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Glycaemic Indices of Commonly Consumed Single and Mixed Meals as Eaten by Apparently Healthy Young Adults in Southwestern Nigeria

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Abstract: Diabetes mellitus is one of the metabolic diseases associated with life-threatening complications. Existing dietary management uses information on the Glycemic Index (GI) of single foods. However, foods are usually not consumed as a single item but as mixed meals in Nigeria. This study, therefore, determined the GI of commonly consumed single and mixed meals 'as eaten' by apparently healthy young adults in Southwestern, Nigeria. Thirty-five test meals [24 mixed meals and 11 single foods] prepared from yam, unripe plantain, white-bread, rice, *ogi* (maize paste), and beans were tested. The quasi-experimental study involved eighty apparently healthy young adults. 50g of the reference food (glucose) was dissolved in 350ml of water and served to the participants on two different days after a 10-12 hour overnight fast. Each of the participants served as a control and one day wash-out period was given between test meals. Fasting blood samples were obtained at baseline from groups of eight participants, thereafter they consumed 50g available carbohydrate portion of each test meal. Postprandial glucose concentrations were determined using an Accucheck® glucometer at 0, 30, 60, 90 and 120 minutes. GI for each test meal was calculated as the percentage incremental area under the blood glucose curve (IAUC) for the test meal divided by the average IAUC for the reference food. Data were analysed using descriptive statistics and ANOVA at $\alpha_{0.05}$. All test meals had a high GI value. Boiled-yam+Fried-egg had a GI of 84 while Boiled-yam as a single food had a GI of 94, Unripe-plantain+stew had a GI of 88 while unripe-plaintain as a single food had a GI of 89. White-bread+*moinmoin* and white-bread+*Akara* had GI of 78 and 93. Boiled-rice+fried-plantain+stew+meat, Boiled-rice+boiled-beans+stew+meat, Fried-rice+fried plaintain+meat had GI values of 74, 76 and 78 respectively. *Ogi*+*moinmoin* and *Ogi*+*akara* had GI of 76 and 77 while single foods of Beans-porridge, Boiled-beans, *Akara* and *Moinmoin* had GI of 85, 91, 91 and 94 respectively. The GI of boiled-rice (93) and *ogi (92)* as single foods were significantly higher than when eaten as mixed meals. Boiled-rice+fried-plantain+stew had the lowest GI (74) while beans-porridge+soaked-*garri* had the highest GI (96). The mixed meals had lower GI values compared to the single foods. This study has provided relevant information on the GI of mixed meals in Nigeria which can be useful in dietary recommendations for the management of type 2 diabetes mellitus.

Keywords: Glycaemic Indices, Mixed Meals, Rice, Beans, Yam, Diabetes Mellitus, Plantain, Nigerian Foods

1. Introduction

Diabetes mellitus is a chronic disease that occurs either when the pancreas does not produce enough insulin (a hormone that regulates blood sugar, or glucose), or when the body cannot effectively use the insulin, it produces. The prevalence of type 2 diabetes mellitus is increasing everywhere, especially in the world's middle-income countries. Over the past three decades, diabetes prevalence has risen faster in low- and middle-income countries than in high-income countries [1]. Diabetes is an important public health problem, one of four priority noncommunicable

diseases (NCDs) targeted for action by world leaders. According to the United Nations (UN), it is a chronic, debilitating, and costly disease linked with severe complications that pose severe risks for families, member states, and the entire world [2]. About 60% of the increase in the global burden of Non-Communicable Diseases (NCDs) is expected to occur in developing countries, and most of the associated mortality is obesity-related and attributable to type II diabetes mellitus (T2DM) and coronary heart disease [3]. The major NCDs related to diet are cardiovascular diseases and diabetes mellitus (DM). Diabetes mellitus is the highest non-communicable disease cause of morbidity and mortality in Africa with its enormous complications imposing significant economic consequences on individuals, families, health systems and countries [1]. With the over 250 tribes having different cultures and food types in Nigeria, the prevalence rate of diabetes has not been uniform, though the International Diabetes Federation reported 5.0% in the 2013 Diabetes Atlas [4]. The prevalence of diabetes mellitus and its complications is progressively rising in Nigeria presenting an immense public health burden with an increased prevalence rate of 2.2% reported in a national survey by Akinkugbe in 1997 to 5.0% in 2013 and a recent meta-analysis reported that approximately 5.8% (about 6 million) of adult Nigerians are living with DM [4-6].

