Original Article

GLYCEMIC INDEX AND POSTPRANDIAL GLUCOSE RESPONSE OF WHOLE WHEAT MUFFINS PREPARED WITH DIFFERENT SWEETENERS IN YOUNG ADULTS

Aqsa Nadeem[1], Saba Nadeem Dar[2], Esha Zubair[3], Kinza Ahmed[4], Mahnoor Fatima[5],

Abstract

Background: As global diabetes cases are on rise, interest in low-glycemic food sources is growing. Despite existing knowledge on coconut palm sugar's general glycemic advantages, its metabolic impact and consumer acceptance in widely consumed baked products like muffins remain understudied. Objective of this study was to examine the glycemic effect of coconut palm sugar (CPS) versus refined white sugar in whole wheat muffins by providing in-vivo data of both sugars, a critical step towards developing healthier bakery options.

Materials and Methods: Twenty healthy volunteers from different BMI groups received both coconut palm sugar and refined sugar muffins in randomized crossover manner. Fasting and 45, 90, and 120 minutes post-prandial blood glucose was measured.

Results: Coconut palm sugar muffins had a lower overall glycemic index (GI = 49.61) compared to refined sugar muffins (glycemic index = 70.37), especially in participants with normal BMI ($p < 0.05$). While inconsistent responses were observed in the underweight group, overall coconut palm sugar muffins produced lower peak glucose and recovery to baseline values.

Conclusion: The results confirm coconut palm sugar as a potential natural sweetener for diabetic bakery products. Future research should explore long-term glycemic effects of coconut palm sugar in larger, more diverse populations and optimize its use across a broader range of bakery products to further establish its suitability as a healthier sweetener alternative.

Keywords: Glycemic Response, Coconut Palm Sugar, Whole Wheat Muffins, Table Sugar, Young Adults, Sugar Alternatives, Diabetes Mellitus.

doi: https://doi.org/10.51127/JAMDCV0704OA04

How to cite this:
Nadeem A, Dar SN, Zubair E, Ahmed K, Fatima M. Glycemic Index and Postprandial Glucose Response of Whole Wheat Muffins Prepared with Different Sweeteners in Young Adults. JAMDC, 2025;7(4);170-177
doi: https://doi.org/10.51127/JAMDCV07I04OA04

INTRODUCTION

The role of diet in the prevention and management of chronic diseases, as diabetes mellitus and obesity, is very crucial. According to the International Diabetes Federation (IDF) Diabetes Atlas, about 11.1% of the adult population (20-79 years) has diabetes, with over 4 in 10 unaware that they have it.[1] IDF estimates that one in eight adults or 853 million people would have diabetes by 2050, a 46% rise. As per the World Health Organization (WHO), physical inactivity and unhealthy eating habits are among the most important risk factors for these conditions which can be modified. The glycemic index (GI) has emerged as a valued tool for assessing how rapidly the carbohydrate-containing foods show effect on postprandial blood glucose levels in comparison to a reference food (commonly glucose or white bread) in the same

[1,2] Assistant Prof. UMT, Lahore
[3-5] Students of UMT Lahore

Date of Submission: 07-10-2025
Date of 1st Review: 20-10-2025
Date of 2nd Review: 11-11-2025
Date of Acceptance: 25-11-2025

individual. Low-GI foods encourage more gradual rises and better glycemic management thus using coconut palm sugar instead of refined sugar in muffins can result in a lower-glycemic index, healthier version of a popular snack,[2] whereas high-GI foods i.e. GI > or = 70 cause fast spikes in blood glucose and increases risk of diabetic complications.[2,3] Thus, glycemic index can help diabetic patients improve their health outcomes by making better food choices.

Muffins are popular bakery item consumed globally, traditionally made with refined white sugar, which has a high GI and is inappropriate for individuals requiring strict glucose control. To address this, multiple researchers have explored natural sweeteners with low GI. Honey and molasses have medium glycemic index while coconut palm sugar, sorbitol and mannitol have low glycemic index.

