Effect of Low Glycaemic Index and Glycaemic Load Mixed Meals on Postprandial Plasma Glucose in type 2 Diabetes Patients

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ABSTRACT

Background: *Consumption of high glycaemic index (GI) and glyceamic load (GL) mixed meals may pose difficulties in diabetes Medical Nutrition Therapy (MNT)*

Objective*: This study assessed the GI and GL of four mixed meals and their effect on the post prandial plasma glucose (PPPG) response in type 2 diabetes patients (T2DP)*

Methods*: Hundred T2DP on MNT only attending University of Nigeria Teaching Hospital (UNTH) medical outpatient clinic were recruited. Control was made up of 100 non-diabetic healthy UNTH workers who consumed 50g glucose to determine GI and GL. The four test meals included: Maize meal porridge (Pap) and beans pudding (Moinmoin), Meat stew and boiled white rice and spaghetti with spinach (Rice and Spaghetti), Meat stew and boiled white rice and beans and spinach (Rice and Beans) and Meat and beans and yam pottage and spinach (Beans and Yam). Plasma glucose was tested quarter hourly for 2hours for GI and GL values per serving determination.*

Results: *At 30, 45, 60, 90 and 120 minutes, three meals (i.e. Pap and Moinmoin, Rice and Beans and Beans and Yam) delivered lower GI, GL and decreased PPPG peaks compared to Rice and Spaghetti among non-diabetic and T2DP (P<0.05). Beans and Yam had the lowest GI and GL value per serving (33.20±1.41 and 5.78±0.76) while Rice and Spaghetti had the highest values (49.60±3.63 and 11.49±0.31), respectively*

Conclusion*: Pap and Moinmoin, Rice and Beans and Beans and Yam delivered lower GI and GL and decreased PPPG in non-diabetic and T2DP and may provide healthy alternatives.*

Keywords: Mixed Meals, Type 2 Diabetics, Glycaemic Index, Glycaemic Load, Carbohydrate.

INTRODUCTION

Consumption of high glycaemic index (GI) and glyceamic load (GL) diets may pose difficulties in diabetes Medical Nutrition Therapy (MNT). Glycaemic response (GR) to carbohydrate-containing foods can be classified into GI and GL and are used to ascertain diet suitability in post prandial blood glucose control among T2DP (1). The GI is defined as the incremental area under the blood glucose curve (IAUC) after the consumption of 50 grams glycaemic carbohydrate from a test food divided by the IAUC after eating a similar amount of a control food, generally from glucose, over a 2-hour time frame. In conjunction with the GI is the GL, which draws into account the amount of carbohydrate (ie, quantity), as well as the meals' GI (ie, quality) (2). Although the GI of individual foods has been determined, it is essential to find out the values for mixed meals since people usually eat complex mixed meals, not individual food items (3). Foods with a high GI are digested and absorbed speedily causing a large and rapid rise in blood glucose, whereas those with a low GI are digested and absorbed gradually producing small fluctuations in blood glucose. Viscous dietary fibers slow gastric emptying rates, digestion and the absorption of glucose to better immediate postprandial glucose metabolism and long-term glucose control in individuals with diabetes mellitus (1). Low GI foods are beneficial for health because the swings in glucose and insulin production are minimized. This is especially important for persons who are diabetic (3). Low GI or low GL diets have been linked with reduced risk of developing diabetes, cardiovascular disease and may also aid in weight loss. Low GI diets may aid weight control by promoting fat oxidation over carbohydrate oxidation and by promoting satiety and reducing hunger compared with high GI food. Reducing the GI of mixed meals reduces postprandial glycaemia, insulinaemia, improves blood lipid concentrations, lowers body mass index and lessens the risk of colon cancer in adults (3). Intake of high GI foods can cause elevated peak postprandial blood glucose, which can lead to diabetes-related complications, including cardiovascular disease, strokes, obesity, renal failure, loss of vision, erectile dysfunction, amputations, cancer and death (1). It has also been suggested that the quality of carbohydrates (4), as indicated by GI or GL (5), and, in particular, the intake of sugar-sweetened soft drinks (6), whole grains (7) and dietary fibre (4), is associated with the risk of obesity and metabolic disease (8). Eighty percent of individuals living in the Eastern part of Nigeria eat PM, MRS, MRB and MBY 'almost every day' (compiled from food frequency questionnaire, 2019. Unpublished). This study determined the glycaemic index and glycaemic load of four mixed meals and their effect on the PPPG response in T2DP in the UNTH, Enugu.

