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Glycemic Indices and Glycemic Load of Some Nigerian Foods

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Abstract: The concept of glycemic index (GI) lists food items by virtue of their influence on postprandial glucose. Though the glycemic index of common food items has been determined, the GI of the popularly processed and commonly consumed foods in Nigeria is not known. This study determined the GI of ten processed Nigerian foods and revealed their similarity in the release of glucose on consumption. The food items tested were made from yam tubers, cassava tubers and local cereals. These foods were served to human volunteers in several processed forms which resulted in viscous pastes. The GI results are presented and it is recommended that these processed foods should be discouraged in the regular dietary plan of people with chronic diseases such as coronary heart diseases, diabetes and cancer.

Key words: Glycemic index, postprandial glucose, processed Nigerian foods, diabetes mellitus and pastes

Introduction

The concept of glycemic index (GI) was proposed by Jenkins and colleagues to characterize the rate of carbohydrate absorption after a meal (Jenkins *et al.*, 1981). GI is defined as the area under the glucose response curve after consumption of 50g carbohydrate from a test food divided by the area under the curve after consumption of 50g carbohydrate from a control food, either white bread or glucose. (Wolever *et al.*, 1991).

Over the past three decades, the GI of over 800 foods has been determined worldwide and more foods are being tested on weekly basis. The latest update in 2005 has 1300 entries derived from published and unpublished verified sources (Foster-Powell *et al.*, 2002). However, only limited information is available on African traditional foods. Many factors together, including carbohydrate type, fiber, protein, fat, food form and method of preparation, determine the GI of a particular food (Bjorck *et al.*, 1994, Welch *et al.*, 1987, Wolever *et al.*, 1991). High GI foods elicit, calorie for calorie, higher insulin levels and c-peptide excretion than low GI foods (Haber *et al.*, 1997; Jenkins *et al.*, 1987; Wolever and Bolognesi, 1996). The reductions in dietary GI may also lower the risks for various conditions associated with hyperinsulinemia, such as diabetes mellitus (Salmeron *et al.*, 1997) and cardiovascular disease.

There is need for more research into the GI of our locally consumed foods in order to produce data that can effectively enable use of GI along with other dietary recommendations in the treatment, management and prevention of diseases. There are many proven benefits of using the GI in nutrition. These include: (i) decreased risk of cardiovascular disease; (ii) better diabetes management and (iii) more successful body weight management. Inspired in part by a hope to learn to predict better, the GI of variants of foods of known GI value, several groups have studied associations

between GI and defined components in groups of foods (Jenkins *et al.*, 1981; Wolever, 1990; Hollenbeck and Coulston, 1991; Nishimune *et al.*, 1991). Apparently, GI values reflect, mainly, how promptly and rapidly glucose enters the blood after food ingestion. In Nigeria, the adult population eats foods made from yam tubers (*Dioscorea* spp.), plantain (*Musa* spp.), cassava (*Manihot* spp.) and locally grown cereals. The dry powdered forms of these plant storage organs are reconstituted in hot water to form solid pastes which are swallowed with soup. The effects of processing these food items into diet pastes on the GI have not been determined.

Materials and Methods

Experimental design: Fifty healthy human beings were offered in a single meal, one of the ten food samples. Blood samples were collected before feeding and during the 180 min after the meal. Blood glucose was determined. The integrated areas under the postprandial glucose response curves were calculated.

Subjects: Fifty subjects aged between 16 and 40 years (23 male and 27 female) were selected from students and staff of the University of Benin, Benin City, Nigeria. They were clinically normal, non-smokers and non-diabetic. The subjects were appraised verbally and they gave their informed consent.

