

POSTPRANDIAL GLYCEMIC INDEX AND SENSORY ACCEPTABILITY OF FINGER MILLET–LEGUME COMPOSITE PORRIDGES IN HEALTHY ADULTS

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ARTICLE INFO

Article No.: 0178

Accepted Date: 21/01/2026

Published Date: 27/02/2026

Type: Research

ABSTRACT

Dietary management remains a key strategy in managing various diseases, especially with low glycemic impact foods. Traditional cereal porridges are common staple foods but often elicit high postprandial glycemic responses. This study aimed to evaluate the nutritional composition, sensory attributes, and postprandial glycemic effects of legume-based composite porridges formulated from finger millet, soybean, groundnut, and Bambara nut with ginger. Three formulations were prepared: finger millet, soybean, ginger (FSG), finger millet, groundnut, ginger (FGG), and finger millet, bambara nut, ginger (FBG) with spices. Proximate composition was determined using AOAC (2005) methods. Glycemic index (GI) testing was conducted with a relatively small and non-clinical specimen adopting a randomized, open-label, crossover protocol with anhydrous glucose as reference. Postprandial glycemia levels were measured at 30-minute intervals for 2 hours post-consumption. Sensory evaluation was carried out using a nine-point hedonic scale by untrained panellists. Data were subjected to descriptive statistics, group differences assessed using one-way ANOVA at $p \leq 0.05$. FSG had the highest protein (16.00%) and fiber (3.50%) with GI of 38.60, while FGG showed the highest fat (19.07%) and the lowest GI (31.14). FBG exhibited the highest carbohydrate (72.00%) and the highest GI (42.20). All samples were well accepted with no significant differences ($p > 0.05$) in appearance, aroma, taste, or texture. Legume and ginger fortification enhanced the nutritional quality and reduced the glycemic impact of finger millet porridges without affecting sensory appeal. These porridges, particularly FSG and FGG, offer promising potential relevance for dietary option for planning and management of postprandial glycemia.

Keywords: Diabetes, Sensory Evaluation, Porridges, Glycemic Index, Postprandial Glycemia.

Introduction

Diabetes mellitus is a chronic metabolic condition marked by elevated blood glucose and abnormality in carbohydrate, lipid, and protein metabolism due to impaired insulin secretion or function. It is associated with severe long-term complications, such as retinopathy, nephropathy, neuropathy, increase the risk of myocardial infarction, cerebral embolism and blood vessels damages (Aljohani *et al.*, 2024).

Globally, diabetes affects more than half a billion adults, and without effective preventive strategies, its prevalence is projected to continue rising substantially, reaching over 640 million cases by 2030 (International Diabetes Federation [IDF] 2021). The increasing prevalence of type 2 diabetes (T2D) is associated with the obesity epidemic, and diagnosis is occurring at increasingly younger ages (Kate *et al.*, 2011). Diabetes care focus on achieving and maintaining target blood glucose levels because sustained glycemic control has been linked to a lower risk of developing and progressing both micro and macrovascular complications of the disease (ElSayed *et al.*, 2023).

Glycemic index (GI) was introduced more than 2 decades ago to facilitate glycemic control in patients with diabetes (Visuthranuku *et al.*, 2022). It was described as the percentage of incremental area under the 2-hour blood glucose response curve of a test food divided by the corresponding area of a reference food (glucose) containing the same amount of available carbohydrate. Low GI foods provides a slower and steadier glucose release, resulting in moderated insulin responses and better long-term glycemic regulation compared with high-GI foods, and may also increase insulin sensitivity by minimizing fluctuations in blood glucose levels and reducing the secretion of insulin over the day (Visuthranuku *et al.*, 2022).