METHODS

Ethical registration and approval

The joint University of Ibadan and University College Hospital, Ibadan (UI/UCH) Institutional Review Board and the UNTH, Ituku-Ozalla, Enugu, Institutional Review Board registered and approved the study protocol. The registration numbers were **UI/EC/18/0275 and IRB00002325** respectively. All the participants understood the study procedures performed and gave their written consent.

Participants

One hundred subjects (43 men and 57 women) on MNT only, diagnosed with type 2 diabetes and randomly recruited from the Diabetes Outpatient Clinic, UNTH, Ituku-Ozalla completed the study. Participants were between 40 and 75 years old (mean±standard deviation=57.64±7.92 years of age), with duration of diabetes less than 5 years, body mass index (BMI) of <30 (mean±standard deviation=28.10±3.64) and fasting plasma glucose <11.2 mmol/L. One hundred (43 men and 57 women) non-diabetic (fasting plasma glucose <5.8 and >3.33mmol/L; and 120 minutes plasma glucose after ingestion of 75g oral glucose > 7.7 mmol/L) UNTH workers serving as control were age and sex-matched with T2DP. Their BMI was <30 (mean±standard deviation=22.81±3.78). They did not have congestive heart failure, hypertension, history of renal and liver disease, fever and gastrointestinal disease. Individuals who had severe hypoglycemic episodes during the past year, had taken prednisone or cortisone medications in the previous 30 days, had surgery within the previous 6 months preceding the study or currently on any medications were ineligible to participate.

Test Meals

Four different meals were used for testing:

Test meal 1: Pap and Moinmoin (PM) Yellow maize was fermented, ground, filtered, squeezed and further dissolved in water to give a thin paste. Boiling water was poured into the thin paste to form pap. The cowpea seeds were washed, peeled, wet-milled and reconstituting with hot water in which onions, salt, fresh red pepper, soya oil, cayenne pepper (sombe), one maggi cube and ground dry shrimps were added for palatability. An acceptable quantity was poured into leaves, wrapped and steamed for 45 minutes to form moinmoin and was consumed along with maize pap.

Test meal 2: Meat stew and boiled white rice and spaghetti with spinach (MRS). Stew ingredients included fresh tomatoes, fresh red pepper, tomato puree, onions, soya oil, salt, stock cube, ground dry shrimps, curry, thyme, spinach leaves and beef meat. White rice and spaghetti were cooked differently until soft and then drained. Stew was cooked with the above ingredients. The cooked white rice and spaghetti were consumed with stew.

Test meal 3: Meat stew and boiled white rice and beans and spinach (MRB). Beans were soaked overnight and cooked for 90 minutes. White rice was cooked until soft and drained. The cooked beans and white rice were consumed with stew prepared as mentioned above.

Test meal 4: Meat and beans and yam pottage and spinach (MBY). Beans were soaked overnight and cooked for 60 minutes. Yam was added and cooked for another 30 minutes. Fresh red pepper, onions, salt, stock cubes, ground dry shrimps and palm oil were included to the cooking. The beans and yam pottage were consumed with boiled spinach leaves and beef meat. Association of Analytic Communities method was used to obtain macronutrient composition of the meals in cooked weight basis (Table 1). The serving portion of each meal was provided in portions equivalent to 50g glycaemic carbohydrate which is defined as total sugar plus starch, according to the recommendation of the Joint Food and Agricultural Organization of the United Nations/World Health Organization Expert Consultation (9) (Table 2). The same dietitian measured and prepared the required portion of each test meal on each test day. The reference food for the non-diabetic group was 50g of glucose dissolved in 240ml of water.

