Influences of Glycemic Index and Glycemic Load of Two Mixed Diets on Postprandial Responses among Healthy Young Adults in Benin City, Nigeria

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ABSTRACT

There is scarce literature on the glycemic indices and glycemic loads of most Nigerian foods. Diseases and disorders associated with the consumption of carbohydrate foods are on the increase. This study aimed to provide insights into the dietary management of metabolic disorders linked to carbohydrate foods, such as diabetes mellitus, by providing glycemic index and glycemic load data on two commonly consumed Nigerian foods using standard documented methods. Healthy volunteer subjects were selected from among the undergraduate students of the Faculty of Life Sciences, University of Benin, Benin City, to participate in the study. Glucose was served as the control food while Titus sardine with bread and Titus sardine with Indomie noodles were the test foods. All the participants were subjected to an overnight fast of at least 12 hours. The postprandial responses were measured with a standardized glucometer. Hitherto, the proximate analyses of the foods were all determined by standard methods. The results obtained indicated that the glycemic index and the glycemic load of the test foods were low: 23 and 47 for Titus sardine with bread, and Titus sardine with Indomie noodles respectively, indicating that the mixed foods could be consumed by both diabetic and non-diabetic individuals. Consumption of single foods like white bread alone indicated a high glycemic index which is not healthy for diabetic individuals. However, in view of the demonstrated lowering of glycaemic index, the mixed diets evaluated in this study could be recommended for diabetic individuals.

Keywords: Diets, Postprandial, Response, Glycemic, Index, Load

INTRODUCTION

The word “glycemic” is coined from “glycaemia”, which has to do with the presence of glucose in the blood. The glycemic index (GI) has drawn broad interests worldwide for its implications in health and disease. GI refers to the glycemic effect of available carbohydrate in food relative to the effect of an equal amount of glucose. Simply put, glycemic index is a measure of the rate at which ingested food causes the level of glucose in the blood to rise. The GI concept is based on the differences in blood glucose response after ingestion of the same amount of carbohydrates from different foods and possible implications of these differences for health, performance and wellbeing. Although GI is tested with individual foods, this data has been used to obtain the GI of a whole diet in which each food's GI is weighted according to its carbohydrate contribution.[1] Differences in the glycemic response to various carbohydrate-containing foods were first investigated by Otto.[2] These discoveries led to the development of the glycemic index, a concept that ranks carbohydrate-containing foods based on their effect on blood glucose levels.[3]

GI is usually tested with individual foods, but as very few foods are consumed solely as a meal GI needs to apply to mixed meals also. The GI of mixed meals can be determined according to available carbohydrate contribution in the meal. Carbohydrates that are rapidly digested release glucose quickly into the blood and thus have a high GI. The rapid digestion and absorption cause marked fluctuations in blood glucose levels. Therefore, they are marked as dietary factors that favour the development of chronic diseases.[4] Carbohydrates that are digested slowly, releasing glucose into the blood gradually, have low GI. These foods produce a gradual increase in glucose and insulin level, and are proven to be beneficial health-wise, such as in weight control because they help control appetite and delay hunger.[5]

Glycemic load (GL) is the theoretical cumulative exposure to glycemia over some

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time and is derived from GI. GL appears to be a significant factor in dietary programs targeting metabolic syndrome, insulin resistance, and weight loss; studies have shown that sustained spikes in blood glucose and insulin levels may lead to increased diabetes risk.[6] Because some foods typically have a low carbohydrate content, Harvard researchers created the GL, which takes into account the quantity of carbohydrates in a given serving of food and so provides a more useful measure.[6] Liu *et al.* were the first to show that based on their calculation, the glycemic load of a specific food-calculated as the product of that food's carbohydrate content and its glycemic index value-has direct physiologic meaning in that each unit can be interpreted as the equivalent of 1g carbohydrate from white bread or glucose depending on the reference used in determining the glycemic index.[7] It became immediately apparent that such direct physiological quantification of glycemic load would allow patients with diabetes to do "glycemic load" counting as opposed to the conventional "carbohydrate counting" for monitoring the glycemic effect of foods.[8]

The aims of this study were as follows:

1. To determine the GI and GL of two Nigerian mixed diets: *Titus* sardine mixed with bread, and *Titus* sardine mixed with *Indomie* noodles.
2. To examine the influence of the components of the mixed diets on the glycemic response in non-diabetic subjects.

MATERIALS AND METHODS

Food Samples Collection

The *Titus* sardine was bought from the same batch of production in a carton from a shopping mall. The white bread was purchased from Nadia Bakery in Benin City. The *Indomie* noodles were bought from the same batch of production in a carton from a shopping mall.

Experimental Design and Subjects

Twenty-two subjects aged between 18 and 23 years were selected from the Faculty of Life Sciences of the University of Benin, Benin City, Nigeria. Eleven of the subjects were served bread and *Titus* sardine while the other eleven were served *Indomie* noodles and *Titus* sardine, with one control. They were all clinically normal, non-smokers and non-diabetic. The subjects were appraised verbally and they gave their informed consent one week before the commencement of the exercise. They also all agreed to observe a twelve-hour overnight fast. The study was commenced after due approval by the approving body, the Academic Board of the Faculty of Life Sciences of the University of Benin.

