Exploring Low Glycemic Index Innovations in Bakery Products: A Review

Abstract

Diabetes can becaused by various factors such as high sugar intake, hormonal imbalances, and genetics.Eating low-GI meals can reduce blood lipid levels, decrease postprandial blood glucose levels, decrease insulin demand, increase colon fermentation, and enhance satiety. The intention and the purpose of this review is to provide insight into the Glycemic Index (GI) and its effects on the human body. Low-GI foods are associated with a decrease in contemporary lifestyle conditions such as obesity, diabetes, some cancers, and heart attacks. This review discusses the significance of low GI foods, the factors influencing GI, and the fundamental processes and strategies for creating low-GI products. Additionally, the review summarizes research trends on the benefits of eating low-GI foods for health. Different formulations of snacks are also discussed, which incorporate several types of flours and fruit pulps that contribute to the reduced GI of the food and increase in fiber.

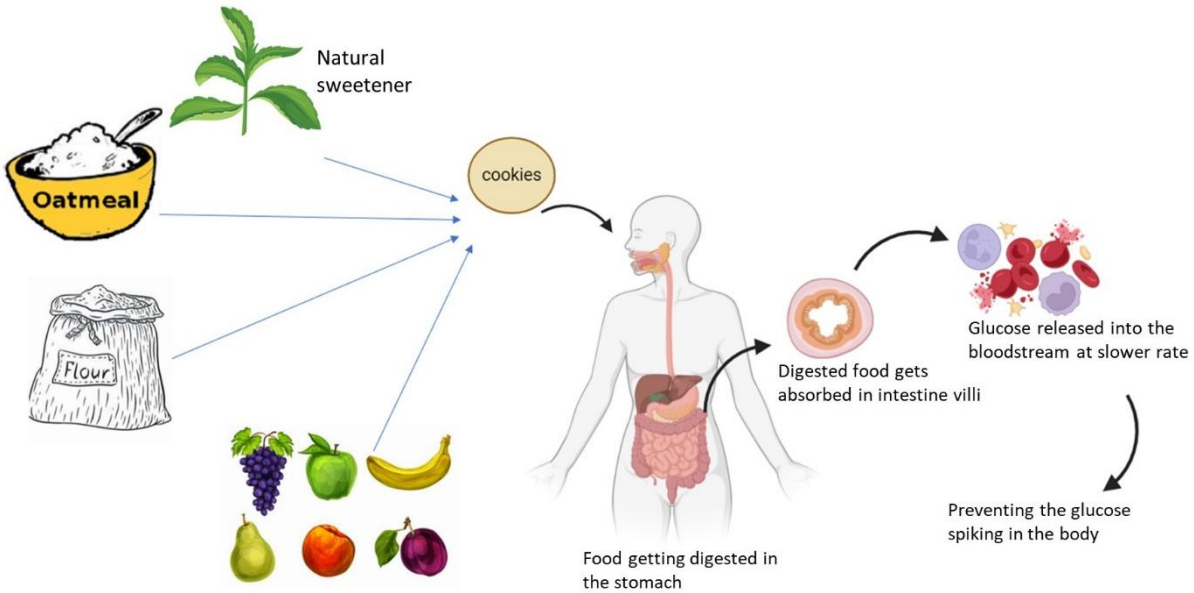

Figure 1. Ingredients and metabolism of low glycemic index cookies.

