Glycaemic Index and Load of Acha (Fonio) in Healthy and Diabetic Subjects

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Acha or Fonio is a popular cereal consumed by the diabetics' subjects and it contributes substantially to the total food intake of the diabetic subjects in Nigeria. It has become very expensive as the only major acceptable carbohydrate food and therefore it is necessary to determine its glycaemic index and load of Acha among the Type II diabetic and healthy control subjects. Ten volunteer Type II diabetics and seven healthy subjects consented for the metabolic studies. Fifty grams available carbohydrate of Acha (*Digitaria exilis* Stapf) meal and okra (*Abelmoschus esculentus* L Moench) soup was used as test food while 50 grams of glucose served as the reference food. The blood glucose responses were used to calculate the area under the blood glucose curve (AUC) to determine the glycaemic index of the meal. The percentage of carbohydrate in the meal multiplied by glycaemic index was equal to glycaemic load. The glycaemic index in Type II diabetics and healthy subjects were found to be 49 and 35 respectively. The glycaemic load of Acha meal was 17.5 for control groups and 24.5 in Type II diabetic subjects. The Glycaemic index (GI) of Acha meal is low in both Type II diabetics and healthy subjects. The glycaemic load of the Acha (*D exilis)* meal is just enough for control and high for the Type II diabetic subjects. The GL could explain why despite the consumption of Acha by Type II diabetic their blood glucose could not be controlled because they regularly consume it in their homes more than the portion size served in this research. Therefore, it is necessary to adjust the quantity of Acha (*D. exilis*) meal consumed by diabetics' subjects.

Key words: Glycaemic index, Glycaemic load, Acha, Type II diabetes.

Digitaria exilis Stapf is an indigenous food of West Africa with common names such as acha, fornio, or hungry rice. It belongs to the grass family; *poaceae*, and grows under condition of low rainfall with relatively high yields. *D. exilis* was relatively less well known than sorghum which grows in the same arid regions (Rooney *et al*., 1986). It has small yellow or cream coloured grains after it has been processed for food. The small grains are attractive and are used without grinding or milling for porridge, couscous meal (Tuwo) and many other dishes in northern Nigeria where some ethnic groups may consume acha three times a day in various forms (Jideani *et al.*, 1990). It can be ground and mixed with flour to make bread. The proteins and carbohydrates of acha have been characterized (Jideani *et al.*, 1994; Jideani *et al.*, 1996). It is presently a popular meal among the diabetics because of the claim that it helps in controlling blood glucose in diabetics, and so it contributes

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substantially to their total meal intake in Nigeria. Consequently, it has become one of the most expensive cereals in the country. Some studies have not evaluated the GI or GL but have found lower risk of diabetes among men and women consuming higher amount of whole grain (Fung *et al.*, 2002; Manson *et al.*, 2000; Liu *et al.*, 2003) and higher risk for those consuming refined grains (Liu *et al.*, 2000a). A meta-analysis supported the use of the GI as a scientifically based tool to enable selection of carbohydrate-containing foods to improve the overall metabolic control of diabetes as the low-GI diets significantly improved blood glucose control in Type II diabetics' subjects (Opperman *et al.*, 2004).

Based on the available epidemiological evidence, a diet with a low-GI may play a role in the prevention of Type II diabetes, and the same is true with a diet rich in dietary fiber and whole grain foods. However, on the basis of these studies one cannot rule out that other factors in whole grains, or factors associated with whole grain consumption, may contribute to the preventive effect rather than the direct effect of GI or GL on glucose and insulin response (Arvidsson-Lenner et al., 2004).

Glycaemic index (GI) of food has important preventive and therapeutic implication in the management of conditions such as diabetes, lipidaemia and obesity while the Glycaemic Load (GL) gives specific food portion the body has to deal with to keep the blood glucose levels within normal range when eaten. The aim of this study was to determine the glycaemic index and glycaemic load of a realistic meal of acha in Type II diabetes compared to healthy control subjects using tests acha meal as normally prepared locally.

MATERIAL AND METHODS

Ten volunteer Type II diabetic subjects who consented for the study were selected. Subjects were informed of the nature of the study and the time involved. All the subjects were Type II diabetic and they were all in good health apart from the diabetes. Those on drugs were told to stop for one week before the commencement of the study to avoid drug interference with the study and verbal confirmation of adherence to protocol of research were obtain before starting. Metabolic studies were carried out on two different mornings after an overnight fasting of ten-twelve hours. The control and diabetic groups took glucose solution and acha (*D. exilis) meal* on different days at interval of 3-4 days. On the day of the studies, fasting venous blood samples was drawn from each subject then the standard food (glucose) or the test food (Acha (*D. exilis)* meal) was administered. They were instructed to eat the entire meal within 15 minutes which approximate the O time. At 30, 60, 90, 120 and 150 minutes, 2mls venous blood samples were collected. The blood collected from each subject was immediately centrifuged and analyzed for glucose using glucose oxidase method (Trinider, 1961). Glycaemic Index was calculated as incremental area under the blood glucose curve as proposed by Wolever and Jenkins (1986). Information on age, sex, anthropometric measurements, and the type of drugs and how long they have been diagnosed were obtained from the subjects.

