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Glycemic index and COVID-19 management: A comprehensive review of low, medium and high glycemic index foods

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Abstract

The influence of low, medium, and high glycemic index (GI) plants on the management of COVID-19, with a particular focus on their effects on blood sugar levels, inflammation, and immune function is examined in the present review. COVID-19 patients, especially those with underlying conditions like diabetes, hypertension, and cardiovascular diseases, often face more severe outcomes. The GI of foods plays a vital role in managing these conditions by affecting postprandial blood sugar levels and insulin sensitivity. Low GI plants are emphasized for their ability to stabilize blood sugar levels and reduce inflammatory responses, which are essential for managing COVID-19 symptoms and preventing severe complications. Conversely, medium and high GI plants, despite their nutritional benefits, can cause rapid increases in blood sugar and enhance inflammatory processes, necessitating careful dietary planning. The review consolidates current research on how various GI foods impact immune function, highlighting the importance of diets that support anti-inflammatory and immune responses. It offers practical dietary recommendations to optimize health outcomes for COVID-19 patients, advocating for greater consumption of low-GI foods such as vegetables, legumes, and whole grains, while recommending moderation in the intake of high-GI foods like refined sugars and certain processed items. By exploring the relationship between diet, blood sugar regulation, inflammation, and immune response, this review underscores the importance of personalized nutritional strategies in improving the recovery and long-term health of COVID-19 patients.

1. Introduction

The COVID-19 pandemic has underscored the critical significance of nutrition in the management of health and disease, particularly for individuals with preexisting metabolic conditions like diabetes and obesity (Liu *et al*., 2021). The glycemic index (GI) has emerged as a valuable tool among various nutritional strategies for assessing the impact of carbohydrate-rich foods on blood glucose levels. Foods are categorized based on their post-consumption effect on blood glucose levels, with low, medium, and high GI foods exerting varying influences on metabolic health and disease outcomes (Borges-Argaez *et al*., 2019). This comprehensive analysis seeks to explore the role of plant-based foods with different glycemic indexes in the management of COVID-19. The association between dietary selection and immune function has gained considerable attention, especially in the context of the pandemic. Diets rich in refined carbohydrates and sugars, typically falling under the high GI classification, can lead to rapid spikes in blood glucose and insulin levels, triggering inflammation and oxidative stress (Shahrdami *et al*., 2020; Fernández-Quintela *et al*., 2020). Conversely, low GI foods facilitate a slower, more controlled release of glucose into the bloodstream, improving glycemic control and reducing inflammatory reactions (Hussain *et al*., 2020). The severity of COVID-19 has been associated with underlying metabolic dysfunctions, emphasizing the importance of dietary approaches that enhance metabolic well-being (Rajpal *et al*., 2020). High GI foods, like white bread and sugary beverages, may exacerbate metabolic issues and potentially worsen COVID-19 outcomes (Foster-Powell *et al*., 2002). In contrast, low GI foods, such as legumes, whole grains, and many fruits and vegetables, have demonstrated positive effects on blood sugar regulation and inflammation reduction, which is crucial for individuals at high risk of severe COVID-19 (Augustin *et al*., 2002).

Medium GI foods, including specific fruits and whole grain products, offer a balanced approach to blood sugar control, providing nutritional advantages without the pronounced impacts associated with high GI foods (Atkinson *et al*., 2008). Understanding the influence of these foods on immune function and inflammation is crucial for developing dietary recommendations to alleviate the consequences of COVID-19 (Hussain *et al*., 2020).

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This review shows an existing research on the effects of low, medium, and high GI plant-based foods on the body's response to COVID-19. We investigate the mechanisms by which these foods influence immune function, inflammation, and overall metabolic equilibrium. Through the classification of foods based on their glycemic index, this review delivers a comprehensive understanding of how particular dietary choices can either bolster or impede the body's ability to combat COVID-19. Additionally, this review deliberates practical dietary approaches and interventions that leverage the glycemic index to enhance immune resilience and overall health during the pandemic. By spotlighting specific plant-based foods and dietary patterns, our goal is to provide practical insights for healthcare professionals, researchers, and the general public to promote metabolic health and enhance COVID-19 outcomes.

By giving a detailed overview of the glycemic index and its relevance to COVID-19 management, this review aims to empower stakeholders with the necessary knowledge to make well-informed dietary decisions. The ultimate aim is to advocate for dietary practices that not only improve metabolic health but also fortify the body's defence against COVID-19 and other infectious ailments.

2. Glycemic index and glycemic load

The Glycemic Index (GI) is described as the incremental area under the blood glucose curve after the ingestion of a specific food item, presented as a proportion of the corresponding area following a carbohydrate-equivalent quantity of standard food. Initially, glucose served as the benchmark substance, however, in more recent times, white bread has been embraced as the normative reference. Utilizing white bread as a benchmark, the GI varies from below 20 to roughly 120 per cent (Hatekar and Ghodke, 2009) Carbohydrates metabolize swiftly during the digestive process leading to a rapid release of glucose into the bloodstream and exhibiting a high GI. Conversely, carbohydrates that metabolize slowly result in a gradual release of glucose into the bloodstream and demonstrate a low GI. Food items with a high GI are digested and absorbed quickly, causing notable fluctuations in blood sugar levels. As a consequence, it is suggested that high GI foods may contribute to the onset of chronic ailments (Batisha *et al*., 2008).

Conversely, low-GI foods induce a gradual elevation in blood sugar and insulin levels and offer established health advantages (Mulholland *et al*., 2009). Low GI diets have exhibited enhancements in both glucose and lipid profiles (Philippou *et al*., 2009). They are advantageous for weight regulation as they aid in appetite management and postponement of hunger. Furthermore, low-GI diets diminish insulin concentrations and insulin resistance (Pal *et al*., 2008). The concept of Glycemic load (GL), which evaluates the comprehensive glycaemic impact of the diet, is especially valuable in epidemiological investigations (Liu *et al*., 2000). It is the outcome of the dietary GI multiplied by the total dietary carbohydrate content. GL reflects the calibre and quantity of carbohydrates along with their combined effects.

The glycemic index (GI) indicates how carbohydrates in food can impact blood sugar levels, while glycemic load considers the overall composition of the food, providing a more accurate assessment of its effect on blood glucose levels. While GI predicts potential sugar spikes from specific foods, glycemic load accounts for the food's entirety, offering a more realistic view of its impact on blood sugar. Therefore, understanding glycemic load is crucial for accurately assessing the blood sugar response to food consumption.

Approximately, one GL unit is equivalent to the glycemic impact of 1 g of glucose. An average diet typically contains about 100 GL units per day, with a variability spanning from 60 to 180 units. GL offers an assessment of the overall glycemic reaction to a food item or meal (Beulens *et al*., 2007).