1. Introduction

The glycemic index helps determine how much a food can change blood sugar levels. Several factors, including cooking method, nutritional composition, and degree of ripeness in the case of fruits, impact the glycemic index of the foods. Whole grains and legumes are examples of complex carbohydrates with a lower glycemic index (GI) because they release glucose into the bloodstream more gradually, which helps to maintain stablebloodsugar levels. Fruits, vegetables, and nuts are foods high in fiber that can lower a meal's GI by decreasing the influence of carbs on blood sugar levels through slower digestion and absorption. The concept of GI emerged in 1988; the idea of GIwas first proposed byJenkins etal.,(1988) to measureglycemic response to carbohydrates in different food products. Generally, GI measures the quality of carbohydrates in meals and is a relative glycemic response. On the other hand, depending on GI and the total amount of carbohydrates consumed, theGlycemic level(GL) is calculated. GL indicates the number of carbohydrates that affect the glucose response (Ferrer et al. 2012).Foods are classified into three categories in the GI classification system: high, medium, and low GI foods (Cairano etal., 2022). The metabolic impact that was postulated has to do with how quickly glucose is absorbed in the small intestine. After consuming low-GI carbohydrates, glucose absorption will be slower, which will lessen the postprandial rise of gut hormones, including incretins and insulin. Over time, the extended absorption of carbohydrates will continue to block the counter-regulatory reactions and free fatty acids (FFA), resulting in a lower blood glucose content (Jerkins et al.1988).Over time, glucose is removed from the circulation more quickly due to decreased FFA concentrations and increased respiratory quotient brought on by tissue salinization. Consequently, blood glucose levels return to baseline even though glucose is still absorbed by the small intestine. This leads to a decrease in the peak postprandial blood glucose rise as well as the incremental blood glucose area above baseline. Living in an obesogenic atmosphere increases hunger and increases the risk of diabetes in many metropolitan countries; approximately 425 million people worldwide suffer from diabetes mellitus (DM), which has emerged as the world's first non-infectious epidemic. This represents 8.8% of the population between 20 and 79(Jemal et al. 2005). The International Diabetes Federation reports that the number of patients continues to rise quickly. Frequent use of processed foods, such as white bread, is a dietary factor that aggravates these metabolic problems. The international tables of GI and GL values show that breads have an average GI value between

24 and 100.Wheat white bread has a significantly high GI [GI > 70]. The GI, or glycemic index, measures how much a portion of food is high in carbohydrates and influences blood glucose levels after a meal compared to a reference product (usually white bread or mostly glucose) with an equivalent amount of readily available carbohydrates.

It is crucial to effectively control postprandial glycemia and insulinemia to minimize the chances of developing cardiovascular disease and type 2 diabetes (Klimek M et al. 2019). In contrast, the rise in glucose levels is not as noticeable after eating foods low in GI. The glycemic index (GI) was created to measure "the blood glucose-raising potential of available carbohydrates in high-carbohydrate foods" to manage postprandial glycemia and insulinemia.It is commonly known that while a low GI diet can enhance health, high GI foods can raise the chances of obesity, diabetes, several types of cancer, and cardiovascular disorders (Giacco et al. 2001). Low GI foods emerge as an innovative and delicious choice for satisfying sweet cravings without compromising health. People are becoming aware of their health and have started choosing a new and healthy lifestyle. This awareness gives a positive boost to such different products. These products are crafted with ingredients that have a slower impact on blood sugar levels, offering a balanced alternative to traditional high-GI treats.Some grains food products (oats, quinoa, or brown rice) are popular low-GI ready-to-eat foods that come in the form of crackers, chips, and bars, remade salads using low-GI ingredients, such as tofu or grilled chicken. Frozen meals include many veggies, lean proteins, nutritious grains, pasta dishes, casseroles, and stir-fries. There are many options for a healthy breakfast, such as healthy grains, nuts, seeds, granola bars, oatmeal sachets, and low-GI morning cereals. Nuts, seeds, and dried fruits are provided in snack bars.Energy and protein bars provide low-GI and easily portable food options. As people prioritize controlling blood sugar levels for improved health, there is a growing demand for low-GI ready-to-eat meals due to increased consumer awareness of the glycemic index (GI).

Various studies have described the health benefits of consuming the low GI food. In the study of (Barbosa et al. 2015),theyfound that most respondents stated that they had used natural resources—especially plant species—as a treatment or supplement in their studies, and people have been using medicinal herbs for ages worldwide. It also lowers blood sugar levels and is a more accessible source than other medications. Inthe work done by (Salehie et al.2019),it has been found that conventionally used therapeutic Plants work well. Many plants have been shown to have glucosidase-lowering, anti-hyperglycemic, and anti-diabetic effects.The phytochemicals found in plant extracts are a group of compounds that give plants

