

Assessment of the Glycemic Index and Glycemic Load of Selected Plant-Based Functional Foods

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Abstract

Background: The glycemic index (GI) is a tool to examine the postprandial glycemic response of ingested carbohydrates. Glycemic index valuation includes ingesting food containing 50 grams of digestible carbohydrates to healthy individuals and measuring their blood glucose levels on fasting and then every 30 minutes for two hours. This study was designed to examine the glycemic index and glycemic load of plant-based functional foods. **Methods:** healthy volunteers aged 22-29-year old who fasting for approximately 10-12 hrs. examined their fasting blood glucose then ingested the sample containing 50 grams of digestible carbohydrates along with one cup of water within 10 minutes then examining their blood glucose very 30 minutes on two hours intervals using blood glucometer tool. Pure glucose and white bread were used as a standard in Glycemic index and glycemic load equations. **Results:** Ceylon and cassia cinnamon, Ziziphus spina-christi and Oak have shown the highest glycemic index, GI =64.26, 25.16, 23.39 and 21.63, respectively. While Cordia myxa and Walnut have shown low glycemic index 16.66 and 13.94, respectively. The study stated that walnuts, Cordia myxa, and Oak are optimal for individuals seeking to regulate their blood glucose levels; however, high-glycemic load foods such as Ceylon cinnamon should be limited

Key words **Cordia myxa , Ziziphus spina-christi, functional food, glycemic index, glycemic load**

Introduction

Glycemic index (GI) and glycemic load (GL) are valuable metrics for assessing dietary patterns in both healthy and diabetic patients since diabetes management is heavily impacted by carbohydrate consumption and the quality of meals that affect postprandial blood glucose [1]. GI is

frequently taken into account when evaluating the quantity and quality of carbohydrates, along with characteristics like dietary fiber content, liquid-to-solid ratio, starch-to-sugar ratio, and added sugars, all of which might alter the glycemic response following food consumption [2].

While GL represents both the glycemic quality of the food and the quantity of accessible carbohydrates in a serving, GI is used to measure the impact of foods high in carbohydrates on blood glucose levels following consumption [3]. This is because the dietary GI and GL have been implicated in various chronic diseases such as cancer, polycystic ovarian syndrome, and gestational diabetes mellitus [4]; [5]; [3, 6]. Nonetheless, little is known about the local contributions of fruits and spices to postprandial glucose response, especially those that vary in the carbohydrate composition, fiber content, and bioaccessibility [7, 8]. Here, fruits are especially important in that they possess different amounts of hexose and disaccharide sugar and hence can lead to rapid elevation in blood glucose, depending on their composition and structure [9-11]. On the other hand, some of the fruits have fibers that slow down the process of digestion, increase the rate of intestine motility and therefore assist in glycemic regulation [12]. Therefore, it cannot be assumed from the general nutritional or therapeutic value of fruits that their effect on postprandial glucose will be similar [7, 8]. The GI index, which was developed by Jenkins et al., categorizes foods that contain carbohydrates based on their influence on postprandial blood glucose level [13]. The GI is calculated as the incremental area under the curve (IAUC) after eating the test food over a period of two hours compared to the IAUC of the standard reference food with 50 grams of available carbohydrate [14]. GL is determined as the product of the GI index and amount of available carbohydrate in a serving, while the foods

Material and Methods

Fresh Samples Preparation

are classified into three categories, i.e., low, medium, and high GL depending on the carbohydrate load [15]. This way, the GI and GL indices are essential in discerning foods that show significant differences in metabolism, for example, those with high GI and low GL or high GI and high GL depending on the portion size [13]. Consumption of high GL diets for a long time increases the risk of developing type 2 diabetes and metabolic disease [16]. In the current study, the selected fruits and spices have been screened out for their suitability in terms of postprandial glycemic response due to their constituent composition. *Cordia myxa* is a sweet fruit which contains sucrose, glucose, and dietary fiber, and this makes it potentially interesting in terms of the nature of glycemic response and nutrition [12]. *Ziziphus spina* possesses many biological activities. However, in this case, this fruit was used because of the interest in the glycemic effect in this fruit and not because of its biological activity in general [17]. Cinnamon is a spice which is very well known in terms of its sensory quality and the bioactive components of this plant [18, 19]. In this case, walnuts contain phenolic acids, tannins, flavonoids, vitamins, minerals, and fatty acids, thus making them potentially interesting in terms of nutrition and the glycemic response of mixed foods [20-22]. Similarly, the oak species contain bioactive components such as phenols, lipids, peptides, and polysaccharides [23, 24]. Thus, the objective of the current study is to investigate the glycemic index and glycemic load of selected plant-based functional foods in healthy volunteers.

