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Determination of Glycemic Indices (GI), Glycemic Load (GI) and Proximate Analysis of unripe Plantain (*Musa paradisiaca*) and Cocoyam (*Colocasia esculenta*)

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ABSTRACT

The results of the present study show the glycemic index GI values calculated using the trapezoidal rule, of fried plantain, boiled plantain, roasted plantain, fried cocoyam, boiled cocoyam and roasted cocoyam were 88.8, 96.5, 92.0, 88.5, 97.3 and 80.0, respectively. Maximum values (96.5 and 97.3) was recorded for boiled plantain and boiled cocoyam while minimum GI (80) was recorded for roasted cocoyam. As evident, most of these foods have a high GI value (i.e., GI=70 0r more). The glycemic load GL values of fried plantain, boiled plantain, roasted plantain, fried cocoyam, boiled cocoyam and roasted cocoyam were 44.4, 48.25, 46.0, 44.25, 48.65 and 40, respectively. The maximum value (48.65) was recorded for Boiled cocoyam while minimum glycemic load (40) was recorded for Roasted cocoyam. These data indicate that all the cereal foods investigated in current study have high GI and GL. The incremental area under the curve (iAUC) of samples showed values as; glucose (3.75), fried plantain (3.33), boiled plantain (3.62), roasted plantain (3.45), fried cocoyam (3.32), boiled cocoyam (3.65), and roasted cocoyam (3.00). Results also show the glycemic load GL of the pulses. The mean of the glycemic index for fried plantain (44.4), boiled plantain (48.25), roasted plantain (46.0), fried cocoyam (44.25), boiled cocoyam (48.65) and roasted cocoyam (40).

Keywords : Glycemic Index, Glucose, Plantain, Cocoyam, Proximate.