Nutrition is of extreme importance in intensive diabetes management and has been defined as the keystone of care [7, 8]. A key emphasis of nutritional management of diabetes is the improvement of glycaemic control by harmonizing food intake with endogenous and or exogenous insulin levels. The concept of the glycaemic index (GI) introduced over 30 years ago was considered as a metric for the dietary management of type II diabetes [9]. The glycaemic index (GI) is a measure of how rapid blood glucose levels increase postprandially. It is defined as the incremental area under the glucose response curve following consumption of a 50 grams food portion relative to that produced by a 50 grams portion of a control food, either glucose or white bread [10, 11]. The Glycaemic Index (GI) is a scale that ranks carbohydrate-rich foods by how much they raise blood glucose levels compared to standard food. Glycaemic index is rated on a scale of 1 to 100. According to this scale system, the GI values of carbohydrate-containing foods are graded into three categories as High (≥ 70), intermediate (55 – 69) and low (< 55). This categorization depends on the rate at which blood sugar level rises, which in turn is related to the rate of digestion and absorption of sugars and starches available in that food [12].

The Glycaemic index is currently used as a medical nutrition therapy tool. Low glycaemic index food reduces postprandial blood glucose levels preventing hyperglycemia and glycosuria. There is also enough evidence of long-term benefits associated with using low glycaemic index diets as a primary strategy in meal planning for the management and prevention of diabetes [8, 13, 14]. Conversely, consuming high GI foods is associated with an increased risk of type 2 diabetes mellitus and coronary heart disease [14, 15]. Consumption of high GI and GL mixed meals may pose difficulties in diabetes Medical Nutrition Therapy (MNT) [16]. Currently, there is high interest in the role of low GI foods in preventing and managing metabolic-related diseases [17]. Knowledge of the GI values of foods such as developed ready-to-eat mixed meals can provide increased menu choices thus having an important implication in the prevention and treatment of type 2 diabetes, obesity, and CVD [18]. However, the paucity of information on GI and glycaemic load (GL) for many Western African traditional foods is still a major hindrance to the application of the GI in the management of these metabolic diseases [19, 20]. This is made difficult because the GI value of many commonly consumed foods in Nigeria is not known. This study, therefore, determined the glycaemic index of commonly consumed single foods and mixed meals as eaten by apparently healthy young adults in Southwestern Nigeria.

2. Materials and Methods

2.1. Recruitment of Study Participants

Interested candidates were recruited through the students' representatives and informed of the study protocol. Thereafter they were screened for age, gender, body weight, height, medical history, physiological status and clinical characteristics of fasting blood glucose, blood pressure and haemoglobin levels to ensure that the participants were apparently healthy young adults. The Inclusion criteria to participate in the study were age (17 to 35 years), BMI (18.5 - 25kg/m^2), fasting blood glucose (<126mg/dl), blood pressure (<120/80mmHg), and those who were not on any regular medication (except oral contraceptives). Any candidate with a history of diabetes or gastrointestinal disorder, currently pregnant or lactating was also excluded from the study. Verbal and signed informed consent were obtained from all participants before the commencement of the study. Eighty (females: 53 and males: 27) apparently healthy young adults from the University of Ibadan voluntarily participated in this quasi-experimental study.

2.2. Ethical Considerations

This study was done at the Department of Human Nutrition and Dietetics, University of Ibadan (UI). The Joint University of Ibadan and University College hospital (UI/UCH) Ethics Review Committee granted the ethical approval for this study with approval number: UI/EC/15/0432. The guidelines from the Declaration of Helsinki such as voluntary participation and confidentiality of data were strictly adhered to.

2.3. Purchase of Test Foods and Preparation

Thirty-five test meals [24 mixed meals and 11 single foods] prepared with yam, unripe plantain, white bread, rice, ogi (maize paste), and beans were prepared as eaten in Southwestern, Nigeria. The ingredients for these test meals were purchased from Bodija Market, Ibadan and prepared according to the common cooking practices for these meals

in the Kitchen unit of the Department of Human Nutrition, University of Ibadan. The ingredients and preparation methods used were according to the Nigerian Cookery Book [21, 22]. The weight of foods and ingredients used for cooking are attached as an addendum.

