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Glycemic Index of Food Crops: Implications for Human Health, Crop Improvement and Sustainable Nutrition

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***Abstract*--** **The glycemic index (GI) is a physiological classification framework which ranks carbohydrate-containing foods in their postprandial blood glucose reaction in contrast to a reference food(Jenkins et al.,1981(1)). Cereals, pulses and starchy roots and tubers, which provide most of the body's carbohydrate intake in the global diet, represent a highly important subject of study in the context of the rising global rate of metabolic diseases (FAO,2020 (6)). This is a critical review of available published material on the glycemic index of food crops and major food crops, the standardized procedures of GI determination, and the intrinsic and extrinsic factors that regulate the variability of GI. GI comparisons are done through the use of figures to support comparative discussions of cereals, pulses, and tubers (Atkinson et al.,2021 (4)). The consequences of low- and high-GI diets on the metabolic health condition, such as diabetes, cardiovascular disease, and obesity are critically reviewed (Brand-Miller et al.,2009 (2);Augustin et al., 2015(3)). Moreover, crop improvement opportunities and food processing solutions with the objective of enhancing the quality of carbohydrates and sustainable nutrition is discussed(Henry and kaur,2016 (27)).**

***Keywords*--** **Glycemic index; cereals; pulses; tubers; carbohydrate quality; metabolic health; sustainable nutrition.(Jenkins et al., 1981 [1]; Augustin et al., 2015 [3]; FAO, 2020 [6]).**

I. Introduction

The world is based on carbohydrate-rich food crops as they supply over 50-60 percent of the total caloric consumption per day worldwide ((FAO, 2020 [6]). The major foodstuffs in both the developed and developing countries are cereals, pulses and starchy root and tubers as staple food (FAO/WHO, 1998 [31]). Though originally listed as one macronutrient group, carbohydrates vary significantly in their rate of digestion, rate of absorption and their metabolic effects (Englyst et al., 1992 [18]; Henry and Lightowler, 2002 [22]).

The differences have gained even greater topicality in the face of the increasing prevalence of obesity, type 2 diabetes mellitus, cardiovascular disease, and other noncommunicable diseases dependant on dietary factors (Drewnowski and Popkin, 1997 [24]; Ludwig, 2002 [16]).

Jenkins et al. (1981) were the pioneers in introducing the idea of the glycemic index (GI) (1). As a physiological foundation of the ranking of carbohydrate sources of food based on their capacity to elevate the postprandial glycogen levels in the blood. GI uses the incremental area under the response curve of blood glucose of test food with a set level of available carbohydrate and compares it to that of a reference food, typically glucose or white bread (Wolever, 2006 [7]). GI has now become a common instrument in nutritional epidemiology, clinical nutrition, and the development of dietary guidelines since its debut(Brouns et al., 2005 [9]).

High-GI foods are quickly absorbed and digested increasing blood glucose levels and insulin levels drastically. Long-term intake of high-GI diets has been linked to insulin resistance, pancreatic b-cell stress, dyslipidemia, as well as the risk of developing type 2 diabetes and cardiovascular disease (Brand-Miller et al., 2009 [2]; Willett et al., 2002 [11]). Conversely, low-GI foods lead to slower and more prolonged glucose release, which leads to better glycemic control, increased insulin sensitivity, longer satiety, and decreased postprandial oxidative stress (Augustin et al., 2015 (3)). Considering that staple food crops play a major role in the global catacombs, it is important to understand the GI traits of cereals, pulses, and tubers in order to enhance the quality of the diet and subsequent health conditions of the population(Barclay et al., 2008 [13]). The review will (i) provide a summary of standardized methods of determining GI, (ii) critically review GI values of major food crops, (iii) propose important factors that affect variability of GI and (iv) discuss implications of GI on human health, crop improvement and sustainable food systems.

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The glycemic index (GI) can be explained as the change in area under the blood glucose response curve (iAUC) following ingestion of a test food that has 50g of available carbohydrates relative to the change in area under the blood glucose response curve (iAUC) following ingestion of the same amount of carbohydrates in a reference food (Jenkins et al., 1981(1)).

GI classification:

- Low GI: ≤ 55
- Medium GI: 56–69
- High GI: ≥ 70(Foster-Powell et al., 2002 [8]).

