The Pharma Innovation Journal 2023; 12(5): 2380-2383

www.ThePharmaJournal.com

The Pharma Innovation

ISSN (E): 2277-7695
ISSN (P): 2349-8242
NAAS Rating: 5.23
TPI 2023; 12(5): 2380-2383
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www.thepharmajournal.com
Received: 20-03-2023
Accepted: 24-04-2023

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A comprehensive review: Carbohydrate-based fat replacers and their role in food formulation

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Abstract
Reducing the fat content in food products is an effective way to decrease calorie intake and improve the nutritional profile of foods. However, fat plays an important role in food formulation, contributing to flavour, texture, and mouthfeel. Carbohydrate-based fat replacers are used as substitutes for fat in food products, offering a lower-calorie alternative without compromising on sensory properties. This review provides a comprehensive overview of carbohydrate-based fat replacers, their different types, applications in food products and potential benefits and limitations. Different types of carbohydrate-based fat replacers, such as modified starches, gums and fibers, are discussed in detail, highlighting their unique functionalities and potential uses in food formulation. The article also covers the consumer perception and acceptance of carbohydrate-based fat replacers, as well as the regulatory considerations and safety concerns associated with their use. Overall, this review provides a valuable resource for researchers, industry professionals, and consumers interested in the role of carbohydrate-based fat replacers in food formulation.

Keywords: Carbohydrate, fat replacer, mucilage, gums, food formulations, inulin

1. Introduction
The quantity and composition of ingested fats are crucial in the pathogenesis of several chronic illnesses. Consequently, numerous individuals comply with dietary recommendations concerning fat intake, imposing a demand on the industry to manufacture food items with a reduced amount of fats, sugars, cholesterol, salt and specific additives. However, preserving the sensory qualities and attributes of high-fat products presents a considerable challenge. Therefore, formulating low-fat products requires the use of ingredients with diverse functionalities to compensate for the loss of quality attributes resulting from fat removal (Fernandes & Salas-Mellado, 2017) [1]. Several research studies reveal that fat replacement or fat substitution by carbohydrate-based fat replacers starch, gums, gels, mucilage, and fibers has shown enhancement and modification in the texture and decreased the price of the products (Kianiani *et al*., 2019) [2]. Fat is replaced with mucilage, will which gets extra benefits of increased fiber content in the food, fat is placed by reducing fat content thereby reducing the several habitual diseases, and a functional food product development is happening (Cui *et al*., 2011) [3].
The use of carbohydrate-based fat replacers has several potential benefits to customers such as anti-oxidant, anti-inflammatory, anti-microbial, and anti-cancer, increasing the fiber content of the food products, and contributing to weight management (Fig. 1). However, there are some limitations to their use, such as their impact on the texture and mouthfeel of food products, the regulatory status of these ingredients, and their safety considerations (Tosif *et al*., 2021) [4]. This review article aims to provide a comprehensive overview of carbohydrate-based fat replacers, including their physicochemical properties, applications in food products, potential benefits and limitations, consumer perception, and regulatory considerations. This article will be a valuable resource for researchers, industry professionals and consumers interested in the role of carbohydrate-based fat replacers in food formulation.

2. Carbohydrates-based fat replacer
Carbohydrate-based fat replacers are food ingredients that are commonly used in low-fat or reduced-fat food products to mimic the functional properties of fat. They are made from complex carbohydrates such as starches, fibers and sugars that have been modified to mimic the texture, mouthfeel, and other sensory characteristics of fat. By replacing some or all of the fat content in a food product with carbohydrate-based fat replacers, food manufacturers can

reduce the overall calorie and fat content of their products, making them a healthier option for consumers. Examples of carbohydrate-based fat replacers include inulin, maltodextrin, cellulose, and polydextrose, among others (Table. 1). Each of these ingredients has unique functional and nutritional properties that can be tailored to specific food applications. Overall, carbohydrate-based fat replacers provide an alternative to fat that can help improve the nutritional profile of food products without sacrificing taste or texture (Colla *et al*., 2018) [10].

