



Glycaemic Indexes of Selected Carbohydrate-based Staple Foods, and the Effects of some Culinary Vegetables on Post-prandial Glycaemia

^{1,2}*Ejike, C. E.C.C., ¹Okezie, A. K., ¹Opara, E. V. and ¹Oche, F. C.

¹Department of Biochemistry, College of Natural Sciences, Michael Okpara University of Agriculture, Umudike, PMB 7267 Umuahia, Abia State

²Department of Medical Biochemistry, Faculty of Basic Medical Sciences, Federal University Ndufu-Alike, Ikwo, PMB 1010 Abakaliki, Ebonyi State

Abstract: There is a growing interest in low glycaemic index (GI) foods especially for diabetics and people at risk of diabetes. Similarly, the use of plant products in the management of chronic diseases is currently receiving a lot of attention. Therefore, the glycaemic indexes of wheat, *garri* and semolina were investigated (Study I); and the abilities of three culinary vegetables (reported to have significant blood glucose modulatory properties) – *Vernonia amygdalina* (VA), *Occimum gratissimum* (OG) and *Gongronema latifolium* (GL) – to positively modulate post-prandial glycaemia were investigated (Study II). Both studies were done with apparently healthy human subjects, following internationally accepted protocols. Data from Study I show that the glycaemic indexes of the foods were 87.7%, 85.6% and 83.2% for *garri*, wheat and semolina, respectively. There were no significant differences ($P > 0.05$) in the GI values of any given test food, compared to any of the other test foods. Study II shows that the AUCs (min.mg/dl) for subjects who ate the test soups (VA, 9995; VA+OG, 9675; GL+OG, 10042) were statistically similar ($P > 0.05$) to that of the control subjects (9779), suggesting that the incorporation of the culinary vegetables in the soup did not significantly alter the post-prandial glycaemia of the subjects. These data debunk the belief that wheat is superior to *garri* or semolina from a GI point of view; and show that whereas VA, OG and GL reportedly have beneficial properties with respect to diabetes, the said properties are lost when they are used as culinary vegetables.

KEYWORDS: Culinary vegetables, Diabetes, Glycaemic index, Post-prandial glycaemia

1.0 Introduction

Diabetes mellitus is currently a growing healthcare concern globally, affecting 382 million people (as at 2013) and expected to affect 592 million people globally by 2035. As much as 80% of diabetics live in low and middle income countries, including all the countries in sub-Saharan Africa. In fact, the number of people suffering from diabetes in sub-Saharan Africa is expected to rise from 21 million to 35 million by 2035 (IDF, 2015). A recent study in Umudike, Abia State reported a prevalence of 3.0% (3.6% for females and 2.3% for males) for diabetes (Ejike *et al.*, 2015). Management of diabetes includes lifestyle modifications which

require rigorous dietary controls that emphasize the consumption of low glycaemic index (GI) foods. Consequently, it is now common to find diabetics and those at-risk of the disease replacing the traditional carbohydrate-based staples with wheat flour. This is driven by the belief (often advanced by healthcare workers) that wheat meal is “low in sugar”. The validity of this belief has not, to the authors’ knowledge, been tested scientifically; yet such a “validation” is sorely warranted.

Given the reported side-effects of using pharmacological agents in the management of diabetes, the high cost of the drugs, and the fact that they do not reverse the diabetic state, etc. (Gellad *et al.*, 2011), there has been a recent surge in research efforts aimed at identifying phyto-pharmaceuticals that can replace or

*Corresponding Author

Tel.: +23408036066777

E-mail: nonsoejikecc@yahoo.com

complement orthodox medicines. In this direction, the antidiabetic, hypoglycaemic, and blood glucose lowering properties of many plant parts have been reported (Patel *et al.*, 2012). Some of such plants (for example *Vernonia amygdalina*, *Occimum gratissimum* and *Gongronema latifolium*) are culinary vegetables consumed widely in the South-Eastern parts of Nigeria. Ejike *et al.* (2013) reported that decoctions of the above vegetables synergistically modulated post-prandial glycaemia positively. However, since getting patients to stick to drug regimens, or to swallow unpleasantly tasting decoctions, is challenging even for those taking the so-called “natural products”, it is important to investigate whether or not the diabetes-related benefits ascribed to these vegetables are available to those who consume meals prepared with the vegetables.