their anti-diabetic properties. Alkaloids, glycosides, phenolic acids, stilbenes, saponins, flavonoid polysaccharides, and tannins are the main phytochemicals with anti-diabetic properties.The use of muesli in pasta preparation is justified, according to Oliveira et al. (2018), because it improves the nutritional value of the product and results in a healthier meal due to its significant increase in fibre content and decrease in glycemic index. This generally happens with conditions that call for a diet that includes a small amount offiber to reduce blood glucose. The study done by Li etal. 2016, demonstrated that overweight patients' glycolipid metabolism benefited from a low-fat, high-fiber diet; these benefits were amplified when oatsconsumption was included. This suggests that this food can be useful in managing excess weight and, primarily, lowerglycemic levels.Santiago et al.(2017) highlighted the high amount of minerals and proteins in diet cookies made with flour derived from passion fruit peel and their low energy value and nutritional benefit from dietary fiber like pectin. Robert et al.(2016) demonstrated that bread's blood sugar response and blood sugar index can be considerably decreased by using fenugreek seeds instead of 10% refined wheat flour. As a result, fenugreek powder is regarded as a useful component that can effectively reduce blood sugar.

1.1 Glycemic index of different foods

The glycemicindex of different foods depends on composition and factors like the making process, use of sweeteners, etc. Based on the variouslevels of GI, the foods are classified as low GI, where the GI of food ranges from 55 or less; medium,where food GI levels range from 56 to 69; and high,where the glycemic index ranges more than 70. Fruits, legumes, and dairy products have also beenshown to have low GI values. Some of the glycemic values of various common foodsare represented in Table 1.

Table 1Different types of foods with glycemic index and glycemic load

S.no	Foods	GI index	Glycemic load
1	Almonds	15	1.9
2	Apple juice	41	4.5
3	Avocado	10	0.9
4	Banana	48	10.1
5	Barley flour	30	16.8
6	Bread	47	19.2
7	Brown rice	50	36.5
8	Cashew nuts	25	3.1
9	Cherry	25	4
10	Chick pea	10	6.1
11	Green apple	36	5
12	Kiwi	50	7.3
13	Milk	49	28.9
14	Multi grain cookies	51	33.2
15	Glucose	100	10
16	Cornflakes	92	24
17	Potato (Baked)	85	26
18	Instant rice	75	28
19	Bread (white)	70	10
20	Coca-Cola	63	16
21	Bread (Wheat)	52	10
22	Carrot	47	3
23	Spaghetti	41	20
24	Apple	40	6
25	Lentil beans	29	5
26	Peanuts	13	1

Source :Arya, Shalini. (2009). Glycemic index:An overview. Agro Food Industry Hi-Tech. 20. 30-32.

2.Different low-GIbakery foods

Many bakery food products are staple foods in various countries, eaten as breakfast, snacks, and decadent treats. These are accessible sources of energy, carbohydrates, and pleasure for dieters. Obesity and diabetes are among the common health problems caused by the excessive concentrations of processed carbohydrates and harmful fats in many traditional bakery items. Reducing sugar content and adding whole grains can increase nutritional value and decrease the glycemic index to overcome these issues. Healthy fats and fruits, vegetables, nuts, seeds, and baked goods must be added to boost nutrient density.

2.1Low GI biscuits

A biscuit is a tiny, baked, flour-based food item that can be savory or sweet, depending on the recipe and local variations. Biscuits are usually crispy. A baked good with a low glycemic index is composed of components that gradually release glucose into the bloodstream, promoting stable blood sugar levels. Frequently used components in low-GI biscuits are wholegrain flour, almond flour, among other nut flours, natural sweeteners (such as erythritol, date syrup, and stevia), components high in fiber (such as flaxseed and oats), and unsaturated fats (such as avocado and olive oil). Addingfiber and good fats from whole grain and nut flour encourages slower digestion and a lower glycemic index. Natural sweeteners provide sweetness without quickly raising blood sugar levels. Ingredients high in fiberpromote fullness and slow down digestion, and unsaturated fats help keep blood sugar levels stable.A study conducted by (Anju et al. 2010**)** on the development of low glycemic index biscuits concluded that based on the results obtained, refined wheat flour and millet flour were used in the ratio of 45% and 55%, And other ingredients were eggs (5.5), powdered sugar (14%), hydrogenated fat (23%), baking powder, and curd (11.5%). This product has the highest crude protein, crude fiber, ash, carbohydrate, physiological energy, starch, various minerals, low GI, and better sensory quality, storage stability, and nutritional quality.This delicious product has been formulated and has had a great health benefit for human health.The case study done by (Hussain, S.Z et al. 2020) developed biscuits using waterchestnutandbarleyflour. Combining WCF and BF in a 70:30 ratio made it possible to

