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ORIGINAL ARTICLE

Glycaemic Response to some Commonly Eaten Fruits in Type 2 Diabetes Mellitus

La réponse glycémique due aux fruits les plus consommés au cours du diabète de Type 2

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ABSTRACT

BACKGROUND: **It is not known which of the commonly consumed fruits in Nigeria are suitable for persons with diabetes mellitus especially with regards to the attendant plasma glucose response (PGR) to consumption of such fruits.**

OBJECTIVES: **To determine and compare the PGR to commonly eaten fruits in patients with diabetes mellitus.**

METHODS: **Ten persons with type 2 diabetes mellitus were studied. Fifty gram portions of five fruits containing 50g carbohydrate [banana, *Musa paradisiaca*; orange, *Citrus sinensis*; pineapple, *Ananus comosus*; mango, *Magnifera indica*; pawpaw, *Carica papaya]*, and glucose were randomly fed to the study subjects at one-week intervals. Blood samples were collected in the fasting state and half hourly over a 2-hour period post-ingestion of the fruits or glucose for plasma glucose determination. Plasma Glucose Responses were assessed by the peak plasma glucose concentration (PPPG), maximum increase in postprandial plasma glucose (MIPG), two-hour postprandial plasma glucose level (2hPG) and incremental area under the glucose curve (IAUGC).**

RESULTS: **The mean ± s.e.m. PPPG in mmol/L were: banana, 9.0± 1.6. orange, 8.1± 0.8; pineapple, 9.2±1.1; mango, 8.0 ± 1.1; and pawpaw, 7.8±0.9. The mean ± sem IAUGC in mmol.min/L were: banana, 131.7±53.4; orange, 108.7±29.8; pineapple, 115.3±33.2; mango, 101.6 ± 28.7; and pawpaw, 124.1± 46.1. However, mango showed the least MIPG (1.8 ± 0.5 mmol/l) by followed by orange and pawpaw. The IAUGC also followed this pattern. There were no significant differences among the glycaemic indices of the fruits. Glucose load produced a significantly higher IAUGC than the fruits (orange, pineapple, mango, pawpaw, p<0.005; banana, p<0.025).**

CONCLUSION: **The plasma glucose response to consumption of Nigeria fruits are similar. The PGR indices to all fruits were less than the PGR after an equivalent carbohydrate load of glucose. It appears safe to recommend these Nigerian fruits to persons with diabetes within the prescribed daily total calorie intake. WAJM 2011; 30(2): 94–98.**

Keywords: **Glycaemic response, fruits, diabetes mellitus, non-insulin dependent diabetes mellitus, diet.**

RÉSUMÉ

CONTEXTE: On ignore encore lequel des fruits les plus consommés est le plus approprié pour les sujets présentant un diabète de type 2, en particulier par rapport à la réponse glycémique plasmatique (RGP) qu'entraine la prise de ces fruits.

OBJECTIF: Déterminer et comparer la RGP des fruits les plus consommés chez les patients présentant un diabète de type 2

METHODES: Dix patients présentant un diabète de type 2 ont fait l'objet de cette étude. Des portions de 50 grammes de cinq fruits différents [banane, *musa paradisiaca*; orange, *citrus sinensis*; ananas *ananus comosus*; mangue, *magnifera indica*; papaye, *carica papaya*], et du glucose ont été administrées de façon randomisée aux patients sur des intervalles d'une semaine. Des prélèvements de sang ont été effectués dans la période de jeun et toutes les trente minutes sur une période de deux heures après l'ingestion du fruit ou du glucose pour la détermination du pic de concentration plasmatique du glucose (PCPG). Les RGP étaient évaluées par la PCPG, le pic maximal de la glycémie post prandiale (PMGP), la glycémie postprandiale à 2h (GP2h), et la surface de l'aire sous la courbe de glycémie (ASCG).

RESULTATS: La moyenne du PCPG étaient exprimée en mmol/l ainsi qu'il suit : banane, 9.0±1.6. orange, 8.1± 0.8; ananas , 9.2±1.1; mangue, 8.0±1.1; and papaye, 7.8±0.9. La moyenne de l'ASCG exprimée en mmol.min/l était repartie ainsi qu'il suit : banane, 131.7±53.4; orange, 108.7±29.8; ananas, 115.3±33.2; mangue, 101.6 ±28.7; and papaye, 124.1±46.1.