This study therefore sought to answer two questions: (1) is the glycaemic index of wheat meal significantly lower than those of *garri* (made from grated, slightly fermented, sieved and roasted cassava tubers) and semolina (a popular commercial blend of flours)? (2) Does the inclusion of *Vernonia amygdalina*, *Occimum gratissimum* and *Gongronema latifolium* (culinary vegetables with reported antidiabetic/hypoglycaemic/blood glucose lowering properties) in soups positively affect the blood glucose concentrations of normoglycaemic subjects who consume carbohydrate-based meals? The answers will hopefully contribute to the public health awareness by debunking or affirming popular beliefs and probably open up new vistas of research.

2.0 Materials and Methods

2.1 Subjects

The study was advertised locally within Michael Okpara University of Agriculture, Umudike. A one-day seminar on diabetes was organised and the aim and objectives of the study were explained to the participants. Thereafter participants who were willing to participate in the study were orally examined. From these willing participants, forty apparently healthy subjects aged 25 – 34 years who met the inclusion criteria were recruited for the study.

The inclusion criteria, by the way, included absence of: (1) a history of diabetes or impaired glucose tolerance; (2) any other diseases; (3) a history of, or current cigarette smoking; (4) alcohol-abuse or any other drug-abuse; (5) use of prescription or herbal medicines; (6) morbid obesity (as determined by anthropometry); and (7) pregnancy in females.

2.2 Baseline Oral Glucose Tolerance Tests

The subjects were asked to fast overnight in preparation for the oral glucose tolerance test (OGTT). Each subject was given 50 g of white bread to be eaten with 250 ml of water within five minutes. Thereafter, blood glucose concentrations of each subject were checked at 0 (corresponding to 15 minutes after the first bite), 30, 60, 90 and 120 minutes using an automated digital blood glucose monitor (Accu-chek Active, Roche Diagnostics, Mannheim, Germany).

2.3 Study I: Determination of Glycaemic Index of Carbohydrate-based Foods

Three popularly consumed carbohydrate-based meals – *garri*, semolina and wheat – were chosen for this study. *Garri* was chosen because it is popularly consumed especially by the lower socioeconomic status (SES) group of the society; semolina was chosen because it is often consumed by middle- and upper SES groups who consider *garri* a “poor man’s food”; and wheat was chosen because it is recommended to, and consumed by, diabetics, those at risk of diabetes, and those (in the middle- and upper SES groups) who are conscious of eating “healthy” foods. The three foods were reconstituted into thick pastes in hot water following the traditional methods of preparing them. Fifty grams of each of the three foods was served to fifteen (properly fasted) subjects divided into three groups of five each, with 25 g of *egusi* soup (made with ground seeds of *Citrullus colocynthis*) prepared without vegetables, following traditional methods. Water (250 ml) was made available to each subject. For each subject, the blood glucose concentrations were determined as previously described.

From the data collected on the blood glucose concentrations over time, the glycaemic indexes (GIs) of the foods were determined, using data from white bread as the reference standard. The incremental area under the curve (AUC) method as described by Brouns *et al.* (2005) was used for GI determination.

The AUCs were calculated using the equation:

$$\text{AUC} = (t_1 - t_0)/2 (C_0 + C_1) + (t_2 - t_1)/2 (C_1 + C_2) + (t_3 - t_2)/2 (C_3 + C_2)$$

where t = time;

C = concentration of glucose;

while GI was calculated as:
 $[\text{AUC}_{\text{test}}/\text{AUC}_{\text{reference}}] \times 100$

where AUC_{test} = AUC of the test food,
 $\text{AUC}_{\text{reference}}$ = AUC of reference food.