2.4. Food Preparation and Cooking Methods

1. Yam – boiled: The yam was peeled, sliced, and cooked until softened with salt added to taste.
2. Yam Pottage: Raw yam was peeled, cut into small pieces, and cooked until soft after which ground fresh pepper, onions, palm oil, Maggi and salt were added to taste. The mixture was stirred until the right consistency and texture were obtained.
3. Fried Egg: One medium-sized egg with a pinch of salt was fried with little quantity of groundnut oil.
4. Plantain (boiled): Plantain was cut and cooked in water. A pinch of salt was added to taste.
5. White rice – boiled: Raw grains of rice were washed and cooked until soft with salt added to taste.
6. Plantain (fried): Plantain was peeled and thinly sliced into hot groundnut oil until it turned golden brown.
7. Egg (Boiled): Medium-sized egg was put into a pot containing water and allowed to boil until cooked.
8. Fried Rice: Raw rice was cooked until soft. This was then fried in groundnut oil, with green pepper, green beans, and carrot. Seasonings of Maggi and salt were added to taste.
9. Jollof rice: Raw rice, ground pepper, groundnut oil, and tin tomatoes were cooked together until soft. Seasonings of Maggi and salt to taste.
10. Ogi/Pap – Semi–solid yellow maize paste was mixed with water in a bowl. Hot boiling water was then added while stirring continuously until cooked to the desired thickness and consistency.
11. Bread – Sliced Foodco bread was purchased from Foodco supermarket and bakery.
12. Beans boiled- Whole beans were rinsed with water and cooked by boiling in water until tender with salt added to taste.
13. Beans porridge – Whole beans were rinsed with water and cooked by boiling in water until tender with salt, onions, pepper, and palm oil added to taste.
14. *Akara* (Beans cake) – Whole beans were soaked, washed and dehulled with water after which pepper, and onions were added before being wet milled to a consistent paste. Salt was added to the beans paste and fried into small balls until it had a golden brown colour with vegetable oil.
15. *Moinmoin* – Whole beans were soaked, washed and dehulled with water. Fresh pepper and onions were added to the dehulled seed and grinded into a consistent paste. Thereafter, the paste was poured in a bowl, then vegetable oil, seasonings and salt were added to taste and enhance texture. The mixture was stirred, and some little water added. This was then wrapped with leaves and steamed to cook.
16. Stew – Freshly grinded pepper, tomatoes and onions was boiled until cooked. This was then fried in vegetable oil with boiled meat stock, meat, salt and other seasoning (Maggi, curry, thyme) added to taste.

2.5. Analytical Methods

The standard methods of the Association of Official Analytical Chemists [23], was used to determine the proximate content of staple single foods. The moisture, energy, fat, protein, crude fiber, and ash content were determined in triplicate at the Nutrition Laboratory of the Department of Human Nutrition and Dietetics. Carbohydrate by difference was estimated to determine the available carbohydrate for the single food test meals. The factors of 4 kcal and 9 kcal were used to calculate the energy values of the test foods. The Food composition database for Nigeria was used to determine the available carbohydrate for unripe plantain and ogi (yellow maize paste) [24].

2.6. Study Experimental Procedures and Measurement of Blood Glucose

At 30 minutes interval over a 2-hour period, finger-prick blood samples were taken from all the study participants who consumed the reference food- 50g glucose on two separate mornings after 10-12 hours overnight fast using an Accucheck glucometer. In the subsequent week, prior to consumption of the test meals (0 min), blood samples were obtained using sterile hypodermic lancets from sets of eight participants out of the selected 80. Thereafter, portions of either the single or mixed test meals (selected for that test day) which contains 50g available carbohydrate was weighed and served with 350ml of water to the participants. The participants were told to reduce physical activity and remain sited to consume the served test foods in 10 -15 minutes at the nutrition laboratory. After consumption of the test food, further capillary finger-prick blood samples were obtained and inserted into the glucometer at 30, 60, 90, and 120 minutes. Readings were taken after 15 seconds in line with the glucose oxidase method and the glycemic response of the participants was derived following the procedure described by [25]. With a one-day wash out interval between meals, another set of test single or mixed meals was served to another group of eight participants on the next alternate day; and the procedure was repeated in a randomized order for each of the single and mixed meals made with yam, unripe plantain, white-bread, rice, *ogi* (maize paste), and beans. Proximate analysis carried out for each of the single foods was used to calculate 50g of available carbohydrate and also used to estimate the amount of food served to each participant. For each test meal consumed, the participants stood as their own control. The proportioning of the mixed meals was done in accordance with common eating practices in Nigeria as shown in Table 3.