Cependant la mangue présentait le PMGP le moins élevé , suivi par l'orange, et la papaye. L'ASCG a suivi le même profil. Il n'y avait pas de différence significative sur les indices glycémiques des fruits. La charge en glucose a produit une ASGC significativement plus importante que pour les fruits (orange, ananas, mangue, papaye, p< 0.005 ; banane, p<0.025)

CONCLUSION: La réponse glycémique plasmatique à la consommation de fruits du Nigéria est la même. Les indices de RPG notées pour tous ces fruits étaient moins importants que ceux obtenus avec une charge en glucose équivalente. Il apparait sans risque de recommander ces fruits du Nigéria aux diabétiques dans les limites de la charge calorique quotidienne recommandée. **WAJM 2011; 30(2): 94–98.**

Mots Cles: Réponse glycémique, fruits, diabète, diabète non insulinodépendant , Régime alimentaire

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Abbreviations: BMI, Body Mass Index; **GI,** Glycaemic index; **IAUGC,** Incremental area under the glucose curve; **PGR,** Plasma glucose responses; **MIPG,** Maximum increase in pplasma glucose; **PPPG,** Peak plasma glucose concentration; **PWDM,** Persons with diabetes mellitus; **SEM,** Standard error of the mean; **WC,** Waist Circumference.

INTRODUCTION

Diet therapy is one of the cornerstones in the management of diabetes mellitus[1] Recommending readily available foods to persons with diabetes mellitus (PWDM) enhances dietary adherence. Oli *et al.*[2] reported the glycaemic responses to eight Nigerian foods. They noted that roasted yam, boiled cocoyam, boiled yam and boiled unripe plantain had high glycaemic responses; boiled beans had low glycaemic response, while "eba" (meal of cassava flour) and rice both had intermediate responses. Ohwovoriole and Johnson[3] reported the glycaemic responses to five Nigerian meals and found high glycaemic responses to rice, yam and "dodo" (fried ripe plantain), intermediate response to "eba" and low glycaemic response to boiled beans. Akanji *et al.*[4] observed that "lafun"(a form of cassava meal) produced the least glycaemic response compared to cassava meals in the form of eba or parboiled cassava flakes. Balogun[5] also reported high glycaemic responses to boiled yam, rice, "amala"(meal of yam flour); with eba showing intermediate response while beans and rice/bean mixture had low glycaemic responses.

However, none of these Nigerian studies[2–5] addressed the plasma glucose response to fruits, which are very important items in a balanced diet. Several types of fruits are widely available in Nigeria. They are used as desserts, snacks, and in mixed meals. Fruits are rich in vitamins, minerals, antioxidants and dietary fibres[6–7] and they are desirable in the diet of all persons with or without diabetes mellitus. Edo and Oladele[8] noted that pineapple had higher postprandial glycaemic response than apple in normal glucose tolerant Nigerians. However, it is not known which of the commonly available fruits in Nigeria are suitable for inclusion in the diet of persons with diabetes mellitus especially with regards to their plasma glucose responses. This study investigated the plasma glucose response to some commonly eaten fruits in Nigerian with a view to identifying suitable fruits for the diet of persons with diabetes mellitus.

SUBJECTS, MATERIALS, AND METHODS

Subjects

The clinical characteristics of the study participants is summarized in Table 1.The study group consisted of ten persons (males, four, females, six) with type 2 diabetes mellitus. The four men had a mean age of 60 years (range, 49–64) and a body mass index (BMI) of 26.5kgm^{-2} (range, 24.1 to 29.4). The six females had a mean age of 52.2 years (range, 36 to 66) and a BMI of 26.8 (range, 20 to 29.7) Kgm^{-2}. Four of the subjects were on treatment with glibenclamide 5mg daily only; one was on metformin 500mg bd; three were on metformin 500mg bd plus glibenclamide; one was on chlorpropamide 250mg daily and another was on rosiglitazone 4mg daily. Subjects took their regular medications 5–10 minutes before commencement of each trial. All subjects had been ON diets that regularly contained at least 150g carbohydrate per day. Subjects came at weekly intervals in the morning after a 10-hr overnight fast to the Metabolic Unit of the Department of Medicine, Lagos University Teaching Hospital, Lagos, Nigeria. All the subjects voluntarily gave informed consent. The Hospital Ethics and Research Committee approved the study.

Meal Composition

The test meals contained 50g carbohydrate equivalent portions of fruits or glucose. The nutrient compositions of the fruits meals were derived from a food table[7] and are shown in Table 2. All fruits were purchased from the open market in April – May 2002. The fruits were peeled and served fresh. Only edible portions of the fruits were used. The fruits were purchased in bulk to minimize variation in the source of the fruits.

