

The impact of amylose and amylopectin content in determining the GI of food stuffs

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Abstract:

The increasing incidence of non-communicable diseases and their management has ignited the desire to become healthier, and for many, this begins with the foods eaten. One of the major contributors to the postprandial blood glucose response is dietary carbohydrates. There is some understanding about the way in which amylose and amylopectin types of starch and their varying covalent linkages affect the rate of carbohydrate digestion and glucose absorption, and the extent to which this will impact the glycemic index of different foodstuffs. There is an inverse relationship between the amylopectin content of foods and their glycemic index. Furthermore, the type of non-covalent linkages between amylopectin influences the blood glucose response of individuals. In light of this, the influence of amylose and amylopectin should be further analyzed as it provides an opportunity for an individual to select a diet lower in glycemic indices, which may contribute to a reduced risk of insulin resistance and the development of metabolic disease. The growing interest in these aspects of nutrition and health emerges from the critical aim of identifying food habits and practices that are particularly conducive to overall health and well-being. The principal objective of the study is to extensively explore the relationship between carbohydrate structure, the ensuing metabolic response, and their associated relation in determining glycemic index of the foods.

Keywords: Glycemic Index; Amylose; Amylopectin; Food Chemistry.

Introduction

The role that the glycemic index (GI) of various foods may play in influencing diet and overall health is of significant and great current interest to both researchers and health professionals. Therefore, in an effort to become more familiar and knowledgeable about the glycemic index, the various carbohydrate sources that occur within the typical diet are the primary subjects of ongoing research in the field of nutrition. The specific aim of this study was to determine the impact of the amylose and amylopectin content, with varying quantities of indigestible carbohydrates, in determining the glycemic index of a diverse variety of foodstuffs that many people commonly consume. The specific objectives of this study were to thoroughly assess the amylose and amylopectin starch components along with the overall carbohydrate content in the diverse foodstuffs, and to comprehensively determine the in vitro digestibility of both amylose and amylopectin present in these foodstuffs. Furthermore, the amylose/amylopectin ratio of starch is a genetically determined property and has been widely classified into three distinct types which include waxy starch containing 0-2% amylose, low amylose waxy starch containing 0-10% amylose, and normal starch containing 20-30% amylose and 70-80% amylopectin. The role of amylose and amylopectin within the starch and food systems is subject to intense and dedicated research, reflecting the ongoing interest in optimizing dietary choices for better health outcomes. (Varghese et al.2022)(Wang et al., 2024)(Li et al.2021)

Carbohydrates have been comprehensively classified into simple sugars and complex carbohydrates or polysaccharides, each of which plays a unique role in nutrition and metabolism. Among these, starch stands out as one of the most abundant types of carbohydrates found in nature, constituting approximately 40-70% of some conventional foodstuffs that people consume daily. Starch serves as the major reserve of carbohydrates in the human diet, critically accounting for more than 40% of the total energy requirements of the human body, emphasizing its importance in our nutritional intake. Major polysaccharides include not just starch, but also

glycogen and cellulose, each contributing differently to health and physiological functions. There are numerous points in the complex carbohydrate metabolism process where clinical, analytical, or methodological measurements can be effectively carried out to further understand these processes. The classic classification of carbohydrates is primarily based on the polymerization of the basic sugar units, which can vary widely in structure and function. Numerous academic papers have been written on various aspects surrounding carbohydrates, including their intricate structure, the mechanisms behind absorption, how energy is utilized from these compounds, the effects of food matrix, and the impacts of food processing and cooking methods on these substances. Such studies offer vital insights that summarize the metabolic activities of macromolecules that include varying percentages of non-encapsulated foods and analyze their interaction in cross-sections of human tissues and juices. Additionally, reviews on the influences of food processing and cooking techniques on the metabolic activities of foods have garnered significant attention. The growing interest in these aspects of nutrition and health emerges from the critical aim of identifying food habits and practices that are particularly conducive to overall health and well-being. The principal objective of these meta-analysis studies was to extensively explore the relationship between carbohydrate structure, the ensuing metabolic response, and their associated risk factors for obesity and related health issues. Notably, prior to the formal establishment of this study, there was an evident gap, as no substantial review articles existed in the area connecting gastrointestinal health, nutrition, and health that effectively explored these significant factors concerning amylose and amylopectin specifically. (Phukan and Nongkhlaw2022) (Zhang et al.2021)(Suri & Singh, 2023)(Bai et al., 2021)