I. INTRODUCTION

The concept of a glycemic index was developed to provide a series classification of carbohydrate foods on the assumption that such data would be useful in situation where the patient is suffering from diabetes. The glycemic index concept was an extension of the dietary fiber hypothesis of Burkitt and Trowell, who proposed that foods that are more slowly absorbed may have metabolic benefits in relation to diabetes and to the reduction of coronary heart disease (CHD) risk (Burkitt and Trowell, 1977). At the same time the dietary fiber hypothesis was formed, the concept of a cluster of diseases related to central adiposity and intra-abdominal fat mass with attendant insulin resistance was being created. The comparison of many of the issues that were raised after the formulation of both concepts further defined possible preventive and therapeutic roles for the glycemic index classification of foods (Jenkins *et al.*, 2002). Plantain (Musa spp. AAB) is an important staple in West and Central Africa, Latin America and Asia. It closely similar to dessert banana, yet the fruits is consumed cooked as the starch component of a dish. Although Musa spp. Originate from South East Asia, West and Central Africa is a secondary center of diversification for plantain with more than 100 cultivars (Swennen, 1990; Swennen *et al*., 1995) and thus has the world's highest diversity (Blomme *et al*.,2013). Musa spp.is referred to by groups which indicate their ploidy and putative genomic constitution with respect to the parents. Plantain (AAB) is thus triploid, has two genomes from Musa acuminata (A) and one from Musa balbisiana (B). Cocoyams (*Colocasia esculenta*and *Xanthosomasagittifolium*) are herbaceous perennial plants belonging to the family araceae and are grown primarily for their edible roots (Adewale *et al*, 2016). The glycemic index is a ranking system for carbohydrates based on their immediate effect on blood glucose levels. The concept was invented by Jenkins and his colleagues in 1981 at the University of Toronto" (Jenkins, Wolever and Taylor, 1981). In 1981, Jenkins introduced glycemic index concept (GI) in the early 1980s as a ranking system for carbohydrates based on their immediate impact on blood glucose levels. GI was originally designed for people with diabetes as a guide to food selection, and was advised to select foods with a low GI (Jenkins, Wolever, Jenkins, Thorne, Lee and Kalmusky, 1983). Lower GI foods were considered to confer benefit as a result of the relatively low glycemic response following ingestion compared with high GI foods. The GI concept has been extended to also take into account the effect of the total amount of carbohydrate consumed. Thus glycemic load (GL), a product of GI and quantity of carbohydrate eaten provides an indication of glucose available for energy or storage following a carbohydrate containing meal. Although GI is usually tested on individual foods, there are methods described whereby the GI and GL of meals and habitual diets can be estimated (Wolever and Jenkins, 1986; Salmeron *et al*., 1997a). In addition to a role in the treatment of diabetes, low GI and GL diets have more recently been widely recommended for the prevention of chronic diseases including diabetes, obesity, cancer and heart disease and in the treatment of cardiovascular risk factors, especially dyslipidaemia (Jenkins *et al*., 2002). According to Booher *et al.,* (1981), the conditions which increase the digestibility of starches include those modifications that produce obvious hydration of the granules distinct from changes in chemical nature, or disruption of the organized structure. In general, it appears that the greater the change in the physical form of a food the higher is the glycemic response it will produce. The concentration of carbohydrate varied between unripe (32.6%) and ripe (29.6%) plantain samples (Giami *et al*., 1994). A range between 21 and 26% starch content was reported in unripe plantain (Zakpaa *et al*., 2010). Glycemic index describes the rate of blood glucose absorption after food consumption (Wolever *et al*., 1991). Several reports had associated high glycemic index food to metabolic disorders such as diabetes mellitus and cardiovascular disease (Jenkins *et al*., 2002; Brand-Miller *et al*., 2003; Sun *et al*., 2010). The concept of glycemic index (GI) provides away to rank carbohydrate-rich foods according to the blood glucose response following their intake. The GI calculated by measuring the incremental area under the blood glucose curve following ingestion of a test food (glucose or white bread) providing 50 g of carbohydrate, compared with the area under the blood glucose curve following an equal carbohydrate intake from the reference food. All tests are conducted after an overnight fast (Burke *et al*., 1998). Glycemic Load (GL) defines the concept of GI to quantify the impact that a carbohydrate-containing meal or a single food eaten in a "normal" portion has on blood sugar (Ebbeling *et al*., 2001). To the best of our knowledge, there is scarcity of research work and data on the GI and GL of our local foods. Cereal and cereal products are one of our staple foods consumed in large quantities on daily basis. In the absence of information on the blood glucose response of these foods, the physicians and dietitians find it difficult to suggest diets to patients with symptoms of hyperglycemia. Glycemic indices (GI) and glycemic loads (GL) of various cereal foods have been determined (Farukh et al., 2013). In one research, 49 male individuals of an institution were recruited and were divided into seven groups, with seven students in each group. Rice and macaroni were boiled in tap water before feeding to the individuals, salty biscuits, macaroni, *namakparae* and wonder bread were purchased from the local bakery shop. Maize and wheat bread and wheat chapatti were also fed. 50g of glucose dissolved in 300 ml of water (as control diet) was given to each individual of all the groups on day first and amount of the boiled cereal foods equivalent to 50 g carbohydrate were given to each individual of the assigned group on the next day. Blood samples were collected at various time-points i.e., at 0 (fasting), 30, 60 and 120 minutes after ingestion of glucose and test foods. GI was determined from the area under curves of glucose concentration for reference and test foods. Glycemic load (GL) was determined by taking the percentage of the carbohydrate content in a typical serving multiplying by its GI. The GI values of rice, macaronis, wonder bread, salty biscuits, namakparae, maize bread and wheat chapatti were 66, 51, 64, 69, 45, 56 and 67, respectively. The GL values of rice, macaronis, wonder bread, salty biscuits, namakparae, maize bread and wheat chapatti were 25, 24, 9, 13, 8, 17 and 20, respectively. The results of the study indicated that cereal based foods have higher GI and GL and hence could be used with precaution in the diet of patients with hyperglycemic complications. The work was aimed at determining complex carbohydrate foods that has high glycemic indices resulting in potential harmful health effects and development of chronic diseases. It also aim at evaluating the glycemic index (GI) of the foods using different processing methods and to compare the GI and GL of the food at the raw and processed states.