Local *Cordia myxa* collected from Al Jamaa Neighborhood in Baghdad city, Iraq. The Iraqi National Jamaa Neighborhood in

Baghdad city, Iraq. The Iraqi National Herbarium, Baghdad, Iraq, identified the fruit with certificate no.1743 on 18 March 2025 [25]. Only undamaged fruit were collected, Washed one times with tap water and once with distilled water. The fruits' seeds were extracted by pressing them [26]. The fruits were then allowed to dry in the room temperature for two weeks to dry. BALDR digital mini hygrometer & indoor thermometer was used to check the temperature and humidity in the shade. The average was 40 °C with 25% relative humidity. Finally, Hamilton electric grinder was used to grind the dried fruit into powder [26]. local *Ziziphus spina-christi* L. was also collected from Al Jamaa Neighborhood in Baghdad city, Iraq. Washed with tap water and distilled water two times. Fresh peel and pulp were separated from the seeds [27]. Fruits then left to dry in room temperature for 10 days. A was used to check the temperature and humidity in the shade. The average was 40 °C with 25% relative humidity. Finally, Hamilton electric grinder was used to grind the dried fruit into powder

[26]. A portion of the dry sample was sent to the laboratory for analysis of its chemical composition, while the rest of the amount was stored in a polyethylene bag in the refrigerator for subsequent experimentation.

Dry Samples Preparation

Cinnamon was from local store in Erbil city. Grind to powder and sent to the laboratory for analysis of its chemical composition, while the rest of the amount was stored in a polyethylene bag in the refrigerator for subsequent experimentation. Oak conversely was obtained from Hawraman city, Kurdistan, Iraq. Oak was dried by oven at temperature of 50±5°C for 16-18 h and stored at 4°C until analysis [28]

Standards Bread preparation

White bread was produced in accordance with Iraqi Standard Specifications #677 established in 1981. The standardized quantity of white bread is presented in Table (1) were manually combined to achieve a uniform dough. It was kept to be fermented in temperature (25°C ± 2°C). It was roasted in an electric oven at a temperature of (230± 10 °C) for 3-5 minutes.

Table1 Shows standard bread dough ingredients

Constituents	Amount in grams
Flour	100
Yeast	1
Salt	1
Sugar	0.5
Water	60-65 ml on 30 °C

The chemical tests have been conducted in the Central Laboratory of the College of Agriculture and Forestry of the University of Mosul. The determination of proximate composition of moisture, fat, protein, ash, and crude fiber has been done using standard methods as outlined in [29]. Methodological descriptions have been given briefly here as proximate determination is a relatively straightforward procedure. The moisture content of samples

Chemical determinations

has been determined using Brabender rapid moisture tester at 105°C to constant weight. The fat content has been determined through Soxhlet extraction using petroleum ether. The protein content has been determined using micro-Kjeldahl method with 5.7 conversion factor. The ash content has been estimated through incineration in a muffle furnace at 550°C to constant weight. Crude fiber content has been estimated through acid-base hydrolysis using the standard cited method [12, 30]. The carbohydrate content has been estimated as a difference (100 – [moisture + ash + fat + protein + crude fiber]).