Protocol

Participants were tested on four separate occasions allowing a washout period of 1 week preceding the next test. The non-diabetics (control group) had their fifth and sixth bi-weekly visit for the 50g glucose administration. The subjects (diabetics and control) reported at the hospital at 7am after a 12-hour overnight fast. Two readings of fasting plasma glucose were taken and the average of the two values recorded. Participants consumed one of the four meals randomly with 240ml of water within 15 minutes. The non-diabetics also drank 50g glucose within 15 minutes on separate days. During the 2-hour study period, subjects remained seated and sedentary, with the exception of trips to the washroom. The study was completed by all the subjects. Venous blood samples were collected using an intravenous catheter placed in the upper arm in the antecubital vein before consumption of the test meal and at 15, 30, 45, 60, 90 and 120 minutes after test meal intake. Venous blood glucose (plasma with potassium oxalate and sodium fluoride anticoagulant) was determined in the UNTH Chemical Pathology laboratory by a Medical Laboratory Scientist in accordance with the glucose oxidation method (Roche/Hitachi 902 auto analyzer, Japan). Participants were compensated for travel, time and effort upon completion of study.

Statistical Analysis

The trapezoid rule was used to calculate the GI and the IAUC, excluding the area under the fasting baseline. The non-diabetic subject GI was determined by dividing the IAUC of the test meal by the average IAUC of glucose multiply by 100 (10). The GL per serving was calculated by multiplying the GI by the grams of carbohydrate per serving and dividing the product by 100 (11). Mean±standard deviation, one-way analysis of variance and student's t-test were employed to interpret data, determine meal timing effects on glucose and compare the IAUC between the groups respectively. In all of the statistical tests, a P value <0.05 was considered to be significant. Statistical Package for Social Sciences (SPSS) version 20.0 was used to carry out statistical analysis.

Results

Significantly higher fasting plasma glucose was recorded in T2DP than control group ($P<0.05$), however within the two groups values were not significantly different ($P>0.05$) as demonstrated in figure 1 and 2. Significantly lower IAUC for glucose was recorded for all the meals among the non-diabetics than the T2DP ($P<0.05$) as demonstrated in figure 3. Among the non-diabetic participants, there were significant differences in the mean PPPG levels at 30 and 60 minutes as shown in Figure 1.

In the non-diabetic participants, the consumption of 50g glucose led to a significant increase ($P<0.05$) in IAUC at 154.15±19.23 with respect to 50g glycaemic carbohydrate from PM at 52.95±11.53, MRS at 76.20±17.25, MRB at 51.60±11.37 and MBY at 51.00±11.93 (figure 3). This led to a GI value of PM of 34.47±2.69, MRS of 49.60±3.63, MRB of 33.59±1.58 and MBY of 33.20±1.41. The meals of PM, MBY, and MRB were considered to have low GI. The meals of PM, MBY and MRB had significantly lower ($P<0.05$) GL values for a serving (1 milk tin) of 4.81±0.32, 5.78±0.76 and 4.98±0.32 respectively than that of MRS at 11.49±0.31. The GL values per serving of PM, MRB and MBY were considered to be low GL per serving while that of MRS was moderate.

In T2DP, the IAUC for blood glucose in PM at 202.50±19.08, MBY at 133.80±17.95 and MRB at 168.15±18.94 were significantly lower than MRS at 405.00±21.03 ($P<0.05$) (figure 3). At 60 minutes, the ingestion of meals of PM, MBY and MRB significantly reduced plasma glucose concentration reaching a peak value of 9.62 mmol/L (173.16 mg/dl), 8.94 mmol/L (160.92 mg/dl) and 9.23 mmol/L (166.14 mg/dl) respectively, while the consumption of MRS

Table 1: Test meals and macronutrient composition of 100g edible portion

Macronutrient Composition	PM*	MRS[1]	MRB[2]	MBY[3]
Glycaemic Carbohydrate (g)	9.30±0.05	15.97±0.00	9.87±0.07	11.61±0.16
Starch (g)	5.67±0.02	9.39±0.02	5.87±0.01	6.81±0.04
Total Sugar (g)	3.63±0.02	6.58±0.00	4.00±0.02	4.81±0.02
Dietary Fibre (g)	2.62±0.01	5.28±0.02	3.22±0.01	5.80±0.02
Moisture (g)	78.93±0.04	63.95±0.01	72.30±0.01	63.30±0.01
Protein (g)	4.64±0.02	7.55±0.09	9.26±0.05	11.53±0.64
Fat (g)	1.84±0.00	4.20±0.02	2.62±0.04	4.12±0.04
Ash (g)	0.80±0.00	1.31±0.04	1.59±0.00	2.51±0.02

°Glycaemic carbohydrate (g) = Total sugars (g) plus starch (g)
Pm* Pap and moinmoin. MRS[1] Meat stew and boiled white rice and spaghetti with spinach. MRB[2] Meat stew and boiled white rice and beans with spinach. MBY[3] Meat and beans and yam pottage with spinach. Values are mean±standard deviation of mean.

