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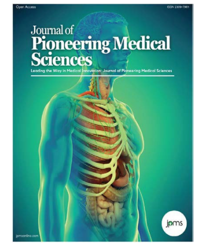

Postprandial Glucose and Insulin Responses to Traditional Sudanese Carbohydrate-Based Meals in Adults with Type 2 Diabetes: A Clinical Study

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Abstract: Background: Blood sugar levels are affected after eating, and moderation in eating meals and their glycemic index content is a crucial factor in controlling blood sugar levels and reducing the risk of cardiovascular disease in patients with type 2 diabetes. Preparing and consuming food in the form of mixed meals leads to different post-meal glycemic responses compared to single foods. This is attributed to cooking methods, heat treatments, food fermentation, macronutrient interactions, and food matrix effects. Understanding the glycemic responses to mixed meals from traditional Sudanese diets is crucial for dietary guidance in diabetes management. The Sudanese diet is based primarily on carbohydrate-rich foods such as kisra, sorghum porridge, millet porridge, and gurasa; however, there is limited research on their effects on blood glucose and insulin levels. **Objective**: To evaluate the glucose and insulin response in adults with type 2 diabetes after consuming a mixed Sudanese popular meal. **Methods**: A randomized trial was conducted to 120 adults with type 2 diabetes. Participants consumed five standardized mix traditional Sudanese meals (Sorghum Kisra with mullah tagalia, Sorghum Porridge with milk, Gorasa with damaa, Millet Porridge + milk and Adassia) on separate days. Blood glucose and serum insulin levels were measured fasting and 30, 60, 90, and 120 minutes after eating. The increased area under the curve (iAUC) was measured, calculated and converted to the glycemic index (GI%). **Conclusion:** Consuming traditional Sudanese meals which is rich in carbohydrates leads to a significant rise in glucose and insulin levels, with considerable variation depending on the meal's composition and ingredients. Several strategies and recommendations can be implemented, such as increasing legume intake, adding protein, and following a balanced diet, to help mitigate blood sugar fluctuations in type 2 diabetes patients in Sudan.

Key Words: Type 2 Diabetes, Postprandial Glucose, Traditional Diet, Glycemic Control, Sudan

INTRODUCTION

Prevalence rates of Type 2 diabetes mellitus (T2DM) are increasing across the globe, with urbanisation and changes in diets fuelling a particularly rapid increase in Africa [1]. For instance, in Sudan, the prevalence of T2DM has increased substantially over the last thirty-forty years, driven primarily by a reliance on traditional diets rich in carbohydrates.

An increase in blood glucose levels after eating can result in endothelial dysfunction, oxidative stress, and a deterioration in long-term glycaemic control. Postprandial glycaemic fluctuations (PPG) are now viewed as reliable predictors of microvascular complications and cardiovascular disease [2,3,4]. To manage diabetes effectively, there is a vital need for strategies designed to support postprandial glycaemic control.

By categorising foods according to their impact on blood glucose levels compared with glucose, the glycaemic index (GI) can serve as a useful indicator of carbohydrate quality [5]. This is because glucose from high GI foods is absorbed extremely quickly, leading to an acute insulin response, whereas low GI foods result in slower rates of absorption and blood glucose levels that are more stable [6]. Both the GI response and post-meal blood glucose levels are significantly impacted by the protein, fibre, and fat content of food, in conjunction with cooking and preparation methods [7].

In Sudan, the diet is strongly dependent on sorghum and millet, which are prepared as sorghum porridge and/or kisra (a flatbread). Such foods are low in protein and fiber and usually high in carbohydrates. Wheat bread is also regularly eaten with legumes. Research carried out in a number of African countries has identified foods made from sorghum and millet as being a strong source of nutrients [8]. However, the GI of sorghum porridge is believed to range from medium to high. This GI can, however, be lowered by fermentation, such as in sorghum kisra, because gastric emptying is slowed by the presence of organic acids [9]. A low GI is usually found in legumes like beans and lentils as their protein and fibre content is high [10].