Preparation of experimental diets: The dry powdered food samples were purchased from Edaiken Market in Benin City, Nigeria. The food samples were powdered maize, rice, millet, wheat, sorghum, yam and cassava. These were each sieved to pass through a 100-mesh filter and then reconstituted into solid pastes in hot water by a trained cook to ensure consistency (Table 1). The pastes obtained were as follows:

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Table 1: Processing and Preparation of the Diet Pastes (Okoh, 1998)

Agricultural Form	Pre-Processing	Paste Preparation
1. Cassava tuber (<i>Manihot utilisima</i>): Eba/Garri Cassava Starch	Tuber was homogenized in water. The starch was allowed to settle, filtered out and dried at 28°C.	Dry powdered starch was reconstituted in hot water with addition of small quantity of palm oil.
2. Cassava tuber (<i>Manihot utilisima</i>):	Tuber was grated and dried then fried in shallow heated pots.	Dry powder was added to boiling water to form a paste.
3. Yam tuber (<i>Dioscorea rotundata</i>): <i>Amala</i>	Fresh tuber was sliced into thin pieces. and sun-dried for 7 days. Dried slices were milled to powder	Dry powder was added to boiling water and stirred until a solid paste was obtained
4. Maize (<i>Zea mays</i>): <i>Agidi</i>	The dry grains were soaked in water and fermented for about 3 days. The fermented grains were milled and sieved to remove pericarp and bran fractions. The starch fraction was dried slowly.	Dry powder was added to boiling water and stirred until a semi-solid paste resulted. Paste hardened further on cooling.
5. Maize seeds (<i>Zea mays</i>): <i>Tuwo Masara</i>	Clean, dry grains were moistened with water and milled. The hulls were removed by aspiration while the endosperm and germs were removed by passing through a sieve leaving the maize grits.	Dry powder was added to boiling water and stirred until a solid paste resulted.
6. Millet grains (<i>Pennisetum typhoides</i>): <i>Tuwo Gero</i>	The grain was pounded in a wooden mortar. The bran was winnowed off. The separated grain was then pounded into flour.	Dry flour was added to boiling water and stirred until a solid paste resulted
7. Sorghum seeds (<i>Sorghum bicolor</i> L. Moench): <i>Tuwo Dawa</i>	The moist grain was pounded with a wooden pestle in a mortar until most of the pericarp was removed. The bran fraction was removed by winnowing. The dehulled grain was again pounded to make flour.	Dry flour was added to boiling water and stirred until a solid paste was obtained.
8. Rice (<i>Oryza sativa</i>): <i>Tuwo Shinkafa</i>	Polished rice was pounded and filtered through a sieve.	Dry flour was added to boiling water and stirred until a solid paste was obtained.
9. Wheat (<i>Triticum aestivum</i>): <i>Semovita</i>	Wheat grains were cleaned, conditioned and milled into flour.	Flour was added to boiling water and stirred until thick and consistent paste cooked for additional 1-2 minutes.
10. Wheat (<i>Triticum aestivum</i>): <i>Semolina</i>	Wheat grains were cleaned, conditioned and milled into flour.	Flour was added to boiling water and stirred until thick and consistent paste was obtained. Paste was cooked for additional 1-2 minutes.

1. Cassava: Starch
2. Cassava: *Eba Garri*
3. Yam: *Amala*
4. Maize: *Agidi*
5. Maize: *Tuwo Masara*
6. Millet: *Tuwo Gero*
7. Sorghum: *Tuwo Dawa*
8. Rice: *Tuwo Shinkafa*
9. Wheat: *Semovita*
10. Wheat: *Semolina*

Preliminary trials were carried out using local foods prepared in a similar manner from plantain (*elubo*), yam (pounded yam), cassava (*lafun*) and fermented cassava (*akpu*). The processed pastes were analyzed for proximate composition of moisture, ash, crude fat, crude fibre and protein (AOAC, 1983). Carbohydrate was determined by difference. 50g of available carbohydrate for each test food sample was calculated from the results of the proximate analysis and the measured portion of the food was served to the subjects.

Determination of blood glucose: All subjects for the investigation fasted overnight. Their blood samples were collected through finger prick using a hypodermic needle or 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 glucose oxidase assay method. The determination of glucose level was done at intervals i.e. 0 (fasting level), 30mins, 60mins, 120mins and 180mins.