Determination of glycemic index

This study used Jenkins et al. (1981) methodology to examine the glycemic index of each samples in the study, the samples were measured upon available carbohydrate in each sample and using the formula below to calculate 50 grams of carb available in each sample for each participant. The study involved 39 healthy volunteer subjects, comprising undergraduate and postgraduate students from Hawler Medical University,

College of Health Sciences and Cihan University, College of Health Technology. The volunteers' ages ranged from 22 to 32 years, whose Body Mass Index (BMI) between 22 and 30 kg/m² and they were in good health, free from chronic disorders, such as diabetes. The participants were organized into groups, three individuals each, six of them were assign to examine glucose and white bread, three volunteers each sample [31]. Blood samples collected from finger prick capillary for each participant using Contour Plus Glucometer and blood glucose test strips by Contour Plus. The glycemic index examination was done early morning following a fasting night between 10- 12 hours. Each sample for the study was made to include 50 g of available carbohydrates as it is shown in table2. Each sample was consumed within 10 minutes along with a cup of water. Fasting blood glucose was measured and at intervals of 30, 60, 90, and 120 minutes after the consumption of the each sample.

$$\text{Weight of test food (g)} = \frac{\text{Desired available carbohydrate}}{\% \text{available carbohydrate}} \dots\dots\dots [2]$$

Table2. Amount of tested samples that contains 50 gram of available carbohydrate

sample	carbohydrate%	gram of sample required
flour	71.02	70.4
Walnut	18.49	270.42
cinnamon Ceylon	73.49	68.04
cinnamon cassia	75.54	66.19
Aok	70.69	70.73
Ziziphus spina-christi L.	81.85	61.09
Cordia myxa	78.29	63.87

Blood glucose response (BGR)

Glucose concentration levels were determined over a two hour period following the ingestion of a meal and IAUC was determined in relation to the reference

curves for glucose and white bread. Values for IAUC were determined in Microsoft Excel using the trapezoidal method, and these were then used to determine the GI and GL based on the postprandial response caused by the test food and compared

against the responses of the glucose and white bread as control [31].

The equation below was used to calculated GI:

$$GI = (IAUC \text{ tested sample} / IAUC \text{ reference food}) \times 100$$

$$GL = GI \times \text{Available Carbs (g)} / 100$$

Statistical analysis

Results

Chemical compositions analysis

As it is shown in table3. the results of the chemical composition analysis revealed a marked disparity between all analyzed samples for all parameters under study ($p \leq 0.05$). For example, walnut was found to have the highest content of dry matter (95.36%), fats (56.9%) and proteins (18.68%). This indicates its densest and

The analysis was done through the use of analysis of variance (ANOVA) in a randomized complete block design (RCBD), where the GENSTAT statistical analysis computer program (version 12) was used. The subject acted as the blocking factor to account for individual variations among the subjects in terms of their glycemic response. Means of the treatment groups were compared using Fisher's LSD test at $\alpha = 0.05$ (Steel and Torrie, 1980).

richer composition compared to others due to the highest percentage of lipids and proteins. In turn, Ceylon cinnamon and cassia cinnamon had the highest fiber content (37.45%) and 38.50%, correspondingly). It is essential to note that higher amounts of fiber can slow down carbohydrate availability and lead to lower glycemic response. Ziziphus spina-christi has the highest amount of carbohydrates (81.84%).

Table3. shows the chemical composition of tested samples

Fiber%	Carb%	Protein%	Fat%	Ash %	Humidity%	Dry sample%	Sample type
10.76c	71.02e	11.32b	2.7c	0.43e	14.53a	85.47f	Flour
14.97c	18.49f	18.68a	56.9a	1.3c	4.63e	95.36a	Walnut
37.45a	73.49d	7.66d	1.85e	5.97a	11.03b	88.97e	Cinnamon Ceylon
38.5a	75.53c	7.66d	1.3f	4.33b	11.18b	88.81e	Cinnamon casia
17.58bc	70.69e	8.88c	8.22b	1.85c	10.36c	89.64d	Oak
17.54bc	81.84a	6.43d	1.28g	1.5c	8.96d	91.04b	Ziziphus-spina-christi
19.25b	78.28b	5.21e	1.93d	4.63a	9.96c	90.04c	Cordia myxa

Values are presented as mean $\pm$ SD ($n=3$). Different superscript letters within the same column indicate significant differences among means at $p \leq 0.05$, while means sharing the same letter are not significantly different

Samples impact on Blood glucose

Following 10 to 12 hours of fasting, test samples were fed to the subjects, wherein 50

grams of carbohydrates was obtained from each sample. Postprandial glucose responses varied with each treatment within the 120-minute measurement period in table4. The *Cordia myxa* and *Ziziphus spina-christi* recorded low levels of glucose readings after

120 minutes than the initial levels after ingestion, whereas the cinnamon cassia and cinnamon ceylon exhibited reduced glucose level after 120 minutes. In the same manner, walnut and oak exhibited lesser variations in terms of decreased glucose level.