Understanding Glycemic Index (GI)

Glycemic index (GI) has become a major concern in nutritional science, particularly for individuals faced with difficulties in controlling their blood sugar or interested in losing weight. GI represents either the incremental area under the blood glucose response curve after food consumption, expressed

as a percentage of the response area following a reference food or the slope of the increase in glucose immediately after the consumption of the considered food, divided by the slope observed after the consumption of a reference food. In simpler terms, GI is a numerical value about how individual carbohydrates or a mixed meal affect blood sugar or glucose in comparison to the similar content of glucose. (Lal et al.2021) (Atkinson et al.2021)(Singh et al.2021)(Penlioglou et al., 2021)

For food, an analysis of the GI can be simply defined as the measure (on a scale of 0 to 100) of the influence, in terms of glycemia, of the consumption of a determined quantity of carbohydrates. This has, of course, as a result and useful interpretation that individuals at increased risk of becoming hyperglycemic or simply desiring to avoid the risk of rising hyperglycemia can make appropriate shopping or consumption choices using this information. It is assumed that low GI foods can ensure an alimentary regime with fewer risks. Even if the biomolecular details of the signal from the release of glucose at ingestion have not yet been elucidated, from the GI studies it emerges that all foods are not the same in terms of effect on the glucose load, be it for the nature of the carbohydrates or for the interactions that they establish with the food matrix. (Lal et al.2021)(Schulz & Slavin, 2021) (Hammer et al.2022)

Definition and Significance

The glycemic index (GI) is a scientific term that describes how specific quantities of carbohydrate-containing foods affect blood sugar levels. This term is significant today in the field of nutrition science for a number of reasons. The value of a food categorized by low, medium, or high GI simply distinguishes the rate at which the carbohydrate within these foods is digested and absorbed through the gastrointestinal tract into the bloodstream as glucose. It is this provision of glucose into the blood that is crucial for every living human to survive and function optimally. A growing number of studies undertaken with men, women, and children show that consuming predominantly low GI carbohydrate foods is preferable to those that contain medium or high GI carbohydrates for health outcomes such as weight control

and the prevention and management of chronic conditions, particularly type 2 diabetes mellitus and heart disease. Over the last decade, significant interest has been generated in the GI both in Australia and internationally. This is primarily due to a growing public awareness of health, greater education in consumer empowerment, an increasing understanding of the role of food, diet, and physical activity for good health, and the role of healthy lifestyle and dietary interventions for the prevention and management of chronic disease. It has been stated that the interest in GI is primarily from health professionals and consumers. Whether or not GI consumers are motivated by the belief that low GI foods will help them control their appetite and therefore weight is not known. However, low GI carbohydrate-containing mixed meals do lower the overall metabolic response, both hormonal and metabolic, following a meal, and therefore this remains an area for continued research and possible links to obesity. (Lal et al.2021)(Li & Hu, 2022)(Singh et al.2021)(Butterworth et al.2022)

Factors Influencing GI

The glycemic index (GI), a measure of the increase in blood glucose (BG) during the 2–3 hours following food ingestion, relative to the increase in BG following ingestion of a reference food, can be influenced by several factors. Intrinsic factors include the type of carbohydrate. The physical barrier caused by the food structure also influences the exchange rate of carbohydrate content with gut absorption and glycemic response, insofar as changes in the milling of grains from whole grain flour to white flour alter GI. The presence of other food constituents or ingredients, such as fiber and saturated fatty acids, can mitigate the effect of high carbohydrate content in raising the BG response. This is why the glycemic response can vary significantly among different food products within a food subgroup with similar macronutrients. (Lal et al.2021) (Atkinson et al., 2021)(Atkinson et al.2021)