Dietary modification remains a cornerstone in the prevention and management of T2D, particularly interventions aimed at lowering postprandial glycemic excursions, which are strongly associated with long-term complications. Staple carbohydrate-based porridges are widely consumed across populations, yet many traditional formulations contribute to high glycemic response (Softic *et al.*, 2017). Formulating composite porridges enriched with nutrient-dense ingredients and tailored to elicit a low-to-moderate glycemic response offers a promising and sustainable nutritional approach for diabetes management. Conducting comprehensive nutritional analysis of these formulations together with evaluations of their effects on postprandial glycemia is crucial to guide evidence-based preventive and therapeutic dietary recommendations for people with diabetes (Zhu *et al.*, 2024).

Cereals and legumes are major carbohydrate sources, and their metabolic effects vary with processing and fiber content; whole grains and legumes are linked to improved insulin sensitivity and lower type 2 diabetes risk through better postprandial glycemic control and weight regulation, while refined forms may elevate hyperglycemia and insulin resistance. Functional cereals such of finger millet rich in resistance starch, fibre, and bioactive compounds, contribute to lower glycemic responses and have potential benefits for diabetes management. Evidence shows millet consumption including finger millet is associated with improved glycemic profiles and metabolic outcomes in adults. (Naik *et al.*, 2025). However, despite evidence of finger millet's benefits, there is limited research on the long-term effects of finger millet-based composite foods and their postprandial glycemic responses, particularly when combined with other nutrient-dense ingredients for diabetes management.

Material and Methods

All the grain samples were purchased from the popular local Kasuwar Baci Market Kaduna.

Samples	Pre-Processing	Formulation	Porridge Preparation
FSG	The grains were sorted for deterioration, dirt and shafts, rinsed with distilled water. The millet was oven-dried at 60°C for 16 hours to facilitate milling using a 0.5mm sieve after rinsing. Soya beans was soaked for 8hrs and dehulled, dried at 60°C for 16 hours, roasted to enhance flavor and finally milled into flour (0.5mm sieve). The ginger was washed, peeled, and sliced into pieces (3 mm), oven-dried at 50°C for 8 hours and also milled into flour using 0.5 mm sieve. The prepared flours were kept in a glass jar at 4°C until analysis (Mohammed Ali <i>et al.</i> , 2024).	50 % finger millet, 35 % soya beans, 10% ginger and 5% spices (Cinnamon, ginger and clove) (Milkesa <i>et al.</i> , 2021)	50 g of the formulate was mixed with small amount of cool distilled water to form smooth slurry, boiled water was added to the slurry and evenly stirred to make porridge.
FGG	The samples were sorted for deterioration, dirt and shaft ones, rinsed with distilled water. Groundnut was roasted at 120°C for 30min and blanched, oven-dried at 50°C and milled into flour. Ginger was washed, peeled, and sliced into pieces (3 mm), oven-dried at 50°C for 8 hours and also milled into flour using 0.5 mm sieve. The prepared flours were kept in a glass jar at 4°C until analysis (Mohammed Ali <i>et al.</i> , 2024).	50 % finger millet, 35 % groundnut, 10% ginger and 5% spices (Cinnamon, ginger and clove) (Milkesa <i>et al.</i> , 2021)	50 g of the formulate was mixed with small amount of cool water to form smooth slurry, boiled water was added to the slurry and was evenly stirred to make porridge.
FBG	The samples were sorted for deterioration ones and rinsed with distilled water. Bambara nut was soaked for 12hrs, dehulled, pressure cooked for 30min at 120°C, oven-dried for 8 hours and milled into flour using 0.5mm sieve. Ginger was washed, peeled, and sliced into pieces (3 mm), oven-dried at 50°C for 8 hours and also milled into flour using 0.5 mm sieve (Mohammed Ali <i>et al.</i> , 2024).	50 % finger millet, 35 % Bambara nut, 10% ginger and 5% spices (Cinnamon, ginger and clove) (Milkesa <i>et al.</i> , 2021)	50 g of the formulate was mixed with small amount of cool distilled water to form smooth slurry, boiled water was added to the slurry and evenly stirred to make porridge.