2.1 Measuring the GI and GL

The incremental area under the blood glucose response curve (IAUC), excluding the area below the baseline, was calculated using geometric methods (Al Dhaheri *et al*., 2015). The IAUC for each test meal consumed by each participant was expressed as a percentage of the mean IAUC for the reference food consumed by the same participant, using the formula: GI = (IAUC for the test food containing 50 g of available carbohydrate / IAUC for a standard food with an equivalent carbohydrate portion) × 100. The GI for each tested food was determined as the average value from the entire group of participants. The glycemic load (GL) was calculated using the formula: GL = (GI of test food × amount of carbohydrate in a serving of the test food (g)) / 100 (Al Dhaheri *et al*., 2015).

2.2 Classification of glycemic index

The glycemic index (GI) is stratified into three classifications based on the carbohydrate composition of different food items, by standardized procedures. The determination of GI involves the application of internationally recognized protocols, where a quantity of 50 g of digestible carbohydrate is ingested by a group of 10 or more subjects, followed by the monitoring of their blood glucose levels after 2 h to evaluate the food's influence on glycemic response. These methodologies culminate in the segmentation of the glycemic index into three distinct categories (Tables 1 and 2; Figures 1 and 2).

Low glycemic index foods

Foods characterized by a glycemic index between 0 to 55 are classified as low glycemic index foods. These particular food items do not induce a significant spike in blood sugar levels and are suggested for incorporation into the dietary plans of diabetic patients.

Moderate glycemic index foods

Foods falling within the glycemic index range of 56 to 69 are deemed to possess a moderate glycemic index.

High glycemic index foods

Foods having a Glycemic Index ranging from 70 to 100 fall under the category of high glycemic index foods. Such food items lead to a substantial elevation in blood sugar levels and are not advisable for individuals with diabetes.

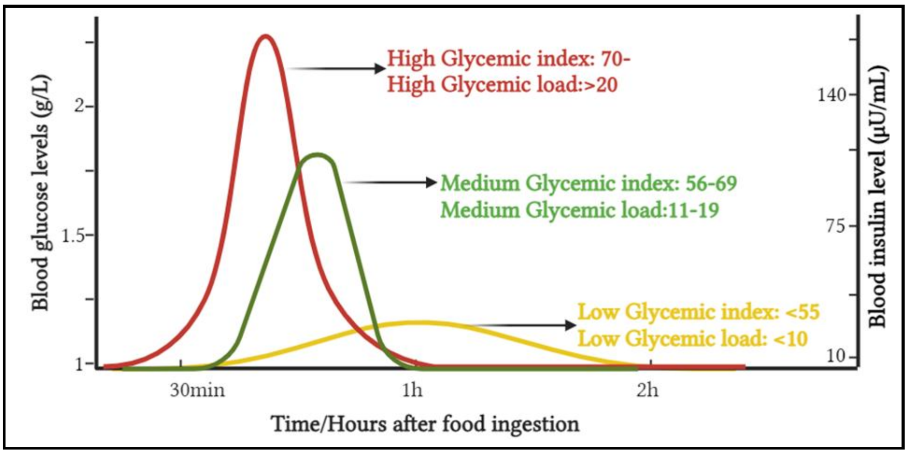

Figure 1: Influence of GI and GI on blood glucose level.

Table 1: Glycemic index food chart

Food groups	Low GI (0-55)	Medium GI (56-69)	High GI (70-100)
Fruits	Apple, apricot, berries, grapefruit, kiwi, orange, peach, pear, plum, raw banana	Dry fruits, figs and raisins, grapes, mango, muskmelon, papaya, pineapple, ripe banana	Watermelon
Vegetables	Beans, brinjal, broccoli, carrots, cauli-flower, cucumber, green beans, green leafy vegetables (spinach, fenugreek, amaranth), peas, tomato	Peas, sweet potato, yam	Pumpkin, russet potatoes, white potato
Cereals	Barley, daliya, oat bran, poha, quinoa	Brown rice, muesli, rye	Cereal bars, cornflakes, instant oats, poha, rice porridge
Dairy products	Buttermilk, cheese, greek yogurt, milk, paneer, plain yogurt	Ice cream	Flavored yogurt, rice milk
Pulses	Black-eye peas (lobia), chickpea, green gram, kidney bean, soybean	-	-
Others	Almonds, eggs, flaxseeds, peanuts, seafood, sunflower or pumpkin seeds, vegetable soup, walnuts	Honey, soft drinks	Chocolate, fast food, jaggery, pizza, sugar

(Source: https://www.sugarfit.com/gi-indian-food)

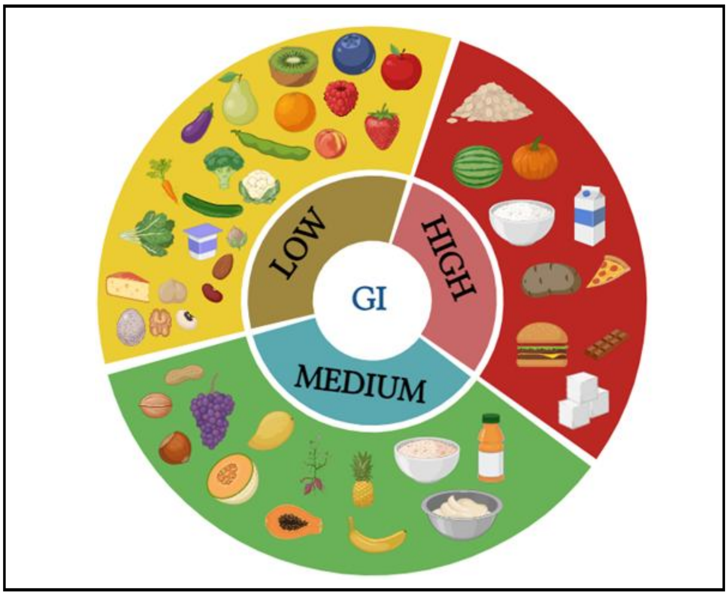

Figure 2: Glycemic index chart for common foods.

