Original Article

Acute effects of five Ghanaian carbohydrate diets on serum glucose, triglyceride and insulin in NIDDM

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Glycemic indices have been used to predict useful carbohydrate sources of food for patients with non-insulin-dependent diabeties mellitus (NIDDM) on dietary management programs. The present study has revealed that glycemic indices alone are not adequate predictors of useful carbohydrate meal sources. We observed for the first time that glycemic indexes inversely correlate with triglyceride indices. In our test mixed meals varying in five Ghanaian carbohydrate food types for nine non-insulin dependent diabetics, the correlation between glycemic and triglyceride indices was ($r = –0.63$; $P = 0.005$). The atherogenic potential of triglyceride makes a critical review of the sole use of glycemic indices as useful carbohydrate predictors necessary. We also observed that unripened big plantains (a staple Ghanaian food) could be a useful carbohydrate source for NIDDM patients.

Key words: glycemic index, triglyceride index, insulin index, non-insulin-dependent diabetes mellitus, plantain, carbohydrate, Ghana.

Introduction

Non-insulin-dependent diabetes mellitus (NIDDM) is a leading cause of disability and death in developed and developing nations.[1–3] The present mode of treatment begins with dietary management and proceeds to oral antidiabetics drugs.[4,5] Dietary treatments may vary as a result of the different dietary habits in different countries. Ultimately, the diets aim to reduce fat as energy and blood glucose which, when increased, are channelled into triglyceride synthesis, leading to obesity and risk of cardiovascular disease.[6] In patients with NIDDM, the increase in plasma triglyceride concentration is mainly caused by an increased endogenous synthesis, which may fall with improved glycemic control.[7] Most case-controlled and epidemiological studies have reported that triglyceride is the sole risk factor correlating with the incidence of coronary artery disease (CAD).[8,9] Improved glycemic control, therefore, reduces triglyceride synthesis and the risk of CAD.[10]

In Ghana, the diet for NIDDM patients is usually a mixed meal varying in its sources of carbohydrates. In a preliminary experiment, we observed that five Ghanaian carbohydrate diets showed different post-prandial responses to blood glucose in normal individuals. The glycemic indices suggested a good dietary regimen for diabetics. In order to pursue further the usefulness of these diets in regulating plasma glucose in diabetics, we studied the acute effects of the five diets on post-prandial plasma glucose, triglyceride and insulin in patients with NIDDM.

Subjects, materials and methods

Subjects

Ten male, non-insulin dependent diabetics aged 45–70 years were recruited from the Diabetic Clinic of the Korle-Bu Teaching Hospital, Accra, Ghana. The ninth patient was later excluded after revealing that he was also undergoing chemotherapy. All patients satisfied the criteria as defined by the World Health Organization (WHO), and the American National Diabetic Data group.[11,12] The patients' mean fasting blood sugar was 8.9 mmol/L and they were on dietary treatment only. They were matched for duration of diabetes and body mass index (BMI; 26.1). The experimental protocol was approved by the ethics committee of the University of Ghana Medical School, Accra, Ghana.

Collection of blood specimen

The subjects were all housed at one location 3 days before the beginning of the experiment and fed a nutritious diet. Prior to the beginning of the experiment, each of them had an average daily intake of 200 g carbohydrate in their meals. A glucose tolerance test was performed on each subject on Day 0 (the day preceding the use of test diets) and then performed again for each test diet on each succeeding day. The meals were given randomly to the participants.

Blood specimens were collected in fluoridated heparinized tubes via an indwelling intravenous catheter up to 2 h post-prandially for glucose and triglyceride assays. In the case of insulin assays plain tubes were used. Serum or plasma samples obtained after centrifugation were stored at –40°C until analysis.

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Biochemical assays and meal composition

Glucose was analysed using the glucose oxidase procedure, triglycerides enzymatically and insulin by an enzyme immunoassay method.[13] The sources of carbohydrate for the test meals were rice (*Oryza sativa*), gari, big unripened plantains (*Musa paradisiaca*), white yam (*Discorea* species) and Ga kenkey. Gari is made by grating cassava (*Manihot utilissima*) and then dehydrating the fibre in sacks for 3 days, after which the residue is roasted. Ga kenkey is a fermented corn dough formed into the size of a fist and boiled in corn sheaves. Each test meal was a mixed meal containing 35% fat and 17% protein, with the only variable being the source of carbohydrate. The compositions of the meals were calculated from food composition tables. The indices for glucose, triglyceride and insulin were calculated as follows:

$$\text{Glycemic index (GI):} \quad \frac{\text{incremental area under 2 h plasma glucose curve of 50 g carbohydrate load}}{\text{incremental area under 2 h plasma glucose curve of 50 g glucose load}} \times 100$$

$$\text{Triglyceride index (TG):} \quad \frac{\text{incremental area under 2 h plasma triglyceride of 50 g carbohydrate load}}{\text{incremental area under 2 h plasma triglyceride curve for 50 g glucose load}} \times 100$$

$$\text{Insulin index (II):} \quad \frac{\text{incremental area under 2 h serum insulin curve of 50 g carbohydrate load}}{\text{incremental area under 2 h serum insulin curve for 50 g glucose load}} \times 100$$