2.7. Calculation of Glycemic Index

The GI was calculated using the method described by

FAO/WHO [25] as the area under the blood glucose response curve for each food taken by each subject and expressed as a percentage of the mean area under the curve (AUC) for the reference food (glucose) taken by the same subject; the average of the resulting values was taken as the overall GI of the single or mixed meal [18]. The GI values were then classified as high (70 – 100), intermediate (55 – 69) or low (< 55).

2.8. Statistical Analysis

Analysis of data was done using SPSS (version 20.0) for windows and MS Excel. Descriptive statistics such as frequencies and mean ± standard deviation (SD) was also used to summarize and present the results for GI and AUC (Area under the curve). The difference in means of frequencies was tested with Analysis of Variance (ANOVA) and correlations were used for comparisons of quantitative data for categorical variables at $p<0.05$.

2.9. Quality Control

Participants were admonished to refrain from consuming alcohol, reduce physical activity, adhere to observing the 10–12 hours overnight fast prior to the experimental session and remain seated during the duration of the test to reduce inter and intra within variations.

Daily calibration of the instruments such as glucometer and weighing scales were done and trained research assistants were involved in the collection and accurate recording of data in line with research procedures.

3. Results

A total of 80 subjects were studied, 27 males and 53 females. Anthropometric and clinical measurements were obtained from these participants after the entire experimental protocol. Their baseline characteristics are shown in Table 1. The proximate analysis conducted was used to calculate the amount of available carbohydrate (g/100g) of every single food as represented in Table 2. The portion size for the single foods based on 50g available carbohydrate and the serving proportion for the composite mixed meals making up to 50g available carbohydrate are shown in Table 3. The GI for all the single and mixed meals prepared with yam, unripe plantain, white-bread, rice, *ogi* (maize paste) and beans is shown in Tables 4, 5 and 6. The Thirty-five test meals [24 mixed meals and 11 single foods] included in this study had high glycemic index values ranging from 74 in Boiled-rice+fried-plantain+stew to 96 in beans-porridge+soaked-*garri.* Test meals from the single and mixed meals prepared with yam, plantain and white-bread had GI values of 84 - 94, 88 – 89 and 78 – 93 respectively while the single and mixed meals of rice, *ogi* and beans had GI values of 74 -93, 76 -92 and 84 -91.

Table 1. *Characteristics of Study participants.*

Characteristics	Female	Male	p-value
Number of Participants	53	27	
Mean Age (years)	21.3 ± 2.78	24.18 ± 4.02	0.017
Mean BMI (kg/m^2)	20.84 ± 2.57	20.79 ± 2.60	0.401
Mean Fasting Blood Glucose (mg/dl)	85.21 ± 8.15	84.07 ± 5.41	0.007
Mean Systolic Blood Pressure (mmHg)	109.71 ± 9.93	116.63 ± 11.60	0.963
Mean Diastolic Blood Pressure (mmHg)	72.68 ± 8.45	73.04 ± 9.12	0.587
Mean Hemoglobin (g/dl)	12.2 ± 0.92	14.78 ± 1.06	0.025

Table 2. *Proximate Composition of Commonly Consumed single foods (per 100g edible portion).*