Study Design

Subjects had their preprandial blood glucose level determined on arrival at the test venue using a glucometer. If the preprandial blood glucose measurement was between 4.4 and 7.8 mmol/L, then the subject proceeded with the test procedure outlined below after resting for 30 minutes, otherwise, the test procedure was postponed.

Table 1: Characteristics of study subjects

	Mean ± SEM (min-max)
Age (years)	55.3±3.0(36–66)
BMI (kgm^{-2})	26.7±1.1(20–9.7)
WC (cm)	96.8±7.0(87–106)
Duration of DM(years)	4.4±1.2(1.0–15)

A tourniquet was applied to the arm above the elbow. After cleaning the antecubital region with swab and methylated spirit, an indwelling cannula placed into a forearm vein was kept patent with physiological saline. A separate syringe was used to withdraw each test sample from the cannula after removal of the cocking syringe containing the saline to minimize mixture of saline with the blood collected. Fasting blood samples were collected from the indwelling cannula. Thereafter subjects consumed either a test fruit or a glucose load using the latin square design.[9]

The glucose solution was ingested over five minutes while subjects were asked to complete consumption of each fruit within five minutes. The study was considered to have commenced with the first bite of the index fruit. Additional blood samples for determination of postprandial plasma glucose levels were obtained at 30, 60, 90, and 120 minutes after each fruit or glucose meal.

Blood samples for glucose estimation were put into fluoride oxalate bottles. Blood samples were centrifuged immediately after the end of each trial for eight min at 12 500g at room temperature. Plasma was pipetted into Eppendorff tubes and stored at -20^{0}C over night where analysis could not be done on the day of collection. Glucose estimation was done by the glucose oxidase method of Trinder.[10] The mean within – assay and weekly between – assay precisions (coefficient or variations, CVs) were both <6%.

Data Management, Calculations and Statistical Analysis

Data were entered into Microsoft Excel Spread Sheet and after cleaning exported to Statistical Package for SSSocial Sciences v.10 for Statstical Analysis.

The results are expressed as mean ± SEM. The cumulative changes in postprandial plasma glucose for each fruit were quantified as the incremental area under the 120-min response curve (IAUGC), which was calculated by the trapezoidal rule with fasting concentrations as the baseline and truncated at zero.[11] Statistical comparisons between subjects at the peak values, maximum increase in plasma glucose values, 2-hour postprandial plasma glucose value, and incremental area under the plasma glucose curve were made by the paired or unpaired student's t-tests as appropriate. The level of statistical significance is set at $p < 0.05$.

RESULTS

Figure 1 shows the trend of the average plasma glucose response after the ingestion of the five different fruits and glucose drink. Pawpaw gave the lowest postprandial glucose responses at all time points. Pineapple peaked at 30mins; banana, orange, mango and pawpaw peaked at 60mins while glucose load peaked at 90min. Among the plasma glucose responses of the fruits, there was no statistically significant difference in the peak postprandial plasma glucose level, maximum increase in the plasma glucose, two-hour postprandial plasma glucose and incremental area under the plasma glucose curve (see Table 3). Glucose load had a higher peak postprandial plasma glucose level than all the fruits but the difference did not attain statistical significance.

Glucose load resulted in a significantly higher MIPG level than the fruits (mango and pawpaw, $p<0.025$; orange and pineapple, $p<0.01$). Significant difference in 2hPG was observed only between post glucose load and ingestion of pawpaw, 7.9±0.9 mmol/L vs 5.5±0.6mmol/L, $p<0.05$. Mango exhibited the least PGR in terms of MIPG and IAUGC, followed by orrange and pawpaw. Banana and pawpaw occupied the first and second positions respectively in terms of IAUGC following fruits ingestion. However, these differences were not significantly different. All the fruits showed a 2-hr postprandial glucose levels that were comparable to their corresponding preprandial plasma glucose levels. All the fruits also showed similar IAUGCs. Postglucose load, however, had a significantly higher IAUGC than all the fruits (orange, pineapple, mango and pawpaw; $p<0.005$ and banana, $p<0.025$).