Table4.resents the mean blood glucose response of participants at different time points after consuming each sample.

120min	90min	60min	30min	FB	Treatment
76.67 d	87.3 b	115.3 a	133.3 a	91.67 a	Glucose
126 a	122 a	118.7 a	124.7 ab	95 a	Bread
91.33 b	93.7 b	101.7 ab	98.3 bc	92 a	<i>Cordia myxa</i>
85.67 bc	91.3 b	94.3 bc	121.3 ab	93 a	<i>Ziziphus-spina-christi</i>
82 cd	71.3c	93 bc	144 a	92.33 a	Cinnamon cassia
86.33 bc	95 b	114.7a	143 a	94 a	Cinnamon Ceylon
92 b	88 b	83.5 c	90c	102.5 a	Walnut
88.33 bc	95.7 b	104.3 ab	109.7 b	94.67 a	Oak
7.891	16.28	15.24	24.24	NS	L.S.D 0.05
4.9	10	8.4	11.5	3.9	C.V

Note: Means sharing the same letter within a column are not significantly different. Different letters indicate significant differences at the stated probability level ($p \leq 0.05$). A numerical LSD value indicates that differences larger than this value are statistically significant.

Glycemic index and glycemic loading response

These compositional differences were evaluated to aid the interpretation of the glycemic index results since foods with high amounts of fiber, fat, and protein are usually expected to yield a lower glycemic response than foods containing more carbohydrates. Table5. Shows *Cordia myxa*, *Ziziphus*

spina-christi, Oak and Cinnamon casia and exhibit considerable glycemic indices reduction in glycemic index compared to glucose 16.66, 23.39, 21.6, 25.16 and, respectively. Nonetheless, this study did not yield significant results regarding Ceylon cinnamon; it demonstrated a non-significant reduction in glycemic index compared to glucose 64.26.

Table5. glycemic Index, Glycemic Load and IAUC of the samples

Glg and GLg glycemic index and glycemic load, respectively, compared glucose to samples.

Glb and GLb glycemic index and glycemic load, respectively, compared white bread to samples.

GLb	Gib	GLg	Glg	IAUC mg/dl/min	Blood glucose response mg/dl					Food type
					Time/min					
					120	90	60	30	0	
			100	3120	106	116	112	138	90	Standard glucose
			70.673	2205	115	90	111	109	84	White bread
21.696	8.3333	23.583	16.667	520	91.333	93.667	101.67	98.33	92	Cordia myxa
30.789	11.699	33.107	23.397	730	85.667	91.333	94.333	121.333	93	Ziziphus- spina-christi
32.872	12.58	35.601	25.16	785	82	71.333	93	144	92.333	Cinnamon casia
85.474	32.131	90.93	64.263	2005	86.333	95	114.67	143	94	Cinnamon Ceylon
-17.56	-6971	19.73	13.94	-435	88	84	79	90	89	Walnut
28.98	10.817	30.612	21.635	675	88.333	95.667	104.33	109.67	94.667	Oak

The Incremental Area Under the Curve (IAUC)

Figure1. demonstrated that Walnut, *Cordia myxa*, Oak and *Ziziphus spina-christi* have shown a significant reduction in the IAUC (-435, 520, 675 and 730) respectively.