Sample Description	Protein (g)	Fat (g)	Crude Fibre (g)	Ash (g)	Moisture (%)	CHO (g)	Energy (Kcal/g)
Yam – Boiled	1.32 ± 0.05	0.08 ± 0.02	0.51 ± 0.02	1.10 ± 0.04	70.77 ± 0.24	26.22 ± 0.23	110.91 ± 0.79
Yam Pottage	1.20 ± 0.07	3.21 ± 0.14	0.35 ± 0.01	1.47 ± 0.01	72.02 ± 0.81	21.75 ± 0.74	120.72 ± 3.96
Plantain - unripe boiled	0.92 ± 0.03	0.50 ± 0.22	5.60 ± 0.33	0.40 ± 0.16	61.53 ± 0.21	31.04 ± 0.54	132.37 ± 0.61
Plantain - fried in veg oil	1.30 ± 0.05	13.85 ± 0.01	0.18 ± 0.01	1.37 ± 0.02	47.85 ± 0.02	35.44 ± 0.02	271.65 ± 0.18
White rice – boiled	2.88 ± 0.04	0.25 ± 0.02	1.03 ± 0.04	1.05 ± 0.02	65.38 ± 0.20	29.41 ± 0.22	131.40 ± 0.76
Jollof rice	2.79 ± 0.03	2.77 ± 0.02	0.40 ± 0.01	1.71 ± 0.02	64.89 ± 0.43	27.43 ± 0.41	145.84 ± 1.96
Fried Rice	2.64 ± 0.02	3.30 ± 0.02	1.17 ± 0.01	1.49 ± 0.01	59.03 ± 0.02	32.37 ± 0.05	169.71 ± 0.11
Ogi' yellow	8.83 ± 0.02	4.04 ± 0.01	8.24 ± 0.04	1.03 ± 0.01	10.12 ± 0.03	67.75 ± 0.03	342.62 ± 0.10
Boiled Beans	10.79 ± 0.02	0.49 ± 0.02	1.17 ± 0.01	1.99 ± 0.03	64.06 ± 0.02	21.50 ± 0.08	133.54 ± 0.08
Beans Porridge	7.38 ± 0.05	4.48 ± 0.02	1.45 ± 0.02	2.26 ± 0.06	62.07 ± 0.15	22.36 ± 0.13	159.26 ± 0.63
"Moinmoin"	6.50 ± 0.03	2.48 ± 0.03	1.12 ± 0.01	1.72 ± 0.03	72.45 ± 0.07	15.73 ± 0.04	111.27 ± 0.26
"Akara"	12.07 ± 0.07	8.30 ± 0.25	0.87 ± 0.02	2.45 ± 0.06	52.55 ± 0.26	23.76 ± 0.03	218.03 ± 2.40

*CHO – Carbohydrate: expressed as the difference between the total weight of the food samples and the addition in grams of protein, fat, crude fibre, ash, and moisture.

Table 3. *Portion sizes of single and mixed meals containing 50g of available carbohydrate.*

Mixed meals			Single food	
Food	**Weight (g)**	**Available carbohydrate (50g)**	**Food**	**Equivalent weight of food containing 50g carbohydrate**
Bread	78	40g	Boiled yam	190.69
Akara	42.1	10g		

Mixed meals			Single food	
Food	**Weight (g)**	**Available carbohydrate (50g)**	**Food**	**Equivalent weight of food containing 50g carbohydrate**
Bread	58	30g	Yam pottage	229.78
Moin-moin	127.1	20g		
Bread	38.9	20g	Unripe plantain	161.29
Beans porridge	134	30g		
Boiled beans	46.5	10g	Ogi yellow (raw)	67.75
Boiled rice	136	40g		
Boiled rice	102.1	30g	Boiled rice	170.01
Boiled beans	46.5	10g		
Plantain	20	10g	Jollof rice	182.28
Boiled rice	135	40g		
Plantain	20	10g	Fried rice	154.46
Boiled beans	185.9	40g		
Plantain	20	10g	Bread (FoodCo)	97.5
Jollof rice	145.8	40g		
Plantain	20	10g	Boiled beans	232.34
Jollof rice	145.8	40g		
Moin moin	63.6	10g	Akara (veg oil)	210.53
Fried rice	123.6	40g		
Moin moin	63.6	10g	Moinmoin (veg oil)	317.66
Fried rice	123.6	40g		
Plantain	20	10g	Beans porridge	223.33

Table 4. *Glycaemic index of single and mixed meals made from Yam and Bread.*

Food	Portion Size (grams)	Mean GI	SEM	Category	p-value
Boiled Yam	191	94[a]	4.6	High	0.349
Boiled Yam and stew	236	85[a]	4.1	High	
Boiled Yam and Fried Egg	246	84[a]	2.10	High	
Yam Pottage	230	88[a]	4.98	High	
Unripe Plantain	161	89[a]	3.9	High	
Unripe Plantain with Stew	206	88[a]	3.4	High	1.791
White bread	98	88[ab]	3.0	High	
Bread and Egg	143	81[ab]	3.9	High	
Bread and *Akara*	120	93[b]	4.4	High	0.094
Bread and *Moin-Moin*	185	78[a]	4.5	High	
Bread and Beans	173	81[ab]	2.9	High	

Note: All values are expressed as mean ± SEM of eight values. Values with different letters on the same column are significantly different ($p < 0.05$). *SEM – Standard Error of Mean.