Coconut palm sugar, a natural sweetener is often promoted as having a lower glycemic index (35–54) relative to cane sugar (commonly 60–70). Coconut palm sugar is created by evaporating coconut sap so variations occur in heating duration, additives (like lime to prevent fermentation), and degree of crystallization, all of which alter sugar composition and impact glycemic index. This lower glycemic index of coconut palm sugar is partly due to its inulin content (approx. 4.7 g/100 g), a soluble fiber known to delay glucose absorption. Its fiber content varies depending on the source of sap (e.g., hygienic vs. fermented neera), which influences glycemic index.[4] Moreover, coconut palm sugar preserves trace minerals (potassium, magnesium, iron, zinc) and antioxidants like polyphenols due to minimal processing. However, compositionally, coconut palm sugar is similar to refined sugar as the former consists of approximately 89% sucrose and 3% of reducing sugars (glucose and fructose) each, whereas the latter is nearly 94% sucrose.[5] Therefore, any potential glycemic index advantage must be interpreted cautiously, as there is only a minor difference, when incorporated into complex food matrices like muffins. According to certain reviews and in vitro research, coconut palm sugar lowers the estimated GI and starch digestibility of wheat based meals, suggesting its use as a functional sweetener in baked products.[6]

Despite promising claims, the effects of coconut palm sugar on glycemic response in muffins remains unclear. Most of researches have been done in vitro, which do not accurately mimic the dynamics of human digestion, including hormonal reactions and metabolic variations, therefore do not predict real blood glucose impact accurately.[7] Limited human trials reveal inconsistent results; for instance, some studies found that utilizing coconut palm sugar decreased GI values, while other studies found no apparent change when coconut jaggery is compared to cane sugar (GI: 65.19 vs. 60.76), classifying both as moderate GI sweeteners.[8] Furthermore, baking may alter chemical composition and affect the glycemic response of the final product that is why it is unclear whether coconut palm sugar sustains its low-GI qualities in baked products or not.

There seem to be several gaps in the literature regarding coconut palm sugar as a substitute for refined sugar in bakery products. First, controlled human studies evaluating the postprandial glycemic response and glycemic index of coconut palm sugar-based muffins are missing, leaving uncertainty about their actual metabolic impact. Second, influence of BMI categories (underweight, normal, overweight/obese) on glycemic response of CPS-containing baked goods has not been explored. Lastly, despite the fact that CPS is frequently promoted as a healthy sweetener, there is not enough empirical data to support these claims when used in frequently consumed baked goods. Current evidence suggests that coconut palm sugar in muffins may slightly reduce glycemic impact in vitro. However, the actual effect in vivo remains inconclusive. In future, researches should directly measure the glycemic index of coconut palm sugar -based muffins in controlled human studies with appropriate sample size. The objectives of this study were to develop whole-wheat muffins using coconut palm sugar and compare their postprandial glycemic response and glycemic index with refined sugar muffins across different BMI categories (underweight, normal, overweight/obese) as well as overall. Furthermore, the study aims to estimate whether coconut palm sugar shows its low glycemic index properties when added to muffins and assess its prospective as a healthier alternative for diabetics and health-conscious individuals. The hypothesis is that whole-wheat muffins prepared with coconut palm sugar show a lower glycemic index as well as lower and steadier mean postprandial glycemic response (0–120 min) compared to the muffins sweetened with refined white sugar.

MATERIALS AND METHODS

It was a randomized, experimental in vivo study conducted at the University of Management and Technology, Lahore Pakistan, in June, 2025. RCT registration number RE-069-2024, dated 12-06-2024. The duration of the study was 3 weeks. According to the ISO-26642 and glycemic index studies that have been conducted, sample size must have at least 10 or more subjects, either only males, females or both. A sample size of 20 participants was selected using convenience sampling as per previous studies.[9,10,11] Participants were informed about study protocols; written consent was obtained. Participants were acknowledged for their voluntary participation and time as per research ethics. Participants aged 18-25 years, fasting blood glucose of 80-110 mg/dL, no past medical history, non-smokers, with no dietary restrictions, and those not involved in any kind of sports or athletes were included.

The exclusion criteria was individuals having diabetes or other medical conditions, smokers, fasting blood sugar > 110 mg/dL, history of medications, food allergies or intolerances, and those who had undergone any surgery in the recent past. The muffins were prepared following the technique described with alterations under standardized laboratory conditions to ensure homogeneity. All the ingredients were purchased from local supermarket in Lahore. The mixture contained whole wheat flour (128 g), salt (2 g) milk (100 ml), baking powder (5 g), white sugar (50 g), olive oil (30 ml), and egg (1). The mixture was beaten at low speed for 80 seconds. Another mixture with the same quantities was prepared with coconut palm sugar (50 g) instead of white sugar. The mixtures were then weighed in cups and baked in the preheated oven for 15-20 minutes at 180ºC. The recipe was repeated in order to get the desired yield of muffins. Each serving of muffin contained 25 g of available carbohydrates which resulted in 63 g and 64 g batter of white sugar muffin and coconut palm sugar muffin respectively. The muffins were made on the prior day in the evening and stored at room temperature after cooling. For reference food, glucose solution (27.7 g of glaxose-D in 250 ml water) was used which provided 25 g of available carbohydrates.