Technological processes can also alter starch digestibility through extrusion, sprouting, and heat treatment, in addition to the dietary fiber content of food. For instance, extrusion of legumes led to a reduction of rapidly available carbohydrate

and BG response. Moreover, extrusion increases the slowly available glucose, which is the fraction of carbohydrate that is slowly digested and absorbed, while gelatinization of starch limits enzyme accessibility by increasing starch hindrance from protein and phytic acid; vice versa, this led to low starch index in cooked and canned legumes. The presence of protein foods changes several caloric-related parameters of the mean SSF curve of healthy subjects and the way different hormones are secreted. These results can have some impact on the propagation of the variation signal due to both hormonal interactions and daily variation in BG. In health-disease cohort populations, proteins play an anti-obesity protective role. However, results are not always reproducible given interindividual responses related to different genetics and gut microbes. (Gu et al.2023)(Pedrosa et al., 2021)(Ciudad-Mulero et al.2022)(Tas & Shah, 2021)

Amylose and Amylopectin: Structure and Function

Starch is one of the most important carbohydrates in the human diet, providing more than 70% of the total caloric energy. It is composed of two types of glucose polymers: amylose and amylopectin. Amylopectin comprises approximately 70–80% of starch in most foodstuffs.

Amylose is recognized as the primary determinant of various physical and organoleptic properties, playing a crucial role in food science. It interacts intricately with lipid inclusions, which helps stabilize gels, leading to a characteristic pastiness that many consumers expect. This interaction significantly influences the high viscosity observed in amylaceous substrates that undergo a setting process after they cool down. Notably, another critical property of amylose is its sluggish digestibility when exposed to alpha-amylase in vitro. This attribute is particularly significant for food researchers and scientists who focus on the digestion of carbohydrates because it is essential to analyze and understand amylose content specifically. This analysis is crucial since the effects of amylose extend beyond the boundaries of just the “unreadily digestible starch.” The significance of the starch content can be intrinsically linked to what is found within the amylose fraction rather than solely attributing it to amylopectin,

thereby highlighting the importance of a comprehensive analysis of these components in food research. (Obadi et al., 2023)(Krishnan et al.2021)(Bonto et al.2021)

Amylopectin, a complex carbohydrate, also engages in intricate interactions with lipid inclusions, thereby playing a significant role in contributing to the texture of various food products. However, it does not do so to the same extent as its linear counterpart, which is amylose. The unique structural properties that define amylopectin lead to a notably lower viscosity. This is primarily due to the high degree of branching present within its molecular structure, which effectively prevents the individual molecules from closely aligning and engaging with one another. This characteristic branching architecture of amylopectin not only enhances its digestibility but also results in a pronounced glycemic response. The complexity of this branching leads to an increase in the activity of the enzyme alpha-amylase. This surge in alpha-amylase activity significantly stimulates the production of maltase, an important enzyme, from the epithelial cells located within the small intestine, further illustrating the vital relationships and effects between amylopectin and digestive processes. (Giuntini et al., 2022)(Deng et al.2023)(Lin et al., 2023)

Relationship Between Amylose and Amylopectin Content and GI

This section elaborates on how the varying content of amylose and amylopectin in different foods can significantly influence the final glycemic index (GI) values that result from their ingestion into the body. In general terms, it is observed that foods which contain higher concentrations of amylose are associated with lower GI values. This phenomenon occurs because amylose takes a longer time to digest, which is primarily due to the presence of a higher quantity of linear chains. These chains form ordered crystalline regions that require specific enzymatic action by α -amylases to break them down efficiently. As these densely packed crystalline regions undergo digestion, glucose is released more gradually into the bloodstream, thus contributing to a reduction in GI values. Conversely, when foods have higher levels of amylopectin, the opposite effect is noticed. In these cases, there are generally

fewer of the more challenging crystalline regions to access, or the branching structure of amylopectin leads to more easily accessible regions in its less ordered structure. This structural characteristic allows for more rapid hydrolysis and absorption of glucose, ultimately leading to higher GI values. A variety of cereals and legumes, along with certain types of cooked and then cooled potatoes, have been thoroughly studied and shown to exhibit the expected properties in relation to their respective amylose content, further validating the relationship between starch composition and glycemic response. (Lal et al.2021)(Kumar et al.2022)(Haini et al., 2022)(Sagili et al.2022)