Glycemic index calculation and statistics: Changes in blood glucose concentration were calculated separately for each post meal period by using the blood concentration before meal (time 0) as a 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 (Wolever *et al.*, 1987). Area increments under the curves for a given food were determined for the 3 hour period after the meal. The

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Table 2: Proximate Analysis of Ten Processed Nigerian Foods (in Dry Weight Percent)

Food Components	Moisture (g% Fresh Weight)	Ash (g%)	Crude Protein (g%)	Crude Lipid (g%)	Crude Fibre (g%)	Carbohydrate (g%)
<i>Starch</i> (cassava)	75.10±0.10	1.06±0.06	2.46±0.62	1.55±0.35	2.25±1.75	92.68±0.05
<i>Eba</i> (cassava)	72.00±1.0	1.10±0.07	4.50±0.35	0.58±0.4	2.15±0.12	86.45±0.27
<i>Amala</i> (yam)	65.50±0.50	1.65±0.05	4.47±0.19	0.25±0.05	0.75±0.25	92.88±0.13
<i>Agidi</i> (maize)	84.80±0.24	2.90±0.10	6.82±0.27	0.35±0.05	1.75±1.2	88.18±0.12
<i>Tuwo Masara</i> (Maize)	74.50±0.5	1.63±0.01	9.94±1.91	0.65±0.25	1.7±0.25	86.03±0.03
<i>Tuwo Gero</i> (Millet)	65.00±0.05	1.58±0.01	9.51±0.23	0.45±0.05	1.03±0.03	87.43±0.06
<i>Tuwo Dawa</i> (Sorghum)	60.30±0.25	1.58±0.01	9.28±0.43	0.40±0.05	1.25±0.25	87.49±0.02
<i>Tuwo Shinkafa</i> (Rice)	73.50±1.50	1.65±0.03	9.23±0.43	0.90±0.20	1.0±0.50	87.22±0.12
Semovita (wheat) + 10% corn supplement	44.70±0.10	2.10±0.60	10.63±0.46	1.00±0.30	1.25±0.25	85.02±0.18
Semolina (wheat)	54.90±0.10	2.48±0.08	10.73±0.41	1.50±0.05	1.26±0.38	84.03±0.14

Values are expressed as mean±SEM (n = 3 determinations).

Table 3: Available Carbohydrate in Processed Foods (Serving Size)

Samples	Serving Size (Processed) (g)
<i>Starch</i> (Cassava)	162.15
<i>Eba</i> (Cassava)	206.50
<i>Amala</i> (Plantain)	156.25
<i>Agidi</i> (Maize)	373.13
<i>Tuwo Masara</i> (Maize)	158.00
<i>Tuwo Gero</i> (Millet)	163.40
<i>Tuwo Dawa</i> (Sorghum)	144.00
<i>Tuwo Shinkafa</i> (Rice)	160.90
<i>Semovita</i> (Wheat) + 10% Corn supplement	106.70
<i>Semolina</i> (Wheat)	131.90

relative glycemic index of each food was calculated as percent of the mean of individual areas under the glucose response curves. (Wolever *et al.*, 1987) The increase in glucose response area was analysed statistically using one way ANOVA and Scheffe's test (Allison *et al.*, 1995).

Results

The results of the proximate analysis of the test food samples are shown in Table 2. The proximate analysis on the processed food from wheat, sorghum, rice and maize showed low lipid contents compared to the analysis of the unprocessed seeds (Ekpenyong, 1973; Okoh, 1998). The cereal flours had higher crude protein content than the tuber flours. From previous studies yam and cassava tubers were naturally low in fat (Osagie and Opute, 1981; Bradbury and Holloway, 1988). Thus, all the processed powders used in making the experimental pastes can be regarded as having low fat content. The two test samples made from cassava tuber (*starch*) and (*eba*) differed significantly in crude protein content. Semolina and semovita are wheat products and their proximate composition was similar.

The serving size for each meal was calculated from the carbohydrate content (Table 3). The glucose concentration attained after consumption of the test foods and glucose (reference food) are graphically displayed in Fig. 1 - 10. The Glycemic Index and

