Glycaemic response to different preparations of yam in diabetic and non-diabetic Nigerians

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Abstract
Post-pandial glycaemic responses to food can be affected by the method involved in the preparation of the food. Dietary intervention with food modification forms the cornerstone of management of type 2 diabetes worldwide. The effect of processing on yam, a staple food in Nigeria, was studied among diabetic and non-diabetic Nigerians. Despite undergoing more processing, amala prepared from yam flour had a better post-pandial glycaemic response index (PGRI) compared to other yam preparations, and this was also significantly higher among the diabetic subjects. Yam-based products, particularly amala, should be encouraged among diabetic Nigerians.

Introduction
The glycaemic response to carbohydrate meals can be altered by modifications and cooking method during preparation. A much greater blood glucose response occurs after the consumption of cooked compared with raw starch, and pureed compared with whole foods.[1–3] The glycaemic response to both whole white and brown rice is significantly and dramatically higher when the rice is ground into flour.[3] Similar results are seen with whole and ground lentils.[4] When white flour is given in the form of spaghetti, blood glucose levels rise less than when the same amount of white flour is given in the form of bread.[5] In recent years a great deal of attention has been focused on the variable metabolic responses seen after ingestion of different types of simple and complex carbohydrates.[6]

The prevalence of type 2 diabetes is rising globally.[7] Dietary modification forms the cornerstone of management of the disease, especially in Nigeria where most anti-diabetic drugs are either not readily available or are not affordable. Lifestyle intervention including dietary modification can reduce the occurrence of diabeties in high-risk individuals. One of the major staple foods eaten in Nigeria is yam. The objective of this study was to determine if there was any difference in the glycaemic response to different forms of yam meals in diabetic and non-diabetic Nigerians.

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Patients and methods
Subjects
A total of 48 subjects were recruited into the study comprising 24 non-diabetic subjects (12 male, 12 female) and 24 type 2 diabetic patients (12 male, 12 female), as defined by World Health Organization (WHO) criteria.[8] The age, height, weight, blood pressure, and baseline fasting plasma glucose (FPG) were determined for all subjects.

Non-diabetic subjects had no family history of diabetes, were not on any drug that could affect carbohydrate metabolism, and had a body mass index (BMI) <30 kg/m^{2}. Impaired fasting glycaemia (FPG 6.1–7 mmol/L) were also excluded from controls.

Diabetic subjects recruited were maintained with diet alone or diet and oral hypoglycaemic agents (OHAs), had good glycemic control (FPG at recruitment 4.0-6.7 mmol/L), and BMI <30.0 kg/m^{2}. Diabetic subjects on OHAs did not take treatment on the morning of the test meal consumption.

Food preparation and test procedure
The three yam meals were prepared as follows:
- Boiled yam: peeled yam sliced and cooked until softened, with salt added to taste.
- Pounded yam: peeled yam sliced and cooked until softened and pounded in a mortar using a pestle to a smooth dough consistency.
- Amala: this was prepared from browned yam flour. In Nigeria browned yam flour 'elubo', is traditionally made by parboiling yam chips at about 80^{o}C till the chips are pliable, then the chips are sun-dried for about 72 hours and ground into flour. The yam flour was reconstituted by boiling in water and cooked with continuous stirring until a thick brown or grey-coloured smooth paste is formed (amala).[9]

Fifty grams (50 g) of glucose, as recommended by the

WHO/FAO (Food and Agriculture Organization) expert consultation panel,[10] were weighed and dissolved in 350 ml of drinking water and given to the control subjects following the overnight fast and after the fasting blood samples had been taken. This was to determine the glycemic index for each yam meal. Blood samples were collected every 30 minutes for 2 hours. The food varieties were prepared in the morning of the test by the same cook. The test procedure commenced at 08:00 in the morning after an overnight fast of at least 12 hours. Using food composition tables for local foods,[11-14] weighed amounts of each food to contain the equivalent of 50 g glucose (i.e. 175 g of boiled yam, 225 g of pounded yam, and 280 g of amala) were measured. These were eaten with about 30 ml of the prepared stew composed of fresh pepper and tomato cooked with red palm oil and salt added to taste, with a piece of meat (beef only) of uniform size (about 35 g) and 350 ml of water. Blood samples were collected every 30 minutes for 2 hours. Timing for sample collection was commenced with the initiation of consumption. There was at least a 48-hour interval between the reference meal consumption and the test food consumption for the control subjects.

Analysis

The glycaemic index was measured as the incremental area under the glucose curve (IAUGC) of each yam meal eaten by the control subjects, expressed as a percentage of the IAUGC to the glucose ingested. Maximum increase in plasma glucose (MIPG), peak plasma glucose (PPG), and 2-hour post-prandial plasma glucose (2HPPG) were determined for each food.