II. METHODS AND MATERIAL

Experimental

The study was carried out using standard glycemic index testing protocol as outlined by Wolever et al., (1981) Glucose was used as the reference food with a GI score of 100, tested in the subjects at baseline of the study. Subjects were appraised both verbally and in writing of the study protocol, and all gave written informed consent before participation. Recruitment took place between March 2018 and April 2018 during which subjects were screened for any illness at the Crawford University Health Center. Anthropometric data and lifestyle factors were derived from questionnaires. Only non-diabetic individuals between the ages of 19 and 25 years were eligible to participate in the study. Smokers, overweight, and obese individuals were excluded from the study. Emphasis was placed on subjects who were healthy, with an active lifestyle, without any diagnosed diseases, and not on prescribed medication. During the study, subjects were advised to continue their customary daily activities without any change in their physical activities. Freshly harvested, mature Green Plantain (*musaparadisiaca*) and Red Cocoyam (*colocasiaesculenta)* were purchased from Lusada market and was identified by a plant taxonomist at Crawford University. Samples used for the GI studies were thoroughly washed then cooked by boiling, roasting, and frying for use on the day of glycemic index analysis. Foods processed by frying were peeled and cut to 10mm thickness and submerged in preheated, cholesterol-free vegetable cooking oil, until slightly brown. Foods processed by roasting were washed and roasted (skin intact) using preheated charcoal for 45 minutes in an open system. Foods processed by boiling were washed, peeled, and cut into 25mm slices. They were then cooked in water (gentle boiling) with the lid of the cooking vessel on for 20 minutes, followed by simmering heat (lid of cooking vessel off) for a further 10 minutes. After the boiling process, the available carbohydrate content was determined, to assess the loss of sugars that may have occurred during cooking. The foods were then served in 50 grams available carbohydrate portions, required for GI analysis. A randomized cross-over study design was conducted with 10 healthy non-diabetic subjects (5 males and 5 females). Fifty grams (50 g) available carbohydrate portions of the test foods were administered to the subjects on separate mornings after a 10–12 hour overnight fast. Subjects were asked not to perform any strenuous activities, take long walks, or consume alcohol on the day of glycemic index determination. They were asked to remain seated for the duration of the test. Test meals were consumed within 10minutes and supplemented with 250mL of water. Capillary pricked-finger blood samples were taken at baseline (0 mins), 15, 30, 45, and 60 minutes after the meal was consumed. While blood glucose was measured using an automated glucometer analyzer the (ACCU-CHECK Advantage II, Roche Diagnostics (GmbH, Germany) and ACCU-CHECK Advantage II test strips. The incremental areas under the curve (iAUC), excluding the area beneath the fasting level, was calculated geometrically using trapezoidal rule(Gibaldi*et al.*, 1982). The GI was then calculated by expressing the glycemic response area for the sweet potato as a percentage of the mean response area of the reference food (glucose) taken by the same subjects. The GI was calculated by the method of Jenkins *et al.* (1981). The values of blood glucose were plotted against time. For each person, the area under 1hr blood glucose response (glucose iAUC) and the food eaten was measured. The glycemic index value for the test food was calculated for each person by dividing glucoseiAUC for the test food by glucose iAUC for the reference food. The final glycemic index value for the test food was the mean glycemic index value for the 10 people. GI was calculated by the formula: GI= iAUC for test food ÷ iAUC for reference glucose ×100 Blood glucose curves were constructed from blood glucose values for each individual at time 0, after 15, 30,45, and 60 minutes intervals after consumption of the reference food and test food of each group. The Incremental Area Under the Curve (iAUC) was calculated for reference food (glucose) by the trapezoidal rule (Gibaldi *et al.*, 1982) in every individual separately as the sum of the surface of trapezoids between the blood glucose curve and horizontal baseline going parallel to x axis from the beginning of blood glucose curve at time 0 to the point at time 60 min to reflect the total rise in blood glucose concentration after eating the reference food (glucose). The Incremental Area under the Curve (IAUC) for the test food of the same individual was obtained similarly. GL defines the concept of GI to quantify the impact that a carbohydrate containing meal or a single food eaten in a normal portion has on blood sugar. The GL was calculated as the GI (%) multiplied by the grams of carbohydrate in the serving of food eaten. The GL for a meal would be the sum total of the GI of each food that is part of the meal. GL was calculated by the formula: GL= Net grams of carbohydrates × GI ÷100. The Anthrone method (AOAC, 1990) was adopted for the glucose determination.