Table 4: Glycemic Index and Glycemic Load of the Processed Food

Food Samples	Glycemic Index	Glycemic Load
<i>Starch</i> (Cassava)	98.60±2.68	49.30±3.5
<i>Eba</i> (Cassava)	82.25±0.05	41.13±3.3
<i>Amala</i> (Yam)	84.35±2.68	42.18±4.2
<i>Agidi</i> (Maize)	92.30±0.05	46.15±3.1
<i>Tuwo Masara</i> (Maize)	86.80±0.5	43.40±1.5
<i>Tuwo Gero</i> (Millet)	93.60±2.25	46.80±3.4
<i>Tuwo Dawa</i> (Sorghum)	85.30±1.05	42.65±3.2
<i>Tuwo Shinkafa</i> (Rice)	95.30±1.25	47.65±2.2
<i>Semovita</i> (Wheat) + 10% Corn supplement	95.80±0.28	47.90±2.5
<i>Semolina</i> (Wheat)	95.28 ± 0.04	47.64±1.5

Values are mean ± SEM (n = 3 determinations)

Glycemic Load of the food samples were calculated (Table 4). All the test samples are high Glycemic Index foods. Cassava starch gave the highest GI value followed by semovita. In two hours, these foods deliver as much glucose as the free sugar (control) to the blood system. In the absence of adequate insulin delivery, these foods would certainly overwhelm the sugar metabolic system. They are thus not considered suitable or adequate meals for type II diabetics.

Discussion

Before plant foods are consumed by man, they are generally processed. The processing methods include cooking, (i.e. boiling, roasting, frying, steaming, baking, autoclaving), drying, mashing, grinding into flour and fermentation. In this study, the test foods were basically dried, ground into flour, sieved and then reconstituted to paste with hot water. Thus the particle sizes were reduced, fine and the starch was retrograded (gelatinized) to a variable extent. These treatments might have led to their having high glycemic indices (Ludwig, 2003; Bjorck and Elmstahl, 2005). This is similar to reports that increased processing and starch retrogradation can affect GI (Foster-Powell *et al.*, 2005). Processing the seeds removes the fiber-rich outer bran and the vitamin and mineral rich inner germ leaving

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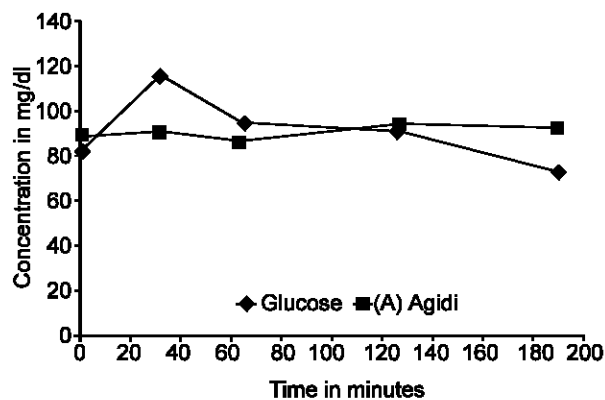


Fig. 1: Graphical representation showing the glucose response area of test food A (*Agidi*) and reference food (Glucose D).

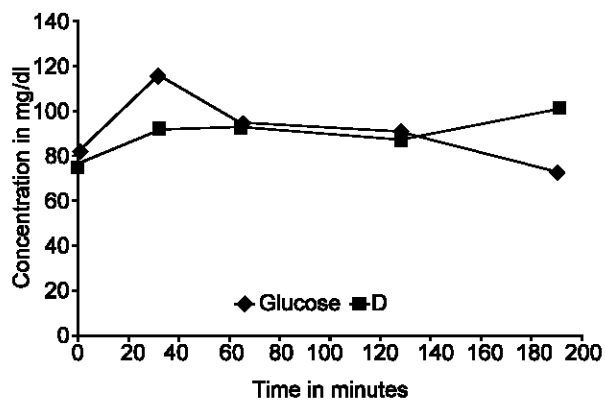


Fig. 4: Graphical representation showing the glucose response area of test food D (*semovita*) and reference food (Glucose D).

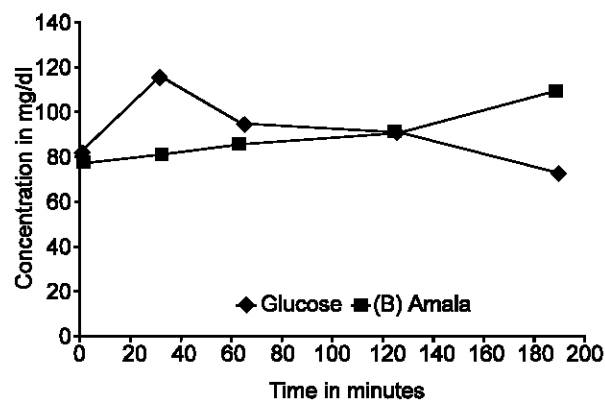


Fig. 2: Graphical representation showing the glucose response area of test food B (*Amala*) and reference food (Glucose D).