2.1 Chia seed mucilage

Chia (*Salvia hispanica* L.) is an herbaceous plant that originates from the southern regions of Mexico and northern Guatemala. Upon contact with water, the seeds of chia produce a transparent mucilaginous gel primarily composed of soluble fiber. The properties of this gel include high water-holding capacity and good viscosities, even at low concentrations. These properties, which contribute to its nutritional and technological significance, suggest that chia seed mucilage is a promising candidate for various food applications, such as a thickener, gel former, fat replacer, and chelator (Ribes *et al*. 2021) [11]. The researchers investigated the use of chia seed mucilage as a fat replacer in bread and cakes. The study aimed to evaluate the effect of chia seed mucilage on the texture, sensory attributes and physicochemical properties of baked products. The results indicated that the addition of chia seed mucilage at 2.5% and 5% levels resulted in a significant reduction in fat content while maintaining the desirable textural and sensory attributes of the baked products. Additionally, the incorporation of chia seed mucilage was observed to increase the water-holding capacity and decrease the syneresis of the bread and cakes. The study's findings suggest that chia seed mucilage is a promising ingredient for reducing the fat content of baked products without compromising their quality (Fernandes & Salas-Mellado, 2017) [1]. The recent research data investigated the potential of chia seed mucilage as a fat replacer in yogurt, focusing on its effect on nutritional, technological, and sensory properties. The results revealed that the addition of chia seed mucilage significantly reduced the fat content of yogurt, without negatively impacting its nutritional value. Furthermore, the addition of chia seed mucilage did not significantly affect the texture, viscosity, or stability of yogurt. In terms of sensory evaluation, the yogurt with added chia seed mucilage was well accepted by consumers, with no significant differences in overall liking compared to the full-fat yogurt. The study suggests that chia seed mucilage can be a viable and effective alternative to fat in yogurt, without compromising its quality or consumer acceptance (Ribes *et al*. 2021) [11].

2.2 Aloe vera mucilage

Aloe vera (*Aloe barbadensis miller*) is a succulent, flowering plant that comes under the family of Asphodelaceae. It is used as a traditional medicine for skin infections and also for other purgative effects. Nowadays worldwide, these ingredients are used as highly valuable ingredients for functional foods like health drinks and same kind other beverages. Its applications also spread over cosmetics and drugs (Añibarro-Ortega., *et al*., 2019) [12]. Studies reveal that aloe vera has good anti-oxidant properties and it acts against reactive oxygen species which cause damage to DNA, proteins, and lipids. And researchers also reveal that aloe vera juice which is added to several foods like candies, dairy products, drinks, and jams increases the functionality of the developed food products. The polyphenols and flavonoids present in aloe vera, give a preventive approach to various cancers, heart diseases and degradation issues of neurons (Khursheed *et al*., 2019) [13]. The study investigated the potential of aloe vera gel as a fat replacer in low-fat meat emulsions. The research data revealed that the use of aloe vera gel significantly reduced the fat content in the meat emulsion without affecting the overall quality attributes of the final product. The addition of aloe vera gel improved the water-holding capacity and texture of the emulsion, resulting in a product that was more tender and juicier. The study also found that the aloe vera gel did not affect the color, pH, or sensory properties of the emulsion. The findings suggest that aloe vera gel has the potential to be used as a natural and effective fat replacer in meat products (Kumar *et al*., 2015) [9].

2.3 Basil seed mucilage

The research data investigated the potential of hoary basil seed mucilage (HBSM) as a fat replacer in chicken meat products. They found that HBSM exhibited good water-holding capacity and fat-binding capacity, leading to a reduction in the fat content of the chicken meat model by up to 50%. Furthermore, the use of HBSM did not significantly affect the pH, cooking yield, or texture of the chicken meat model. However, the addition of HBSM resulted in a slight increase in the lightness and yellowness of the meat, which may affect the overall sensory properties. Overall, the study suggests that HBSM could be a promising alternative fat replacer in chicken meat products without compromising their quality characteristics (Saengphol & Pirak, 2018) [16].

2.4 Guar gum

Guar gum is a polysaccharide derivative extracted from the endosperm of the seeds of the *Cyamopsis tetragonoloba* plant, which belongs to the Leguminosae family. This odorless, white-yellowish powder has numerous applications in the food, cosmetics and pharmaceutical industries as an extensively used thickener. Due to its high molecular weight hydrophilic polysaccharide derivatives, guar gum is soluble in both hot and cold water but insoluble in alcohols, esters, ketones, fats, and hydrocarbons. Of note, guar gum is distinct from other plant gums due to the absence of uronic acid in its composition. The GRAS status of guar gum has led to its widespread use, with consumers and manufacturers alike favoring this plant-derived, cost-effective additive. Research indicates that guar gum is a promising ingredient in food formulations, with the ability to serve as a fat replacer and dietary fiber source, resulting in the production of high-quality food products (Theocharidou *et al*., 2022; Mudgil *et al*., 2014) [17, 18]. The study investigated the use of polydextrose and guar gum as fat substitutes in rice cookies and its effects on physical, textural and sensory properties. Results showed that the addition of polydextrose and guar gum increased the cookie's water activity and decreased its hardness. Sensory analysis indicated that cookies with the highest polydextrose and guar gum content received lower ratings for appearance, texture and overall acceptance. However, the addition of these fat substitutes did not significantly affect the cookies' color and taste attributes. The study concluded that the use of polydextrose and guar gum as

fat substitutes in rice cookies may have the potential to produce cookies with lower fat content without compromising the product's overall quality (Samakradhamrongthai *et al*., 2022) [19].

2.5 Inulin

Inulin is a soluble dietary fiber derived from the roots of various plants, such as chicory, and has been suggested as a potential fat replacer in food products. The study investigated the effect of inulin as a fat replacer in pea protein vegan ice cream. The results showed that the addition of inulin resulted in a reduction of fat content and an increase in fiber content, without significantly affecting the texture of the ice cream. The ice cream with inulin had better sensory attributes and was rated as creamier and smoother by the panelists. The study suggests that inulin can be a viable option for reducing fat content in vegan ice cream without compromising on the texture and sensory quality (Narala *et al*., 2022) [20].