III.RESULTS AND DISCUSSION

The quantitative determination of the glycemic indices (GI) and proximate analysis of unripe plantain (Musa paradisiaca) and cocoyam (*Colocasia esculenta)* shows the following results:

Sample Time (min^{-1})	Glucose mg/L	Fried Plantain mg/L	Boiled plantain mg/L	Roasted plantain mg/L	Fried cocoyam mg/L	Boiled cocoyam mg/L	Roasted cocoyam mg/L
0	88.7	83.5	79.5	88.0	82.1	86.1	79.6
15	118.6	108.6	116.1	109.5	108.2	118.1	94.2
30	110.8	99.0	108.5	106.4	101.1	114.7	88.1
45	107.3	92.6	101.0	98.5	91.0	101.5	86.5
60	103.1	82.9	95.4	93.0	82.6	94.5	83.8

Table 1- Average mean of the glucose values of the 10 subjects

Samples	iAUC values	Glycemic indices	Glycemic load values
Glucose	3.75		
Fried plantain	3.33	88.8± 3	44.40
Boiled plantain	3.62	96.5± 2	48.25
Roasted plantain	3.45	92.0± 3	46.00
Fried cocoyam	3.32	88.5± 3	44.25
Boiled cocoyam	3.65	97.3± 2	48.65
Roasted cocoyam	3.00	80.0± 4	40.00

Table 2 iAUC values of the samples

Test meals	Carbohydrate content(mg/ml)	Protein content (mg/ml)	% Crude fiber	% Ash content	%Moisture content
Raw cocoyam	0.318 ± 0.002	0.028 ± 0.007	16.34 ± 0.03	9.69 ± 0.010	64.5 ± 0.107
Raw plantain	0.28 ± 0.02	0.043 ± 0.006	12.03 ± 0.02	25.00 ± 0.006	68.7 ± 0.102

Table 3 Proximate composition of Green plantain and cocoyam

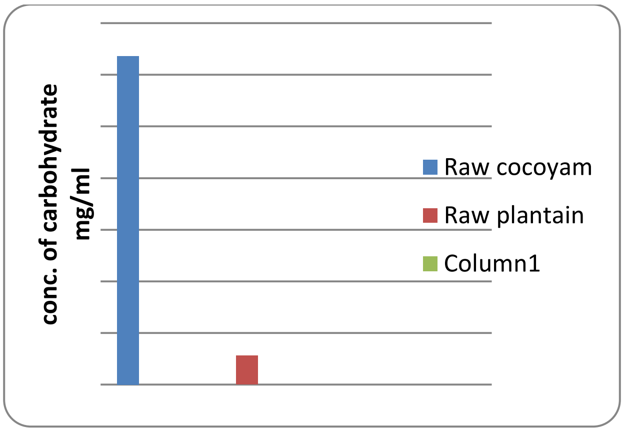

Fig 1: A bar chart of carbohydrate concentration.

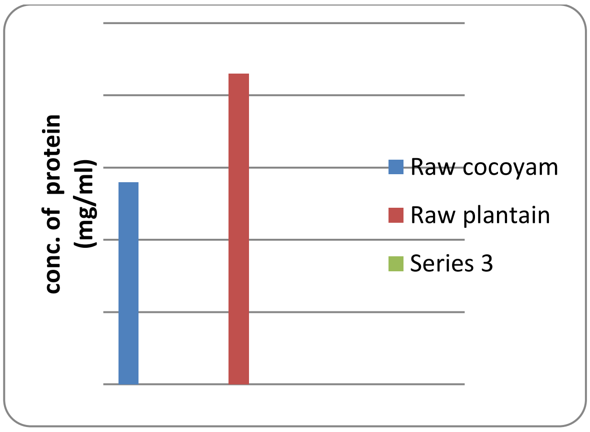

Fig 2: Bar chart of protein concentration of the samples.