Statistical analysis

Results are given as mean ± SD. The paired Student's *t*-test was used to compare the means of the indices after performing analysis of variance. Pearson's correlation coefficient was used to assess the association between the indices.

Results

Table 1 summarizes the composition of each of the test meals. The only variable in each meal was the source of carbohydrate.

Table 2 depicts the results of the glucose tolerance test for the patients.

Table 3 gives the glycemic, triglyceride and insulin indices of the test meals. Ranking from lowest to highest, the following order was obtained:

GI: rice < plantain < Ga kenkey < gari < yam

TI: yam < gari < plantain < Ga kenkey < rice

II: yam < Ga kenkey < rice < gari < plantain

The TI correlated inversely with the GI ($r = -0.63$, $P = 0.005$), with rice accounting for the least and highest glycemic and triglyceride indices, respectively. Rice and yam show opposing responses for glycemic and triglyceride indices. Taking all of the indices together, plantain emerged as the most favourable carbohydrate source for the diabetics. Ga kenkey was the next most favourable, followed by gari.

Student's *t*-test for pairs of meals for triglyceride, insulin and glycemic indices (TI, II, GI) are shown in Table 4.

Table 1. Composition of meals with different sources of carbohydrate (CHO)

Ingredients	Weight (g)	Energy (kcal)	CHO (g)	Protein (g)	Fat (g)
Boiled rice					
Rice	172	200	48	4	0
Oil (salad)	12	141	0	0	15
Fish	40	63	0	4	1
Onions	12	4	1	0	0
Tomatoes	25	4	1	0	0
Total		412	50	18	16
Boiled yam					
Boiled yam	178	203	48	3	0
Oil (salad)	12	141	0	0	15
Fish	40	63	0	14	1
Onions	12	4	1	0	0
Tomatoes	25	4	1	0	0
Total		412	50	18	16
Ga kenkey					
Ga kenkey	174	216	48	5	1
Oil (salad)	12	141	0	0	15
Fish	40	63	0	14	1
Onions	12	4	1	0	0
Tomatoes	25	4	1	0	0
Total		428	50	19	17
Boiled green big plantain					
Big plantain	152	201	48	2	0
Oil (salad)	12	141	0	0	15
Fish	40	63	0	14	1
Onions	12	4	1	0	0
Tomatoes	25	4	1	0	0
Total		413	50	16	16
Gari					
Gari	56	196	48	1	0
Oil (salad)	12	141	0	0	15
Fish	40	63	0	14	1
Onions	12	4	1	0	0
Tomatoes	25	4	1	0	0
Total		408	50	15	16

Table 2. Glucose tolerance test (GTT) in non-insulin dependent diabetics (glucose values mmol/L)

No.	Subject time (min)				
	0	30	60	90	120
1	9.4	15.1	18.0	18.0	13.8
2	9.9	19.6	21.4	18.9	18.5
3	9.3	21.7	24.0	19.1	16.6
4	7.3	12.5	14.3	14.2	14.1
5	7.7	15.6	15.1	17.7	15.6
6	9.1	15.8	19.6	17.1	15.6
7	8.4	15.8	23.3	20.4	16.3
8	7.2	10.0	10.1	7.1	6.2
9*	9.5	16.6	22.3	18.5	20.2
10	10.0	16.1	23.4	24.6	21.9

*Subject No. 9 was excluded after revealing that he was also undergoing chemotherapy.