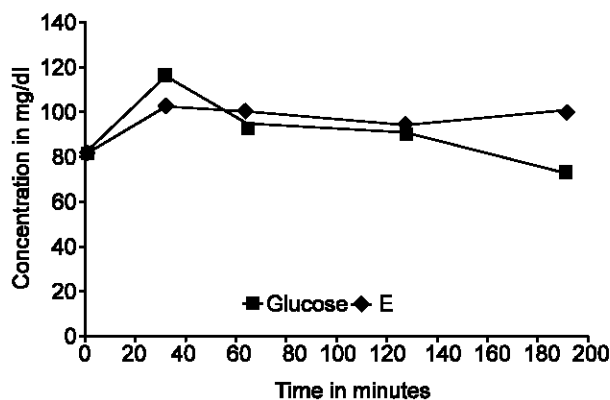


Fig. 5: Graphical representation showing the glucose response area of test food E (*Semolina*) and reference food (Glucose D).

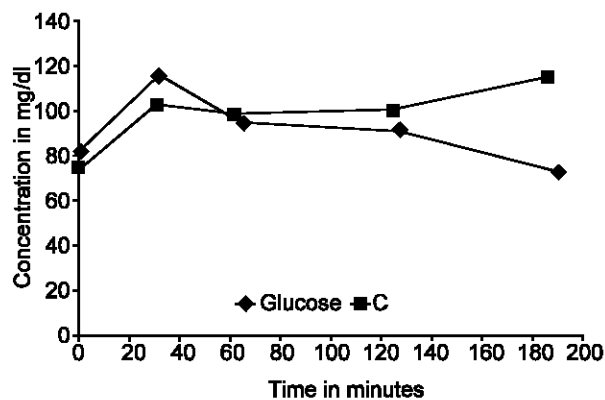


Fig. 3: Graphical representation showing the glucose response area of test food C (*Starch*) and reference food (Glucose D).

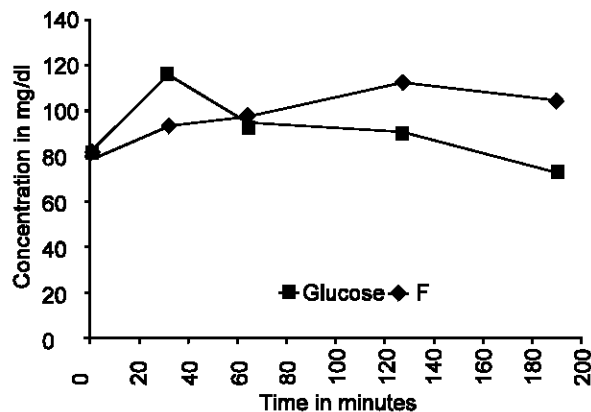


Fig. 6: Graphical representation showing the glucose response area of test food F (*Eba*) and reference food (Glucose D).

endosperm. This treatment caused reduction in particle size and faster gelatinization of starch, thereby

increasing the GI. Our study agrees with the finding in Kenya where similarly processed maize flour

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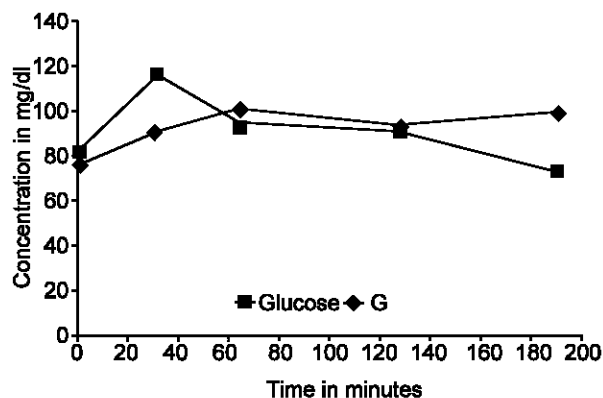


Fig. 7: Graphical representation showing the glucose response area of test food G (*Tuwo* Rice) and reference food (Glucose D).