The experiment was completed in three sessions. The participants were blinded to the type of test meal. They were given glucose solution and two test meals on separate days. According to the glycemic index methodology and evidenced by multiple researches, 50 or 25g of available carbohydrates can be served in each portion.[14,15] There was a washout period of 2-3 days between sessions. The trial started in the morning at 8:30 AM after 8-12 hours fast overnight. The fasting blood glucose of participants was checked. After that, they consumed the test meal within 10-15 minutes along with 250 ml distilled water. Participants consumed glucose solution, table sugar muffin, and coconut palm sugar muffins in random order. Blood samples of participants were collected at fasting then 45, 90, and 120 minutes postprandial. The physical activity of the participants was kept to minimum and was asked to be seated for most of the time during test period. Blood glucose monitoring was performed with the help of validated Accu-Chek ®Performa glucometer following a standardized finger-prick methodology. Participants warmed their hands to enhance peripheral blood flow before testing. Capillary blood samples were obtained using sterile lancet puncture, with gentle hand massage. To ensure reliable measurements, the first two blood drops were wiped away to prevent potential contamination, the third drop was analyzed by the glucometer. After recording the blood glucose levels from 0-120 minutes, a curve was constructed for each individual for test samples and reference food.

The incremental area under the curve (IAUC) was geometrically calculated using the trapezoid rule, ignoring the area under the baseline (fasting level of the individual). Glycemic index of the food i.e. the mean glycemic index

for entire sample size, was calculated using the formula:

$$\frac{IAUC\ for\ the\ test\ food}{IAUC\ for\ the\ reference\ food} \times 100$$

A statistical analysis was conducted using SPSS v25. Data and figures were processed in Microsoft Word. IAUC and GI values were calculated using trapezoid method. Data was interpreted as mean ± standard deviation. Pair wise comparisons were done by applying paired t-test. The criteria for significance was a two-tailed $p < 0.05$.

RESULTS

A sample comprising 20 participants was selected, of which 12 were females and 8 were males. The mean age of participants was 21.40 ± 1.64 years. The mean height was 164.30 ± 7.88 cm, while mean weight was 57.40 ± 13.52 kg. The sample consisted of individuals from different BMI categories, of which 2 were underweight, 14 were normal, 4 were overweight/obese, in Table 1. As shown in Table 2, the glycemic index (GI) values of table sugar muffins and coconut palm sugar (CPS) muffins were calculated and compared across BMI groups. In participants with normal BMI (n = 14), the GI of coconut palm sugar muffins (41.0 ± 24.1) was significantly lower than that Among overweight/obese participants (n = 4), no significant difference was found between of table sugar muffins (67.51 ±43.95; $p < 0.05$). coconut palm sugar muffins (5.75 ± 6.18) and table sugar muffins (78.28 ± 85.07; $p > 0.05$). Similarly, in underweight participants (n = 2), no significant difference was observed between coconut palm sugar muffins (197.55 ± 215.60) and table sugar muffins (74.55 ± 55.79; $p > 0.05$). Standard deviations were large in some groups, particularly underweight and overweight/obese indicating high inter-individual variability in glycemic responses.

Table: 1 Demographic of Participants

Gender	Frequency (n)	Percentage (%)
Male	8	40
Female	12	60
Underweight (>18.5)	2	10
Normal (18.5- 24.9)	14	70
Overweight (25-29.9)	3	15
Obese (<30)	1	1

Table: 2 Glycemic index (GI) values and its classification among different BMI categories

Participants	n	Table Sugar Muffin	Coconut Palm Sugar Muffin
Overall response	20	70.37 ± 51.47	49.61 ± 74.91
Normal BMI	14	67.51 ± 43.95	41.0 ± 24.1
Overweight / Obese	4	78.28 ± 85.07	5.75 ± 6.18
Underweight	2	74.55 ± 55.79	197.55 ± 215.60

