Evaluation of the Glycaemic Index of some Staple Foods of South Eastern Nigeria

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Excessive release of glucose into the blood from food substances associates with metabolic disorders like diabetes. This study assessed the Glycaemic index (GI) of some staple carbohydrates foods consumed in Calabar and Southern part of Nigeria. Sixty (60) healthy volunteers aged 16 to 70 years. The test diets consisted of five food samples: Fried ripe plantain with stew and meat (FPSM); unripe plantain porridge with meat (UPPM), Garri and afang soup with meat (GASM), Fufu afang soup with meat (FASM), Abacha and fried groundnut (AFG). Fasting blood glucose, GI and available carbohydrate were estimated using standard methods. Results show that GASM and FASM had the highest GI, while FPSM had the least GI relative to glucose. The glycaemic load (GL) measured in 2 hours was highest in AFG, while FPSM had least GL. After 30 minutes, AFG had significantly (p<0.05) higher GI (6.74 ±0.12) compared with other subjects. But 120 minutes after, FPSM consumers recorded the lowest GI (4.829 ±0.10), while GASM (7.61 ±0.12) and FASM (7.34 ±0.14) were the highest. In conclusion, garri and fufu diets (AFG, FASM and GASM) have very high GI, yielding high levels of blood glucose compared with plantain diets (FPSM and UPPM) consumed in Calabar, Nigeria.

**Keywords:** Glycaemic index, staple food, Nigeria

**INTRODUCTION**

Glycaemic index is defined as a ranking of carbohydrate foods from 0 to 100 according to the extent to which they raise blood sugar levels after meals, (Roder, 2005; Aston et al., 2008; Atkinson et al., 2008). It is a measure of how quickly blood glucose levels rise after consuming a particular type of food. Brand-Miller, (2009) views it as an estimate of how much each gram of available carbohydrate in a food raises blood glucose level following consumption of the food relative to consumption of pure glucose, (Brand-Miller, 2003; 2009). The concept of glycaemic index (GI) was proposed by Hodge and colleagues to characterize the rate of carbohydrate absorption after a meal (Hodge et al., 2004). Glycaemic load of a diet is the product of the glycaemic index of a specific food and its carbohydrate content. It is a variable representing the quality and quantity of carbohydrate and it bear significant relationship with the risk of type-2 diabetes (Al-Jiffri and Abd El-Kader, 2015; Gabriele et al., 2008).

Carbohydrates that break down quickly during digestion and release glucose rapidly into the blood stream have a high glycaemic index, while carbohydrates that break down more slowly releasing glucose more gradually into the blood have low glycaemic index (Jenkins, 2008). According to experts, nutritional habits play a decisive role in increasing the burden of chronic conditions such as diabetes mellitus (Mcmillan-Price et al., 2006; American Diabetes Association, 2010). Therefore, modifying dietary habits could exert a positive impact on the prevention and treatment of diseases associated with dysfunctional glucose metabolism. Under such circumstance, it would be helpful in reducing the amplitude and duration of post prandial hyperglycemina. Some carbohydrate rich foods such as garri, rice and yam induce less post-ingestion hyperglycemina than others (Bahado-Singh et al., 2011; Al Dhaheri et al.,2010). Therefore selecting the right kinds of carbohydrate foods could actually represent a strategy in the prevention and treatment of diabetes mellitus (Ley et al., 2014; Jenkins et al., 2008; Krishnan et al., 2007; Babio et al., 2010; Bantle et al., 2008).

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Many specific interventions have been carried out in the prevention and management of diabetes mellitus. One of such intervention options has been the use of clinical nutrition (Ntui, 2006). High GI foods elicit calorie for calorie, higher insulin level than low GI foods (Al Dhaheri et al., 2010; Sacks et al., 2014; Hartman et al., 2010; Runchey et al., 2012). The reduction in dietary GI may also lower the risks for various conditions associated with hyperinsulinemia, such as cardiovascular disease and diabetes mellitus, (McMillan-Price et al., 2006; Vrolix and Mensink, 2010).

Diabetes mellitus is a degenerative disease and if not properly managed will lead to a lot of complications. Diabetes mellitus is a longstanding metabolic disorder associated with dysfunctional metabolism of glucose. It is a disease condition with many complications like high blood sugar, kidney failure, blindness etc. It is common both in the western and in the third world countries (Bhupathiraju et al., 2014). In Nigeria, the prevalence of diabetes mellitus is on the increase (Aediwura et al., 2011; Eleazu, 2016), and this disease affects both the old and the young populations.