Proximate Analysis

The standard methods of the Association of Official Analytical Chemists, AOAC (2004) for the determination of proximate analysis were adopted.[9] The moisture content of each mixed food (in the form in which it would be eaten) was determined by the heating and weighing method until a constant weight was achieved. The semi-micro Kjeldahl procedure was used for crude protein determination.[10] The lipid content was determined by the Soxhlet extraction method.[11] The crude fibre was determined by exhaustive extraction of soluble substances in a sample using 5% H_2SO_4 and 5% NaOH and thereafter the residue was ashed for 6 hours at 600^oc. The loss in weight was recorded as the fibre.

The ash content was determined by taking a known weight of the sample tarred in a porcelain crucible and ashed in a muffle furnace for 4hours at 600^oc.[9] The difference in weight was recorded as the weight of the ash. The percentage carbohydrate content was established by subtracting the sum of the percentages of the other constituents from 100.

Feeding of Subjects

The control subjects were each fed with 50g glucose D dissolved in 200ml of distilled water while the test subjects were fed with 50g available carbohydrate calculated from the proximate analysis result of the test foods.[12] Thereafter the subjects rinsed the particles of food in their mouths down into their stomachs each with 200ml of distilled water.

Determination of postprandial response

Standard materials and Trinder's glucose oxidase method were used for this exercise.[10,11] The materials used included lancet, test strips, glucometer (*Accu-Check/One-touch*), stopwatch, cotton wool, methylated spirit and latex gloves. Capillary blood samples were obtained via thumb pricks using lancets. Each blood sample was placed on a test strip which was inserted into a calibrated glucometer (*Accu-Check/One-touch*) which gave direct readings after 45 seconds based on the glucose oxidase assay method. The determination of glucose level was done at intervals of thirty minutes within three hours. The relative glycemic index of each food was calculated as a percentage of the mean of individual areas under the glucose response curves.[14] The data obtained were used in plotting the postprandial response curves.

Statistical Analysis

The data collected from this work were analyzed by using ANOVA and all results were expressed as the mean of ±SEM of duplicate determinations.
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GI and GL Calculations

The blood glucose values were used in the construction of curves for the individual control subjects and the test subjects. The trapezoidal rule described by Jenkins *et al.*[15] was used in the calculation of the incremental area under the blood glucose response curve (or incremental area under the curve, IAUC) for 50g carbohydrate of the test food and control food (glucose). The GI and GL were calculated with the formulae below by way of ratings with figures (no units) after calculation:

$$GI = \frac{\text{AUC for 50g carbohydrate from test food}}{\text{AUC for 50g carbohydrate from glucose}} \times 100$$

$$GL = \frac{\text{Carbohydrate content per serving of food}}{100} \times GI$$

RESULTS

The following nutrients were detected in the test foods; moisture, fat, protein, ash, fibre and carbohydrate. The values of the nutrients were present in varying concentrations. The fat/oil and protein contents had higher values while moisture had the highest value. The available/equivalent carbohydrate of the test food was calculated from the proximate analysis result. These findings are displayed in Table 1.

The results of postprandial responses of the control and test subjects were also in varying concentrations. The mean postprandial blood glucose responses of the control and test subjects are as presented in Table 2 and Table 3. These were used in plotting the glucose response curves shown in Figure 1 and Figure 2.

The calculated glycemic indices for both mixed foods were of low rating, while the glycemic load of bread and sardine, and sardine/*Indomine* noodles were of medium and high rating respectively. The mean glycemic indices and loads for both test foods, as well as their respective ratings, are as shown in Table 4.

Table 1: Mean of Proximate Analysis of the test foods

Test food	% Moisture	% protein	% Fat/Oil	% Fibre	% Ash	% Carbohydrate
Sardine and bread	42.34±0.67	19.86±0.22	28.42±0.28	1.56±0.03	2.67±0.02	47.49±0.55
Sardine and noodles	49.58±0.35	19.40±0.42	32.99±0.21	1.32±0.05	2.52±0.00	43.78±0.16

Table 2: Mean of postprandial responses in blood glucose of subjects after the sardine and bread consumption

Subjects	Baseline	30min	60min	90min	120min	150min	180min
Control	72	95	107	140	131	106	70
Test food	78	81	88	94	93	87	73

Table 3: Mean of postprandial responses in blood glucose in subjects after sardine and *indomie* noodles consumption

Subjects	Baseline	30min	60min	90min	120min	150min	180min
Control	74	103	107	97	94	79	66
Test food	76	82	86	87	89	79	69

Table 4: Mean glycemic index and glycemic load of the test foods

S/N	Test food	GI	GI class	GL	GL class
1	Sardine and bread	23.40±1.29	Low	11.1±0.61	Medium
li2	Sardine and noodles	46.80±5.65	Low	20.49±2.48	High

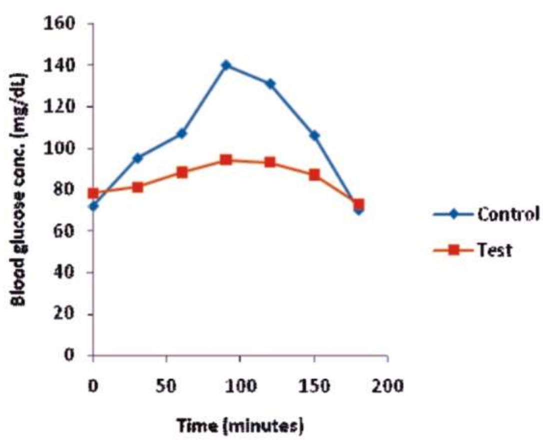

Figure 1: Postprandial response of control and mean postprandial response of test after consumption of bread and sardine.