II. Methodology For Determination Of Glycemic Index

GI is measured through standardized in vivo in human subjects. The methodology is most commonly accepted according to ISO 26642:2010 (Brouns et al., 2005 [9]). Healthy volunteers in these protocols intake test foods with 50g of available carbohydrate after an overnight fast. In order to determine blood glucose levels, they are tested at baseline and periodically, usually during the twohour postprandial interval.(Atkinson et al., 2021 [4]). The incremental area under the curve (iAUC) is estimated using the trapezoidal rule and has been stated against the reference food (Foster-Powell et al., 2002 [8]).

Although standardized, the values of GI can differ between studies because the studies have different subject features (age, metabolic health, insulin sensitivity), food preparation, and cooking duration, particles size, and methods of analysis (Henry and Lightowler, 2002 [22]).

Also, inter-individual difference in glycemic response has been noted to be on the increase. In result, GI values can be discussed as some indicators of the carbohydrates quality instead of a constant (Livesey et al., 2008 [10]). GI tables on an international scale, like those compiled by are averages of various studies and are regularly utilized in research and diet planning(Atkinson et al., 2021 [4]. Much of the GI related literature on food crops is based on these tables.

III. Glycemic Index Of Major Food Crops

A Cereals and Cereal-Based Products

Cereals, including rice, wheat, maize, barley, and oats, are the most widely consumed staple foods globally(FAO, 2020 [6]). The GI of cereal-based foods varies widely depending on grain type, starch composition, degree of processing, and cooking method (Ragaee & Abdel-Aal, 2006 [26]). Refined cereal products, such as white bread and polished white rice, typically exhibit high GI values due to the removal of fiber-rich bran and germ fractions, resulting in increased starch accessibility to digestive enzymes(Atkinson et al., 2021 [4]). Whole-grain cereals generally exhibit lower GI values owing to higher dietary fiber content, intact cellular structures, and a higher proportion of amylose relative to amylopectin(Seal & Brownlee, 2015 [34]). Among rice varieties, long-grain and parboiled rice, such as basmati rice, show significantly lower GI values compared to short-grain or sticky rice varieties(Jenkins et al., 1981 [1]; BrandMiller et al., 2009 [2]). Similarly, intact kernels and minimally processed cereal products tend to elicit lower glycemic responses than finely milled flours.

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TABLE I
GLYCEMIC INDEX OF COMCEREAL PRODUCTS. REFINED CEREALS SUCH AS WHITE RICE AND WHITE BREAD EXHIBIT HIGHER GI VALUES THAN WHOLE-GRAIN AND MINIMALLY PROCESSED CEREALS DUE TO ENHANCED STARCH DIGESTIBILITY.

Food item	Processing	GI (mean range)
White rice	Polished, boiled	70–90
Brown rice	Whole grain, boiled	60–85
Basmati rice	Long-grain, boiled	50–60
White wheat bread	Refined flour	70–85
Whole wheat bread	Whole grain	55–70
Maize (corn)	Boiled kernels	50–65
Oats	Rolled/steel-cut	50–60

B Pulses and Legumes

Pulses, including lentils, chickpeas, peas, and common beans, are consistently classified as low-GI foods(Singh et al., 2021 [5]). Their favorable glycemic profile is attributed to a combination of high dietary fiber content, resistant starch, protein, and the presence of intact cell walls that slow enzymatic hydrolysis and glucose absorption(Tiwari et al., 2011 [30]).

Numerous intervention and epidemiological studies have demonstrated that regular pulse consumption improves postprandial glycemic control, reduces insulin demand, and lowers the risk of type 2 diabetes and cardiovascular disease. Pulses also contribute to improved satiety and weight management, further enhancing their role in metabolic health (Augustin et al., 2015 [3]; Ojo et al., 2018 [29]).

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TABLE II
GLYCEMIC INDEX OF PULSE CROPS. PULSES CONSISTENTLY DEMONSTRATE LOW GI VALUES DUE TO THEIR HIGH FIBER, PROTEIN, AND RESISTANT STARCH CONTENT.

Pulse type	GI (mean range)
Lentils	20–40
Chickpeas	25–45
Common beans	20–60
Peas	35–55
Cowpeas	30–55

C Roots, Tubers, and Starchy Crops

Roots and tubers, such as potato, cassava, yam, taro, and sweet potato, serve as major energy sources in many tropical and subtropical regions(FAO/WHO, 1998 [31]). These crops often exhibit moderate to high GI values, particularly when cooked using methods that promote starch gelatinization, such as boiling, baking, or mashing(Brand-Miller et al., 2009 [2]). However, substantial variability exists among tuber species and cultivars. Cooking methods, cooling after cooking, and processing techniques that promote starch retrogradation can significantly reduce GI by increasing resistant starch content. For example, cooled boiled potatoes exhibit lower GI values compared to freshly cooked potatoes.(Nugent, 2005 [19]; Sajilata et al., 2006 [20]).