Keys; FSG: Finger Millet, Soya Beans, and Ginger. **FGG:** Finger Millet, Groundnut, and Ginger. **FBG:** Finger Millet, Bambara nut, and Ginger

Proximate Analysis

Moisture, protein, fat, ash, crude fiber and carbohydrate content of the porridges were analyzed as described by the Association of Official Analytical Chemist (AOAC, 2005). All analyses were done in triplicates.

Study Design and Participants

A randomized, open-label, crossover test was conducted to evaluate postprandial glycemic responses to the test porridges compared with a glucose reference. The study recruited 20 healthy adult volunteers, both male and female, aged 21–24 years, all participants had normal fasting plasma glucose 8-12 hours prior the research. Inclusion criteria requires participants to be non-smokers with no history of chronic metabolic disease, and not taking medications known to affect glucose metabolism. Participants were provided written informed consent before enrollment.

Blood Glucose Protocol

Participants were randomly assigned to a sequence of consumption for the reference food (50 g anhydrous glucose) and each of the three test porridges (FSG, FGG, FBG). Each subject consumed all four study foods in random order, with at least a 48-hour washout period between test days to minimize carry-over effects. This within-subject crossover design ensures that each participant serves as their own control, reducing inter-individual variability in glycemic responses. Blood samples were drawn at 30 minutes intervals for 2 hours after feeding each day, using capillary pricked-finger samples instead of venous blood sample, which may show variability. Each of the drawn blood samples was applied to the test region of the test strip, and immediately inserted into glucometer (Accu-Chek SF1033560084-180 Mannheim, Germany) with quality-controlled test strips. Each participant repeated the procedure for the reference food and for each of the three test foods (FSG, FGG, and FBG) on separate days according to the randomized sequence. These time points allow for a detailed glycemic response curve and calculation of incremental area under the curve (iAUC).

Sensory Evaluation

Consumer sensory evaluation was conducted to access general liking of the porridges. Five untrained panelist (21-24 years) who were regular consumers of related kinds of porridges participated in the evaluation. Panelist were selected base on their background in food science and trained to recognize and score parameters. Each panelist received all three prepared porridges (10 g each) made from the formulations in identical disposable containers and coded with three alphabets i.e. FSG, FGG and FBG respectively. Serving order was randomized and balanced across panelists, samples were prepared using the same recipe and served at warm temperatures immediately prior to evaluation. Clean water and plain crackers were provided for palate cleansing between samples evaluation. Liking was rated using a 9-point hedonic scale (1-dislike extremely to 9-like extremely) for specific individual attributes and overall acceptability (Addo-Preko *et al.*, 2023). Mean hedonic scores were calculated for each porridge samples.

Determination of Area Under the Curve (AUC)

The area under curve was determined using trapezoid method of different time intervals. A plot of concentration against time was used for the calculation, $AUC = \frac{Conc_2 + Conc_1}{2} \times (t_2 - t_1)$.

Glycemic Index Determination

The sum of area under curve for each formulates; FSG, FGG and FBG was divided by the sum of area under curve for standard glucose and multiplied by 100. The value obtained is the glycemic index adopting the formula below:

Glycemic index (GI) = %AUC of test food/AUC of standard (glucose) x 100 (Brouns *et al.*, 2005).

Statistical Analysis

Graph Pad Prism 8 statistical package was used for the analysis, using one-way analysis of variance (ANOVA) at $F = 0.05$ and t-test at $P = 0.05$ to determine the level of significance of the each of the formulates for proximate analysis and sensory acceptability.