develop biscuits with the desired sensory properties. The finished product was found to have a greater resistant starch concentration than WCF and BF. Research has shown that adding BF instead of 30% WCF can result in biscuits with the right sensory qualities and a low glycemic index. According to the storage investigation, the created metalized polyethylene biscuits could be kept in a refrigerator for up to 35 days and in an ambient environment for up to 28 days. (overall acceptability rating more than 3 on a 5-point scale).Another case study by Marangoni et al.2008)developed low glycemic index bread and biscuits and described thetime and temperature combination and glucose content while baking the biscuits. The control and modified samples had 75g of carbohydrates available in a person after eating the low glycemic index biscuits.After baking, the nutritional value of the low glycemic index biscuit was 481 calories, carbohydrate % 55, fat% 25, protein % 9, total fiber % 6, and the water was 5%

2.2. Low GI cookies

Low glycemic cookies are the type of cookies that are formulated to have a low impact on blood sugar levels. To obtain such results, the cookies are made with low GI ingredients like whole grain flour and multigrain flour, including fibers, which have a significant impact on the GI, by lowering the starch digestion time and slower glucose absorption.One of the studies on the cardaba banana flour was used to make the cookies (B. Olawoye et al. 2020). The cardaba bananas were de-bunched, peeled underwater, sliced, and dried in a traditional hot air oven at 50 C for eight hours. The recipe from (Giubertiet al. 2015) was used to make the gluten-free cookies. To put it briefly, The ratio of modified cardaba banana starch to cardaba banana flour was 20:80 (w/w) (Olawoye et al. 2020). The results of the experiments conducted by (Olawoye et al. 2020) indicated L*, a*, and b* values of cookies were 49.83 0.84–61.39 0.80, -4.93 0.03–1.85 0.01, and 9.38 0.21–11.60 0.09. The Maillard reaction may have started or accelerated during the cookie-making process, as evidenced by the reduction in L and a value and increase in b values that followed an increase in baking time and temperature. Additionally, the hardness (which is correlated with the force needed to shatter them) varied from 43.11 0.53 to 67.92 1.06 N for the cookies. The study's findings showed that, as baking time increased, neither the baking temperature nor the cookies' breaking strength increased.

In another studyby Naseer et al.(2021)low glycemic, gluten-free cookies weremade from high amylose rice flourusing broken grains of white rice (Lalat variety). The carboxymethyl cellulose concentration, baking time, and temperature were adjusted to range from 0.2 to 1%, 12 to 25 minutes, and 170 to 190 °C. Conversely, the anticipated glycemic load and glycemic index declined as the carboxymethyl cellulose concentration increased. Design experts determined that 0.8% carboxymethyl cellulose content, 185 °C baking temperature, and 22 minutes of baking time would be ideal for creating rice flour to make these gluten-free andlow-glycemic index cookies. The generated cookies' dietary fiber content was found to be 4.66%. According to in vitro studies on starch digestibility, resistant starch rose from (2.85% in rice flour to 7.20% in cookies). Meanwhile, for rice flour, the expected glycemic load and index dropped from 50.12 to 30.07, and for cookies, from (44.60 to 17.51). The cookie's overall acceptability was rated at 8.90 (on a 9-point hedonic scale).

Ng et al.'s (2020) investigation examined the nutritional content, sensory evaluation, and gluten sensitivity of chocolate cookies prepared with overripe banana residue (OBR) in substitution of wheat flour (8%) and overripe banana sweetener (OBS) in substitution of some sugar (10, 15, and 20%). The nutritional qualities of chocolate cookies were increased with the incorporation of OBR and OBS. With an 8% OBR + 20% OBS formulation, chocolate cookies had the most significant (Total dietary fiber) TDF (7.80%) and ash (1.47%) concentration. The amount of sucrose in chocolate cookies decreased significantly as the OBS level rose. The control and 8% OBR-incorporated cookie groups' sensory scores did not significantly differ in any sensory qualities. Furthermore, adding up to 15% of OBS resulted in better ratings on flavor, aroma, and acceptance in general.For GI testing, three chocolate cookie formulations (control, 8% OBR, and 8% OBR + 15% OBS) were used, and the GI values for each were 63, 56, and 50. This study concludes that overripe bananas are useful for low-GI and high-fiber cookie recipes.