Table 2. Macronutrient composition of served portions and serving size of test meals consumed by by participants

		Per test portion				Per serving size (1 evaporated milk tin)			
	Glucose	PM*	MRS[1]	MRB[2]	MBY[3]	PM*	MRS[1]	MRB[2]	MBY[3]
Portion weight (g)	50	537.63	313.09	506.59	430.66	150	145	150	150
G. carbohydrate (g)°	50	50	50	50	50	13.95	23.16	14.81	17.42
Starch (g)	0	30.48	29.40	29.74	29.33	8.50	13.62	8.81	10.22
Total sugars (g)	50	19.52	20.60	20.26	20.67	5.45	9.54	6.00	7.20
Dietary fiber (g)	0	14.09	16.53	16.31	24.98	3.93	7.66	4.83	8.70
Protein (g)	0	24.95	23.64	46.91	49.66	6.96	10.95	13.89	17.30
Fat (g)	0	9.89	13.15	13.27	17.74	2.76	6.09	3.93	6.18
Energy (KJ)	200	388.81	412.91	507.07	558.33	108.48	191.23	150.14	194.67

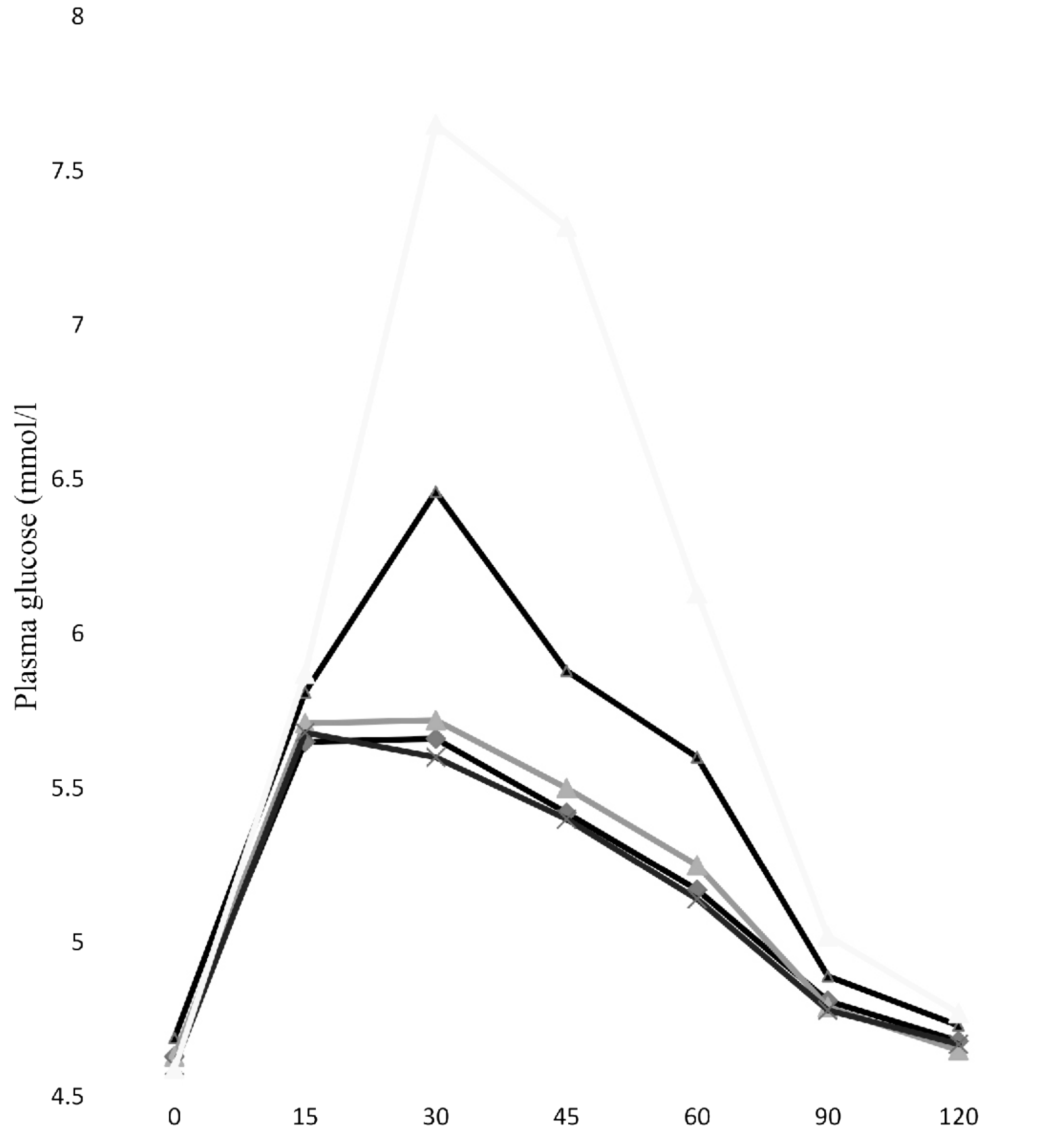
°Glycaemic carbohydrate. PM Pap and moinmoin. MRS[1] Meat stew and boiled white rice and spaghetti with spinach. MRB[2] Meat stew and boiled white rice and beans with spinach. MBY[3] Meat and beans and yam pottage with spinach.