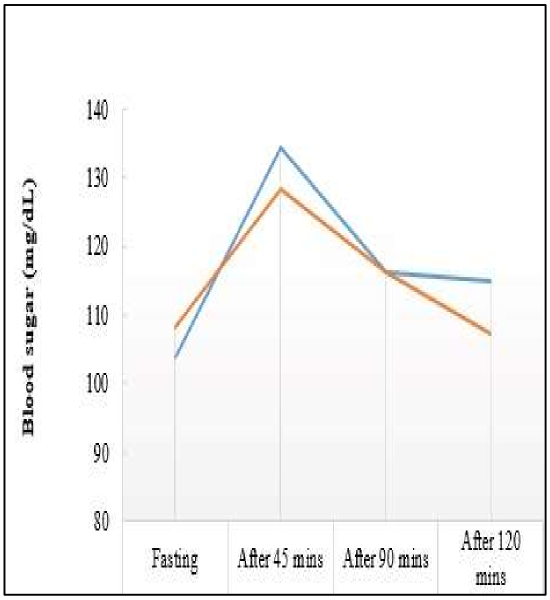

Figure: 1

Figure 1. Illustrates mean postprandial blood glucose (mg/dL) of the entire sample after consuming table sugar vs. coconut palm sugar muffins 0-120 minutes

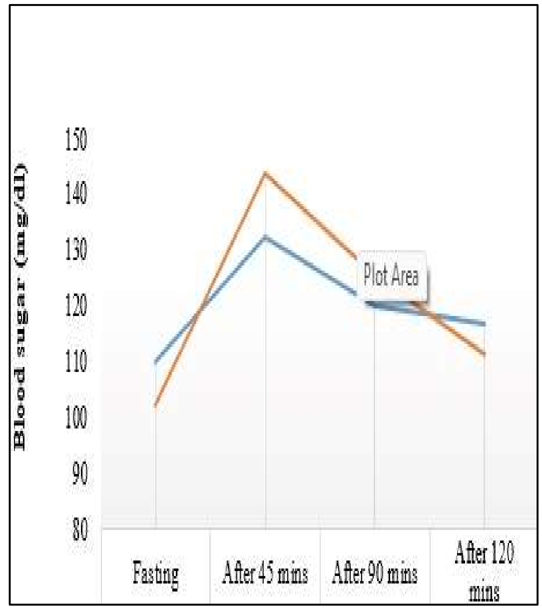

Figure 2

Figure 2. Illustrates mean postprandial blood glucose (mg/dL) of the underweight BMI after consuming table sugar vs. coconut palm sugar muffins from 0-120 minutes. Figure

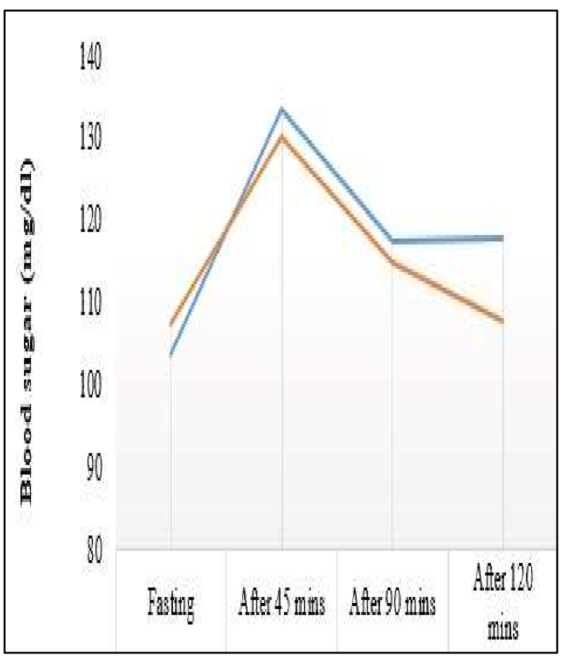

Figure: 3

Figure 3. Illustrates mean postprandial blood glucose (mg/dL) of the normal BMI after consuming table sugar vs. coconut palm sugar muffins 0-120 minutes