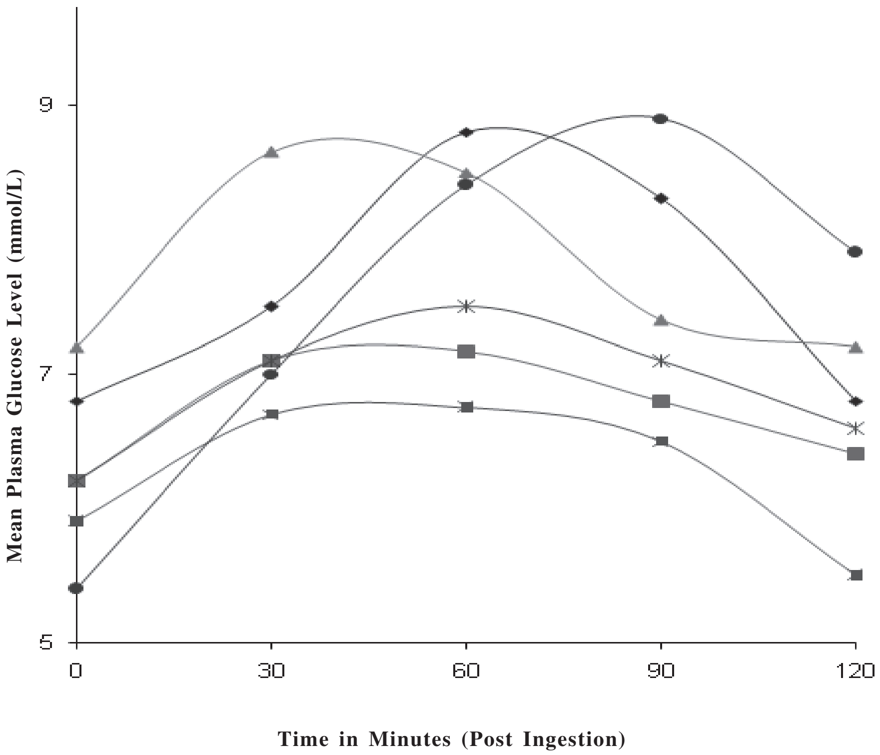

Fig. 1: Mean glucose responses after consuming 50g carbohydrate equiva-lent portions of five different fruits and glucose. Mango, pawpaw, and orange showed the most desirable responses. Banana Orange Pineapple Pawpaw Mango Glucose

DISCUSSION

The results show that banana, orange, pineapple, mango and pawpaw exhibit similar postprandial plasma glucose response profiles which were lower than those of post-glucose load. Pineapple gave a rapid and early postprandial peaking in blood glucose level. All the fruits and glucose load had similar mean PPPG levels.

The mean 2hPG obtained after ingestion of the different fruits were all within the current maximum target 2hPG (7.5mmol/L) in management of DM recommended by the IDF.[12] Pawpaw showed the lowest 2h PG level followed by mango and orange, the differences among the fruits being insignificant statistically. The implication of these favourable 2hPG values post-ingestion of fruits is that these fruit meals may be included in diets of PWDM without adversely affecting their glycaemic control. The serving portions of the fruits tested in this study were large. We believe smaller portions of these fruits will produce lower plasma glucose response. Gannon *et al*[13] reported that in diabetic subjects the blood glucose response increases approximately in proportion to the amount of carbohydrate consumed, at least when the amount of carbohydrate in the meal is less than 50g.

The IAUGC of banana (131.7±53.4mmol/L^{-1}min^{-1}) in this study was larger than the IAUGC of 106±17mMx240min reported by Hermansen *et al.*[14] for over ripe banana in persons with type 2 DM. The IAUGC for under ripe banana was 62±17mM x 240min. in their study. The differences in the mean IAUGC of banana in these studies could be partly ascribed to the effect of the ripeness of banana in increasing its glucose response. Starch is converted to simple sugars as banana ripens. The other contributing factor to the discrepancy in IAUGC of banana may

Table 2: Nutrients and Caloric Content per 50g Carbohydrate Equivalent Portions of Test Fruits

Fruit	(N)	Calorie	Nutrient Content (grams)			
			Protein	Fat	Fibres	Serving weight (g)
Banana	9	414	3.6	1.1	3.6	357
Orange	9	204	3.1	*	1.2	385
Mango	5	210	1.7	*	2.7	333
Pawpaw	6	200	3.3	*	3.9	556
Pineapple	10	203	1.4	*	1.8	357

N, number of subjects who consumed the index fruit. Orange (*Citrus sinensis)*; Banana (*Musa paradisiaca*). Pineapple (*Ananus comosus*); Pawpaw (*Carica papaya*); Mango (*Magnifera indica*). *Insignificant amounts. Source, Platt, reference 7.