gradually raised the post prandial peak glucose at 60 minutes reaching a peak value of 12.01 mmol/L (216.18 mg/dl) ($P<0.05$). Lower postprandial plasma glucose peak were produced in meals of PM, MBY and MRB compared to the meal of MRS at 30, 45, 60, 90 and 120 minutes ($P<0.05$) as demonstrated in figure 2; making them more effective in lowering the postprandial glucose peak.

DISCUSSION

The extent and pattern of post prandial excursion of glucose affect the degree of diabetic control. Lifestyle intervention strategies to improve post prandial glucose reduce the risk of micro and macro vascular complication related to diabetes. The results of this study show that commonly consumed mixed meals: PM, MBY and MRB have low glycaemic response and minimize postprandial glucose peaks and could be recommended to patients with type 2 diabetes. Carbohydrate digestibility is a major influence on the GI of a food and includes factors such as food form, particle size, chemical structure, processing and presence of antinutrients. Macronutrient content (e.g. fat and protein) may also affect the GI by altering gastric emptying and/or hormone response (12). The meal of MRS had a significantly higher GI, GL per serving, peak plasma post prandial glucose, greater IAUC, higher sugar and starch content and thus more glycaemic carbohydrate than the other three meals for the same serving size of 1 milk tin. Polishing of rice and processing of wheat into pasta are frequently accompanied by disruption of starch crystalline structure, enzyme susceptibility and exposure of starch granules to degradation, hydrolysis and digestion (13). This