Statistics

Student's t-test was used to compare the various plasma glucose response indices. Statistical significance was taken as $p<0.05$. Means were calculated with standard errors of the mean (SEM).

Consent and ethical approval

Consent was obtained from all subjects and approval for the study was obtained from the Ethics Committee of the University of Ilorin Teaching Hospital.

Results

Table 1 shows the subdivision of the subjects into three groups based on the yam meals. The mean recruitment FPG was significantly higher ($p<0.05$) in the diabetic group, although the levels still suggested good glycaemic control.

The mean 2-hour PPG was significantly higher in the diabetic group compared with the controls ($p<0.05$) for all the yam meals studied. Mean MIPG was also higher in the diabetic group ($p<0.05$) for boiled yam (4.3±0.4 vs 1.9±0.3) and amala (1.8±0.2 vs 1.3±0.2). The mean IAUGC was higher in the diabetic group but only achieved statistical significance with boiled yam (276±21 vs. 128±19.3; $p<0.05$). The mean 2-hours PPG was significantly higher in the diabetic group ($p<0.05$) for all the yam meals (see Table 2). Among the three yam meal preparations studied, amala had a better PGRI in both studied groups. Figure 1 shows the glycaemic index of the various yam meals compared with that of a glucose drink. Amala has a significantly lower glycaemic index of 36.8% compared with boiled yam (52.9%) and pounded yam (82.6%).

Discussion

In all the indices assessed for post-prandial glucose response, the type 2 diabetic patients had significantly higher values compared with the controls. People with type 2 diabetes have excessive and prolonged increases in post-prandial plasma glucose levels as a result of reduced early insulin release, insulin resistance, and suppression of glucagon secretion.[15,16] As a consequence, overall release of glucose is increased after meal ingestion. Most of the excess release of glucose occurs within the first 2 hours, is correlated with changes in glucagon and insulin,[17] and is the result of both increased release of endogenous glucose and glucose contained in the meal.[18] The increased endogenous glucose release results from reduced suppression of glycogenolysis and gluconeogenesis.[17] The increased release of glucose contained in the meal most likely results from the failure to sequester the glucose as hepatic glycogen due to increased glycogenolysis, although a defect in phosphorylation cannot be excluded.[17]

Food processing played a very significant role in the

Table 1 Characteristics of subjects by the different yam meals (means ± SEM)

Characteristic	Diabetic patients			Non-diabetic controls		
	Boiled yam (n=8)	Pounded yam (n=8)	Amala (n=8)	Boiled yam (n=8)	Pounded yam (n=8)	Amala (n=8)
Age (years)	42±2	39±29	39±2	36±2	41±3	37±2
BMI (kg/m^2)	24.3±0.7	24.6±0.8	22.9±0.8	22.7±0.6	24.1±1.0	24.1±0.8
FPG (mmol/L)	5.5±0.3	5.6±0.2	5.6±0.3	4.4±0.3	4.8±0.3	4.6±0.3

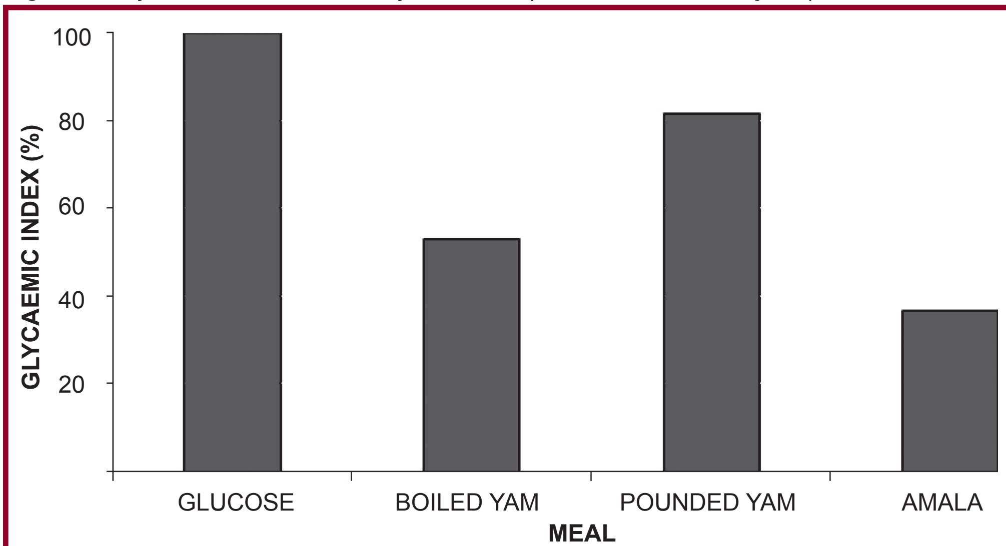
Note
BMI = body mass index
FPG = fasting plasma glucose