TABLE III
GLYCEMIC INDEX OF ROOTS AND TUBERS. POTATOES AND CASSAVA GENERALLY EXHIBIT HIGHER GI VALUES COMPARED TO YAMS AND TARO, DEPENDING ON PROCESSING AND PREPARATION.

Crop	Processi	GI (mean range)
Potato	Boiled/mas	70–95
Sweet po	Boiled	50–70
Cassav	Boiled	65–85
Yam	Boiled	50–70
Taro	Boiled	45–65

IV. FACTORS INFLUENCING THE GLYCEMIC INDEX OF FOOD CROPS

A complex interplay of intrinsic and extrinsic factors controls the GI of the food crops. Among intrinsic factors are the starch content and especially amylose to amylopectin ratio, amount of the dietary fiber, protein matrix, lipids content, and physical structure of the meal(Bjorck et al., 1994 [17]; Englyst et al., 1992 [18]). Foods that have greater amounts of amylase and that retain the cellular structure will have lower GI values. Extrinsic ones are food processing, milling, reduction of particles, cooking mechanism, and meal composition(Henry and Lightowler, 2002 [22]). Fat, protein and organic acid can respectively delay gastric emptying and inhibit postprandial glycemic responses (Jenkins et al., 2000 [23]). These considerations will put into perspective why it is so important to look beyond the carbohydrate content when determining the quality of the food and not to consider solely the food structure and how it is prepared.

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V. Health Implications Of Glycemic Index

There is an increasing amount of literature in favor of low-GI diets to enhance the metabolic health. Diets of low-GI are linked with enhanced glycemic control among patients with diabetes, less insulin resistance, better lipid profiles, and fewer risks of cardiovascular disease(Brand-Miller et al., 2009 [2]; Barclay et al., 2008 [13]). It has also been found that low-GI diets can also be associated with a better satiety and control of the body weight(Slavin, 2005 [15]). Making them applicable to obesity prevention and control. Conversely, high-GI foods could increase postprandial hyperglycemia, oxidative stress, and inflammation that leads to the occurring of chronic metabolic diseases(Ludwig, 2002 [16]; Aston, 2006 [14]). In this regard, GI has been incorporated as a significant instrument in nutrition education and in medical nutrition therapy.

VI. Applications In Crop Improvement And Food Processing

Another viable approach in the reduction of dietary GI at the source involves crop improvement strategies that aim at improving the quality of carbohydrates. Increasing the amylose and dietary fiber, resistant-starch levels of the cereals and tubers through breeding strategies has demonstrated a promise of reducing GI without reducing yields (Behall et al., 2006 [21]; Kumar et al., 2018 [32]). GI may be further modulated by food processing technologies, such as parboiling, fermentation, germination, and minimal refining, without affecting sensory quality(Henry and Kaur, 2016 [27]; Tiwari et al., 2011 [30]). The implementation of GI factors into crop breeding and food processing pipelines can become an important source of sustainable nutrition and population health.

VII. Future Perspectives

Future studies need to focus on uniform GI measurement of region-specific food, incorporation of glycemic load theory, and creation of functional foods, depending on highly metabolically vulnerable population groups(Augustin et al., 2015 [3]). Novelties in the genomics of crops, biotechnology, and food processing provide new possibilities to maximize the quality of carbohydrates and decrease the prevalence of diet-related diseases across the globe (Monteiro et al., 2018 [25]; Saleh et al., 2013 [33]).

VIII. Conclusion

Glycemic index of food crops is highly variable, using the type of crop, the cultivar and the method of food processing (Atkinson et al., 2021 [4]). Whole grains and pulses are always low-GI foods, and refined cereals and most of the tubers are all high-GI foods(Singh et al., 2021 [5]; Brand-Miller et al., 2009 [2]). The innovations that may be instrumental to the enhancement of low-GI diets, metabolic health, and sustainable food systems include strategic crop selection, breeding, and processing (FAO, 2020 [6]; Henry and Kaur, 2016 [27]).

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