2.4 Study II: Determination of the Effects of Culinary Vegetables on Post-prandial Glycaemia

Fresh leaves of *Vernonia amygdalina*, (VA), *Ocimum gratissimum*, (OG) and *Gongronema latifolium*, (GL) were purchased from a local market in Umuahia, Abia State. The leaves were sorted, washed in saline solution and rinsed in tap water before they were chopped into small bits or squeeze-washed (in the case of VA). *Egusi* soup, as used in Study I, was also used as the base soup while semolina was used as carbohydrate meal. Forty sex-matched subjects were randomly assigned into four groups of ten each. Subjects in Group 1 received the control meal, semolina and *egusi* soup (without vegetables), and served as the control group.

Subjects in Group 2 received the control meal with 20g of raw squeeze-washed and chopped VA added to the soup. Subjects in Group 3 had the control meal with 10g each of raw squeeze-washed and chopped VA and chopped OG added to the soup. For Group 4, the subjects received the control meal with 10g each of raw chopped OG and GL added to the soup. Again, as described earlier, the blood glucose concentrations of the subjects were measured at

30 minutes intervals for 2 hours. From the data generated, the blood glucose response curves were plotted and the AUCs calculated.

The studies were designed in accordance with the Helsinki declaration and its subsequent revisions (WMA, 1964), and its design and protocol were approved by the Postgraduate Board of the Department of Biochemistry, Michael Okpara University of Agriculture, Umudike.

2.5 Data Processing and Analyses

The means and standard deviations of the glucose concentrations at each time point in the curves were calculated. One-way analysis of variance was used to separate differences between means of relevant groups with respect to continuous data while the Chi squared test was used for categorical data. A significant threshold of $P < 0.05$ was adopted. Data analysis was done using the IBM-SPSS 20 statistics package for windows (IBM Corp., Armonk, NY). OGTT curves were plotted using Microsoft Excel 2010 (Microsoft Corp., Redmond, WA). The results are presented as bar charts and line graphs.

3.0 Results

The blood glucose curves of the subjects show that mean blood glucose concentrations of the subjects peaked at 30 minutes irrespective of the carbohydrate meal consumed. More importantly, the mean BGC of the subjects at each time point (except at time zero and at 120 minutes) was significantly ($P < 0.05$) lower for each of the three test foods, relative to bread. There were however no significant differences ($P > 0.05$) in the mean BGC of subjects who ate the test foods at any time point (Figure 1).

The glycaemic indexes of the studied foods were 87.7%, 85.6% and 83.2% for *garri*, wheat and semolina, respectively (Figure 2). The Chi-squared analyses show that there were no significant differences in the GI values of any given test food, compared to any of the other test foods; i.e, the GIs of the test food were similar irrespective of which is compared to the other.

The addition of traditionally processed *Vernonia amygdalina* to *egusi* soup did not

significantly alter the course of the blood glucose response curve (Figure 3). Similarly, neither the addition of both *Vernonia amygdalina* and *Occimum gratissimum* to the soup (Figure 4) nor the addition of *Gongronema latifolium* and *Occimum gratissimum* to the soup (Figure 5), significantly changed the mean BGC of the subjects at any time point. Finally, Figure 6 shows that the AUCs for each test curve (Figures 3-5) were similar to that of the control curve (Figure 6), suggesting that the incorporation of the culinary vegetable to the soup did not significantly reduce the post-prandial glycaemia of the subjects.