Numerous studies have been conducted to control and manage blood glucose levels after meals. A study by Shaheen et al. in the United Arab Emirates (2024) demonstrated that consuming vegetables and protein before rice reduces the area of the blood glucose concentration curve by 40% [11]. Similarly, another study found that consuming carbohydrates at the end of a meal significantly reduces fluctuations in blood glucose and insulin levels in patients with type 2 diabetes [12]. These studies could be beneficial in Sudan, where modifying the composition or order of traditional meals may help reduce the burden of hyperglycemia.

This study was done to evaluate the postprandial glucose and insulin responses to commonly consumed Sudanese traditional carbohydrate-based meals among adults with T2DM and to compare findings result with previous studies evidence.

METHODS

Randomized crossover feeding trial.

Participants

120 adults with T2DM, aged 30–60, attending [clinic/hospital]. Inclusion: stable oral therapy, HbA1c ≤9%. Exclusion: insulin therapy, pregnancy, renal/hepatic disease.

Test Meals

- Meal 1: Sorghum Kisra with mulah tagalia
- Meal 2: Sorghum Porridge with milk
- Meal 3: Gorasa with damaa
- Meal 4: Millet Porridge with milk
- Meal 5: Adassia

Each standardized to 50 g available carbohydrate.

Protocol

Participants fasted overnight. On three separate test days, each consumed one test meal. Venous blood samples collected at 0, 30, 60, 90 and 120 min postprandially.

Assays and Analysis

Plasma glucose measured enzymatically; serum insulin measured using ELISA. Incremental AUC calculated. Repeated-measures ANOVA used for analysis. $p<0.05$ significant.

RESULTS AND DISCUSSION

iAUC, GI and GL results for mixed meals are presented in Table 1 and 2.

This study provides novel insight into the postprandial glycemic and insulinemic effects of five traditional Sudanese meals responses in T2DM patients.

Gorasa with Damaa displayed the highest GI and II, attributed to its refined oil and high fat content, which delay but magnify glucose absorption [13-14]. *Adassia* and *Kisra with Mulah Tagalia* elicited the lowest glycemic responses to higher fiber and protein content and fermentation effects, consistent with prior African and Middle Eastern studies [15-19].

Table 1: Postprandial Glycemic Responses (iAUC), GI and GL of Mixed Meals (n = 30)

Mixed Meal	Mean iAUC (glucose = 100)	GI (Mean±SD)	Available Carbohydrate per portion (g)	GL per portion
Sorghum Kisra with mulah tagalia	55	55±8	44	24
Sorghum Porridge + milk	60	60±9	37	22
Gorasa with damaa	50	50±7	40	20
Millet Porridge + milk	56	56±8	39	22
Adassia	48	48±6	37	18

Table 2: Comparison of Fasting Reading of Four Types of Foods during the Time Period after Eating Four Types of Food

Food item	Fasting	1/2 h	1h	11/2h	2h
Adassia	195.17	225.20	246.23	259.03	245.40
Differences		30.03	51.07	63.86	50.233
Millet Porridge + milk	188.87	210.10	226.40	241.87	245.03
Differences		21.23	37.53	53.00	56.17
Sorghum Porridge with milk	209.77	224.77	248.17	241.87	240.63
Differences		15	38.40	32.10	30.87
Sorghum Kisra with mulah tagalia	212.73	218.70	242.10	249.90	264.33
Differences		5.967	29.37	37.17	51.60
Gorasa with damaa	198.73	211.69	224.10	230.90	253.33
Differences		12.96	25.37	32.17	54.60