Seven healthy volunteers without personal or family history of diabetes served as control. All procedures were described in a protocol submitted to and approved by the scientific and Ethical Committee of Ahmadu Bello University Teaching Hospital, Shika, Zaria, Nigeria

Meals

Fifty grams of glucose was used as standard food while 50 grams of available carbohydrate in Acha and dry okra soup with meat was used as the test meal. Food composition tables by Enwere (1998) were used to calculate the nutrient composition of foods. The meal contained the following approximate macronutrients.

Carbohydrate	-	50 grams (50.8%) of the total meal calorie.
Protein	-	18.2 grams (19.1%) of the total meal calories.
Fat	-	14.0 grams (27.1%) of the total meals calories
Total energy intake	-	409.9 kilocalorie

The percentage composition of carbohydrate, protein and fat was within recommended range as advised by World Health Organization (WHO 1985; WHO 1990). The ingredients were purchased in bulk sufficient to conduct all tests.

Calculation of Glycaemic Index (GI) and Load (GL)

The incremental areas under the blood

glucose curves (IAUC) were determined for each food according to standardized criteria (Wolever and Jenkins, 1986; Wolever *et al.*, 1991) ignoring any area below the baseline. Glucose was used as the reference value and each subject's individual GI for the meal was calculated. The GI for each food was taken as the average of all 10 individuals' values for diabetic subjects and average of all 7 individuals' value for control subjects. The GL was calculated using the carbohydrate content of the serving portion of the meal as percentage multiply by the GI.

Statistical analyses

The glycaemic index responses of the reference and meal were compared using a paired t-test within the group. Unpaired t-test was used between the diabetics and healthy subjects. The level of significance was taken as $P < 0.05$.

RESULTS

Ten Type II diabetic subjects and 7 control subjects participated in the study. The average age for type-2 diabetic subject was 50.10±2.79years (range 35-60years). The control groups mean age was 53.50± 2.81 (range 45 – 65years). The body mass index of the diabetics and the control groups were 28.73±1.94 and 28.93±2.00 (kg/ m^2) respectively. The average duration of diabetes mellitus in the Type II diabetes study group was 3.50 ± 0.76years (range 1-9 years). All the Type II diabetics were on one or combinations of hypoglycaemic drugs plus diet except three who were on diet only. Information obtained from the subjects revealed that the major regularly consumed foods before the study were beans, acha, and wheat; other carbohydrate foods are eaten sparingly. The quantity consumed in their homes depended on how much they could eat and be satisfied.

The glycaemic index of Acha (*D. exilis*) and dry okra (*A. esculentus)* soup in the control was 35 while that of Type II diabetics subjects was 49. The calculated GL of the meal was 17.5 in control subjects and 24.5 in diabetic subjects. The mean blood glucose response to acha meal in the diabetics was significantly lower than the response to glucose only at 120 minutes while it was significantly lower at 60 minutes in the control subjects (Table 1).

The incremental value between glucose and acha in diabetic subjects was also significantly higher after glucose was consumed from 30-150 minutes at $p<0.5$ (Table 1). In the control the incremental value also was only significantly lower ($p<0.001$) at 60 minutes after consumption of acha (Table 1). Individual Type II subjects reached peak serum concentrations of glucose averagely at 90 minutes after the test meals while the peak serum concentration in control was averagely reached at 60 minutes after the test meals. The incremental difference between diabetics and controls were significantly higher in the diabetic subjects at 30, 60, 90, 120 and 150minutes $p<0.05$. The two hours postprandial blood glucose in type-2 diabetic subjects was 14.48±1.66mmol/L after consumption of glucose while it was 11.24±2.12mmol/L after consumption of acha which was significantly lower ($p<0.05$) after acha meal was consumed. In the controls it was 6.20±0.92mmol/L after glucose drinks while it was 4.15±0.33 after acha meal and it was similar (Table 1).