It is crucial to acknowledge that various chemical and physical characteristics within the food matrix can significantly influence the digestion rates of amylose and amylopectin within digestion systems. Additionally, it is noteworthy that empirical studies have adopted ratios other than the standard 100 grams of available carbohydrates per serving when examining a wide range of food products, which may lead to challenges in making valid comparisons across different studies. Nonetheless, there is compelling evidence that clearly indicates the significant influence these starch components have on actual glycemic index (GI) values, particularly since the matrix effect can be effectively minimized during the digestive process. As a result, the integration of both in vitro and in vivo studies can greatly assist in elucidating the GI of various foods that possess different structural characteristics. For instance, the starch derived from the kernel tissues of cereal grains such as triticale, barley, and oat, which is notably enriched in amylose content, has been shown to produce a more favorable glycemic response compared to the lower amylose content found in the tissues that were investigated, such as kernel, endosperm, husk, or fruit coat. The understanding of a food's susceptibility to digestion and absorption, along with its true GI value, stands out as both a significant highlight and a formidable challenge when addressing these specific components. While it is not the primary aim of this work to correlate these aspects, establishing a connection between food structure and nutritional application remains an essential focus. In this regard, the ratio of amylose to amylopectin and the high molecular structure, characterized

by either long-chain formation or cluster arrangement, may contribute to amplifying the resistant starch feature within daily dietary recommendations. This is particularly important for mitigating excessive glucose absorption and regulating bile acid homeostasis. The mechanisms at play here can be further clarified through a comprehensive understanding of glycemic food-based properties, including the GI value, which is vital for informed dietary choices. (Lal et al.2021) (Kumar et al.2022)(Kunyanee & Luangsakul, 2022)(Sagili et al.2022)(Pereira et al.2023)

Methods for Measuring GI

The current standard methods for glycemic index (GI) measurement are internationally accepted. In these tests, glucose is usually used as the reference food, and the capillary method is preferred for blood glucose analysis with several samples collected over 120–180 minutes. The area under the curve (AUC) is calculated as this gives the best measure of total blood glucose concentrations after a meal. By mathematical calculation, the AUCs are then related back to the AUC for the standard food to calculate the GI value. Several important considerations are essential when measuring GI, such as the number of subjects to be included, as this can affect the accuracy of the study as well as the characteristics of the population to which the results can be generalized or from which individual baseline data are obtained, such as fasting plasma glucose concentrations and waist and hip measurements. Any inappropriate meal formulation, even by a small amount, will mean a higher variability in the results. (Zhang et al., 2021)(Selvi et al.2021) (Poudineh et al.2021)(Sempionatto et al., 2021)

It is often quoted that laboratories can get a 20% variation in GI results when measuring the same foods, although the actual difference may be lower, with some reported mean difference of less than 15%. As such, the use of GI data in nutrition research and in national food control measures, most probably based on the results of methods in which the quality characteristics are not defined and there is no guarantee of training and resources available for such methods, is questionable. Such approaches will mean that the