Table 2: Classification of glycemic load

Glycemic load	Status	Remark
1-10	Low glycemic load	Good
11-19	Medium glycemic load	Medium
>20	High glycemic load	High

Table 3: Global table of glycemic index (GI) and glycemic load (GL) values of some food items (Foster-Powell *et al*., 2002, Mavroeidi *et al*., 2024)

Food	Glycemic index (GI)	Glycemic load (GL)	Food	Glycemic index (GI)	Glycemic load (GL)
White bread	75	15	Kiwis	53	9
Cornflakes	81	21	Dates	54	21
Baked potato	85	26	Pear	33	3
Rice crackers	87	22	Apricot	34	3
Watermelon	72	4	Kidney beans	28	8
Brown rice	68	16	Soybeans	16	9
Oatmeal	58	11	Mushrooms	10	1
Sweet potato	63	17	Zucchini	15	1
Whole wheat bread	69	9	Asparagus	32	2
Table sugar (sucrose)	65	7	Cucumber	15	0
Lentils	32	5	Onion	15	<1
Apple	39	6	Yogurt	15	1
Carrots	41	3	Peanuts	14	1
Chickpeas	28	7	Walnuts	20	1
Skim milk	32	4	Almonds	10	1
Oranges	40	6	Pecans	10	<1
Cherries	20	5	Hazelnuts	15	<1
Raspberries	32	3	Spinach	15	1
Lettuce	15	1			

2.2.1 Examples of high glycemic index foods

High glycemic index (GI) foods are those that induce a rapid and significant increase in blood glucose levels following consumption. Presented below are several instances along with their respective sources (Table 3).

White bread

White bread, made from refined flour lacking in fibre and essential nutrients, exhibits a high GI, leading to a quick surge in blood sugar post-intake (Foster-Powell *et al*., 2002).

White rice

Particularly when extensively processed, white rice displays a high GI attributed to its starch content, swiftly transformed into glucose during the digestive process (Atkinson *et al*., 2008).

Potatoes (mashed or instant)

Potatoes, especially when mashed or in instant form, showcase a high GI. Different methods of processing and cooking can impact their glycemic index, with mashed and instant varieties significantly influencing blood sugar levels.

Sugary breakfast cereals

Breakfast cereals rich in sugar, such as cornflakes or sweetened granola, often carry a high GI. Their rapid breakdown in the body results in a swift increase in blood glucose levels (Atkinson *et al*., 2008).

Pineapple juice

In contrast to whole pineapples, pineapple juice has a high GI due to its concentrated sugar content and lack of fibre (Brand-Miller *et al*., 2002).

Watermelon: Despite its high-water content, watermelon possesses a high GI due to its natural sugars, quickly absorbed by the body (Foster-Powell *et al*., 2002).

2.2.2 Examples of moderate glycemic index foods

Foods with a moderate glycemic index (GI) are characterized by inducing a gradual yet slightly accelerated surge in blood glucose levels in comparison to low GI counterparts. Presented below are instances of such foods

Whole grain bread

Despite having a lower GI than white bread, whole grain bread falls within the moderate GI spectrum. Its intricate carbohydrates are metabolized at a moderate pace, leading to a gradual surge in blood sugar levels (Foster-Powell *et al*., 2002).

Brown rice

Brown rice showcases a moderate GI when juxtaposed with white rice. Despite its heightened fiber and nutrient content resulting from minimal processing, it still triggers a relatively quicker increase in blood sugar levels compared to low GI foods (Atkinson *et al*., 2008).

Bananas

Bananas demonstrate a moderate GI due to their natural sugars and carbohydrate structure. Despite furnishing swift energy, they are categorized as moderate GI foods due to their propensity to induce a relatively faster spike in blood sugar levels in comparison to low GI fruits.

Pineapples

The moderate GI of pineapples stems from their intrinsic sugars. Despite conferring numerous health advantages, such as being abundant in vitamin C and manganese, they can incite a moderate elevation in blood sugar levels (Atkinson *et al*., 2008).

Couscous

Couscous falls under the moderate GI classification as it is derived from semolina, a variety of wheat. While acting as a carbohydrate source of energy, its GI is higher compared to certain other whole grains. These exemplifications elucidate moderate GI foods that, while providing energy, might lead to a somewhat hastened increase in blood sugar levels than low GI alternatives (Brand-Miller *et al*., 2002).

2.2.3 Examples of low glycemic index foods

Low glycemic index (GI) foods are those that elicit a gradual elevation in blood glucose levels as a result of their delayed breakdown and absorption process. Here are a few illustrations:

Legumes

Lentils, chickpeas, black beans, and kidney beans are rich in fiber and protein. The fiber content in these legumes decelerates digestion, ensuring a consistent release of glucose into the circulatory system, thus preserving stable blood sugar levels.

Non-starchy vegetables

Vegetables such as broccoli, spinach, cauliflower, kale, and peppers possess a low GI. These vegetables are abundant in fiber, water, and essential nutrients, assisting in slowing down digestion and averting sudden surges in blood sugar (Bran-Miller, 2003).

Whole grains

Whole grains like quinoa, barley, oats, and brown rice have a lower GI in contrast to refined grains. They encompass complex carbohydrates, fiber, and nutrients that are metabolized gradually, leading to a steady glucose discharge into the bloodstream.

Nuts and seeds

Nuts like almonds, walnuts, and seeds such as chia and flaxseeds have low carbohydrate content and have minimal impact on blood sugar levels. Their substantial content of beneficial fats, protein, and fiber enhances satiety and aids in regulating blood sugar (Kendall *et al*., 2010).

Certain fruits

Despite fruits containing natural sugars, some exhibit a lower GI. Examples encompass berries (strawberries, blueberries, raspberries), apples, pears, and cherries. These fruits are rich in fiber and antioxidants, impeding sugar absorption (Buyken *et al*., 2001).

Dairy products

Dairy products like yogurt and milk have a low to moderate GI, particularly if they are devoid of added sugars and flavourings. They deliver protein, calcium, and vital nutrients, contributing to steady blood sugar levels.

Sweet potatoes

Sweet potatoes possess a lower GI compared to regular potatoes. They are abundant in fiber, vitamins, and minerals, rendering them a preferred option for blood sugar management (Buyken *et al*., 2001).

Whole wheat pasta and bread

Whole wheat pasta and bread exhibit a lower GI than refined varieties. They incorporate more fiber and nutrients, facilitating delayed digestion and preventing sudden blood sugar spikes. Integrating these low-GI foods into your dietary regimen can assist in sustaining stable blood sugar levels, enhancing satiety, and promoting overall well-being (Buyken *et al*., 2001).