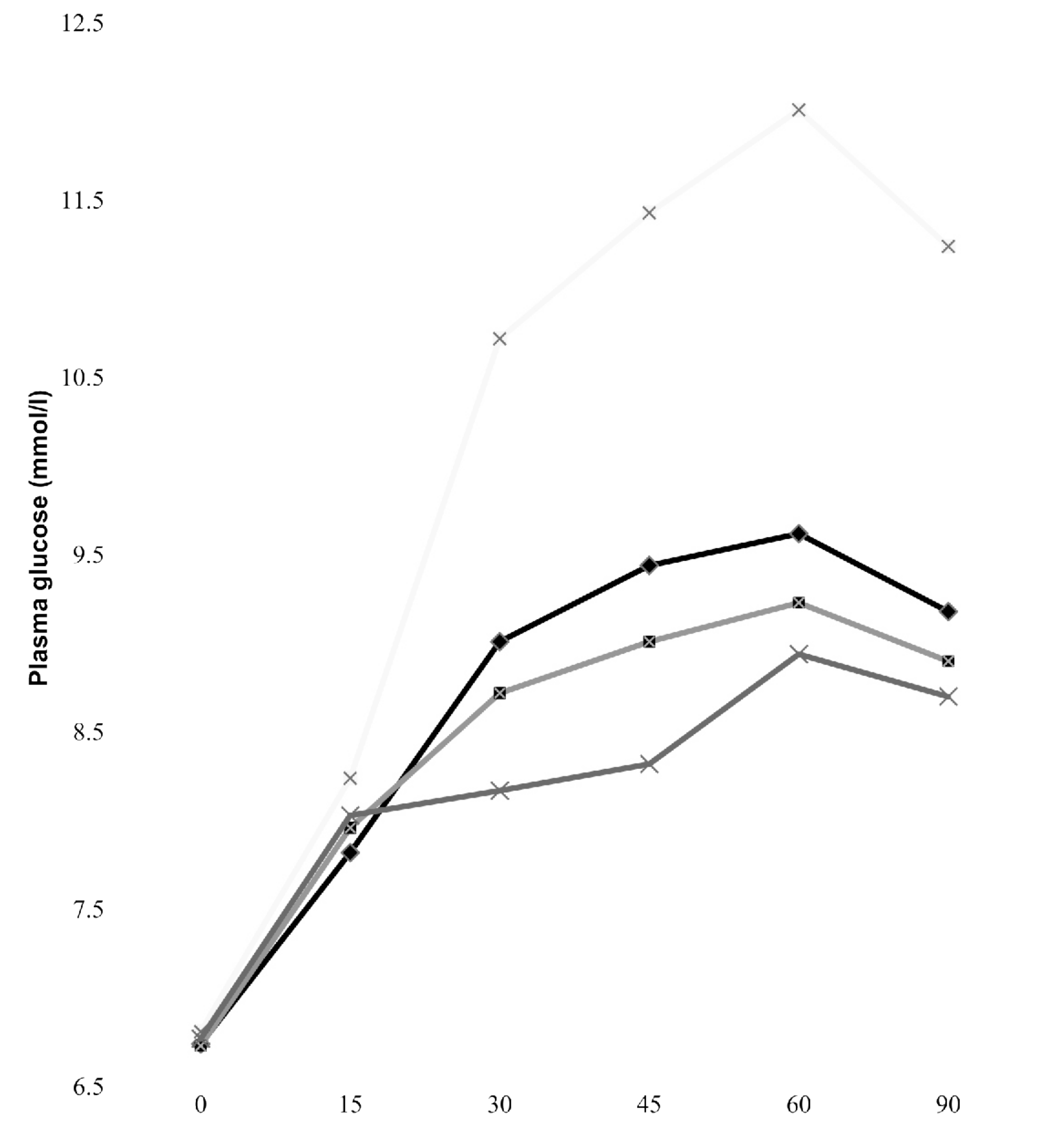
FIG. 1 Mean plasma glucose response curve for each test meal against the reference glucose for the control participants



	0	15	30	45	60	90	120
PM	4.63	5.65	5.66	5.42	5.17	4.81	4.68
MRS	4.69	5.81	6.46	5.88	5.6	4.89	4.73
MRB	4.63	5.71	5.72	5.5	5.25	4.79	4.65
MBY	4.6	5.68	5.6	5.4	5.14	4.78	4.67
Glucose	4.59	5.87	7.65	7.32	6.13	5.02	4.77

PM Pap and moinmoin. MRS Meat stew and boiled white rice and spaghetti with spinach.
MRB Meat stew and boiled white rice and beans with spinach. MBY Meat and beans and yam pottage with spinach.