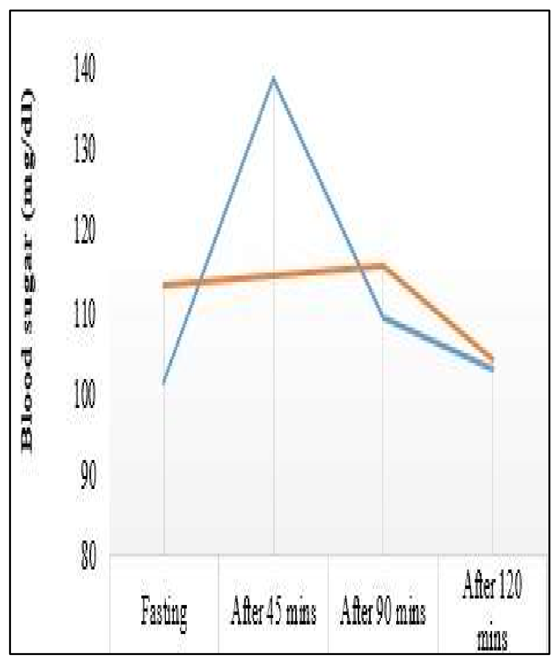

Figure: 4

Figure 4. Illustrates mean postprandial blood glucose (mg/dL) of overweight/obese BMI after consuming table sugar vs. coconut palm sugar muffins 0-120 minutes.

DISCUSSION

The present findings are interpreted within the context of the composite food matrix in which the sweetener was incorporated. Unlike isolated sugar testing, the muffins contained whole wheat flour, fat, and protein, all of which are known to influence gastric emptying and carbohydrate digestion rates. The interaction between sweetener type and the structural properties of a baked product may therefore play a critical role in determining postprandial glycemic behavior. This highlights an important practical consideration: evaluating sweeteners within realistic food systems provides more meaningful dietary insight than testing sugars in isolation, as glycemic response is strongly influenced by mixed food composition, formulation, and processing conditions.[11,12,13] From a translational perspective, the study reflects real-world consumption patterns, as individuals typically consume sugars as part of mixed meals rather than in pure form. Thus, the glycemic behavior observed in this study contributes applicable evidence regarding how sweetener substitution performs under practical dietary conditions Another important aspect of this study is the focus on healthy young adults, a population often overlooked in glycemic research that predominantly targets individuals with diabetes. Early dietary modifications during young adulthood may contribute to long-term metabolic risk reduction, particularly in regions where refined carbohydrate intake is high. By using a randomized crossover design and standardized available carbohydrate portions (25 g), the study minimized inter-individual variability and allowed each participant to serve as their own control, thereby strengthening internal validity. Although the sample size was modest, this controlled experimental framework enhances confidence that observed differences were attributable to sweetener substitution rather than external dietary factors. These findings support the concept that incremental formulation changes in commonly consumed bakery products may serve as feasible preventive strategies within broader nutritional interventions.[12] The overall findings that coconut palm sugar may serve as a lower-glycemic index alternative in baked products align with previous glycemic index and palm sugar comparison studies.[9,10] Coconut palm sugar showed lower glycemic index and moderate post-prandial glucose levels, specifically in normal BMI range individuals, which is consistent with previous in vitro and human studies,[6] which suggest that minimally processed sugars like coconut palm sugar can reduce glycemic response when compared to refined sugars. This characteristic is often attributed to its natural polyphenols and inulin content, which may slow down glucose absorption and contribute to better glycemic control.[4] According to the research by Rayappa,[6] a reduction in in vitro digestibility of starch and estimated glycemic index occurs when substituting cane sugar with coconut palm sugar. Whereas a study by Pathirana et al[8] observed no significant difference in glycemic index between coconut jaggery and cane sugar in human trials, and classified both as moderate glycemic index sweeteners, similar to findings reported in palm sugar glycemic response studies.[10] In our study, there is statistically significant difference in glycemic index seen in the normal BMI group, and exceptionally high glycemic index observed in the underweight group for coconut palm sugar muffins. This coincides with previous research showing variability in glycemic response depending on nutritional formulations, metabolic status, and supplement composition.[13,14,15] This variability highlights the importance of the complex interaction within a food matrix and individual physiological responses. The high standard deviation across all participants also highlights this inconsistency, reinforcing the point that in vitro estimates do not always accurately predict real blood glucose response.[7] The drawback faced while performing the study was that blood glucose response might be affected by individual differences in insulin sensitivity, metabolism, and lifestyle which might alter results.

CONCLUSION

Replacement of refined sugar with coconut palm sugar in whole wheat muffins lowered the glycemic response especially in the individuals with normal BMI indicating an improved postprandial glucose control.

ACKNOWLEDGMENTS

The authors would like to thank their supervisor for assistance in all aspects of the study and the Department of Nutrition and Dietetics, School of Health Sciences, University of Management and Technology (UMT), Lahore.