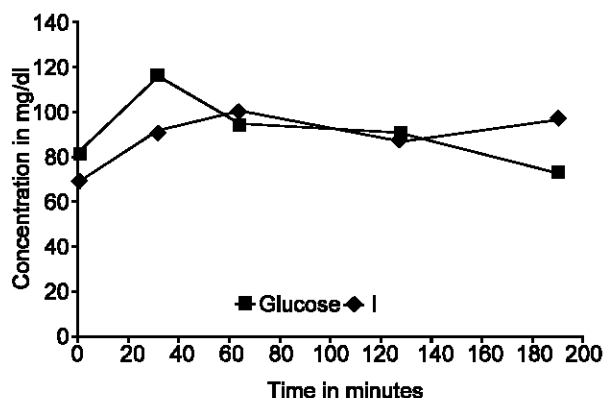


Fig. 9: Graphical representation showing the glucose response area of test food I (*Tuwo* maize) and reference food (Glucose D).

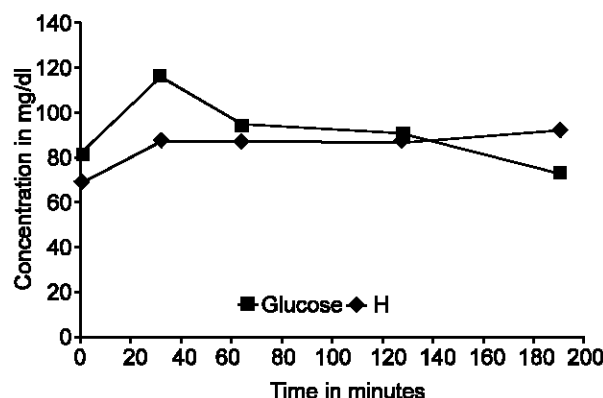


Fig. 8: Graphical representation showing the glucose response area of test food H (*Tuwo* Millet) and reference food (Glucose D).

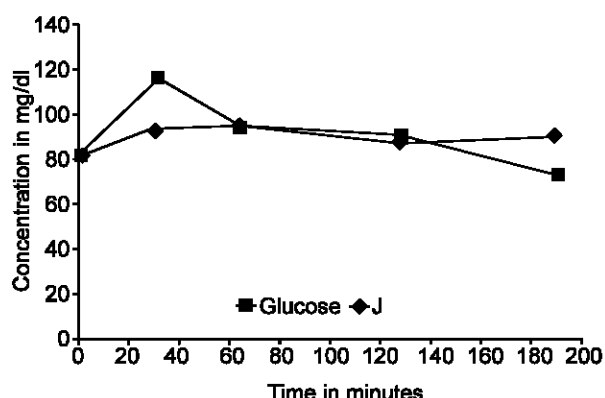


Fig. 10: Graphical representation showing the glucose response area of test food J (*Tuwo* rice) and reference food (Glucose D).

and millet flour made into gruel had high GI (Foster-Powell *et al.*, 2002).

The test foods were swallowed without chewing. Chewing normally reduces the particle size of foods and facilitates mixture with salivary amylase, hence reducing digestion time of carbohydrates. Despite the direct swallowing of these test food pastes, they resulted in the same level of blood glucose as the reference sample, within two hours. This is in agreement with the fact that different food products with similar quality and type of carbohydrate form show different glycemic response. (Thorsdottir *et al.*, 2005). Since these test foods were reconstituted in hot water, the nature of starch retrogradation or the production of resistant starch may be similar. It is desirable that modern food processing techniques be modified so as to reduce preparation time while at the same time preserving slow digestion properties.