Table 3: Plasma Glucose Response Indices to Fruit Consumption

Test item	N	Plasma glucose (mmol/L)			IAUGC (mmol.min/L)	
		FPG	PPPG	MIPG	2hPG	
Banana	9	6.8±1.1	9.0±1.6	2.2±0.9	6.8±1.3	131.7±53.4*
Orange	9	6.2±0.9	8.1±0.8	1.9±0.4*	6.4±0.9	108.7±29.8*
Pineapple	10	7.2±1.2	9.2±1.1	2.0±0.4*	7.2±1.0	115.3±33.2*
Mango	6	6.2±0.9	8.0±1.1	1.8±0.5*	6.6±0.9	101.6±28.7*
Pawpaw	5	5.9±0.7	7.8±0.9	1.9±0.6*	5.5±0.6*	124.1±46.1*
Glucose	10	5.4±0.5	9.4±0.9	4.0±0.6	7.9±0.9	298.0±67.5

Values are mean ± SEM.

PPPG, Peak postprandial plasma glucose; MIPG, Maximum increase in plasma glucose; 2hPG, Two-hour postprandial glucose; IAUGC, Incremental area under the 120minute plasma glucose curve. Significance of difference from glucose: *p <0.05,

be due to the fact that the IAUGC was derived from a glucose response over a 4-hour period compared to the 2-hour period used in this study. The variety of banana used in their study was not stated but it could also have contributed to the difference in the result.

The mean IAUGC of orange of about 109mmol/min/L was the third most favourable in PWDM in this study. This was lower than that of 131±34mM x 240min reported by Gregersen *et al*.[15] in glucose intolerant subjects. This discrepancy could be due to differences in the variety and ripeness of the oranges used and the 4-hour period rather than a 2-hour period used to derive the IAUGC of orange. Roongpisuthipong *et al*[16] reported that the glucose – response curves to mango and banana were significantly less than that of pineapple ($p<0.05$). In this study, the mean IAUGC of mango was similarly less than that of pineapple but that of banana was, however, larger than the IAUGC of pineapple though the differences in the IAUGCs of the fruits in PWDM did not attain any statistical significance. The consistently favourable glycaemic responses of mango may recommend it as the choise for fruit in the diet of PWDM. Banana elicited a greater response than orange in this study. This is similar to the result of an earlier study by Jenkins *et al*.[17] Compared with glucose load, all fruits had lower postprandial glycaemic indices. This finding was expected as fruits are rich in fibres and fructose, which produces lower glycaemic response than glucose.[11,18]

The specfic effect of age, sex and type of oral hypoglycaemic agents consumed by the study subjects on the glycaemic responses to fruits could not be ascertained in this study because of the small sample size of the participants. However, Wolever *et al*.[19] determined the magnitude and sources of variations in the glycaemic index (GI) values obtained by investigators in different international centers.[19] They noted that the GI values were not significantly related to subject characteristics (age, sex, BMI, ethnicity or absolute glycaemic response). There was no association between glycaemic responses and nutrient contents of the fruits.

The plasma glucose response indices of mango, pawpaw, and orange were consistently lower, though not significantly, than those of banana and pineapple especially in terms of the PPPG, MIPG and 2hPG and are therefore may be more commendable fruits in the diet of PWDM.

No symptoms or biochemical evidence of hypoglycaemia was observed during the trials in any of the subjects even though the subjects were maintained on their usual doses of oral hypoglycaemic drugs. This observation could have useful implications in the management of obese diabetic patients. This finding suggests that any of these fruit meals could be used as food exchange or as mixed meals in the management of our diabetic patients.

It is concluded that in type 2 diabetes mellitus consumption of banana, orange, pineapple, mango and pawpaw produced similar glycaemic responses when equicarbohydrate portions were consumed and that they may be used as food exchange or as mixed meals in the management of type 2 diabetes mellitus. However, the best post-consumption glycaemic responses appear to those of mango, pawpaw, and orange.

Further studies are needed to compare the glycaemic response of fruit juice with the whole fruits assessed in this present study and also fruits as part of mixed meals. It should be noted that in earlier studies, Jenkins *et al*[20] found that the glycaemic index (Gl) of apple juice was similar to that whole apples and the Gl of orange juice was similar to that of whole oranges. Concurrent insulin responses were not assessed in this study but may be important in future studies on glucose responses to ingestion of fruits.

Limitations of Study

It should be noted however that the nutrient contents of the fruits derived from food tables are approximation due to variations in the glucose/sugar content even within the same species of fruits. It might be more accurate to chemically analyse the nutrient composition of the fruits before administering them to the study subjects. The GIs of the fruits were not derived among the PWDM because the presence of DM and its treatment have been known to affect postprandial glycaemic response. The GIs of meals are usually derived in non-diabetic subjects because inter-subject variability in glucose response is less in non-diabetic patients and the effects of diabetes and its treatment on glucose responses are avoided.[11]

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