Glycaemic index was conceived as a tool for the dietary management of type II diabetics. The utility of the glycaemic index in managing diabetes is fraught with controversy. However, despite the numerous controversies as reported by Jenkins and Onimawo (2006), there is still strong support of the glycaemic index of diets for promoting weight loss and good health (Fabricatore et al., 2011; Estruch et al., 2013), considering the fact that diabetes mellitus is one of the most prevalent epidemics of the 21st century (WHO, 2016; Beat diabetes 2016; Wole, 2013; Sacks et al., 2014).

Since different foods vary in their glucose quantity and quality in terms of their metabolism and release into the blood, hence their glycaemic index and tendency to elevate blood glucose levels. It was the aim of the study to investigate the glycaemic indices of some staple foods consumed in the southern part of Nigeria, with a view to ascertain the rate at which they release glucose into the blood.

MATERIALS AND METHODS

Study Area

The study was carried out in Calabar South Local Government Area, Nigeria. The area has an estimated population of 219,134 as projected in 2006 national population census.

Selection of Study Population

The study involved 60 healthy volunteers aged 16 years to 70 years. They consisted of two groups of males and females. They were further divided into six sub-groups based on age as shown below. The Ethical approval was obtained before the start of this study from the Cross River State Ministry of Health Ethical Committee.

<table>
<thead>
<tr>
<th>Sex</th>
<th>Age</th>
<th>Number of persons</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male</td>
<td>16 – 25 years</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>26 – 35 years</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>36 years and above</td>
<td>10</td>
</tr>
<tr>
<td>Female</td>
<td>16 – 25 years</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>26 – 35 years</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>36 years and above</td>
<td>10</td>
</tr>
</tbody>
</table>

Inclusion criteria

The study population constituted of normal healthy young adults who were non-diabetic, non-obessed, and did not have any family history of diabetes and were on no medication known to affect glucose or insulin metabolism, such as sibutramine and xenical. The subjects were non-smokers and had normal oral glucose tolerance tests according to criteria of American Diabetes Association (2010).

Subjects were excluded if they reported gastro intestinal disorders, suffered from diabetes, high blood pressure, were taking medication for any chronic disease conditions, or were pregnant, breastfeeding, or intolerant or allergic to any of the foods used in the study.

Preparation of reference food

Glucose D (Evans, Nig. Ltd) was used as the control diet for the study. Fifty gram (50g) of Glucose D was measured and packaged in a sachet, then dissolved in 300ml of clean water.

The test diets consisted of five food samples (selected based on availability and affordability) as follows.

| FPSM | Fried ripe plantain with stew and meat |
| UPPM | Unripe plantain porridge with meat    |
| GASM | Garri and Afang soup with meat        |
| FASM | Fufu and Afang soup with meat         |
| AFG  | Abacha and fried groundnut            |

The food stuffs for this study were bought from Watt market in Calabar. The test foods were prepared using the proximate analysis data. Dry garri powder was added to boiling water to form past and a standard weight was administered with afang soup with meat to the subjects enlisted in this study. All other test foods, FPSM, UPPM, FASM and AFG were prepared and administered same to the respective subjects.

Calculation of available carbohydrate

Based on the results of proximate analysis the test diets were prepared such that each provided about 50 gram of carbohydrate on the average.
Experimental design/ feeding experiment

Sixty (60) healthy subjects were assigned into 6 groups of 10 subjects each and offered the control diet and a single meal of one of the five food samples prepared respectively. They fasted overnight (10-12hours), and their baseline fasting blood glucose (FBG) levels were measured using fine tests glucometer and strips. Feeding of subjects began at 9 am prompt every day. Pure glucose (50g, standard carbohydrate), was served first to the subject, and then the subjects were served 50g portion of the test food. Blood samples were collected from the subject using finger prick with sterile lancet at 30 minutes intervals for two hours after the meal, that is, at 0, 30, 60, 90, and 120 minutes.

Measurement of blood glucose

Blood samples were collected from the subject through finger prick, using hypodermic lancets. A drop of blood on the test strip was inserted into a calibrated glucometer, (Finetest Auto-coding & Premium Test strip made in South Korea). The blood glucose level was read after 9 seconds on the LED display window.

Calculation of glycaemic index

Changes in blood glucose concentration were calculated separately for each post meal period by using the blood concentration before meal (time 0) as a meal baseline. Postprandial responses were compared for maximum increase and incremental area under the glucose curves for each food. The integrated area under the postprandial glucose curve was calculated by the trapezoidal method. Area increment under the curve for a given food was determined for 2 hours period after the meal (i.e. 30, 60, 90, and 120 minutes). The relative glycaemic index of each food was calculated using the method described by FAO (1998) as the incremental area under the blood glucose response curve of a 50g carbohydrate portion of the test food expressed as percent of the response to the same amount of 50g carbohydrate from a standard food (pure glucose) taken by the same subject.