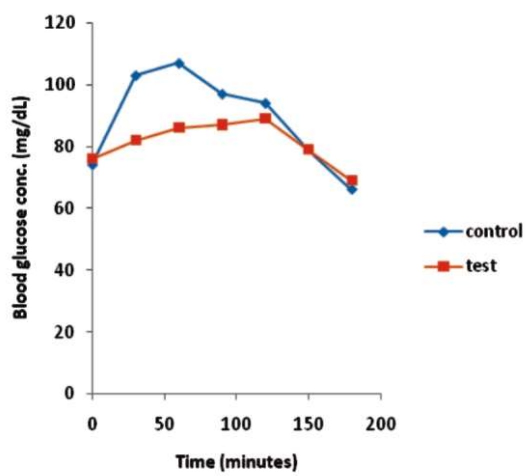

Figure 2: Postprandial response of control and mean postprandial response of test after consumption of sardine and *Indomie* noodles.

DISCUSSION

The composition of the mixed foods studied indicates that they contain good nutrients for healthy living as could be found in a balanced diet. Some factors that could increase or decrease the glycemic index/load besides mode of preparation (roasting methods and time, amount of moisture and heat applied etc.)[16,17] have generated research interests among scientists particularly in the understanding of interactions between food components when they are co-ingested and the overall consequences on postprandial responses. There is however a relative scarcity of studies on the GI and GL of commonly consumed mixed foods in Nigeria, a gap which studies like the index one are intended to fill. For example, to the best of our knowledge and literature search there is no previous study on the effects on human subjects of the GI and GL of the mixed foods evaluated in this study.

The present work has revealed that the consumption of a single diet with 50g of carbohydrate/glucose D could yield a glycemic index value of 100 (standard value), whereas a mixed diet that contains the same amount of carbohydrate and sardine yielded a glycemic index of 23 (bread and sardine) and 46 (sardine and *Indomie* noodles). The glycemic index of 100 is rated as high while the Glycemic Index of 23 and 46 are rated as low, by international standard.[17] It has been reported that lipid, proteins and fibre play significant roles in the reduction of postprandial responses.[17-20] The drastically reduced GI values were due to the high levels of protein, fat and oil in the mixed food, which was contributed majorly by the sardine. Previous work by Omoregie et al has also shown that the inclusion of fat in meals with high carbohydrate lowers the glycemic response and thus GI by delaying gastric emptying and/or reducing starch gelatinization.[18] Protein may lower the glycemic response and GI by increasing insulin secretion.[18] Otemuyiwa et al reported that the combination of high-GI and GL foods (such as white bread, which many consume alone or with water or soft drinks) with high-protein foods in adequate amounts as a mixed meal results in a significant lowering of the GI and GL compared to when ingested alone.[21] Asinobi and colleagues demonstrated that Nigerian mixed diets rich in dietary fibre contribute significantly to a lower postprandial blood glucose response.[22] Our present work, therefore, complements these earlier findings.

Furthermore, it is noteworthy that although wheat bread is commonly recommended (instead of white bread) for the diabetic diet, depending on the production process, it is also a high-glycemic index food, according to studies done in Europe.[23] Chinese steamed bread is a staple food among the Chinese population, which though made from wheat, has also been reported to have a high glycemic index.[24] In spite of much research in various parts of the world, the demand for low- and moderate-glycemic index bread is currently largely unmet. This demand continues to rise with the rising incidence of chronic metabolic disorders in the population such as diabetes and obesity.[24,25] The pragmatic solution for now appears to reside with the consumption of bread as part of a glycemic index-lowering combination[24] as demonstrated in this work. Although wheat bread was not used in this study it may be deduced from the observed outcome with white bread that the consumption of wheat bread as part of a mixed diet with sardine will improve the postprandial response.

CONCLUSION

This work has revealed that the co-consumption of some food nutrients in mixed foods have the potential of lowering the postprandial response of the high carbohydrate portion in such mixed diets, especially in the case of sardine and bread. White bread if eaten as a single meal produces a glycemic index of 70 but when it was consumed with sardine the glycemic index was reduced to a low value. The consumption of bread should be recommended with sardine for diabetic patients who desire to eat bread. A similar effect was observed when sardine and *Indomie* noodles were eaten together as a mixed diet.

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CONFLICT OF INTEREST

The authors declare that there is no conflict of interest whatsoever.

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