The health implications of the high GI of the processed foods are that they could cause a fast and short - lived

rise in blood sugar, with the result that one is lacking in energy and hungry within a short time, thus the desire to eat will arise. If this pattern is repeated, there is the likelihood of gaining weight as a result of constantly eating. The overall effects are that the individual will gain weight i.e. obesity might result. It could trigger diabetes in individuals that are prone to the disease, or worsen the management of the disease (Gilberston *et al.*, 2001). Type II diabetes which is associated with insulin insensitivity may also result in elevated blood sugar levels and increased insulin demand; thus overburdening the ability of the pancreas to produce insulin. Reports by workers like Salmeron *et al.* (1997) have indicated a positive correlation between high GI and risk of type II diabetes. Again, the consumption of the processed foods under reference in these studies might have serious health implications in such diseases like the heart diseases via insulin resistant syndrome called metabolic syndrome X (Ludwig, 2003). Additionally, high blood sugar levels have been

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associated with increased blood pressure, blood clot formation and reduced endothelial dependent blood flow (Ludwig, 2003).

In recent years, the GI has been transformed by its popularizers from a potentially useful tool in planning diets for diabetic patients to a key player for the prevention of diabetes, dyslipidemia, cardiovascular disease and even certain cancers in the general population. The debate concerns whether such a transformation is justified. That is, whether it is wise and reasonable to set as a public health policy for the entire population the avoidance of certain foods because of their high GI. To explore this question, one needs to examine the supporting data, their quantity and quality, their relation to causation and the possible presence of confounders.

There are 2 theories about how high - GI foods increase food intake. The first is that it is a result of the elevation in glucose and the second, more commonly expressed recently, is that it is the result of a high insulin response. This high insulin response has been related to several phenomena including increased food intake leading to obesity (Roberts, 2000), hyperinsulinaemia leading to insulin resistance (Frost *et al.*, 1998), cell exhaustion leading to type 2 diabetes (Salmeron *et al.*, 1997), dyslipidemia leading to coronary heart disease (CHD) (Liu *et al.*, 2001) and unknown factors leading to certain kinds of cancers.

The foods tested in this study were selected to represent the nutritional variability that adult Nigerians consume. Many of them suffer from chronic diseases such as coronary heart diseases, obesity and diabetes. Direct relationship of these diseases to consumption of high GI foods will require further enlarged and long-term studies. There is also need for more research into the GI of our locally consumed foods in order to produce data that can effectively enable use of GI alongside other dietary recommendations in the management and prevention of diseases. In conclusion, this study could assist food manufacturers and processors to develop a greater range of low-GI processed foods from African farm produce. The findings have obvious importance in formulating rational dietary and therapeutic goals for diabetic patients and others with clinical conditions necessitating carbohydrate restriction.

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References

Allison, D.B., F. Paltre and M.I. Goran, 1995. Statistical considerations regarding the use of ratios to adjust data. *Int. J. Obesity*, 19: 644-652.

- AOAC, 1983. Official Methods of Analysis, 13th Edn. Association of Official Analytical Chemists. Washington, DC., pp: 755-800.
- Bjorck, I. and H. Elmstahl, 2005. The glycemic index: Importance of dietary fibre and other food properties. *Proc. Nutr. Soc.*, 62: 201-206.
- Bjorck, I., Y. Granfeldt, H. Liljeberg, J. Tovar and N.G. Asp, 1994. Food properties affecting the digestion and absorption of Carbohydrates. *Am. J. Clin. Nutr.*, 59: 6995-7055.
- Bradbury, J.H. and W.D. Holloway, 1988. The chemical composition of tropical root crops. *ASEAN Food J.*, 4: 3-31.
- Ekpenyong, T.E., 1973. Problems of maize quality improvement. *W. Afr. J. Biol. Appl. Chem.*, 16: 3-8.
- Foster-Powell, K., S.H.A. Hoh and Brand-Miller, 2002. International tables of glycemic index and glycemic load: *Am. J. Clin. Nutr.*, 76: 5-56.
- Frost, G., A. Leeds, G. Trew, R. Margara and A. Dornhorst, 1998. Insulin sensitivity in women at risk of coronary heart disease and the effect of a low glycemic index diet. *Metabolism*, 47: 1245-1251.
- Gilbertson, R., S. Evans, C. Brand-Miller, P. Chondros, A. Thornburn and G. Werther, 2001. The effect of flexible low glycemic index dietary advice versus measured carbohydrates exchange diets on glycemic control in children with type 2 diabetes. *Diabetes Care*, 24: 1137-1143.
- Haber, G.B., K.W. Heaton, D. Murphy and L.F. Burroughs, 1979. Depletion and disruption of dietary fibre. Effects on satiety, plasma-glucose and serum-insulin. *Lancet*, 2: 679-682.
- Hollenbeck, C.G. and A.M. Coulston, 1991. Effects of dietary carbohydrate and fat intake on glucose and lipoprotein metabolism in individuals with diabetes mellitus. *Diabetes Care*, 14: 774-785.
- Jenkins, D.J., T.M. Wolever, R.H. Taylor, H. Barker, H. Fielden, J.M. Baldwin, A.C. Bowling, H.C. Newman, A.L. Jenkins and D.V. Goff, 1981. Glycemic Index of foods: A physiological basis for carbohydrate exchange. *Am. J. Clin. Nutr.*, 34: 362-366.
- Jenkins, D.J.A., M.J. Thorne, T.M.S. Wolever, A.L. Jenkins, A.V. Rao and L.U. Thompson, 1987. The effect of starch-protein interaction in wheat on the glycemic response and rate of in vitro digestion. *Am. J. Clin. Nutr.*, 45: 946-951.
- Liu, S., J. Manson and M.J. Stampfer, 2001. Dietary glycemic load assessed by food-frequency questionnaire in relation to plasma HDL-cholesterol and fasting plasma triacylglycerols in postmenopausal women. *Am. J. Clin. Nutr.*, 73: 560-566.
- Ludwig, D., 2003. Dietary glycemic index: Physiological mechanisms relating to obesity, diabetes and cardiovascular disease. *JAMA*, 287: 2414-2423.