Table 3. Glycemic, triglyceride and insulin indices of test meals

Carbohydrate source	Glycemic index	Triglyceride index	Insulin index
Rice	40.2 ± 6.0	1.37 ± 1.1	1.1 ± 0.5
Plantain	40.9 ± 5.1	1.02 ± 0.6	1.25 ± 0.5
Ga kenkey	43.7 ± 5.7	1.09 ± 0.6	0.91 ± 0.3
Gari	49.0 ± 2.9	0.95 ± 0.9	1.17 ± 0.8
Yam	64.9 ± 7.0	0.93 ± 0.8	0.82 ± 0.4
n	9	9	9

Table 4. Student's *t*-test between pairs of meals for each test

Pairs of meals	GI	TI	II
Kenkey and Yam	*	NS	NS
Kenkey and Plantain	NS	NS	NS
Rice and Kenkey	NS	NS	NS
Kenkey and Gari	NS	NS	NS
Plantain and Yam	*	NS	*
Rice and Yam	*	NS	NS
Gari and Yam	NS	NS	NS
Plantain and Gari	NS	NS	NS
Rice and Gari	NS	NS	NS
Rice and Plantain	NS	NS	NS

GI, glycemic index; TI, triglyceride index; II, insulin index; NS, not significant; *significant, $P < 0.05$.

Discussion

The treatment of NIDDM is aimed at selecting a diet that minimises the level of metabolic risk factors for CAD. In NIDDM patients, the risk factors for CAD are increased blood glucose concentration, increased post-prandial and total very low density lipoprotein (VLDL) triglyceride, increased post-prandial insulin levels and reduced high density lipoprotein (HDL) cholesterol concentration.[10] Glycemic indices have been used conventionally to select suitable meals for the NIDDM patient.[14] The factors affecting the glycemic index, including the nature of starch, processing and cooking methods are not the same within and between countries. Therefore, it is not easy to select a common meal for diabetics.[15–18] The development of new approaches of treatment is therefore necessary. The results of the experiment with the five Ghanaian test meals show that on the basis of only the glycemic index, rice is the best choice among the five as a carbohydrate source, whereas yam is the worst. However, the triglyceride index gives the very opposite indication. This means that glycemic index alone is not an adequate index for selecting an appropriate carbohydrate source for diabetics. We are aware that the peak triglyceride level in the blood post-prandially is 4 hours; nevertheless, because we are looking at correlation and not at the absolute values of the figures, the results are relevant. Triglyceride has been observed as the sole risk factor which correlates the strongest with CAD in diabetic populations.[8,9,19] Considering that NIDDM patients already have the tendency for hypertriglyceridemia, any diet that tends to cause an elevated serum triglyceride may not auger well for a patient on a sustained intake of the particular carbohydrate.[20]

It has been documented that raised serum triglyceride levels result from higher VLDL-TG.[21,22] It may be that for the test meals with low GI, a slow rise in blood glucose did not lead to an adequate tissue supply. This then is compensated for by an increased lipolysis in peripheral tissues, providing free fatty acids and glycerol. In the presence of normal circulating insulin levels, this leads to an increased hepatic VLDL-TG synthesis and secretion and elevated plasma triglyceride. It may be interesting to examine why the carbohydrates show such varied responses.

When the results are taken together, plantain appears as the choice carbohydrate, among those tested, for diabetics. Its effect in causing a significant elevation in the insulin index while maintaining a low GI and average TI is worth noting. Most diabeties clinicians in Ghana have long suspected that plantain meals are useful for diabetics. Our results provide the first direct evidence of this supposition. Following plantain, Ga kenkey and then gari appear to be the most beneficial for diabetics. We think that the selection of either rice or yam must be based on the individual responses of the patients because of the diametrically opposed responses evident in the glycemic and triglyceride indices, respectively. Even though the statistical differences in the indices are not significant, a sustained intake of the various diets could effect significant responses.

Our data reveal that glycemic indices alone are not adequate predictors of useful carbohydrate meals. When all three indices are compared, plantain should serve as a useful carbohydrate source for NIDDM patients.

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血糖值已被用爲非胰島素依賴性糖尿病患 (NIDDM) ，在飲食處理上預測含有用碳水化合物的食物來源。目前的研究顯示僅有血醣值不足以預測有用的碳水化合物飲食來源。我們首度觀察到血糖值和三酸甘油脂值的相互關係背道而馳。在我們測試混合餐中，用不同的五種迦納碳水化物食物型態給予非胰島素依賴性糖尿病患，而其血糖值和三酸甘油脂值間的關係爲 ($r = -0.63$, $p = 0.005$) 三酸甘油脂致血管粥樣硬化的可能性在單獨使用血糖值作爲有用的碳水化合物必然的預測做一個重要的覆審。我們同時也觀察到未成熟，大塊的Plantain (一種迦納的主要食物) 可以作爲非胰島素依賴性糖尿病患有用的碳水化合物來源。

附註：Plantain產於熱帶地區。成長期需要大量的雨水和陽光。其樣子類似香蕉，但比香蕉大約二至三倍。不可以稱它爲水果，因爲它必須經煮，炒或烤時方可食用。其顏色爲綠色時，即採摘烹煮，含糖量甚少卻非常可口。

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