Figure 1: Mean plasma glucose response curve for each test meal against the reference glucose for the control participant

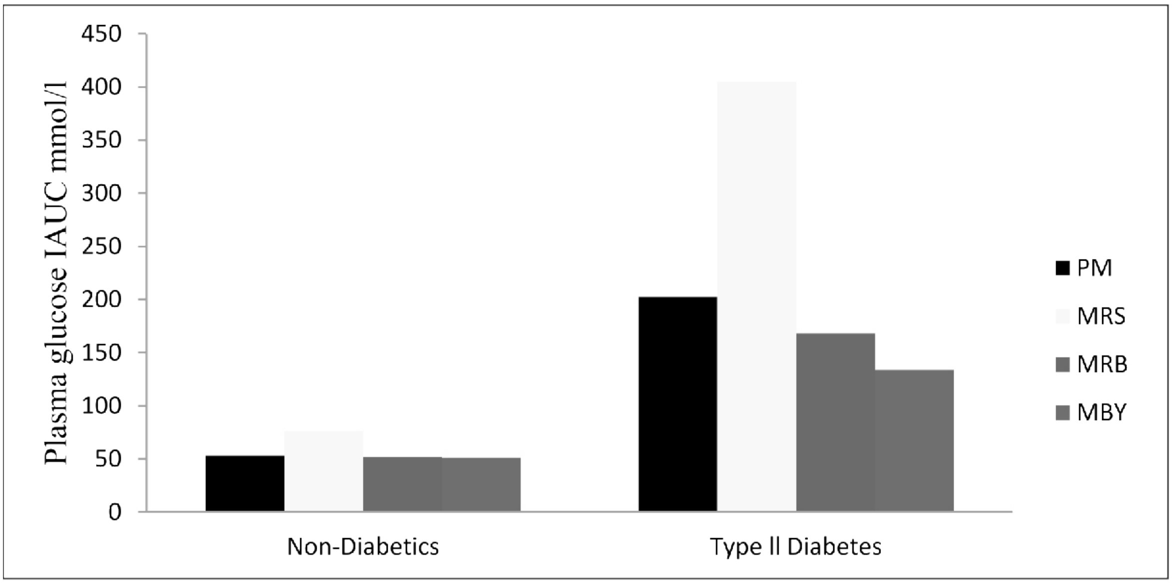


	0	15	30	45	60	90
PM	6.74	7.82	9.01	9.44	9.62	9.18
MRS	6.81	8.24	10.72	11.43	12.01	11.24
MRB	6.73	7.96	8.72	9.01	9.23	8.9
MBY	6.77	8.03	8.17	8.32	8.94	8.7

PM=Pap and moinmoin. MRS=Meat stew and boiled rice and spaghetti with spinach. MRB=Meat stew and boiled rice and beans with spinach. MBY=Meat and beans and yam pottage with spinach. Values were obtained in healthy adults without diabetes (control) and in those with type 2 diabetes.

FIG 2 Mean plasma glucose response curve of test meals for type II diabetes

Figure 2: Mean plasma glucose response curve of test meals for type 2 diabetes subjects



may be associated with the higher glycaemic response recorded in MRS compared with the other three meals. Refined grains have most of their disease preventing nutrients, phytochemicals and antinutrients removed (such as lignans, tocotrienols, phenolic compounds, phytic acid, tannins and enzyme inhibitors (starch blockers)) and were strongly associated with metabolic syndrome in women (14). High GI foods such as refined starches contribute to a quick rise in post prandial blood glucose (15). For Japanese, white rice is the major contributor to the dietary GL (16) which has been shown to increase risk of type 2 diabetes (5). The meals of MBY and MRB contain beans which are rich in soluble fiber associated with delayed gastric emptying and low glycaemic response. The beans were cooked intact which seems to restrict access of intestinal hydrolytic enzymes to ingested beans starch thereby slowing down the rate of digestion and absorption of glucose. In the meal of PM, moinmoin is minimially processed from beans which may be associated with the low glycaemic response recorded. Highly processed carbohydrates are more readily available for immediate absorption by the gut than are minimially processed carbohydrate and they therefore produce a greater and faster rise in postprandial plasma glucose (17). Legumes release their products of carbohydrate digestion more slowly than other starchy foods. The consumption of beans is protective against developing diabetes (18).