Tested foods:
A = pure glucose serving fifty gram (50g)
A1 = test diet
GI = A1 X 100
A

Available carbohydrate

Available carbohydrate is defined for GI testing purpose as the sum of starch plus sugar, including sugar alcohol and other slowly absorbable sugar derivatives. A total of 5 diets were analyzed. The results were used to calculate the amount in grams of the food to serve the volunteers during the course of carrying out this research which was used to determine the glycaemic index of the test diets.

RESULTS

Glycaemic index and glycaemic load of the different food samples

In table 1, GASM and FASM had the highest glycaemic index (GI) of 67% respectively relative to glucose, that is the blood glucose response to the carbohydrate in GASM and FASM were 67% respectively of the blood glucose to the same amount of carbohydrate in pure glucose. This was closely followed with AFG having a GI of 65% relative to glucose, then UPPM was next with a GI of 62% relative to glucose. FPSM had the least GI was 55% relative to glucose.

The glycaemic load (GL) measured in 2 hours was highest in AFG, with a glycaemic load of 38, GASM had GL of 34, FASM 34 and UPPM, 33 while FPSM with a value of 29 had the least glycaemic load in two hours.

Glycaemic index of the different subjects at varying durations

As shown in figures 1, 30 minutes after the consumption of the different meals, subjects who consumed AFG had significantly (p<0.05) higher GI (6.74 ±0.12) compared with other subjects.

In figures 2 and 3, at 60 and 90 minutes, consumers of UPPM, GASM, FASM and AFG had significantly raised GI compared with those who consumed FPSM.

UPPM, GASM, FASM and AFG had GI of 6.98 ±0.15, 6.87 ±0.11, 6.88 ±0.14 and 6.92 ±0.15 respectively at 60 minutes; and 6.69 ±0.13, 7.29 ±0.12, 7.17 ±0.14 and 6.92 ±0.24 respectively at 90 minutes) amongst the different test meals.

Figure 4 shows that at 120 minutes, the GI of consumers of GASM (7.61 ±0.12) and FASM (7.34 ±0.14) was significantly (p<0.05) higher compared with other groups. FPSM recorded the lowest GI (4.829 ±0.10) amongst the different food samples.

Blood glucose tolerance test using the different test meals

The result for blood glucose tolerance test in the male subjects is shown in figure 5, a gradual steady and sustain rise in blood glucose level was observed in consumers of GASM and FASM from the 0 minute of administration of oral glucose to the last minute, 120 minutes of the test.

For those who consumed AFG, the blood glucose level increased gradually from the 0 minute up to the 100 minutes, where it stop and a fall in blood glucose was noticed from the 100 minutes to 120 minutes.

Those who consumed UPPM and FPSM exhibited transient increases in blood glucose level. Their blood
glucose levels increased from 0 minute to 20 minutes, thereafter, it dropped gradually until the end of the sampling at 120 minutes, figure 5.

Figure 6 shows that blood glucose tolerance test for female subjects, showing similar pattern with the male subjects for all the food samples tested.

Table 2: Glycaemic index and glycaemic load values for selected foods (Relative to glucose)

<table>
<thead>
<tr>
<th>Food</th>
<th>Glycaemic index (glucose=100)</th>
<th>Serving size</th>
<th>Carbohydrate per serving</th>
<th>Glycaemic load per serving</th>
</tr>
</thead>
<tbody>
<tr>
<td>FPSM</td>
<td>55</td>
<td>336</td>
<td>53</td>
<td>29(^a)</td>
</tr>
<tr>
<td>UPPM</td>
<td>62</td>
<td>375</td>
<td>52</td>
<td>33(^b)</td>
</tr>
<tr>
<td>GASM</td>
<td>67</td>
<td>386</td>
<td>50</td>
<td>34(^c)</td>
</tr>
<tr>
<td>FASM</td>
<td>67</td>
<td>401</td>
<td>50</td>
<td>34(^c)</td>
</tr>
<tr>
<td>AFG</td>
<td>65</td>
<td>31</td>
<td>59</td>
<td>38(^d)</td>
</tr>
</tbody>
</table>

Figure 1: Comparison of 30 minutes glycemic index among local staple foods consumed in Calabar Metropolis. Values are expressed as mean + SEM, n = 30.

*p<0.05 vs FPSM;
\(a = p<0.05\) vs UPPM;
\(b = p<0.05\) vs GASM.

Figure 2: Comparison of 60 minutes glycemic index among local staple foods consumed in Calabar Metropolis in male and female subjects. Values are expressed as mean + SEM, n = 30.