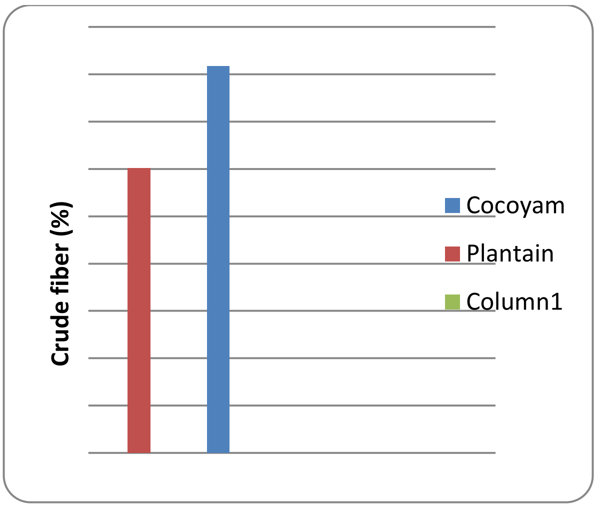

Fig 3: Bar chart of the crude (%) fiber of samples.

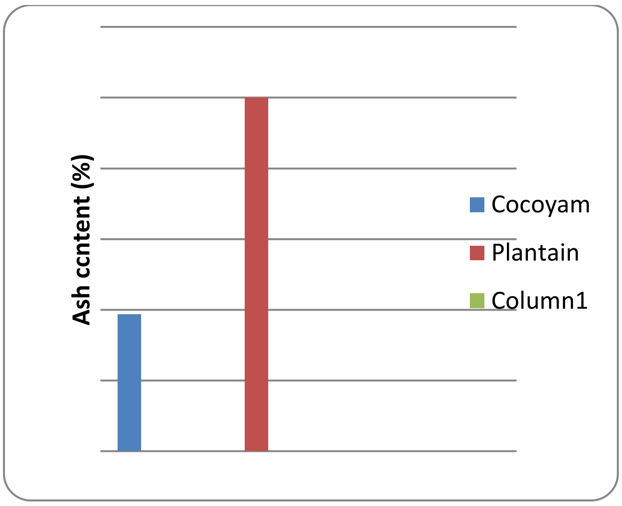

Fig. 4: Bar chart of the (%) Ash of plantain and cocoyam

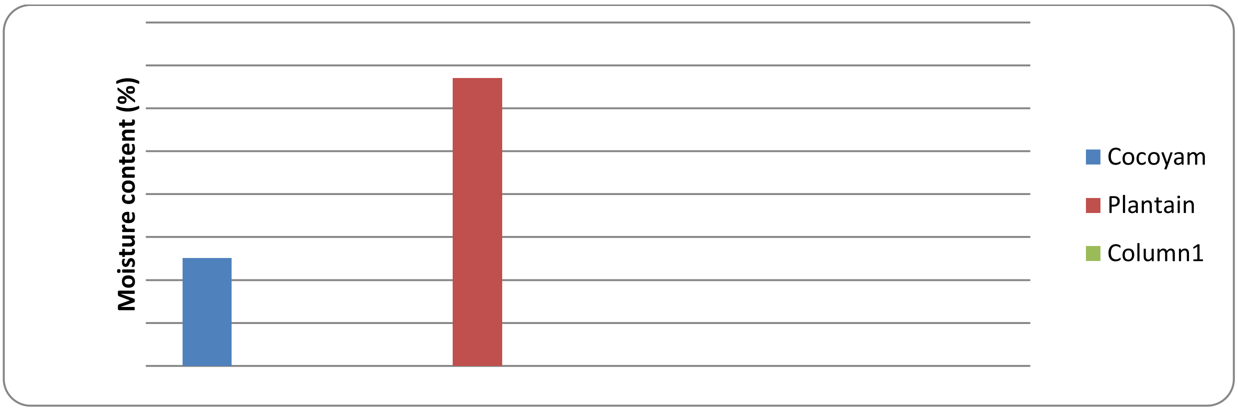