2.3 Mechanism of action of glycemic index

The metabolic advantages of low glycemic index (GI) foods arise from the delayed absorption rate of glucose within the small intestine. The consumption of low-GI foods results in a diminished and more gradual elevation in circulating insulin and gastrointestinal hormones, including incretins, gastric inhibitory polypeptide (GIP), and glucagon-like peptide-1 (GLP-1) (Esfahani *et al*., 2009). This sustained yet decreased postprandial insulin release offers various benefits, such as prolonged suppression of free fatty acids and decreased counterregulatory responses linked to fluctuations in high blood glucose levels. Reduced levels of free fatty acids enhance cellular glucose metabolism, leading to a more consistent blood glucose level approaching baseline, notwithstanding the continuous absorption of glucose. This enhanced glycemic management is especially advantageous for individuals dealing with insulin resistance, prediabetes, and diabetes. Conversely, diets high in GI can stimulate excessive insulin production, resulting in postprandial hyperinsulinemia and potential downregulation of insulin receptors in peripheral cells. Research emphasizes the importance of 30 min post-challenge insulin levels in forecasting weight reduction in individuals following low glycemic load diets (Chaput *et al*., 2008). Hyperinsulinemia worsens metabolic syndrome and correlates with a 60% heightened risk of ischemic heart disease (IHD) among men aged 45 to 76 for each standard deviation increase in fasting insulin levels (Despres *et al*., 1996). Elevated postprandial glucose levels also amplify the risk of cardiovascular disease (CVD) (Levitan *et al*., 2004). Mechanisms influencing weight reduction encompass the lipogenic impact of hyperinsulinemia, which is associated with obesity. An intense insulin response after high-GI or high-glycemic load meals may provoke quicker hunger and overeating by depleting metabolic resources (Ludwig, 2002). Low-GI foods might augment satiety, as indicated by fifteen short-term investigations demonstrating increased satiety and diminished voluntary food consumption with low-GI foods like psyllium, guar, oatmeal, and legumes. Additional research is imperative to validate these theories and clarify the mechanisms underlying how low-GI or low-glycemic load foods impact appetite regulation (Ludwig, 2000) (Figure 3).

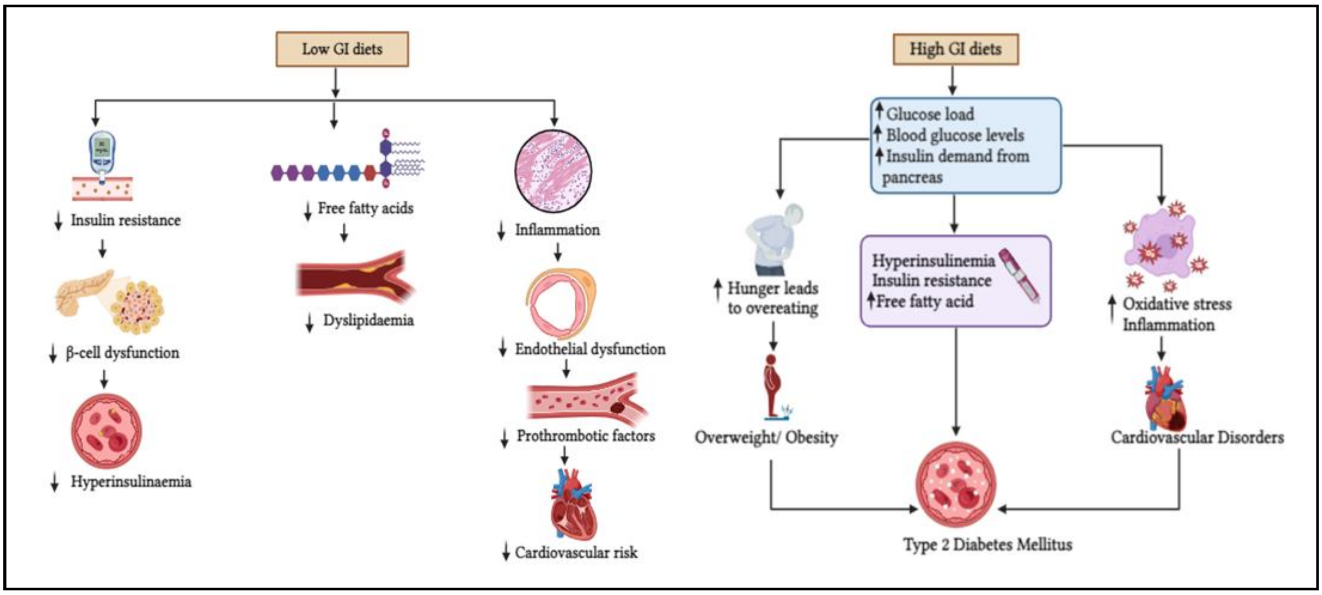

Figure 3: Mechanism of action of low and high GI diets.

2.4 Factors affecting glycemic index

2.4.1 Carbohydrate content in the foods

Diets abundant in carbohydrates have the potential to elevate blood glucose concentrations, particularly after meals, thereby increasing the susceptibility of individuals with diabetes (both type 1 and severe type 2) to challenges in glycemic regulation and the development of microvascular and macrovascular complications (Riccardi *et al*., 2008). These dietary patterns have also been associated with heightened levels of plasma insulin and triacylglycerol, as well as other risk factors related to cardiovascular health. Nevertheless, it is noteworthy that not all foods rich in carbohydrates lead to hyperglycemia, as the postprandial responses of blood glucose can significantly differ even when the carbohydrate content remains constant. This variability is impacted by various factors, including the composition and characteristics of starch (such as digestibility, amylose/amylopectin ratio, gelatinization, and retrogradation), the presence of dietary fiber, sugar levels, as well as additional elements like the body's insulin reaction, protein concentration, methods of food processing, diversity of food options, particle size, fat levels, acidity, and the circumstances surrounding storage and timing of harvest (Figure 4). This analysis delves into specific aspects such as starch composition and characteristics, dietary fiber, insulin reaction, protein concentration, processing techniques, diversity of food options, particle size, fat levels, and acidity (Bahado-Singh *et al*., 2011; Urooj and Puttraj, 1999).

2.4.2 Starch composition

Starch constitutes approximately 70-80% of the total carbohydrates present in conventional diets (Dona *et al*., 2010, Urooj and Puttraj, 1999) and is categorized into three groups based on the rate and extent of digestion: rapidly digestible starch (RDS), slowly digestible starch (SDS), and resistant starch (RS) (Sajilata *et al*., 2006). RDS undergoes rapid digestion in the duodenum and proximal small intestine, leading to a swift increase in blood glucose levels and potential hypoglycemia. Predominantly found in starchy foods prepared through moist heat, such as bread and potatoes, RDS is quantified as the starch converted into glucose within 20 min of enzyme digestion (Sajilata *et al*., 2006). These rapid spikes in glucose can be detrimental to cells, tissues, and organs. SDS, on the other hand, is digested slowly but thoroughly in the small intestine, providing a gradual glucose release with minimal initial glycemia and prolonged energy supply (Aller *et al*., 2011). This category encompasses physically inaccessible starch and specific crystalline structures present in grains and cooked dishes. SDS is measured as the starch converted into glucose after an additional 100 min of enzyme digestion and can assist in regulating stable glucose metabolism and diabetes management (Sajilata *et al*., 2006). RS, unlike the former types, evades digestion in the upper gastrointestinal tract but undergoes fermentation by gut microflora, resulting in the production of short-chain fatty acids. Characterized as the portion of dietary starch that remains undigested in the small intestine, RS is assessed as the variance between total starch and the sum of RDS and SDS.