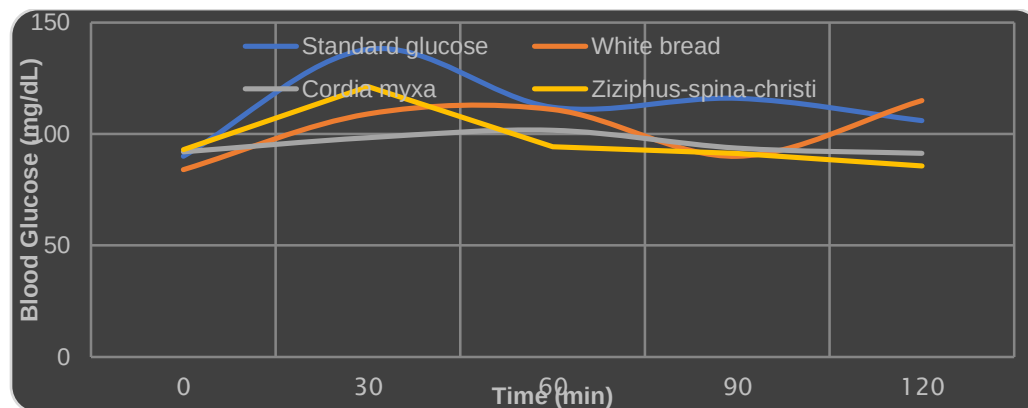


Figure 1. Blood glucose response, glycemic index and glycemic load of fresh fruits

Figure2. a notable IAUC reduction was found in walnut were (-435), followed by oak which shown a significant reduction in the IAUC (675). Nonetheless, this study determined no significant reduction in the daily postprandial glucose incremental area under the curve (IAUC) regarding Ceylon cinnamon when compared to standard glucose, with glycemic index value of 2005.

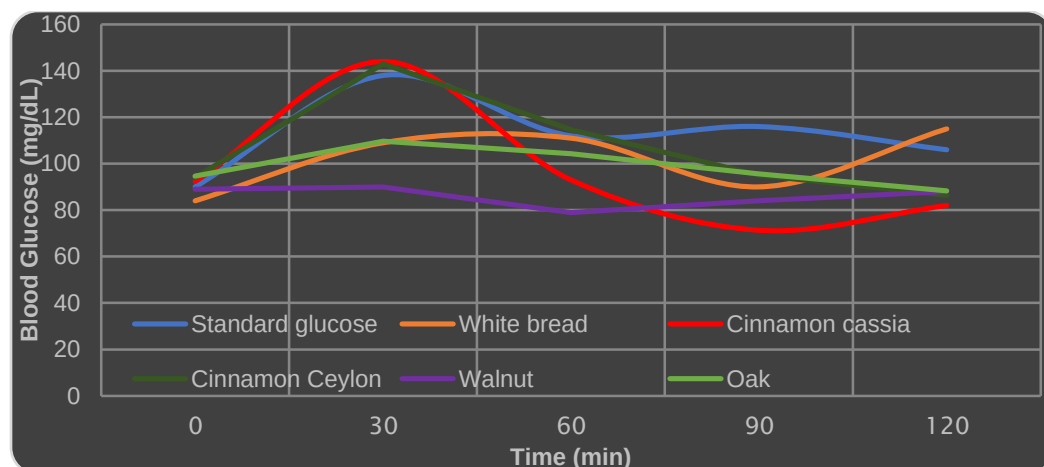


Figure 2. Blood glucose response, glycemic index and glycemic load of dry samples

Discussion

The current study shows that the postprandial glycemic response of the samples used cannot be predicted solely based on carbohydrate percentage. Some samples containing high amounts of carbohydrate showed lower values of GI, GL and IAUC than the glucose and white bread as control, suggesting that the physiological effect of carbohydrate depends on the matrix in which it is incorporated. This hypothesis correlates with modern knowledge about food-matrix effect and indicates that not only the amount of carbohydrate in a meal is responsible for glycemic response of an individual, but also food matrix, fiber structure and interactions among macromolecules affecting digestibility and release of glucose [32-34]. Hence, in the current experiment, the most important finding is the disconnection between carbohydrate concentration and postprandial glycemic response. This disconnection can be best seen when comparing white bread with such botanical samples as *Ziziphus spina-christi*, *Cordia myxa*, *Cinnamomum cassia* and *Cinnamomum ceylon*. Despite the fact that white bread had a lower carbohydrate percentage than these samples, it caused the

