

3.1. Protein-based

Protein-based fat substitutes are fat substitutes that mimic the physical and sensory properties of fats by using natural polymeric proteins as a substrate, which are produced through steps such as thermal treatment and enzymatic digestion [11]. The treated proteins have a more compact and continuous matrix that produces a fat-like microstructure.

With the help of natural macromolecular proteins such as soy, whey, collagen, and wheat proteins, which are the main sources of fat substitutes, their original water-binding properties and emulsifying properties can be altered by treatments such as cooking, cutting into pellets, or rapid reduction. These alterations can create a texture similar to that of emulsified fatty foods, and therefore help to mimic the fat portion of meat products [12].

Researchers such as Guangjuan Liu [13] found that if the soy protein content of sausages and patties was increased to 18%, the taste and specificity of traditional meat foods would not be negatively affected, but instead, the foods might taste better. Moreover, this is supported by the findings of researchers such as Moon Kang [14], who also elaborated on the high utility of animal fat substitutes prepared using elements extracted from soybean, yam, and corn oils in simultaneously reducing the fat content of sausages while maintaining the taste and safety of the food products. And Kwon et al [15] found that the addition of sodium dodecyl sulfate to whey protein isolate improved its gel-forming ability, reduced protein coagulation, and significantly improved the taste, hardness, and other characteristics of low-fat sausages during cooking.

Currently, protein-based fat substitutes have a wide range of applications in low-fat minced meat products, but they also have certain limitations. The key limitations are: once treated at high temperatures, proteins will deteriorate, making them lose their fat-like touch and properties; on the other hand, in low-fat meat products, proteins are prone to chemical reactions with flavor components, which in turn lead to the reduction or loss of flavor components [16].

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3.2. Carbohydrate matrix

Fat substitutes in carbohydrate matrices based mainly on modified starches such as potato, tapioca, corn, rice, and oats are supplemented with fibers, gums, and polysaccharides. Most of these types of fat substitutes form a gelatinous structure after absorbing water as a way to mimic the appearance, organizational properties, and texture of fat [10].

Eunze Lee et al [17] showed that the oil holding capacity and rheological properties of oleogel in meat patties were better mimicked by the addition of 15% or more of gelling agent and that 3:7 compounding of MG with CLW maximized the mimicry of the physical characteristics of butter and had the highest phyto-patty acceptability. SCHMIELE et al [18] showed that the addition of swallow fiber to low-fat beef meatballs significantly improved the productivity of the meatballs, increased their oil-absorbing capacity, and increased their water content, while at the same time, there was no significant difference in the smoothness, color, and juiciness of their appearance compared with that of high-fat foods. Moreover, Carvalho et al [19] partially replaced fat with hydrated wheat fiber in beef burgers, and found that the larger the percentage of replacement, the lower the fat content, and thus the smaller the subsequent calorie production, and until the fiber mass fraction of 4.69%, the sensory acceptability of beef burgers were not significantly different from the control group. Yimin Yu et al [20] explored the factors affecting the quality characteristics of pork emulsified sausages when KGM-CUD co-gel was used to replace emulsified sausage fat.

Therefore, the carbohydrate matrix class is recognized as the safest fat substitute for consumption, and all carbohydrate-based fat substitutes can be completely digested except polydextrins, however, they are not suitable for high-temperature fried foods due to the presence of viscous sensation and starchy mouthfeel, as well as the inability to dissolve oily condiments [21]. In general, more research has been done in recent years on starch and colloids.

4. Composite fat substitutes

Although certain qualities of meat products can be enhanced by fat substitutes with a single matrix, this does not fully meet the full range of quality requirements for meat products. For this reason, to cope with the quality degradation that may be caused by reducing the fat content, attempts have been made to mix fat substitutes with multiple matrices, in other words, composite fat substitute substitutes [12]. The main types of complex fat substitutes are complex fat substitutes with one matrix (e.g., protein- or carbohydrate-based) and complex fat substitutes with two matrices [22].

According to Marchetti et al. researchers [23], when sausages containing 0.593% carrageenan and 0.320% milk proteins were steamed, the differences in loss and texture characteristics were not very significant when compared to high-fat sausages with 20% fat content. In addition, Tan Wenying et al [24] successfully prepared a complex fat substitute consisting of sucrose esters and sodium alginate. The yield of the composite fat could reach 6.04% under the ratio of sucrose ester and sodium alginate of 2:1, pH value up to 4.5, and mixing temperature of 45°C. This fat substitute appears to be greasy and exhibits superior fat substitution characteristics in terms of water retention, oil retention, emulsification, and emulsion stability. From the results of various academic studies, it can be concluded that fat substitutes with composite matrices have superior simulation properties compared to single matrices. This advantage comes from the fact that the two matrices of the composite fat substitutes are skillfully paired with the use of proteins and carbohydrates to complement and optimize each function [22]. Therefore, the various types of fat substitutes and how their ratios affect food processing and sensory experience have turned out to be a hot topic in modern scientific research.

5. Conclusion

As continued technological advances drive the rapid development of fat substitutes, they also show an extremely wide range of potential in practical applications. Similarly, with the increasing health consciousness of the general public, the manufacture of low-fat or fat-free foods has become an important way to change people's dietary habits to enhance public health. This paper describes the application of fat substitutes in different meat products. By reviewing the findings of different scholars, it is found that most of the single fat substitutes have limited functional properties and are unable to fully replicate all the functional and sensory properties of fat. In addition, the interaction between some fat substitutes and food components is still flawed, e.g., they do not achieve the desired results in fried and other cooked foods, and can even cause gastrointestinal problems such as diarrhea. This paper still suffers from data collection problems and only covers beef and pork products.

In the future, compound fat substitutes also need to be explored and investigated at a deeper level in the search for new fat substitutes. In addition, since numerous food processing steps usually involve high-temperature treatments, there is a need for fat substitutes that are thermally stable, highly absorbent, low in calories, and nutritionally safe.

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