Fig 5: Bar chart of the (%) moisture of plantain and cocoyam

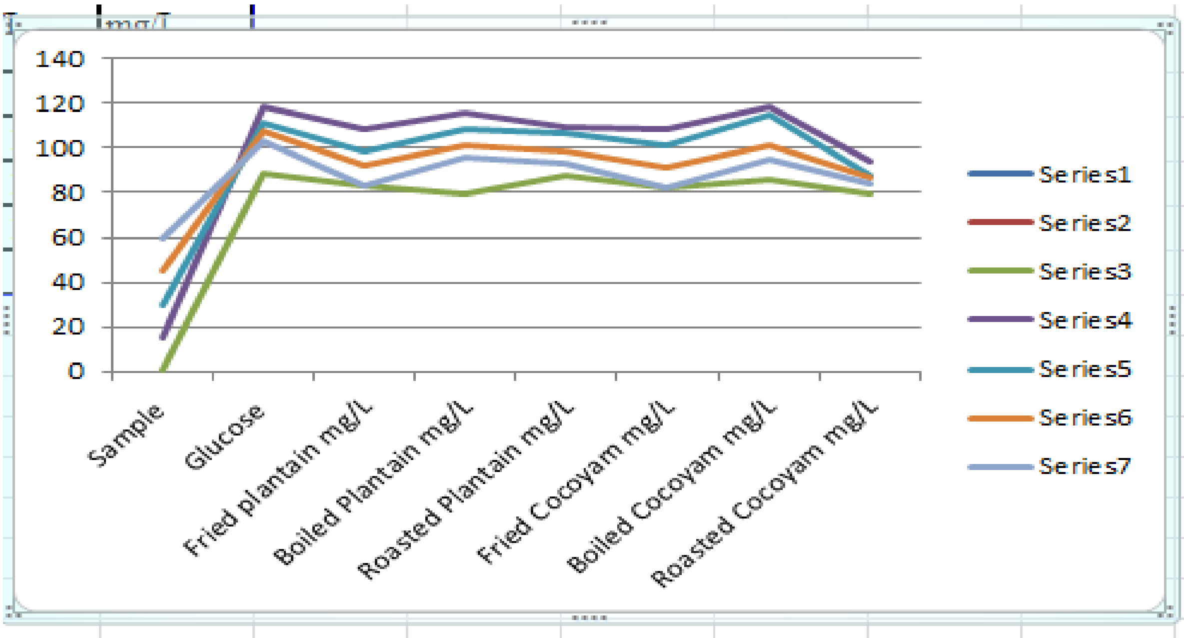

Fig 6: Mean glycemic responses elicited by 50 g available carbohydrate portions of cocoyam and green plantain processed by boiling, roasting, and frying.