greatest glycemic response and showed the highest IAUC and GI values. Based on the current results, this indicates that carbohydrates of the white bread were more rapidly available for digestion and absorption than the carbohydrates of plant samples. Previous studies on glycemic response show that refined starch-based foods are associated with faster glucose release because of lower resistance to digestion provided by its structure than a complex plant matrix [32, 33, 35]. Therefore, current results confirm the disconnection between carbohydrate percentage and postprandial glucose response. Among the plant samples analyzed, *Cordia myxa* revealed one of the lowest values of postprandial glycemic response in spite of its high carbohydrate content. In the current study, this sample showed low GI, low IAUC and only moderate elevation of glucose in blood, differentiating it significantly from glucose and the white bread control. The most probable explanation is that relatively high content of fiber and mucilage in the sample reduced the speed of carbohydrate availability during digestion. However, this interpretation needs to be treated with

caution, as viscosity, enzymatic activity and gastric emptying rate were not studied in the current work. At the same time, recent literature indicates that viscosity or gel formation may decrease postprandial glycemic response by slowing starch hydrolysis and diffusion of glucose [35]. So, the results found in the current research agree with the previous results although the exact mechanism in the case of *Cordia myxa* requires further experimental confirmation. There was a similar result for *Ziziphus spina-christi*. It showed the highest content of carbohydrates among all studied samples but had a low glycemic index (GI) and a limited glycemic excursion. Such results were important since they proved that the matrix rich in carbohydrates could not have a significant postprandial response. The current findings suggest that the positive glycemic profile of *Ziziphus* can be related to the sample structure and associated phytochemicals but such conclusions can only be considered as a hypothesis because there were no data on enzyme inhibition and polyphenols activities. Some earlier studies stated that the matrix rich in fiber and secondary metabolites reduces carbohydrate digestibility and postprandial glycemia [36, 37]. However, the current results confirm these findings only in terms of *Ziziphus spina-christi* having a low glycemic response. Two samples of cinnamon gave interesting results as well. Both *Cinnamomum cassia* and *Cinnamomum ceylon* had similar proximate compositions, and both of them provided significant early increases in blood glucose levels which means that carbohydrates of both plants were rapidly available. However, further glycemic responses differed as the response of *C. cassia* declined more significantly after the peak, while the response of *C. ceylon* remained higher at an intermediate level. Considering the obtained data, it can be said that cinnamon species can show different

postprandial glucose responses even if their proximate composition is similar. Some earlier studies and meta-analyses showed the heterogeneous glycemic effect of cinnamon and the varying metabolic effect depending on species, preparation method, and research design [38, 39]. Although the current study did not reveal the reasons of the difference but confirmed this practical finding, it is supported by Zelicha et al., 2024 that mentioned Cinnamon, an accessible and inexpensive supplement, may enhance glucose regulation when incorporated into the diet of individuals with obesity-related prediabetes [40]. Walnut showed the completely opposite profile compared with other samples because it gave a very low GI and a negative IAUC. It can be said that the response of this sample in the current experiment corresponded with the matrix rich in lipids, proteins, and carbohydrates [41]. The conservative approach assumes that the observed effect may be accounted for by the dominant nature of the matrix of non-carbohydrate substances that may have limited the process of glucose entry into blood circulation; however, this assumption stays speculative since the processes of gastric emptying and hormonal response were not evaluated; it is still in accordance with the available scientific evidence about the ability of fat- and protein-rich matrices to diminish the effect compared to the control group of refined carbohydrates [42]. Additionally, walnuts may elevate leptin and adiponectin concentrations, reduce HOMA-IR levels and body weight, though other glycemic indicators, and obesity-related indices did not change significantly [43, 44]. This hypothesis is inferential as stomach emptying and hormonal responses were not assessed in the current investigation. Nevertheless, the current findings align with prior publications suggesting that walnut consumption may not uniformly affect basic glycemic markers and may only impact