2.3.Low GI bread

Bread is a typical food usually made by baking dough made of flour, typically wheat. Low glycemic bread is a type of bread that has a low glycemic index, meaning that it has a minimal impact on sugar levels in the blood. This bread is made using ingredients that slow the digestive process, as opposed to regular bread, which is usually made from refined white flour that is easily digested and absorbed by the body. This prevents sudden spikes in blood

sugar levels, providing a more sustained energy supply by slowly releasing glucose into the bloodstream (Ostman et al. 2006).Low-glycemic bread is often made using whole grains due to its ability to retain natural nutrients and fiber. In this studyby Prabhahar et al.(2022), Glycyrrhiza glabra extracts were infused into regular bread to transform it into proper herbal bread. Different amounts of Glycyrrhiza glabra, such as 2%, 4%, and 6%, are used to fortify bread. Liquid chromatography-mass spectroscopy (LCMS) examined the Glycyrrhizaglabra's functional components. The extract has a strong antioxidant potency, according to the antioxidant study. The extract's anti-diabetic effectiveness was also examined in this investigation. A number of sensory and flavor factors were reviewed in the enriched bread analysis. The glycemic index and other biochemical tests, such as the in vitro digestibility test, indicate that enriched bread lowers the glycemic index. Compared to 2 and 4%, it was concluded from the study that 6% of infused bread had great potency as a functional food. According to the study, as mentioned earlier, enriched bread lowers the glycaemic index and is, therefore, ideal for diabetics and dieters adhering to a diet.Studies have demonstrated that ingredient reformulation, such as partially substituting resistant starch, dextrin, lentil flour,and wheat flour, can lower baked goods' glycemic index (GI). This is especially crucial for gluten-free goods since their decreased protein, fiber, and mineral content frequently results in a higher GI. It has also been discovered that the GI of cereal-based goods can be reduced by adding pulse components, such as pea and lentil flour. Furthermore, because coconut flour has a high dietary fiber content, its GI can be lowered with increasing amounts in baked products that use it (Jagelaviciute et al., 2023).

2.4. Low GI crackers

Low-GI crackers are a good choice for people who want to control their blood sugar levels efficiently. These crackers are categorized as low-GI foods since their glycemic index (GI) is less than 55. Low GI crackers have been linked to improved sensations of fullness and control over postprandial glycemic reactions, which may benefitglycemic control and weight management. The work done by Diana N et al.(2018) made chocolate crackers with a smooth dough prepared with the appropriate amounts of wheat flour, margarine, stevia sugar, cocoa powder, skim milk,baking soda, yeast, and modified kepok banana flour. The dough was then flattened into sheets (1-2 mm) thick. After that, the sheets are cut into (2 by 2 cm) squares and baked for 20 minutes at 100°C.

Additionally, chocolate crackers made with kepok banana flour felt hard and broke readily because of the flour's low gluten level. These crackers also tasted bland since stevia was used instead of sucrose**.**In terms of flavor, texture, and aroma of the organoleptic properties, the chocolate crackers in the AC group that substituted 50% of the banana flour with kepok had the highest values. Additionally, their starch concentration was the most resistant. Diana N et al.(2018) observed that chocolate crackers made using 75% kepok banana flour using the ACF method had the lowest digestibility of starch (22%) in vitro and the highest resistant starch content (9%). The chocolate crackers in the AC group, which had 50% less banana flour than kepok, exhibited the best organoleptic attributes in terms of taste, texture, and scent. The AC and ACF group crackers had a lower GL and a low GI of less than 55 compared to non-crackers. Kepok banana flour, which is made by autoclaving,cooling, and then fermenting bananas, might be a helpful component in lowering the GI andproducing low-GL snacks for people with type 2 diabetes.