RS provides a multitude of health advantages, such as enhanced insulin sensitivity, decreased blood glucose levels (Nugent, 2005), prevention of colon cancer, support for probiotics, reduced formation of gallstones, hypocholesterolemic effects, inhibition of fat accumulation, and improved mineral absorption (Sajilata *et al*., 2006; Chung *et al*., 2008). The development of RS is influenced by various factors including stirring, water-starch ratio, cooking and cooling processes, and the ratio of amylose to amylopectin (Deepa *et al.*, 2010; Frei *et al.*, 2003).

2.4.3 Amylose composition

Amylose, a helical polymer, consists of α-D-glucose units connected through α (1 $\rightarrow$ 4) glycosidic bonds. It makes up approximately 20-30% of starch, which is one of the primary constituents.

2.4.4 Amylopectin

Amylopectin, a highly branched polysaccharide of glucose present in plants and making up approximately 70% of starch, consists of a range of 2,000 to 200,000 glucose units. Recent studies have pointed out that amylose plays a role in slowing down the process of digestion and the body's response to insulin, consequently leading to a reduction in the glycaemic index (Higgins *et al.*, 2004). One more study that rice varieties exhibiting higher amylose content, such as Doongara with 28% amylose, displayed notably lower glycemic index (GI) and insulin index values when compared to standard amylose and amylopectin rice types like Calrose and Pelde, which contain 20% amylose. Moreover, the ratio of amylopectin to amylose and the complexes developed between amylose and lipids play a vital role in determining the speed of starch breakdown. Generally, the digestibility of starches tends to decrease with an increase in amylose content (Vesterinen *et al.*, 2002) although the digestibility is not solely dependent on amylose content (Htoon *et al.*, 2009; Lopez-Rubio *et al.*, 2008). Additionally, the presence of amylose in conjunction with lipids acts as a barrier against hydrolytic enzyme activity, rendering it more resistant to breakdown than free carbohydrates (Nebesny *et al.*, 2004).

2.4.5 Gelatinization

When starch is subjected to heat at approximately 50°C in the presence of water, the amylose contained within the granule undergoes swelling, leading to the disruption of the crystalline structure of amylopectin and eventual rupture of the granule. As a result, the polysaccharide chains assume a random configuration, causing the starch to swell and the surrounding matrix to thicken. This phenomenon, known as gelatinization, enhances the digestibility of starch. The degree of gelatinization directly impacts the viscosity of the starch, consequently affecting its glycemic index (GI) and subsequently influencing the glycemic load (GL). Gelatinized starch exhibits higher susceptibility to degradation by á-amylase in comparison to native starch granules.

2.4.6 Retrogradation

Upon gelatinization and subsequent cooling, starch undergoes a molecular rearrangement involving its amylose and amylopectin components, leading to an enhancement in the crystalline organization of the starch. This phenomenon, termed retrogradation, becomes more pronounced with time and under decreased temperatures. Starches rich in amylose exhibit a heightened propensity for retrogradation, resulting in enhanced resistance to enzymatic digestion owing to stronger hydrogen bonding, thereby yielding a diminished glycemic index (GI) and glycemic load (GL) (Bahado-Singh *et al.*, 2011). The retrogradation process facilitates the transition of gelatinized or solubilized starch from a disordered to a more structured and crystalline state. Consequently, this physical alteration contributes to the firmness or staleness observed in processed starchy products as they progress towards a more stable, lower-energy configuration. The elevated resistance to amylase breakdown contributes to the reduction in the starch's GI value (Chung *et al.*, 2006). The duration of the initial retrogradation phase is contingent upon the amylose content, with high molecular weight amylose demonstrating a more efficient promotion of retrogradation compared to lower molecular weight polymers (Dona *et al.*, 2010).

2.4.7 Dietary fiber

The American Association of Cereal Chemists defined dietary fiber as carbohydrate polymers with more than three degrees of polymerization that evade digestion and absorption in the small intestine. Recently, the British Nutrition Foundation described dietary fiber as substances in plant foods that resist complete breakdown by human digestive enzymes, including waxes, lignin, cellulose, and pectin. James and Mark (Lattimer and Haub., 2010) categorized dietary fiber into three components: non-starch polysaccharides (NSP) and oligosaccharides, analogous carbohydrates, and lignin substances linked with NSP and lignin complexes. Viscous soluble fiber has been highlighted for its role in modulating postprandial glycemic and insulin responses by influencing gastric emptying and nutrient absorption (Slavin *et al.*, 1999). Nevertheless, certain prospective studies suggested an inverse association between insoluble, rather than soluble, fiber and the risk of type 2 diabetes (Krishnan *et al.*, 2007; Montonen *et al.*, 2003). Clinical investigations examining the impact of dietary fiber on insulin sensitivity have yielded conflicting findings, with some indicating improvements with fiber-rich diets and others showing no significant effects (Pereira *et al.*, 2002). The American Diabetes Association recommends a daily intake of 14 g of fiber per 1000 kcal for diabetic patients to enhance glycemic control, although further clinical trials are necessary to verify the long-term effectiveness of soluble fiber supplements in diabetes management (Babio *et al.*, 2010; Bantle *et al.*, 2008).

2.4.8 Sugars

The glycemic index (GI) of a food is influenced by the sugar composition within it. For instance, sucrose, composed of glucose and fructose, exhibits a lower GI compared to glucose alone. This is because fructose, constituting half of the sucrose molecule, elicits a relatively lower blood sugar response (Pi-Sunyer, 2002).

2.4.9 Other factors

2.4.9.1 Insulin response

The insulin response plays a crucial role in regulating an individual's blood glucose level after consuming a carbohydrate-rich diet. Insulin, the primary hormone responsible for maintaining blood glucose within a healthy range, is activated when hepatocytes detect elevated levels of intracellular glucose. Glucokinase initiates the phosphorylation of excess glucose into glucose-6-phosphate, triggering insulin response and facilitating the conversion of surplus glucose into glycogen through glycogenesis. This process involves the deactivation of glycogen phosphorylase and the activation of glycogen synthase. Elevated insulin levels promote increased glycogen synthesis, while insufficient insulin secretion can lead to improper carbohydrate, protein, and fat metabolism, potentially causing hyperglycemia. An inverse relationship between the glycemic index

(GI) and insulin response of specific foods, such as Calrose brown rice, which had a GI of 83 but insulin index of 51. Despite the known role of fats in enhancing insulin responses to carbohydrate-rich foods, the rice analyzed by Miller *et al.*, 1992 had minimal fat content. Therefore, considering insulin response is essential when selecting suitable carbohydrate foods for individuals with diabetes.