benefits of low glycemic diets on lowering some physiological markers of chronic disease risk may not be realized. The other approach based on a guaranteed standard method and reproducibility is necessary, therefore, to move the current standards and to provide clear links between carbohydrate and other metabolizable energy to health research. A critical evaluation of the current methods used for GI measurement reveals several ways that GI-focused nutrition research has not progressed. Methodological problematic issues generally arise from three critical points: the difficulties in ensuring that study subjects have fasted for the exact length of time, so the fasting blood glucose measurement is at the level for a determined individual to ensure that a normal postprandial response has occurred prior to the test breakfast; the inability to ensure that the whole of the test meal is eaten by the study subjects; and the difficulty of carrying out multiple GI tests within an individual. Consequently, estimates of the GI of foods can be surprisingly fallible. Even when subjects consume carbohydrate meals of identical age and variety, interindividual variability can be high and reaches up to 10 equivalent test meal rating scale units. In addition, within those individuals who participate in a study, intraindividual variation on consecutive days is up to five equivalent test meal rating scale units. One of the reasons for the lack of reproducibility is that care in the provision of food parcels could routinely lead to more uniform glucose concentrations and thus reduced variation. Nevertheless, the implication is that a single figure for GI and even a calculated GL for a food would only be an average value and may misrepresent the general response. It is critical to know the variability in a study population prior to analyzing the results, as this variability will add to the variation associated with the glycemic response caused by physiological parameters. These results suggest that GI is not reproducible. Given the general high variability regardless of the type of carbohydrate, researchers have focused on measuring these responses and understanding the relative responses within the same subject to identify distinct glucose responses, not simply AUCs to report as GI. (Edlow & Pronovost, 2023)(Shi et al., 2022) (Ricardo-Rodrigues et al.2023)

Case Studies and Examples

One interesting case example is to compare two types of rice: white rice and parboiled rice. What is parboiled rice and why compare parboiled rice with white rice? Rice kernels are composed of three layers: the bran, germ, and endosperm. Parboiled rice is produced by partially boiling, soaking, steaming, and drying the rice kernels prior to milling. The parboiling process gelatinizes part of the starch within the rice kernels and causes the migration of the loosened nutrients present in the bran to the endosperm. Knowledge about food processing, starch in rice, and obtained glycemic index (GI) values can also be found in publications. The GI of parboiled rice is lower compared to that of white rice. Recently, glycemic index values for 13 different types of white rice with different tastes were also compared. The results were interesting and were discussed in a study that also compared three different types of rice with steady hardness, namely long grain, medium grain, and short grain rice. They found that all of them exhibited similar GI despite different amylose content. (Muchlisyyah et al.2023)(Iqbal et al., 2021)(Sivakamasundari et al.2022)(Zhang et al.2022)

The purpose of this specific section is to effectively illustrate several important concepts that are presented throughout this comprehensive review. The particular case examples that are thoroughly discussed in this segment will provide detailed and valuable information on how the intuitions and insights obtained from the theoretical frameworks are crystallized and manifested when studying various real-world food products. A total of six studies are outlined and shown to be integral and essential for achieving this illustrative purpose. In particular, both students and professionals who are engaged in the applied sciences will significantly gain from the information presented in this dedicated section. The cases will be examined systematically, both in alphabetical order to provide clarity and in descending order of the glycemic index (GI), which is vital because this index reflects the postprandial blood glucose changes that occur after the consumption of various food items. The glycemic index itself is not only an application of a crucial physiological concept but also serves

as an important aid in maintaining euglycemia. (Lal et al.2021)
(Chiavaroli et al.2021)(Papakonstantinou et al.2022)

Conclusion

Amylose and amylopectin are the two main forms of starch consumed in the diet. Both of these types of starch have been shown to affect blood glucose levels and therefore meal-based glycaemic index. With these key differences between the two forms of starch more fully understood, particularly the delayed release of glucose from digestion of amylose-rich starch, it is becoming increasingly clear that current methods of assessing meal-based glycaemic index are insufficient. It seems timely, therefore, to further explore the effects of amylose and amylopectin on glycaemic index and health outcomes, including the relative amounts of these starches that occur and predominate in many foods. In conclusion, it is apparent that both amylose and amylopectin play dynamic and specific roles in determining food glycaemic index. With our understanding of the factors influencing food glycaemic index and the potential physiological effects of consuming low glycaemic index foods, as well as an increasingly discerning lay public, understanding the structure of available starch and, in particular, the amylopectin to amylose ratio becomes even more crucial. A greater understanding of the kinetics of glucose absorption and the potential further parameters that determine blood glucose response is strongly needed. In terms of the effect of different amylase ratios, there are still only a limited number of studies to highlight this effect and more research is needed.

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