certain cardiometabolic outcomes [43, 45]. This experimental findings support the conclusion about the marked dampening effect of walnut under the studied conditions. Similarly, oak proved to produce favorable postprandial glycemic profile but to a less pronounced extent than walnut. The matrix of the latter plant is likely to decrease the process of carbohydrate availability due to low glycemic index and significant amount of fibers and fats compared to the glucose and white bread control[36]. The current study did not directly examine mechanisms; however, the low-glycemic properties of oak align with previous research on oak-derived foods and *Quercus*, which demonstrated enhancements in glycemic-related outcomes and enzyme-inhibitory activity. In vitro, α -amylase, α -glucosidase inhibitory activity, control appetite and improve glycated hemoglobin in vivo[21, 46]. Nevertheless, like in case with other species, the current research evaluated only the postprandial glucose profile without investigating the underlying mechanisms. Hence, the most justified interpretation of the results is that oak is a lower-glycemic matrix in the context of the current dataset, and this conclusion does not exceed the available evidence. Specifically, the recorded outcomes affect to such parameters as glycemic index (GI), glycemic load (GL), and postprandial blood glucose response. Therefore, the obtained data can be used to make conclusions about comparative glycemic behavior of different products, but not about their effects on diabetes treatment, obesity control, HbA1c levels, cardiovascular risk, insulin resistance, etc. Moreover, even such potential mechanisms of action as α -glucosidase inhibition, GLUT4 translocation, PI3K/Akt activation, increase in insulin production, and enhanced insulin sensitivity can be presented as possible explanations from prior research, but not as

experimentally confirmed outcomes [38, 40]). In this way, conclusions can be drawn in correspondence with evidence obtained during the investigation. In general, based on this experiment, it can be concluded that the glycemic effect of the studied products is more dependent on the food matrix composition rather than carbohydrate content alone. Specifically, white bread produced the strongest glycemic effect even though its carbohydrate content was lower than in some botanical products, whereas *Cordia myxa*, *Ziziphus spina-christi*, walnut, and oak demonstrated lower glycemic effect at equal conditions. At the same time, the comparison of *Cinnamomum cassia* and *Cinnamomum ceylon* implies that closely related botanical products can vary in terms of their postprandial glycemic effects. From the perspective of GI, GL, and postprandial blood glucose response, these results prove the hypothesis about the key role of food matrix properties for glycemic effects [38, 47]. One of the advantages of the presented research lies in the opportunity to compare different matrices with significantly varied macronutrient compositions. Among the tested samples, there was no singular way to achieve a low GI and IAUC; they were reached through diverse patterns of macronutrients organization: high-fiber and mucilaginous composition in *Cordia myxa*, high-carbohydrate but still low-glycemic composition in *Ziziphus spina-christi*, interspecies differences in cinnamon, and domination of lipids and proteins in walnut. Such result suggests that low postprandial glycemic response does not depend on a certain type of the composition of the matrix. The data indicate that various kinds of organization of the matrix are capable to moderate the glycemic response in contrast to refined carbohydrates. This finding is consistent with the modern food science literature where the emphasis is put on the structure and physicochemical properties of

the food, not just the amounts of the nutrients [36]

Conclusion

The experimental results indicate that the postprandial glucose responses of plant-based diets are affected not only by carbohydrate content but also significantly by the characteristics of their food matrices. For example, botanical foods such as *Cordia myxa* and *Ziziphus spina christi*, characterized by elevated carbohydrate content, demonstrated low glycemic index (GI), glycemic load (GL), and incremental area under the curve (IAUC) values. In contrast, a refined white bread sample, although possessing a reduced carbohydrate content, had the most significant glycemic effects, suggesting a complex relationship between food matrix structure and glucose absorption. The analysis indicates that

diverse food structures and compositions can elicit comparable glycemic responses through distinct mechanisms, including the viscous properties of *Cordia myxa*, the carbohydrate content and low-glycemic response of *Ziziphus spina christi*, the species-specific reactions of *Cinnamomum cassia* and *C. ceylon*, and the predominant lipids-protein complexes in walnuts. These findings highlight the importance of analyzing food matrix composition and structure when assessing glycemic effects, indicating that future research should concentrate on microstructural and rheological properties, as well as in vitro digestibility, to enhance understanding of their influence on glycemic responses and aid in the development of low-glycemic functional foods.

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