2.5 Low GI muffins

Muffins are quick breads resembling cakes that can be sweet or savory and baked in individual servings. They are loved by many for their delicious taste and soft texture. However, wheat flour is the primary ingredient in all bakery goods and has a medium to high glycemic index (GI). When additional ingredients like sugar are added, the GI of the baked goods is further increased, making them unsuitable for people with diabetes.The recipe used to make the muffins was created by (Hussain et al. 2019). The recipe involves combining sifted dry ingredients and beating eggs individually with a flat beater in a stand mixer. The beaten eggs are then combined with creamed shortening while being constantly stirred. Water and emulsion are added to the dry mixture and mixed well. The batter is then filled into cupcake pans (65g) and frozen for four hours at a temperature of -20°C. The batter-filled cups are baked for 30 minutes at 180°C in an oven. After cooling to normal temperature, the baked muffins are placed in a bag and stored at -20°C for 72 hours. The glycemic response and qualitative features of muffins were significantly ($p < 0.05$) impacted by the addition of barley flour (BF). It was also discovered that the final product's resistant starch concentration (43.5%) was more than that of BF (5.18%) and water chestnut (40.24%). The study demonstrates that it is possible to create low-GI muffins with the appropriate sensory qualities by substituting 30% of the water chestnut flour (WCF) with BF. The muffins made

with 70% WCF and 30% BF were found to have increased firmness, water activity, free fatty acid, and peroxide value during storage, whereas moisture content and overall acceptability dropped.

2.6 Low GI pasta

Pasta is a cuisine typically made by mixing wheat flour, eggs, and water to form a flat dough. The dough is then shaped into sheets of various shapes and cooked by boiling or baking. Although traditionally, only durum flour was used to create pasta, the term now includes other gluten-free flour substitutes such as rice flour, legumes like beans, and alternates like lentils. While pasta is believed to have originated in Italy and is an essential component of Italian cuisine. The case study of (Pachipulusu M et al. 2020) developed low glycemic index noodles and concluded that these flours can be added to noodle formulations with legume flour (X2-35%), and leafy green vegetable powder (X3-12.5%),millet flour (X1-52.5%) without compromising the sensory and textural qualities of the finished product, out of all the products created, this one contains the most fiber, protein, and low GI content. It is also the most sensory-friendly.A blend of these flours is employed to enhance pasta's sensory qualities. It is possible to create goods that are both nutrient-dense and aesthetically pleasing by utilizing the capabilities of the combination of different ingredient designs and sensory analysis**.** Therefore, this pasta has excellent potential to bring good health benefits to public health.

3. Conclusion

In affluent societies, the increase in the number ofcases of obesity,type-II diabetes mellitus, and cardiovascular diseaseis linked to increased energy intake that is exacerbated by physical inactivity. Consuming too much fat is a significant contributing factor to these conditions. As a result, a low-fat diet is advised by a number of public health groups (like the American Diabetes Association, 1997), (Gabir et al., 1997) dedicated to managing and avoiding obesity and diabetes. One potentiallyharmful consequence of these recommendations might be an actual decrease in fat intake combined with an increase in dietary CHO, which would increase the Glycemic levels and potentially the diet's overall GI. Making low-GI meal choices is crucial for those who see a notable drop in dietary fat intake.This kind of diet has potential benefits like weight reduction (Maziarz et al. 2017)and slowing aging as the foods are rich in antioxidants. Also, the free radicle formation is

minimized by reducing oxidation.Low GI diets also protect the heart from various CVDs and prevent various cancer-causing factors (Liu et al. 2000); this kind of study helps educate people and helps them make better choices for leading a healthy life.This study will help us understand recent advancements. Much research has been done on the topic, and many advancements have been made. Advancements such as using different alternative flours like banana starch, quinoa flour, waterchestnuts, etc., to make the product instead of wheat flour increase the fiber and decrease the GI. Other factors, such as ingredients, also play a major role in decreasing GI, so using ingredients with low glycemic levels can have a significant effect on GI. There are many different options for a healthy breakfast, such as healthy grains, nuts, and seeds, granola bars, oatmeal sachets, and low-GI morning cereals, nuts, seeds, and dried fruits in snack bars. Low-GI and easily portable food options provideenergy and protein. People focus on controlling blood sugar levels for improved health, so there is a growing demand for low-GI ready-to-eat meals due to increased consumer awareness of the glycemic index (GI).

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