The meal of MBY was less processed than PM, MRB and MRS. Cooking to keep the food cells intact may be associated with lower glycaemic index recorded in MBY. Substitution of brown rice for white rice in meals of MRB and MRS could have favorable effects on reducing risk of diabetes. Insoluble fiber in brown rice lowers post prandial blood glucose levels and rice bran oil may lower cholesterol. Increased intake of trace elements and B vitamins found in brown rice might also confer protection against diabetes and other metabolic disorders. Intake of brown rice has been associated with lower risk of diabetes hence partial replacement of white rice with brown rice may have favorable effects on diabetes prevention (19). In general, a dietary pattern that includes whole grains, legumes, vegetables, more fruits and dairy products includes lower-GI foods (20) and is encouraged for good health more than a dietary pattern that includes refined grains, sweets, and desserts (21). The meals differ in their GL values per serving even when they were approximately the same in terms of energy content with respect to a serving size (1 starch exchange). In this context, 2 evaporated milk tins of MBY, PM, MRB and 1 evaporated milk tin of MRS have the same glycaemic effect (GL value per serving approximately 10). This study shows that meals of MBY, PM, MRB are associated with low carbohydrate density than meal of MRS. The larger portion size test meals (MBY, PM, MRB) are of low quality carbohydrate and may be associated with increased fullness and satiety. Consumption of MRS maybe associated with higher postprandial hunger and consumption of more food at the next eating occasion. These larger portions (2 evaporated milk tins of MBY, PM, MRB) would fill the stomach to a greater degree, stimulating pressure receptors in the gut which send feedback signals to the brain centers that regulate satiety than 1 evaporated milk tin of MRS. These filling carbohydrate meals (MBY, PM, MRB) also have low GI values and their slow rate of digestion would prolong the activation of nutrient receptors in the gut and maintain the feeling of fullness. Slowly digested carbohydrate is more satiating per kilocalorie than rapidly digested carbohydrate (1). Palatable refined foods like MRS are likely to be much less satisfying than more traditional meals (MBY, PM, MRB) based on relatively unrefined foods. The bulky less refined meals (MBY, PM, MRB) require more effort to chew and swallow, causing greater gastric distension than soft, energy dense meal (MRS) that can be quickly swallowed. The meals of PM, MBY and MRB contain beans which is a type of pulse. Dietary pulses contribute to satiety, and satiety can in turn help with adherence to diets, it is plausible that the greater effects seen for dietary pulse interventions in negative energy balance trials are due to lessened cravings and/or hunger and thus greater adherence compared to the control groups. Frequent consumption of dietary pulses over 8 weeks in an ad libitum diet resulted in reductions in food intake and waist circumference that were comparable to dietary advice to reduce energy intake.

The T2DP should consume 2 evaporated milk tins of MBY, PM and MRB which are high in fiber, low in glycaemic carbohydrate and moderate in fat as a single meal portion for optimal glycaemic control. Nutrition interventions should emphasize a variety of minimally processed nutrient-dense foods in appropriate portion sizes as part of a healthful eating pattern. Practical tools for day-to-day meal planning and behavior change help type 2 diabetes patients attain glycaemic goal (22). Large portions of low carbohydrate foods may lead to improvements in markers of glycaemic control such as insulin, C-peptide, and leptin (14) Recommendations from the American Diabetes Association are for patients with type 2 diabetes to maintain, "blood glucose levels in the normal range or as close to normal as is safely possible" (23). The European Diabetes Policy Group has set the maximum postprandial glucose peak to not exceed 135 mg/dL (7.5 mmol/L) to reduce arterial risk and 160 mg/dL (9.0 mmol/L) to reduce microvascular risk (24). The meal of MBY, PM and MRB achieved a peak glucose value near that recommended by the European Diabetes Policy Group. The consumption of MBY, PM and MRB could reduce the incidence of kidney disease, blindness, erectile dysfunction, amputations and mortality in T2DP.

CONCLUSIONS

This present study suggests that meals of MBY, PM and MRB were high in fiber, and slowly digestible carbohydrate, minimally processed, with moderate fat and had a significantly lower GI, GL per serving, peak plasma post prandial blood glucose and IAUC than the meal of MRS. These three test meals may provide healthier alternatives and hence their consumption is recommended for patients with type 2 diabetes for optimal glycaemic control. In T2DP, this study recommends that a meal comprising 2 evaporated milk tins of meals of MBY, PM or MRB should be consumed as a single meal portion serving to help improve glycaemic control. Added fat should be reduced and vegetables increased to help lower the fat content and GL of meals.

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None

Conflict of interest statement
The author has no conflict of interest to declare

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