*p<0.05 vs FPSM;
\(a = p<0.05\) vs UPPM;
\(b = p<0.05\) vs GASM.

Figure 3: Comparison of 90 minutes glycemic index among foods consumed in Calabar Metropolis in males and females subjects. Values are expressed as mean + SEM, n = 30.

*p<0.05 vs FPSM;
\(a = p<0.05\) vs UPPM;
\(b = p<0.05\) vs GASM;
\(c = p<0.05\) vs FASM.

Figure 4: Comparison of 120 minutes glycemic index among foods consumed in Calabar Metropolis in males and females subjects. Values are expressed as mean + SEM, n = 30.

*p<0.05 vs FPSM;
\(a = p<0.05\) vs UPPM;
\(b = p<0.05\) vs GASM;
\(c = p<0.05\) vs FASM.

Figure 5: Time course of glycemic index among the different staple food consumed in Calabar Metropolis in male subjects. Values are expressed as mean + SEM, n = 30.
DISCUSSION

The utility of the glycaemic index in diabetes is fraught with controversy. However, despite the numerous controversies as reported by Jenkins (2006) and Henry et al., (2006), there is still strong support of the glycaemic index expanding the virtues of a low glycaemic index diet for promoting weight loss and good health (Bessenen, 2001). American dietetic Association (2010) reviewed the evidence of glycaemic index as a nutritional therapy intervention for diabetics and acknowledges that low glycaemic index foods may reduce postprandial blood glucose levels.

A major metabolic defect associated with type 2 diabetes is the failure of peripheral tissues in the body to properly utilize glucose, thereby resulting in chronic hyperglycaemia (WHO, 2016; Ogbiyi and David-Chukwu, 2016; Vrolix and Mensink, 2010; Sacks et al., 2014). Glucose transport into most tissues is achieved by the action of molecules called glucose transporters. These molecules transport glucose by facilitative diffusion down concentration gradients, in contrast to energy-dependent uptake of glucose in the gut or kidney. Glucose transporters belong to a family of proteins with several members, 4 of which have been cloned and exhibit specificity for glucose transport.

The GI values of different foods have been studied and reported in different parts of the world (Ranawana et al., 2009; Ali et al., 2010; Chen et al., 2010; Mohd Yusof et al., 2009). GI values for different food products range from less than 20% to approximately 120% when using glucose as a reference (Mahgoub et al., 2013; Björck et al., 2000).

From our study, FASM and GASM had the highest glycaemic index, with FPSM having the least glycaemic index. The results from this study correlate with the work of Omoregie and Osagie (2008) and Eleazu, (2016), who also added that diets high in glycemic index may increase blood glucose response. In line with GI scale rating garri, and fufu, produced from the fermented cassava is a high glycaemic food (Brand-Miller et al., 2003). This could imply that fermentation increases the glycaemic index of garri and fufu with time. The reason could be a result of the corresponding increase in their mean glycaemic responses since they are positively correlated, this is in agreement with earlier report of Ostman (2013), which stated maltose is formed in one stage of fermentation of starch which is further converted to D-glucose when hydrolyzed in aqueous solution i.e. starch-dextrin-maltose-glucose. Hence, increase in fermentation period may bring about formation of more glucose and subsequent increase in the rate of digestion and absorbing the food (glycaemic response) and increase in glycaemic index.

The individual blood glucose responses of the subjects showed a gradual but steady increase in blood glucose response of volunteers in the first 30 minutes, garri afang soup with meat and fufu afang soup with meat showed the highest blood glucose response at 120minutes, while abacha with fried groundnut and unripe plantain porridge showed a rise in blood glucose response at 60 minutes an decreases gradually till 120minutes within sexes. Also ripe fried plantain stew with meat showed a steady increase in blood glucose response at 30 minute, but with a steady decrease in blood glucose response till 120 minutes.

In conclusion, AFG, FASM and GASM had higher GI than FPSM and UPPM. Also, AFG, FASM and GASM caused sustained elevation in blood glucose level, while FPSM and UPPM caused transient increase in blood glucose level during the tolerance test.

Suggestions

Both unripe plantain porridge with meat and fried ripe plantain stew with meat consumption should be encouraged for both diabetics and people prone to developing diabetes because of the low glycaemic index in females and males of all ages. While garri afang soup with meat and fufu afang soup with meat consumption should be discouraged especially for diabetes and people prone to developing diabetes because of their high glycaemic index both in females and males of all the age groups.

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Figure 6: Time course of glycemic index among the different staple food consumed in Calabar Metropolis in female subjects. Values are expressed as mean ± SEM, n = 30.
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