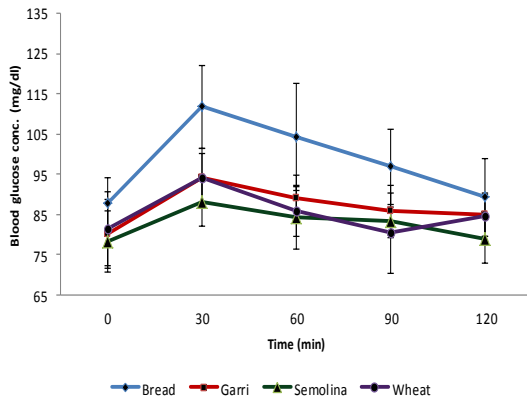


Figure 1: Blood glucose concentrations of subjects fed with different carbohydrate foods

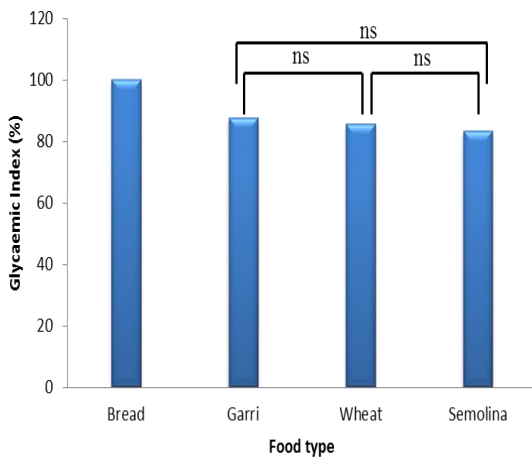


Figure 2: Glycaemic indexes of the selected popularly consumed carbohydrate foods

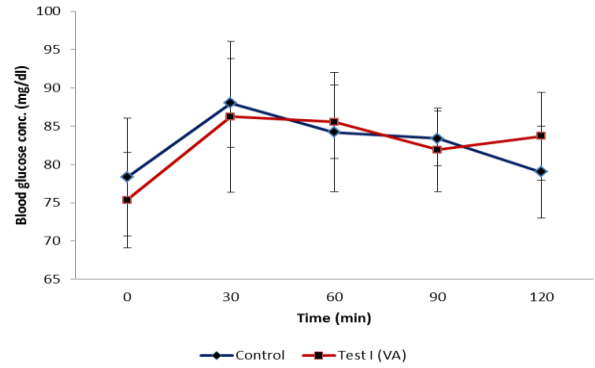


Figure 3: Post-prandial blood glucose concentrations of subjects that consumed the carbohydrate meal with *Vernonia amygdalina*-incorporated soup

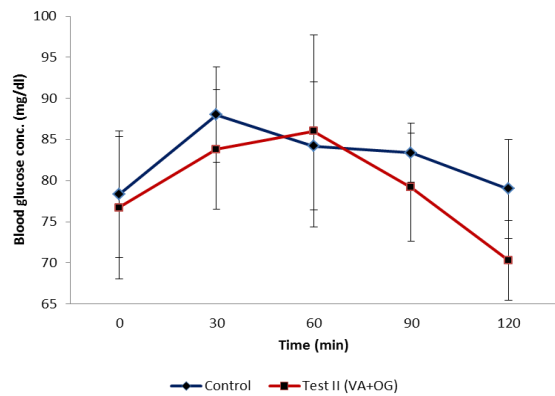


Figure 4: Post-prandial blood glucose concentrations of subjects who consumed the carbohydrate meal with *Vernonia amygdalina* and *Occimum gratissimum*-incorporated soup

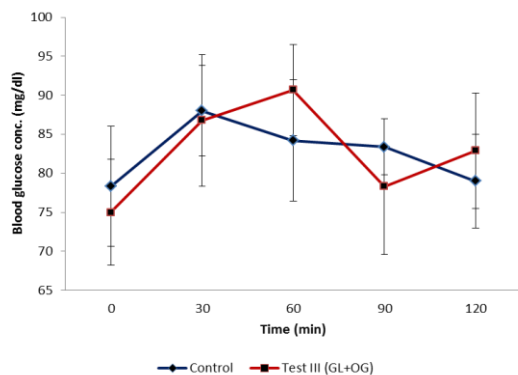


Figure 5: Post-prandial blood glucose concentrations of subjects who consumed the carbohydrate meal with *Gongronema latifolium* and *Occimum gratissimum*-incorporated soup