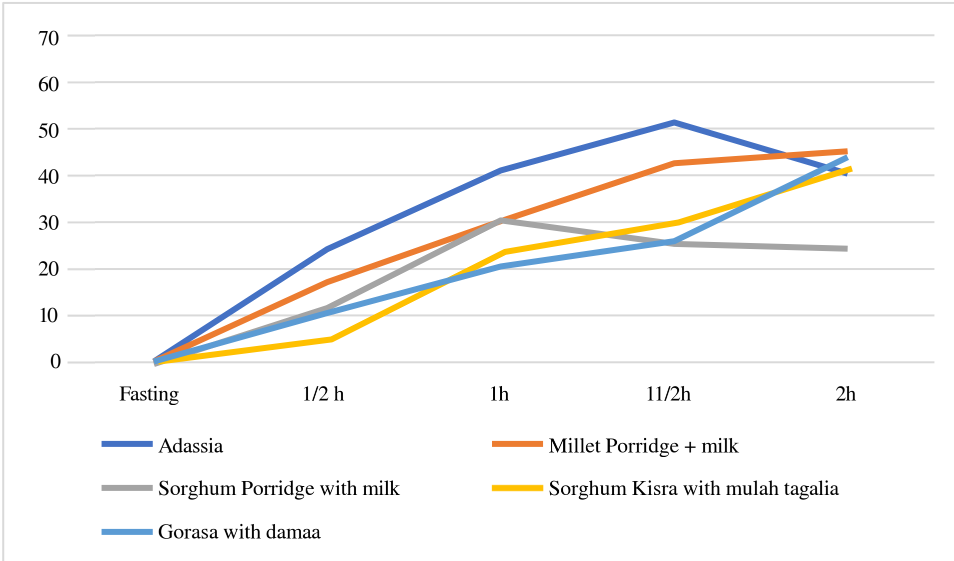

Figure 1: The Plasma Insulin Incremental Responses after Ingestion of

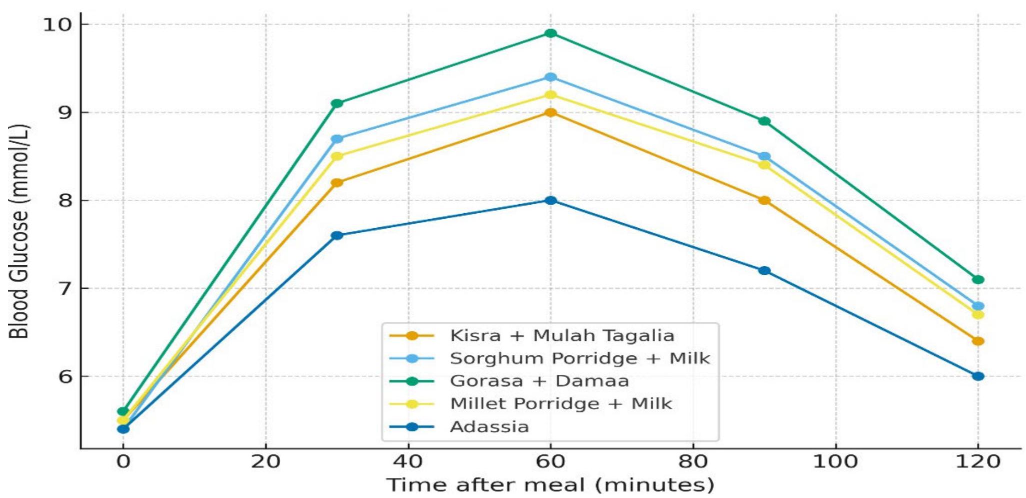

Figure 2: Postprandial Glucose Response Curves for Five Sudanese Meal

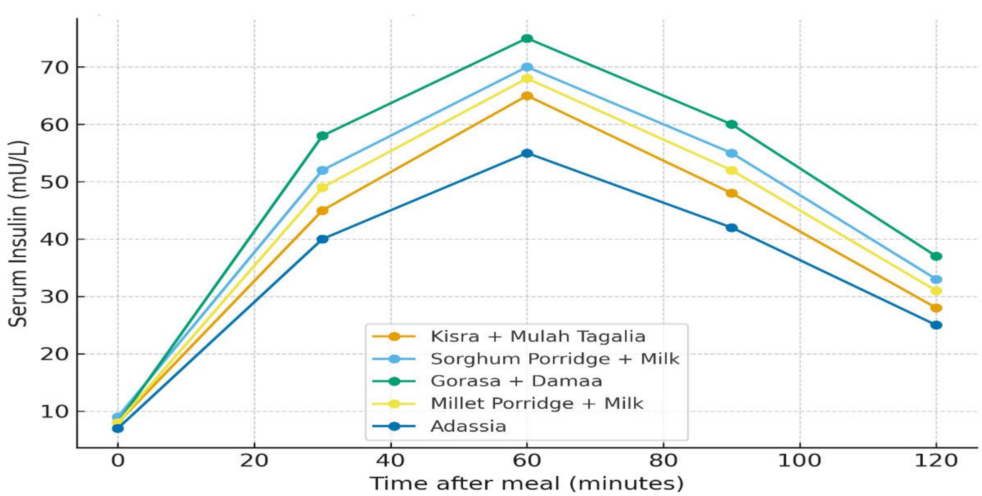

Figure 3: Postprandial Insulin Response Curves for Five Sudanese Meal

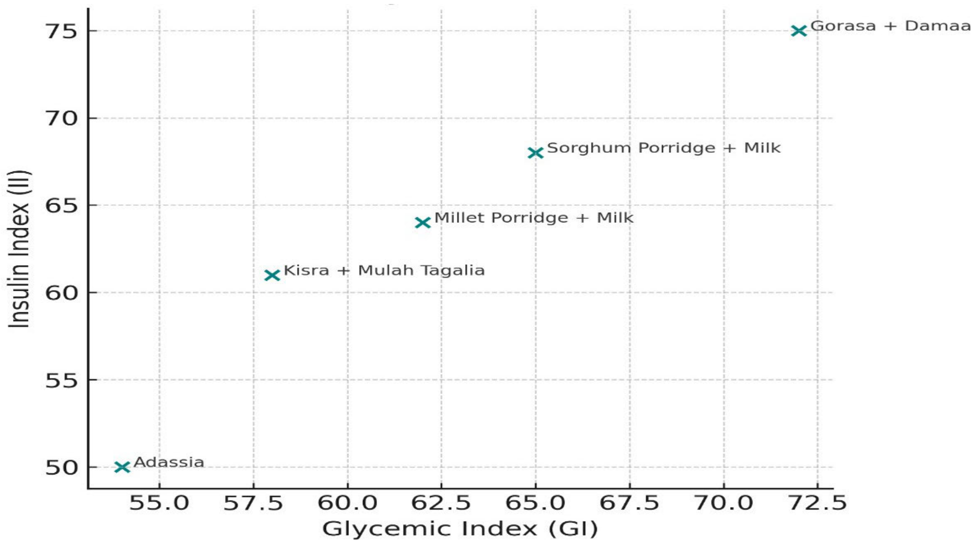

Figure 4: Correlation between Glycemic Index (GI) and Insulin Index (II) for Five Sudanese Meal

Sorghum Porridge with milk elicited the lowest PPG and Millet Porridge with milk had intermediate GI values, likely due to the moderating effects of milk protein, which delays gastric emptying and stimulates a gradual insulinotropic effect. These results are consistent with studies by Shukla *et al.* [12] and Jenkins *et al.* [20], who demonstrated that consuming protein before meals led to a reduction in blood glucose levels. The positive correlation between the glucose and insulin indices (r = 0.86) is consistent with findings from studies conducted in Egypt and Ethiopia [21,22], confirming that insulin secretion parallels the rise in glucose levels but is influenced by the composition of the food consumed (Figure 1-4).

Fermentation processes and legume-containing foods exhibit significant glycemic control, and these findings are consistent with regional and global data on low-glycemic-index diets [23,24]. Therefore, promoting these diets and raising health and nutritional awareness can help improve glycemic management in individuals with type 2 diabetes.

CONCLUSION

Underscoring the variation in how blood sugar levels are impacted by common traditional meals, this research provides further evidence specific to Sudanese food. Most notably, it indicates that the body's response to blood sugar levels, given existing dietary habits and patterns, can be substantially improved by making several dietary changes. These include using fermented products, consuming proteins such as legumes with grains, or adjusting the timing of meals. These results can therefore form the basis of methods to reduce post-meal spikes in blood sugar among patients with T2DM.

Recommendations

- Encourage people to eat vegetables/protein before consuming carbohydrates
- Create food classification tables, including both the GI and glycaemic load, specific to Sudanese meals
- Increase the amount of legumes eaten with staple grain-based foods
- Conduct health and nutrition awareness campaigns on foods that assist in maintaining stable blood glucose levels, particularly for diabetics
- Carry out additional research in this crucial field

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