2.4.9.2 Protein content

Protein-rich foods stimulate insulin production, which results in lower post-meal blood glucose levels. Therefore, the natural protein content in particular meals may explain why their starches undergo slower hydrolysis, resulting in lower glycemic indices (GIs). For example, pasta, which contains grains and gluten, slows the action of pancreatic amylases, contributing to its low GI.

2.4.9.3 Processing techniques

Various methods of processing food have been shown to impact the digestibility of starch, thereby affecting the glycemic indexes (GIs) of these foods. Processing techniques can influence both the gelatinization and retrogradation processes, which in turn affect the formation of resistant starch. For example, roasted and fried foods generally have higher GIs compared to boiled foods (Deepa *et al.*, 2010). Steam cooking has been found to promote the production of resistant starch, with starches isolated from steam-heated legumes containing significant levels of indigestible resistant starch. Conversely, boiling sweet potatoes has been associated with lower GI values compared to frying, baking, or roasting those (Bahado-Singh *et al.*, 2011). However, the beneficial effects of dietary fiber in inhibiting hydrolytic enzyme actions may be diminished when whole grains are ground, as they are hydrolyzed at a similar rate to polished grain flour. An illustration of how food processing impacts blood glucose levels is evident in a study where boiled cocoyam exhibited a high GI, contrary to its traditional use in managing diabetes in Nigerian ethnomedicine. Conversely, oven-dried cocoyam showed hypoglycemic effects in experimental diabetic rats, supporting its traditional medicinal use in managing diabetes. These findings underscore the significant influence of food processing methods on the GIs of food samples. Additionally, processing foods at high temperatures can lead to gelatinization, which permanently alters the amylose-amylopectin structure of the starch complex, making it more accessible to digestive enzymes (Eleazu *et al.*, 2014).

2.4.9.4 Particle size

Grinding starchy foods produces finer particles, which aids digestion and increases their glycemic indexes (Roberts, 2000; Goni *et al.*, 1997). For example, changes in rice GI can be ascribed to differences in particle size (Deepa *et al.*, 2010). Starch digestibility is affected by granule size and surface area available for hydrolytic enzyme action (Urooj and Puttraj, 1999).

2.4.9.5 Fat

Fat causes the stomach to take longer to empty and food to pass through the intestine. This delayed effect on the digestion of dietary carbohydrates in the intestine may result in a slower rise in blood sugar levels and a lower glycemic index (GI) than identical fat-free diets. (Brand-Miller *et al.*, 2003).

2.4.9.6 Acidity

The presence of acid in food delays the emptying of the stomach, which in turn slows down the digestion of dietary carbohydrates. Consequently, increasing the acidity in a meal has the potential to reduce its glycemic index (GI) and blood glucose levels. These various factors outlined above can significantly influence the accuracy and consistency of GIs and glycemic loads (GLs) of foods. Thus, when calculating the GIs of foods, it is crucial to take all these factors into account; otherwise, the reported data may not accurately reflect the GI of the food being studied (Tovar and Melito, 1996).

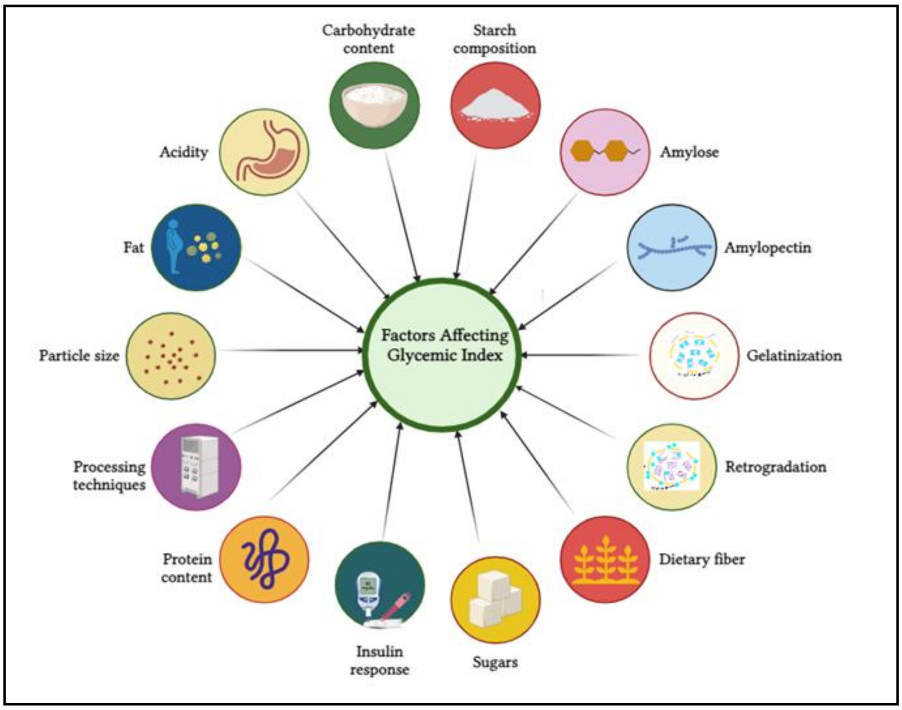

Figure 4: Factors affecting glycemic index.

3. COVID-19 and glycemic index

The COVID-19 pandemic has highlighted significant challenges in healthcare access, particularly for individuals with diabetes, a prevalent global disease. Studies have shown a decline in glycemic control among COVID-19 patients during lockdowns, indicating potential adverse outcomes. Early reports underscored the increased risk of severe COVID-19 infection among diabetic individuals. Recent findings have linked high HbA1c levels to inflammation, hypercoagulability, and low oxygen saturation, further heightening the risk of COVID-19-related complications and mortality among diabetic patients. These observations emphasize the critical importance of maintaining optimal glycemic control in diabetic patients during the COVID-19 pandemic to mitigate risks and ensure overall health (Alshammari *et al.,* 2023)

Previous studies have highlighted a dysregulation of glycemic control and weight gain in diabetic patients during the COVID-19 pandemic. This dysregulation may be linked to increased consumption of sugary foods and snacks, coupled with reduced physical activity levels. Optimizing glycemic control can notably enhance COVID-19 outcomes, even though many underlying mechanisms remain scientifically unexplained. Maintaining well-controlled blood glucose levels within the range of 70-180 mg/dL reduces the need for clinical intervention, lowers all-cause mortality rates, and mitigates major organ deterioration (Boeder *et al.,* 2022).