Results

Table 1: Proximate Analysis and Glycemic Indices of the Porridges

Parameters	Porridges		
	FSG	FGG	FBG
Moisture	3.03±0.22 ^b	4.56±0.20 ^a	3.46±0.41 ^b
Crude Protein	16.00±1.02 ^a	14.23±0.69 ^b	12.56±0.17 ^c
Fat	8.50±0.80 ^b	19.07±0.11 ^a	6.25±0.06 ^c
Ash	2.40±0.25 ^b	3.21±0.44 ^a	3.10±0.20 ^a
Fibre	3.50±0.43 ^a	2.03±0.32 ^c	2.63±0.21 ^b
Carbohydrate	65.37±0.90 ^b	56.91±1.10 ^c	72.00±0.41 ^a
iAUC (mmol.min/L)	76.50±0.25	61.50±0.19	84.00±0.24
Glycemic Indices (%)	38.60	31.14	42.20

Groups with different superscript are statistically different ($p < 0.05$). Values are expressed as mean±SEM ($n=3$)

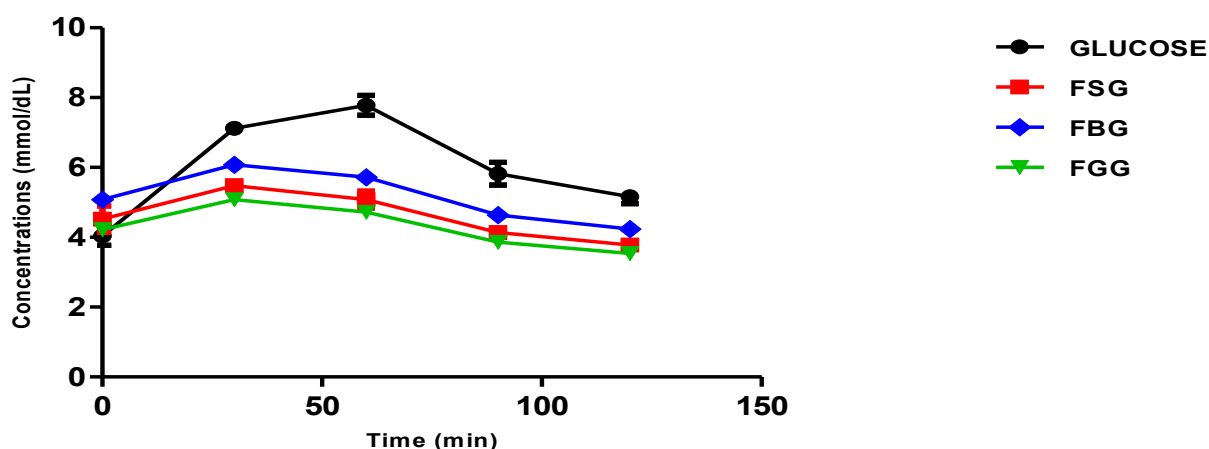


Figure 1: Mean Postprandial Glycemic Responses to the Porridges

Table 2: Mean Sensory Evaluation and Overall Acceptability of the Porridges

Parameters	FSG	FGG	FBG
Appearance	8.00±0.0 ^a	7.60±0.54 ^a	7.60±0.55 ^a
Aroma	8.00±0.71 ^a	7.60±0.55 ^a	7.80±0.45 ^a
Taste	7.00±1.60 ^a	7.60±1.14 ^a	7.60±1.14 ^a
Texture	6.60±0.55 ^a	6.60±0.55 ^a	6.62±0.55 ^a
Overall Acceptability	7.40±0.55 ^b	6.80±0.84 ^b	7.60±0.54 ^b

Groups with different superscript are statistically different ($p < 0.05$). Values are expressed as mean $\pm$ SEM ($n = 5$).

Discussion

The proximate composition and postprandial glycemic responses of the porridges differed significantly ($p < 0.05$), indicating that variation in formulation was associated with differences in measured glycemic outcomes. Moisture content ranged from $3.03 \pm 0.22\%$ to $4.56 \pm 0.20\%$, with the slightly higher value in FGG consistent with reports that groundnut inclusion is associated with greater moisture retention in cereal–legume blends (Olapade & Adeyemo, 2014). However, moisture content was not directly evaluated in relation to glycemic response.