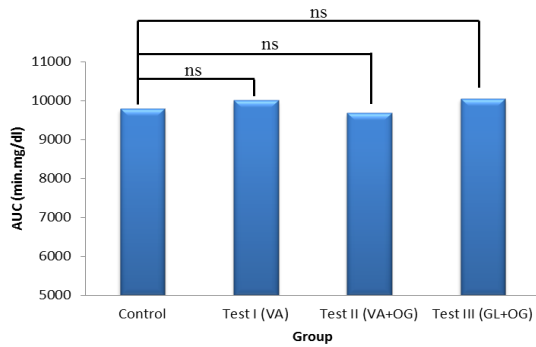


Figure 6: Areas under the blood glucose curves of subjects who consumed the carbohydrate meal with soups containing different culinary vegetables

4.0 Discussion

Prevention and management of diabetes mellitus usually benefit from the consumption of low glycaemic index foods. This is because such foods do not result in rapid increases in blood glucose concentrations and the consequent increases in insulin demands which are thought to lead to pancreatic β -cell exhaustion (Bartoli *et al.*, 2011). This has understandably spurred interest in such foods, leading to the promotion of wheat as a low glycaemic index food, and an informal but aggressive advocacy in this direction that appears to be driven by market economics and not science. The glycaemic indexes of wheat, *garri* and semolina – three popularly consumed carbohydrate foods – were therefore determined with a view to scientifically interrogating the above observation.

Despite the popular claim that wheat is better than (for example) *garri* for diabetics and people at risk of diabetes, this study shows that there is no significant difference in the glycaemic indexes of *garri*, wheat or semolina. It is important to note that a variety of factors affect the glycaemic indexes of foods. These factors include the physical form of the food, processing method adopted, co-ingestion of the carbohydrate with other food classes, and experimentation differences (FAO/WHO, 1998; Oboh and Erema, 2010). Though these factors may have affected the data, their effects may not be consequential as the foods were all obtained and processed following traditional methods,

such that the data represents the glycaemic index values of the meals as they are eaten by the population. Furthermore, the foods were eaten with the same soup thereby foreclosing any introduction of variability as a result of co-consumption. The finding of statistical similarity between the glycaemic indexes of the studied foods is very important, especially for diabetes management education where apparently quantity of the carbohydrate food consumed may be more important than “type”. It is known, for example, that portion size is directly related to insulin responses much more than it is to glucose responses (Lee and Wolever, 1998). Part of the challenge of the “wheat has little sugar” story sold to the general public is that individuals who consume wheat consume considerably large portion sizes in the belief that it contributes little “sugar” to the blood stream. Since this belief is false and without prejudice to the other known benefits of wheat (for example, its better amino acid index relative to cassava-based meals), advocating for reduced portion sizes may therefore be important in diabetes management and prevention.

Interestingly, the finding of statistical similarity between the glycaemic indexes of wheat, *garri* and semolina is not an isolated observation. Fasanmade and Anyakudo (2007) had reported that the glycaemic index of cassava, yam and wheat flours were similar in healthy subjects. In fact in subjects with diabetes, the said authors reported that wheat flour had a glycaemic index that was clearly higher than the other studied flours. Furthermore, Omoregie and Osagie (2008) had shown that *garri* had a lower glycaemic index compared to semolina and wheat flour meals (which gave similar values), despite *garri* having more available carbohydrates per portion size. The high glycaemic index of wheat may be attributable to the fact that wheat fibre is an insoluble fibre which provides bulk, and slows food transit time through the gastro-intestinal tract, yet does not reduce the rate or degree of carbohydrate absorption from the gut (Aston *et al.*, 2008). These reports are corroborated by our findings and together they call for an urgent public health enlightenment exercise to counter the apparently economics-driven wrong

messages peddled by science-naïve business people and even some healthcare professionals.