Table 2 Glycaemic response indices of different preparations of yam meals (means±SEM)

	Boiled yam (n=8)	Pounded yam (n=8)	Amala (n=8)
Non-diabetic controls			
GI (%)	52.9±7 (26–93)	81.6±10.1 (23–127)	36.8±7 (14–78)
IAUGC (glucose 50 g) (mmol.min/L)	241±19 (164–315)	202±19 (127–280)	214±25 (115–355)
IAUGC (mmol.min/L)	128±19.4 (55–195)	160±20 (41–219)	75±14 (22–144)
PPG (mmol/L)	6.2±0.3 (5.2–7.2)	6.2±0.1 (5.6–6.7)	5.4±0.1 (4.7–6.1)
MIPG (mmol/L	1.9±0.2 (0.7–2.7)	2.3±0.23 (0.9–3.2)	1.2±0.2 0.6–1.8)
2HPPG (mmol/L)	4.8±0.14 (4.1–5.2)	4.1±0.1 (3.6–4.6)	4.4±0.1 (3.8–4.8)
Diabetic patients			
IAUGC (mmol.min/L)	276±21 (171–357)	229±55 (107–471)	104±15 (49–165)
PPG (mmol/L)	10.1±0.3 (8.6–11.1)	9.2±0.8 (6.5–12.6)	7.1±0.3 (5.9–8.2)
MIPG (mmol/L)	4.3±0.4 (2.4–5.7)	3.5±0.8 (1.6–7.3)	1.8±0.2 (1.1–2.5)
2HPPG (mmol/L)	6.1±0.13 (5.7–6.8)	6.5±0.2 (5.8–7.5)	5.6±0.1 (4.9–6.2)

Note
GI = glycaemic index
IAUGC = incremental area under the glucose curve
PPG = peak-plasma glucose
MIPG = maximum increase in plasma glucose
2HPPG = 2-hour post-prandial glucose

Figure 1 Glycaemic indices of the yam meals (for non-diabetic subjects)



glucose excursion observed in both study groups. Pounded yam had the highest of the indices except for 2-hour PPG. Pounding of boiled yam (without salt) in a mortar with intermittent addition of water makes the yam softer and finer and increases the surface area upon which digestive enzymes will act, thus bringing about more rapid absorption of the glucose.

Altering the physical form of carbohydrate changes the post-prandial glucose and insulin response,[3] thus pounding of boiled yam increased its post-prandial plasma glucose response. This is consistent with the findings of O'Dea et al[19] in which grounding of brown rice resulted in its postprandial glucose response being higher than the ungrounded rice in both normal and diabetic subjects. The physical form of the food is a determinant of the rate at which the starch is hydrolysed.[4]

Amala had the least of the indices although it undergoes more processing than the others. It is known that the more processed a food is, the higher the glycemic response it will produce.[20,21] This appears to be negated by the response to amala in this study. During the process of boiling of yam in water, gelatinisation of the starch molecule occurs, thus increasing the availability of starch for digestion by digestive enzymes. This is what occurs when boiled yam is eaten directly, and also in pounded yam with no further processing. However, in the preparation of yam flour,[9] the parboiled yam is sun-dried for about 3 days, losing almost all of its water content with a progressive re-association of the starch molecules (retrogradation).[10] This re-association reduces the digestibility of the starch molecule. The processing of yam to produce yam flour results in an increase in the content of fibre.[9] Various studies have shown the importance of viscosity (a property of the fibre content of food) on post-prandial glucose response to food.[21–24] In the preparation of amala, yam flour is usually sprinkled on boiled water and only very rarely is it boiled continuously as in other meals. This might also reduce the availability of starch from it, as observed by Collins et al[1] in other foods. Furthermore, amala is usually swallowed without chewing and this has been reported to reduce the *in vivo* glycaemic effect of meals.[25] Thus the lowered post-prandial plasma glucose response indices of amala, when compared with those of the other yam meals studied, may be due to various factors; most important of which may be the gelatinisation and subsequent retrogradation of the starch molecules that occurs during the processing of the yam to produce yam flour.

With the increasing incidence of diabetes globally,[7] dietary restriction and modification still remains a cornerstone in the prevention and management of the disease. Monotonous consumption of certain foods, e.g. unripe plantain, beans and bean-based products, among Nigerian diabetic patients leads to poor compliance and subsequent poor glycemic control. Dietary guidelines[26]that include other local staple foods like amala should be encouraged.

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