Crude protein content was highest in FSG, followed by FGG and FBG, and these differences coincided with differences in glycemic index (GI) and incremental area under the curve (iAUC), with FSG showing lower glycemic responses. Previous studies have reported associations between higher protein content in mixed meals and postprandial glycemia (Nilsson *et al.*, 2012), but insulin secretion and gastric emptying were not measured in this study. Therefore, the present findings are interpreted strictly as associations between protein content and observed glycemic responses.

Fat content varied widely among the formulations, with FGG exhibiting the highest lipid content and a correspondingly lower GI. Similar associations between dietary fat and postprandial glycemic responses have been reported in mixed meals (Gentilcore *et al.*, 2006; Riccardi *et al.*, 2004). In the present study, these results indicate an association between fat content and glycemic response, without implying causality or underlying mechanisms.

Dietary fiber content was highest in FSG and lowest in FGG, and the formulation with higher fiber content showed a more moderate GI. This pattern is consistent with previous observations that fiber-rich foods are often associated with lower postprandial glycemic responses (Jenkins *et al.*, 2002). However, digestion and absorption kinetics were not assessed, and interpretation is limited to the observed glycemic outcomes.

FBG had the highest carbohydrate content and also showed the highest GI and iAUC among the porridges. Higher available carbohydrate content has been associated with higher postprandial glycemic responses (Wolever & Jenkins, 2009), and the present findings align with this general pattern. Nonetheless, only acute capillary blood glucose responses were measured, and no inferences can be made regarding longer-term metabolic effects.

However, the overall, all porridges fell within the low-to-moderate GI range and produced lower glycemic excursions than the glucose control. The postprandial glucose curves showed the expected rise and fall, with the control producing a higher peak and greater iAUC, consistent with previous reports linking carbohydrate quality to postprandial glycemia (Jenkins *et al.*, 2002). The lower and more gradual responses observed for FSG, FBG, and FGG therefore reflect more moderate acute glycemic responses. Because insulin, gastric emptying, and long-term metabolic outcomes were not measured, the findings are interpreted strictly in terms of observed associations with acute glycemic response.

Sensory evaluation indicated that all porridge formulations were generally well accepted, with no significant differences ($p > 0.05$) in appearance, aroma, taste, or texture. Similar findings have been reported for cereal–legume and cereal–legume–spice formulations, where overall acceptability and key sensory attributes were comparable across products (Adeyemi & Beckley, 2019; Udeh *et al.*, 2021; Ocheme *et al.*, 2018; Oyeyinka *et al.*, 2020). The comparable sensory ratings across formulations suggest that differences in palatability were minimal and unlikely to have influenced intake during testing.

Within this context of similar sensory acceptance, differences observed in glycemic index (GI), incremental area under the curve (iAUC), and postprandial glucose profiles among the porridges indicate that the formulations were associated with different acute glycemic responses. Thus, the variation in measured glycemic outcomes occurred despite broadly comparable sensory properties.

Importantly, insulin responses, gastric emptying, and long-term metabolic outcomes were not measured in this study. Consequently, the present findings are limited to observed associations between the tested porridges and acute postprandial blood glucose responses. No conclusions can be drawn regarding underlying physiological mechanisms or longer-term metabolic effects, and interpretation is restricted strictly to the measured glycemic response data.

Conclusion

The study demonstrated that the formulation and compositional characteristics of the porridges significantly influenced their postprandial glycemic responses. Porridges with higher proportions of legumes and dietary fiber exhibited a lower glycemic response. These effects are likely due to reduced starch digestibility, increased resistant starch, and the viscous network formed by fiber-protein interactions that slow glucose release and absorption placing them as functional dietary options for managing postprandial glycemia.

Ethical Statement

The research protocol was reviewed and approved by the Research Ethics Committee of Kaduna Polytechnic through the Health Research Ethic Committee (HREC) of Kaduna State Ministry of Health under the approval number NHREC/17/03/2018. All participants provided written informed consent prior to inclusion in the study. Confidentiality and anonymity were maintained throughout the research process, in line with ethical standards of the declaration of the institution.

Conflict of Interest

The authors declare no conflict of interest

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