Table 1. Parameters of participants with glycaemic index and glycaemic load of acha meals fed to diabetic and control subjects

	Age(years)*	BMI(Kg/m^2)*	Duration*	Glycaemic* Index	Glycaemic# Load
Diabetic subjects	50.10±2.79	28.73±1.94	3.50±0.76	49	24.5
Control subjects	53.50±2.81	28.93±2.00	N/A	35	17.5

*Means ± SD. #Calculated rounded up value of the means. N/A= Not Applicable

Table 2. Blood glucose responses and increments to glucose and acha meal in diabetic and healthy subjects

	Diabetic Subjects				Control Subjects			
	Glucose Solution		Acha Meal		Glucose Solution		Acha Meal	
Time (Min)	Blood glucose (mmol/L)	Incremental glucose (mmol/L)	Blood glucose (mmol/L)	Incremental glucose (mmol/L)	Blood glucose (mmol/L)	Incremental glucose (mmol/L)	Blood glucose (mmol/L)	Incremental glucose (mmol/L)
0	7.04±1.19		8.17±1.55		4.22±0.23		3.55±0.24	
30	11.87±1.36	4.83±0.38a	10.36±1.88	2.19±0.56a	6.35±0.89	2.13±0.73	4.62±0.43	1.07±0.54
60	13.85±1.40	6.81±0.96b	11.72±2.02	3.55±0.71b	7.22±0.68g	3.00±0.57h	5.00±0.43g	1.45±0.42h
90	14.80±0.97	7.76±1.14c	12.36±2.16	4.19±0.88c	6.75±0.97	2.53±0.81	4.43±0.17	0.99±0.29
120	14.48±1.66d	7.44±1.44e	11.24±2.12d	3.07±0.80e	6.20±0.92	2.00±0.79	4.15±0.33	0.60±0.41
150	13.46±2.08	6.42±1.41f	10.66±2.07	2.49±0.83f	5.17±0.50	1.00±0.44	3.98±0.22	0.43±0.40

Values in mmol/L are means ± SD. Values in the same row with same superscripts are significantly different ($p<0.5$). Blood glucose concentration at time 0 min corresponds to Fasting blood sugar (FBS). Incremental glucose means increment in blood glucose concentration over fasting blood glucose.

DISCUSSION

The glycaemic index of Acha (*D. exilis*) in both control and Type II diabetic subjects were rated low since they had less than 55. It has been shown by Brand-miller *et al. (2003)* that low GI diets improve glycaemic control over and above that obtained by conventional high GI diets. Although there was no correlation between the control and diabetic GI, the mean blood glucose responses were not strikingly different. In the diabetic Type II subjects there was slightly lower blood glucose in response to acha meal at 120minutes when compared to the response of glucose.

In the control group it was only significantly different between glucose and acha meal at 60minutes, but acha meal did not significantly lower the blood glucose in the diabetics' subjects as expected. The various study in normal, diabetic and hyperlipidemic subjects showed that low GI diet reduced the mean blood glucose concentration (Wolever *et al., 1991;* Wolever, *1997;* Wolever *et al., 1992;* Frost *et al., 1996*). Thus, low-GI cereal foods appear to vary in their potential in improving glucose tolerance at subsequent meals in healthy and diabetic subjects. In addition to the slow release properties of such foods, the content of dietary fiber appears to play a role. Therefore the acha meal of low GI is expected to produce lower blood glucose response which is not too striking as this study has shown. In diabetics subjects the chronic consumption of a low-glycaemic index diet is generally found to improve plasma glucose and lipid profiles (Brand-Miller, 1994), but acha did not significantly lower the blood glucose in the diabetics' subjects.

A reduction in dietary GI improved glucose and lipid metabolism and normalized fibrinolytic activity in Type II diabetics, while maintaining a similar amount and composition of dietary fiber. However, the higher dietary fiber content frequently associated with low-GI foods may add to the metabolic merits of a low-GI diet (Bjorck and Elmstahl, 2003). This may be as result of the high GL of the meal regularly consumed by the diabetic subjects in their homes. The glycaemic Load (GL) of acha meal in the control was within normal while it was high in Type II diabetics. This could explain why many diabetic subjects blood glucose could not be controlled because the higher the GL, the greater the elevation of the blood glucose response. The long term consumption of a diet with a relatively high GL has been shown to be associated with an increased risk of type - 2 diabetes and coronary heart disease (Liu *et al.*, 2000b) and that low GL diet is associated with increased HDL (Ford & Liu, 2001: Frost *et al*., 1999). Low GL has even been found to be a stronger predictor of serum HDL cholesterol than dietary fat intake (Frost *et al*., 1999). Similar relation between GI and GL with HDL and also with lower fasting triglycerides was found in a study by Liu and coworkers (Liu *et al*., 2001).

Subjects with Type II diabetes achieved peak serum concentration of glucose later than healthy subjects with acha test meals. This support the observation by Dahlqvist and Borgstrom (1961) that ingested starch was rapidly hydrolyzed to disaccharides and oligosaccharides by normal subjects.

CONCLUSION

The result clearly demonstrated that apart from knowing the glycaemic index of the meal, it is necessary that the load (total amount consumed) of the meal must also be considered. Though acha has low glycaemic index the quantity consumed by the diabetics' client is by far higher than what they require.

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