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- Nishimune, T., T. Yakuzhigi, T. Sumimoto, S. Taguchi, Y. Konishi, S. Nakahara, T. Ichikawa and N. Kunita, 1991. Glycemic response and fiber content of some foods. *Am. J. Clin. Nutr.*, 54: 414-419.
- Okoh, P.N., 1998. Cereal grains: In *Nutritional Quality of Plant Foods* (Eds.) A.U. Osagie and O.U. Eka, Post-Harvest Research Unit, University of Benin, Benin City, Ambik Press, pp: 32-52.
- Osagie, A.U. and F.I. Opute, 1981. Total lipid and fatty acid composition of tropical tubers. *Nig. J. Nutr. Sci.*, 2: 39-46.
- Roberts, S.B., 2000. High-glycemic index of foods, hunger and obesity: Is there a connection? *Rev.*, 58: 163-9.
- Salmeron, J., A. Ascherio and E. Rimm, 1997. Dietary fiber, glycemic load and rise of NIDDM in men. *Diabetes Care*, 47: 1244-1251.
- Thorsdottir, I., B. Birgisdottir, L. Steingrimsdottir, B. Karistrom, I. Bjorck, A. Flint, O. Kolset, M. Uusittupa, M. Schulze and D. Jenkins, 2005. Glycemic index: From research to nutritional recommendations. *Ekpresson and Kopiceter*, Denmark, pp: 1-84.
- Welch, I.M.L., C. Bruce, S.E. Hill and N.W. Read, 1987. Duodenal and ileal lipid suppresses blood glucose and insulin responses in man: Possible complications for the dietary management of diabetes mellitus. *Clin. Sci.*, 72: 209-216.
- Wolever, T.M.S. and C. Bolognesi, 1996. Source and amount of carbohydrate affect postprandial glucose and insulin on normal subjects. *J. Nutr.*, 126: 2798-2806.
- Wolever, T.M.S., 1990. Relationship between dietary fiber content and composition in foods and their glycemic index. *Am. J. Clin. Nutr.*, 50: 72-75.
- Wolever, T.M.S., D.J.A. Jenkins, A.L. Jenkins and R.G. Josse, 1991. The glycemic index: Methodology and Clinical implications. *Am. J. Clin. Nutr.*, 54: 846-854.
- Wolever, T.M.S., D.J.A. Jenkins, R.G. Josse, G.S. Wong and R. Lee, 1987. The glycemic index: Similarity of values derived in insulin-dependent and non-insulin-dependent diabetic patients. *J. Am. Clin. Nutr.*, 6: 295-305.