AUTHORS CONTRIBUTION

AN: Study Concept
SND: Data Analysis
EZ: Interpretation of Data
KA: Manuscript Writing
MF: Review of literature

SOURCE OF FUNDING

None

CONFLICT OF INTEREST

None

REFERENCES

1. International Diabetes Federation. 2022. Available from: https://idf.org/about-diabetes/diabetes-facts-figures/)
2. Chiavaroli L, Lee D, Ahmed A, Cheung A, Khan TA, Blanco S, et al. Effect of low glycaemic index or load dietary patterns on glycaemic control and cardiometabolic risk factors in diabetes: systematic review and meta-analysis of randomised controlled trials. BMJ. 2021;374:n1651. doi: 10.1136/bmj.n1651
3. Ahmed J, Riaz M, Imtiaz R. Glycemic index and Glycemic load values. Pak J Med Sci. 2021;37(4):1246-1247. doi: 10.12669/pjms.37.4.4555
4. Saraiva A, Carrascosa C, Ramos F, Raheem D, Lopes M, Raposo A. Coconut sugar: Chemical analysis and nutritional profile; Health impacts; Safety and quality control; Food industry applications. Int J Environ Res Public Health. 2023;20(4):3671. doi: 10.3390/ijerph20043671
5. Sarpong F, Anning D, Oduro-Yeboah C. Trends in Coconut Brown Sugar Production–A Review of Health and Future Prospect in the Industry. Turk J Agric Food Sci Technol. 2024 Dec 12;12(s2):2407-14. doi.org/10.24925/turjaf.v12is2.2407-2414.6907
6. Rayappa MK. Palmyrah palm (Borassus flabellifer) non-centrifugal sugar - Current production practices as a natural sugar and a promising functional food/additive. J Agric Food Res. 2023;14:100829. doi: 10.1016/j.jafr.2023.1008297. Sun Y,
7. Zhong C, Zhou Z, Lei Z, Langrish TAG. A review of in vitro methods for measuring the Glycemic Index of single foods: Understanding the interaction of mass transfer and reaction engineering by dimensional analysis. Processes (Basel). 2022;10(4):759. doi: 10.3390/pr10040759
8. Pathirana HPDTH, Wijesekara I, Yalegama LLWC, Garusinghe C, Jayasinghe MA, Waidyarathne KP. Comparison of blood glucose responses by cane sugar (Saccharum officinarum) versus coconut jaggery (Cocos nucifera) in type 2 diabetes patients. Journal of Future Foods. 2022;2(3):261-5. doi: 10.1016/j.jfutfo.2022.06.001
9. Feng S, Allen JC. Glycemic index of products derived from Sweetpotato when compared to their analog white potato product: IJRMCS. 2025;3(1):149-57.
10. Puspareni LD, Fauziyah A, Wardhani S. Are glycaemic response, glycaemic index, and glycaemic load of traditional palm sugar (Arenga pinnata) different from cane sugar?: An oral glucose tolerance test. Amerta Nutr. 2022;6(2):206-11. doi: 10.14710/amnt.v6i2.2022.206-211
11. Lee M, Kang H, Chung S-J, Nam K, Park YK. Validation study of the estimated

glycemic load model using commercially available fast foods. Front Nutr. 2022;9:892403.
doi: 10.3389/fnut.2022.892403

12. Scarton M, Nascimento GC, Felisberto MHF, Moro T de MA, Behrens JH, Barbin DF, et al. Muffin with pumpkin flour: technological, sensory and nutritional quality. Braz J Food Technol. 2021;24:e2020229.
doi: 10.1590/1981-6723.22920
13. Zanini AC, Santos HD, Celes APM, Giuntini EB, Franco BDG de M. Determination of glycaemic response to the consumption of two specialised formulas for glycaemic control. Br J Nutr. 2023;130(7):1137-43.
doi: 10.1017/S000711452300006X
14. Bhoite R, Shanmugam S, Lalithya Pratti V, Satyavrat V, Rajagopal G, Mohan Anjana R, et al. Estimation of glycemic index of liver nutritional supplement and its importance in liver nutrition. J Hum Health Res. 2023;2(1):1-8.
15. Rachana B, Shobana S, Lalithya PV, Sudha V, Vinita S, Gayathri R, et al. Glycemic index of a nutritional supplement designed for people with chronic kidney disease. Food Sci Nutr. 2023;11(9):5379-87.
doi: 10.1002/fsn3.3411