Owing to the reported side-effects of pharmacological therapies for diabetes (Hui *et al.*, 2009) and the movement towards “green medicine” many patients now seek help from plant-derived products. Yet the consumption of medicines and phytotherapeutics present their own challenges, typically adherence, such that the incorporation of useful vegetables in the diet may be an excellent way to go with respect to diabetes prevention and management. This study showed that the incorporation of combinations of VA, OG and GL to *egusi* soup does not significantly affect the post-prandial blood glucose concentration of subjects who eat semolina with any of the vegetables or combinations thereof. This is interesting especially as there are several previous studies documenting the hypoglycaemic, blood glucose lowering and antidiabetic properties of these individual plants (Akpasso *et al.*, 2011; Ijeh and Ejike, 2011; Onaolapo *et al.*, 2011). In fact, our group had shown recently that the three plants synergistically modulated post-prandial blood glucose concentration in apparently healthy subjects, akin to the subjects studied here, positively (Ejike *et al.*, 2013).

However, whereas previous reports have been on extracts and decoctions, this study used the vegetables directly as part of the meal. The only report, known to the authors, of a dietary incorporation of one of the studied vegetable (VA) was done with rats (Ijeh *et al.*, 2013), unlike the human study reported here. The said animal study reported positive effects of the vegetable with respect to blood glucose modulation. Explaining the absence of a positive effect in this study is difficult. It is however plausible that (1) the concentration of the “actives” in the meals was not high enough to exact any physiological effect, (2) the “actives” may be locked-in within vesicles and membranes such that their liberation by processing is required, (3) in the case of VA, the “actives” may have been considerably lost as a result of the squeeze-washing it was subjected to, (4) the leaves contain other phytochemicals that interfered with the effectiveness of the “actives”, or (5) factors within the soup may have interfered with the activity of the “actives”

in the leaves. The above is nonetheless not exhaustive as we recognise that a couple of other explanations are plausible. Furthermore, the interactions of metabolites in plant-derived products are well documented (Rasoanaivo *et al.*, 2011). Irrespective of the explanation, the data from this study shows that whereas these individual plants may have some beneficial properties, their use in meals as culinary vegetables does not confer similar advantages.

This study is apparently limited by factors such as the normoglycaemic population we studied. The regulation of blood glucose in normoglycaemics and diabetics is obviously different and therefore the glycaemic index data may be different for both groups. In fact, the report by Fasanmade and Anyakudo (2007) provides evidence of this variation. Given that the target audience is not just diabetics and those at risk of diabetes, but also the general population who desire nutrition information founded of empiricism, we feel that the studied population is an important first step.

Secondly, human studies are usually more robust if the sample sizes are large such that variations in individual metabolic rates do not introduce confounders.

Our data should therefore be interpreted with some caution. Our sample size and robust design however suffice for this preliminary investigation; after all, Brouns *et al.* (2005) noted that five people per group are sufficient for glycaemic index studies. Thirdly, for convenience purposes and because of limitations of resources, we could not increase the number of carbohydrate-based meals studied. We however hope that this study will re-ignite interest in the area of study such that in the near future appropriate Tables of the glycaemic indexes of local foods may be generated and used to guide food choices especially in the target population. Finally, despite the above limitations, the data presented here is without equivocation more robust than those of animal experiments, and this strength is not lost on the authors.

In conclusion, and in response to the questions raised earlier, this study debunks the claim that wheat is superior to *garri* and semolina from the point of glycaemic index as the data shows that their glycaemic indexes are

statistically similar. Again, the study shows that the reported beneficial properties of *Vernonia amygdalina*, *Occimum gratissimum* and *Gongronema latifolium* (with respect to blood glucose regulation) are lost when the vegetables are used as culinary vegetables in *egusi* soup and consumed as part of the meal.

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