In the field of phytomedicine research, it's typical to uncover various pharmacological properties within a single plant. It's now widely recognized that a single plant can harbour a diverse array of phytochemicals, which makes ethnopharmacology research both promising and complex (Süntar, 2019). The interventions discussed here can generally be grouped into categories such as those with antiviral, anti-inflammatory, immunomodulatory effects, antioxidant and frequently a combination of these effects.

3.1 Glycemic index-based medicinal plants and their role in COVID-19 management

The utilization of medicinal plants has been under investigation for their prospective advantages in the management of COVID-19, predominantly attributed to their anti-inflammatory and immunomodulatory characteristics. Presented below are a few illustrations of these plants accompanied by their corresponding scientific nomenclature (Table 4).

Table 4: Glycemic index-based medicinal plants and their role in COVID-19 management

Medicinal Plants	Benefits	References
Low GI plants		
Curcuma longa	Turmeric is comprised of curcumin, a compound recognized for its potent anti-inflammatory and antioxidant characteristics. The compound has been the subject of a scientific investigation regarding its potential benefits in bolstering respiratory well-being and augmenting immune response to COVID-19.	Sornpet *et al*., 2017
Zingiber officinale	Ginger's low glycemic index helps manage COVID-19 because of its active compounds gingerol and shogaol, known for their anti-inflammatory, antioxidant, and antiviral properties. It aids in reducing respiratory inflammation, boosting immune function, and alleviating symptoms like sore throat, cough, and congestion. Additionally, ginger improves circulation and offers gastrointestinal relief.	Atashak *et al*., 2014; Admas, 2020; Sulochana *et al*., 2020
Cinnamomum verum	Cinnamon, with its low glycemic index, has been used in COVID-19 management for its medicinal benefits. Containing compounds like cinnamaldehyde and eugenol, cinnamon offers anti-inflammatory, antioxidant, and antiviral properties. These helps boost the immune system, reduce inflammation, and alleviate respiratory symptoms related to COVID-19. Additionally, cinnamon's ability to regulate blood sugar levels supports overall health in those affected by the virus.	Moshaverinia *et al*., 2020
Trigonella foenum -graecum	Fenugreek, known for its low glycemic index, has been used in managing COVID-19 due to its medicinal properties. The plant's bioactive compounds, including saponins, flavonoids, and alkaloids, offer anti-inflammatory, antioxidant, and immune-boosting benefits. These effects help enhance the immune system, reduce inflammation, and improve respiratory health, potentially alleviating COVID-19 symptoms. Additionally, fenugreek's ability to regulate blood sugar supports overall health in those affected by the virus.	Gupta *et al*., 2001; Sen *et al*., 2020
Moringa oleifera	Moringa, with its bioactive components like vitamins, minerals, and antioxidants, demonstrates anti-inflammatory, antiviral, and immune-enhancing properties. These attributes aid in fortifying the immune system, alleviating inflammation, and promoting respiratory wellness, potentially easing COVID-19 symptoms. Additionally, moringa's capacity to regulate blood sugar levels contributes to the holistic health of individuals impacted by the virus.	Sofy *et al*., 2022

Allium sativum	Garlic, renowned for its low glycemic index, is utilized in COVID-19 management owing to its medicinal properties. It harbors bioactive components such as allicin, known for its antiviral, antimicrobial, and immune-enhancing effects. These attributes bolster immune function, combat viral infections, and potentially alleviate the intensity of COVID-19 symptoms. Additionally, garlic's capacity to regulate blood sugar levels could enhance the well-being of those impacted by the virus.	Rivlin, 2001; Okoro *et al.*, 2023
***Aloe barbadensis* Miller**	Aloe Vera is rich in bioactive compounds like polysaccharides, vitamins, and antioxidants, it possesses anti-inflammatory, antiviral, and immune-boosting properties. These qualities enhance immunity, decrease inflammation, and potentially relieve COVID-19 symptoms. Additionally, its potential to regulate blood sugar levels adds to its significance in COVID-19 management.	Borges-Argaez *et al.*, 2019
Camellia sinensis	Green tea, with its catechins and polyphenols, possesses antioxidant, anti-inflammatory, and antiviral properties, which support the immune system, alleviate inflammation, and potentially lessen the impact of COVID-19 symptoms. Additionally, its potential to maintain blood sugar levels could enhance the overall well-being of those impacted by the virus.	Yang *et al.*, 2000
Azadirachta indica	Neem contains bioactive components, like nimbin and nimbidin, that have antiviral, anti-inflammatory, and immune-enhancing properties. These characteristics support immune function, fight viral infections, and may relieve COVID-19 symptoms. Additionally, neem's potential to regulate blood sugar levels can benefit the overall health of those impacted by the virus.	Faccin- Galhardi *et al.*, 2012
Ocimum sanctum	Basil contains compounds like eugenol and rosmarinic acid, which have antiviral, anti-inflammatory, and immune-boosting properties. These qualities aid in strengthening the immune system, fighting viral infections, and potentially easing COVID-19 symptoms. Additionally, basil's capability to regulate blood sugar levels could benefit the overall health of those impacted by the virus.	Shree *et al.*, 2022
Moderate GI plants		
Panax ginseng	Ginseng is rich in bioactive compounds like ginsenosides, known for their immune-boosting and anti-inflammatory properties. These attributes can bolster the immune system and potentially alleviate inflammation linked to COVID-19. Furthermore, ginseng's capacity to regulate blood sugar levels could offer health benefits to those impacted by the virus.	Wang *et al.*, 2018
Withania somnifera	Ashwagandha, with its withanolides, has immune-boosting and anti-inflammatory effects, aiding in fortifying the immune system and reducing inflammation, possibly alleviating COVID-19 symptoms. Its adaptogenic properties also enhance resilience to stress. Furthermore, ashwagandha's capacity to regulate blood sugar levels could enhance the health of those impacted by the virus.	Pant *et al.*, 2012
Glycyrrhiza glabra	Licorice contains glycyrrhizin, a compound with proven anti-inflammatory, antiviral, and immune-modulating properties. These characteristics may aid in alleviating COVID-19 symptoms by reducing inflammation and bolstering the immune system. Furthermore, licorice's capacity to regulate blood sugar levels could enhance the overall well-being of individuals impacted by the virus.	Wang *et al.*, 2015