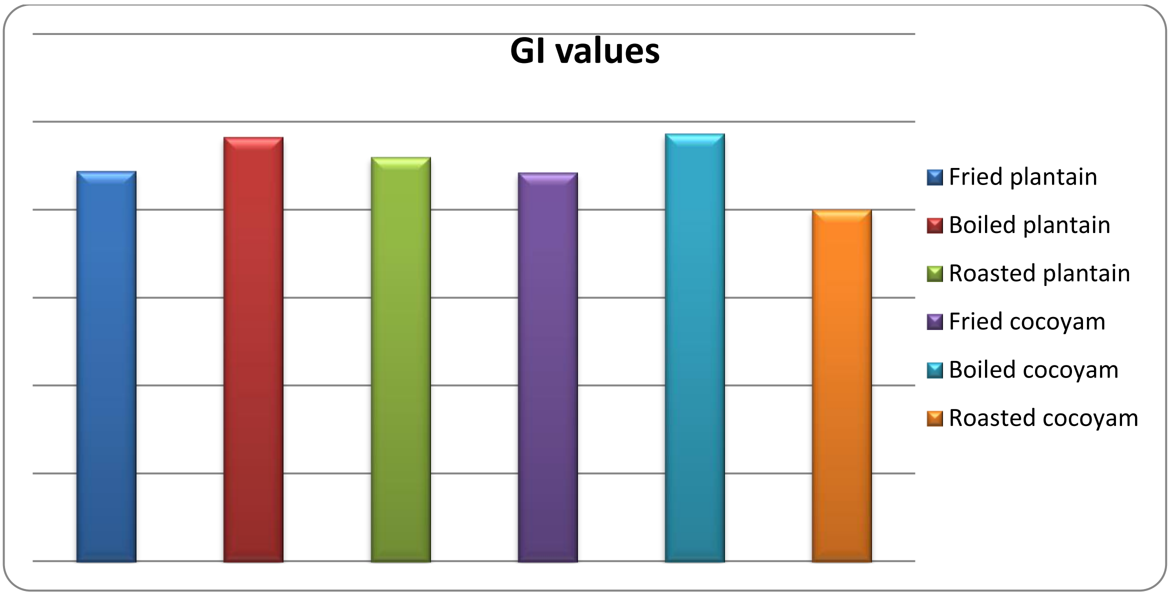

Fig 7: Glycemic indices of fried plantain, boiled plantain, roasted plantain, fried cocoyam, boiled cocoyam and roasted plantain

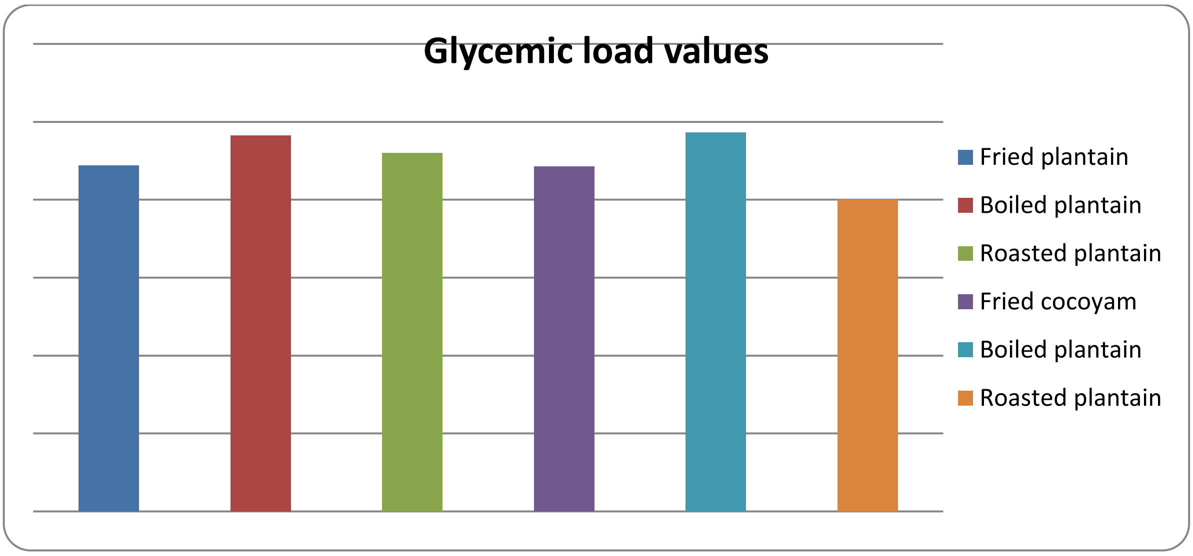

Fig 8: Glycemic load values of fried plantain, boiled plantain, roasted plantain, fried cocoyam, boiled cocoyam and roasted plantain.

Table 1 and Figure 1 show the average mean value of glucose of the 10 subjects that participated in the analysis. At 0 min the values are normal, while at 15min the values increased then started decreasing till from 30 min to 60 min. While Table 2 shows iAUC values of the samples, Glucose (3.75), Fried plantain (3.33), Boiled plantain (3.62), Roasted plantain (3.45), Fried cocoyam (3.32), Boiled cocoyam (3.65), and Roasted cocoyam (3.00). Table 5 shows the GI of the samples. The mean value of glycemic index for Fried plantain (88.8), Boiled plantain (96.5), Roasted plantain (92.0), Fried cocoyam (88.5), Boiled plantain (97.3) and Roasted plantain (80.0) were recorded. Table 6 shows the GL of the pulses. The mean of the glycemic index for Fried plantain (44.4), Boiled plantain (48.25), Roasted plantain (46.0), Fried cocoyam (44.25), Boiled cocoyam (48.65) and Roasted cocoyam (40). Table 3 shows to proximate composition of green plantain and cocoyam showing the available carbohydrate content, protein content, crude fiber, ash content and moisture content to know how much these parameter will support glycemic index.