3. Benefits of carbohydrate-based fat replacer

The use of carbohydrate-based fat replacers in foods offers a promising strategy to reduce dietary intake of fat and mitigate the risk of metabolic diseases. By replacing a portion of the fat in food products with a carbohydrate-based alternative, such as modified starch, mucilage, and gums it is possible to maintain the desired texture, mouthfeel and flavor while reducing overall fat content. Additionally, the presence of high fiber content can offer further health benefits, including improved glycaemic control, increased satiety, and reduced risk of cardiovascular disease. Overall, the incorporation of carbohydrate-based fat replacers in food formulations represents a simple yet effective means of improving the nutritional profile of the food supply and promoting public health (Chen *et al*., 2020) [21].

4. Future perceptive

As the use of carbohydrate-based fat replacers continues to grow, there is a need for further research to address their limitations and optimize their performance in food formulations. One key area of focus is the enhancement of sensory characteristics, as some carbohydrate-based fat replacers have been found to negatively impact the taste and texture of food products. Additionally, more studies are needed to investigate the impact of long-term consumption of these fat replacers on human health. Furthermore, the development of novel carbohydrate-based fat replacers with improved functional properties and health benefits is another area of research that holds promise. In the future, the successful integration of carbohydrate-based fat replacers into food products will depend on a better understanding of their physical and chemical interactions with other ingredients, as well as the preferences and needs of consumers.

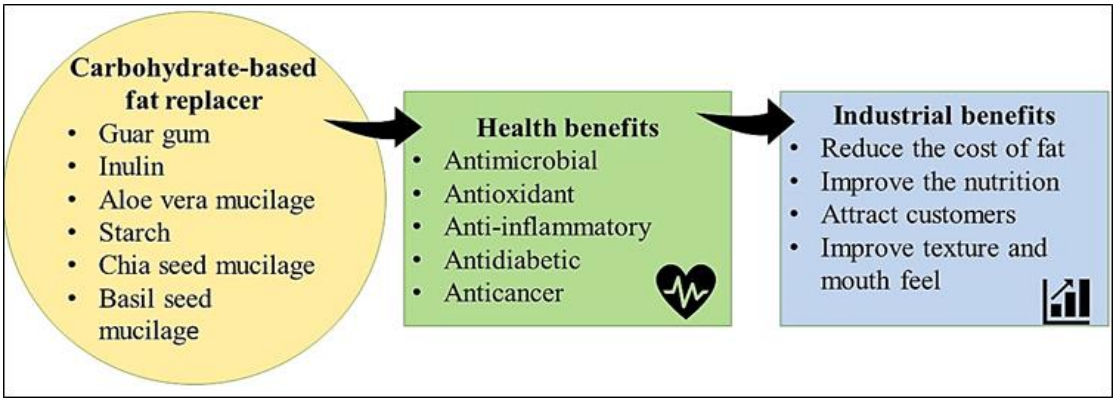

Fig 1: Carbohydrate-based fat replacers and their health and industrial benefits

Table 1: Types of carbohydrate-based fat replacer application on different food formulations with important research findings

Carbohydrate based fat replacer	Food product	Key findings	Reference
Inulin and maltodextrin	Baked savoury legume snacks	• 50% fat replacement • Texture, crispness, and hardness of the snacks were not significantly affected by the 50% fat replacement. • higher levels of dietary fiber	(Colla & Gamlath, 2015) [5]
Pectin and maltodextrin	Croissant	• 50% fat replacement • Pectin makes croissant hard • Maltodextrin effective fat replacer	(Shouk & El-Faham, 2005) [6]
Inulin	Biscuit	• 20% replacement • Reduction in calorific value • Higher replacement causes hardness	(Krystyjan *et al*., 2015) [7]
Guar gum and xanthan gum	Cake	• 50% replacement • Up to 50% no effects on sensory qualities on both gums	(Zambrano *et al*., 2004) [8]
Inulin	Low fat ice cream	• 2-4% substitution of inulin results same as a control sample	(Tiwari *et al*., 2015) [9]

5. Conclusion

In conclusion, carbohydrate-based fat replacers have been widely studied and have shown promising potential as a tool to reduce the fat content in foods while maintaining their sensory and technological properties. The development of these fat replacers has allowed for the production of healthier food products that can contribute to the prevention of diet-related diseases such as obesity, type 2 diabetes, and

cardiovascular disease. Although there are some limitations to their use, such as changes in texture or flavor, carbohydrate-based fat replacers have proven to be effective in a wide range of food products, from baked goods to dairy products and meat products. Overall, further research and development in the field of carbohydrate-based fat replacers can lead to more widespread use of these ingredients in food formulations and ultimately contribute to the creation of healthier food options for consumers.

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