3.2 Case studies and clinical evidence

Impact of hyperglycemia on COVID-19 severity and complications

Prior studies have suggested that elevated blood sugar levels worsen complications in severe coronavirus infections such as SARS and MERS, a pattern similarly observed in COVID-19 where high blood sugar levels are correlated with higher death rates in critically ill individuals (Liu *et al.*, 2021). Therefore, it is essential to effectively manage glucose levels in COVID-19 patients, as this could potentially influence the seriousness of symptoms and complications (Zabetakis *et al.*, 2020). Furthermore, hyperglycemia might indicate decreased responsiveness to insulin, a factor that significantly impacts the management of COVID-19 (Hussain *et al.*, 2020). The pathways connecting high blood sugar levels to an increased risk of COVID-19 involve the heightened expression of ACE2 (Brufsky, 2020), which facilitates the virus's entry into cells, intensifies inflammatory reactions, and is supported by the increased presence of pro-inflammatory cytokines (Rajpal *et al.*, 2020; Zabetakis *et al.*, 2020). Elevated blood sugar levels can compromise immune responses, impede the function of neutrophils, and heighten the likelihood of mortality associated with infections, particularly affecting individuals with diabetes (Jafar *et al.*, 2016). Moreover, poorly regulated diabetes is linked to impaired functionality of immune cells and heightened inflammatory reactions, potentially worsening the severity of COVID-19 (Hussain *et al.*, 2020). Additionally, hyperglycemia in COVID-19 patients might impede the clearance of mucus, thereby increasing the risk of lung infections (Rajpal *et al.*, 2020).

3.3 Role of insulin resistance in complicating COVID-19 severity in diabetic patients

Insulin resistance, coupled with hyperglycemia, plays a significant role in the development of severe complications in diabetic individuals with COVID-19. This phenomenon arises when tissues exhibit an inadequate insulin response, resulting in heightened insulin concentrations and consequent hyperinsulinemia as a mechanism to sustain normal blood sugar levels (Berbudi *et al*., 2020). The prevalence of insulin resistance is notable in type 2 diabetes and obesity, thereby heightening the susceptibility to critical manifestations of COVID-19 (Bonakdaran and Barazandeh Ahmadabadi, 2014; Rajpal *et al*., 2020). At a mechanistic level, insulin resistance enhances the expression of ACE-2 protein, thereby facilitating viral penetration and bolstering the generation of reactive oxygen species within the mitochondria, thereby exacerbating the severity of the infection (Finucane and Davenport, 2020; Cooper *et al*., 2020). Furthermore, insulin resistance prompts the generation of pro-inflammatory cytokines and elevates C-reactive protein levels, thereby contributing to systemic inflammation and oxidative stress, which have the potential to compromise pulmonary function. Remarkably, in obese individuals, insulin resistance may further escalate chronic inflammation and exacerbate the severity of COVID-19 complications (De Luca and Olefsky, 2008).

3.4 Impact of dietary glycemic index and load on insulin Function and COVID-19 management

The correlation between hyperinsulinemia insulin resistance and dietary composition is extensively documented in the literature (Mirabelli *et al*., 2020). Dietary components such as the glycemic index (GI) and glycemic load (GL) play crucial roles in the regulation of insulin function and glycemic control (Shahrdami *et al*., 2020). The GI categorizes foods based on their postprandial glucose impact, while the GL takes into account both the quantity of carbohydrates and their GI. Diets with low GI have been linked to enhanced immune function, potentially attributed to their effects on leukocyte levels (Shahrdami *et al*., 2020). Although the direct relationship between GI/GL and COVID-19 infection has not been thoroughly studied, dietary guidelines for COVID-19 patients often recommend consuming low GI carbohydrates to regulate insulin function and inflammation. High GI foods have been associated with heightened oxidative stress and inflammatory reactions, which can complicate COVID-19 outcomes. Additionally, dietary GI/GL levels are connected to serum inflammatory markers like CRP, TNF-α, and IL-6, which are elevated in individuals with COVID-19 (Fernandez-Quintela *et al*., 2020). Incorporating whole grains and complex non-digestible carbohydrates, characterized by low GI values, can influence gut microbiota and decrease inflammatory responses (Keim and Martin, 2014). Resistant starch, also classified as low GI, encourages beneficial alterations in microbiota composition, potentially reducing inflammation and enhancing glucose regulation (Durganaudu *et al*., 2020). The relationship between dietary GI/GL and modifications in gut microbiota composition is a developing research area, with potential implications for respiratory well-being (Dhar and Mohanty, 2020). Low GI/GL carbohydrates might indirectly lower the risk and severity of COVID-19 by alleviating underlying conditions such as cardiovascular disease and diabetes, which can exacerbate complications associated with COVID-19 (Augustin *et al*., 2002, Rajpal *et al*., 2020).

4. Future perspectives

Future investigations should give priority to conducting clinical trials and longitudinal studies to assess the efficacy of glycemic index (GI) plant-based diets in managing COVID-19, with a focus on examining their effects on disease progression and long-term health results. Tailored dietary strategies, utilizing technologies like metabolomics and microbiome analysis, have the potential to individualize interventions based on specific glycemic responses, thereby enhancing the effectiveness of treatment. Nutritionists, clinicians, and healthcare experts must collaborate closely to seamlessly integrate dietary suggestions into conventional medical practices, particularly for at-risk populations. Efforts in public health should center on raising awareness regarding well-balanced diets that are abundant in low GI plant foods, supplemented by telehealth initiatives aimed at providing remote dietary assistance to individuals with COVID-19. Additionally, policymakers ought to contemplate the integration of GI-focused dietary recommendations into worldwide health policies to promote uniformity in clinical approaches and enhance health outcomes for the population amidst the ongoing pandemic.

5. Conclusion

In conclusion, the incorporation of glycemic index (GI) plants in dietary management displays significant potential in improving health outcomes for individuals with COVID-19. Low GI foods, rich in nutrients and antioxidants, play a role in stabilizing blood sugar levels, reducing inflammation, and enhancing immune function to combat the virus. Foods with a medium GI value offer a well-balanced approach by supplying essential nutrients while moderately affecting blood sugar levels. Conversely, high GI foods, causing sudden spikes in blood sugar and inflammation, should be restricted to prevent exacerbation of COVID-19 symptoms. Practical recommendations for meal preparation, sample meal plans, and cooking methods provide feasible strategies for integrating low and medium GI plants into daily food intake. Furthermore, evidence from case studies and clinical trials underscores the favourable impact of GI-based dietary strategies on COVID-19 outcomes. Embracing these suggestions and advancing personalized nutrition and clinical investigations enable us to leverage the advantages of GI plants to strengthen resilience and facilitate recovery among individuals contending with COVID-19.

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Conflict of interest

The authors declare no conflict of interest relevant to this article.

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