IV. DISCUSSION

The results of the present study (Table 2) show the GI values of Fried plantain, Boiled plantain, Roasted plantain, Fried cocoyam, Boiled cocoyam and Roasted cocoyam were 88.8, 96.5, 92.0, 88.5, 97.3 and 80.0, respectively. Maximum values (96.5 and 97.3) was recorded for Boiled plantain and Boiled cocoyam while minimum GI (80) was recorded for Roasted cocoyam. As evident, most of these foods have a high GI value (i.e., GI=70 0r more) (Foster-Powell et al., 2002). The GL values of Fried plantain, Boiled plantain, Roasted plantain, Fried cocoyam, Boiled cocoyam and Roasted cocoyam were 44.4, 48.25, 46.0, 44.25, 48.65 and 40, respectively. The maximum value (48.65) was recorded for Boiled cocoyam while minimum glycemic load (40) was recorded for Roasted cocoyam. These data indicate that all the cereal foods investigated in current study have high GI (Foster-Powell et al., 2002) and GL. The reason for relatively low value of GI in fried cocoyam and plantain may be the presence of higher amount of fat (cooking oil) added during its preparation (Khattak et al., 2006). Fat and protein reportedly show negative association with GI (Jenkins et al., 1981) on the virtue of their ability to delay gastric emptying and affect insulin secretion. Interestingly, however, their effect on GI is generally not seen unless relatively large amounts (about 30g of protein and 50g of fat per 50g carbohydrates) are added to a meal (Wolever et al., 1996; Wolever et al., 1994). The glycemic index of boiled cocoyam and plantain was 97.3 and 96.5 was high in healthy subjects. It showed that boiled cocoyam and boiled plantain has high glycemic index and high glycemic load 48.65 and 48.25. After a high-glycemic load meal, blood glucose levels rise more rapidly and insulin demand is greater than after a low glycemic load meal. High blood glucose levels and excessive insulin secretion are thought to contribute to the loss of the insulin secreting function of the pancreatic beta-cells that leads to irreversible diabetes. So boiled cocoyam and plantain should not be taken frequently by diabetic people and the quantity must be very small to lower glycemic loads. However boiled cocoyam and plantain will be more suitable for athletes since ingestion of high -GI foods after exercise result in greater synthesis of muscle glycogen 16 compared with ingestion of equal amounts of carbohydrate as a low-GI food. In conclusion boiled cocoyam is of high glycemic index and the 50 gram of available carbohydrate - portion size of this meal was also of high glycemic load, therefore diabetic individuals should only consume boiled cocoyam with low glycemic index food, allowing the portion size of the cocoyam to be less than 50 grams of available carbohydrate. The study also shows that cooking by roasting resulted in spikes in postprandial blood glucose levels for all the green plantain and cocoyam varieties. Cooking with the skin intact increases the availability of free sugars which are immediately hydrolyzed by salivary amylase and are instantly absorbed. Additionally the absence of a water-rich environment as similar to that of boiling would have resulted in less starch gelatinization and by extension production of lower levels of retrograded/RS 3 starch. Additionally, the GI values of these cocoyams and plantains studied could be substantiated by correlating the texture of the cocoyams and plantains as described by studies done by Henry et al. (2005). Furthermore, intra-varietal variations could be related to differences in the starch physicochemical properties and maturity index of the different varieties used. Additionally, it has been reported that precooking or allowing the food to cool and then reheating before consumption may elicit a lower glycemic response compared with consumption immediately after cooking. The glycemic indices of green plantain and cocoyam using the different processing methods differs. However the results of this study suggest that boiled unripe plantain has more promising control effect on blood glucose level and could be better used in the management of metabolic disorder such as diabetes mellitus. The roasted cocoyam (RC) meal had the lowest Glycemic index of all the processed test meal.

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