Table 5. *Glycaemic index of single and mixed meals made from Rice.*

Food	Portion Size (grams)	Mean GI	SEM	Category	p-value
White rice	170	93[b]	2.1	High	
Boiled rice and stew	215	83[a]	1.4	High	
Boiled rice, Fried Plantain and Stew	201	74[a]	1.8	High	0.003
Boiled rice, boiled beans and stew	228	76[a]	3.2	High	
Boiled rice, fried plantain, boiled beans, egg, stew	259	84[a]	4.1	High	
Boiled Rice, Boiled beans, Fried Plantain, Stew and meat	214	82[a]	4.3	High	
Fried rice and meat	154	88[a]	3.6	High	
Fried rice, fried plantain, meat	144	78[a]	3.2	High	0.246
Fried rice, Moinmoin and meat	219.8	88[a]	5.6	High	
Jollof rice and meat	182	79[a]	2.6	High	
Jollof rice, plantain, meat	166	87[a]	5.3	High	0.310
Jollof rice, Moinmoin, meat	209	80[a]	2.5	High	

Note: All values are expressed as mean ± SEM of eight values. Values with different letters on the same column are significantly different ($p < 0.05$). *SEM – Standard Error of Mean.

Table 6. *Glycaemic index of single and mixed meals made from beans and ogi.*

Food	Portion Size (grams)	Mean GI	SE	Category	p-value
Boiled Beans	232	91[a]	3.3	High	
Akara	211	91[a]	3.3	High	0.281
Moin-Moin	318	94[a]	3.5	High	
Beans Porridge	223	85[a]	3.0	High	

Food	Portion Size (grams)	Mean GI	SE	Category	p-value
Boiled Beans and Stew	278	88[ab]	1.4	High	
Boiled beans, fried plantain and stew	251	84[a]	3.02	High	0.086
Beans and garri	235	86[a]	3.3	High	
Beans + Garri and Water	235	96[b]	3.4	High	
Ogi yellow	240	92[b]	2.2	High	
Ogi and Akara	211	77[a]	2.6	High	
Ogi and Moin Moin	318	76[a]	1.2	High	0.000
Ogi and Beans	232	79[a]	1.55	High	

Note: All values are expressed as mean ± SEM of eight values. Values with different letters on the same column are significantly different ($p < 0.05$). *SEM – Standard Error of Mean.

4. Discussion

This quasi-experimental study assessed the glycaemic index of commonly consumed single and mixed meals eaten by apparently healthy young adults in Southwestern Nigeria. The study revealed that mixed meals usually have glycaemic indexes that are quite different from that of the individual food type. Previous studies have suggested that the GI of single foods, may not apply in the setting of mixed meals containing representative amounts of fat and protein [26, 27]. Generally, people do not eat single or individual foods, rather mixed meals made up of two or more individual foods are eaten [28]. The determination of the Glycemic Index (GI) and Load (GL) for mixed meals serve as a dietetic tool in meal planning to reinforce the benefits of low GI meals and decrease the physiological effects of high GI meals [29]. The GI of yam, when consumed as a single food of boiled yam and water, was higher than when the boiled yam was eaten with either peppered stew or fried egg and when it was prepared into yam pottage. A contrast higher value was reported by [30] for a mixed meal of yam vegetable stew. This could be linked to a high surface area obtained from the blended fortified test meals as compared to the consumption of mixed meals of yam in this study. A lower GI value for boiled yam was also reported by [31] which contradicts the results in this study. This could potentially be associated with the reference food of white bread used in the study and the adjustment of GI values obtained relative to glucose.

Globally, cereals and grains are the major staple foods which serve as the main source of dietary carbohydrates. Refined grains are processed to remove the protein, fat-rich germ and fibre-rich bran thereby leaving only the starchy endosperm [32].

In this study, consumption of white boiled rice showed a significantly higher GI than its corresponding mixed meals containing either stew, boiled beans, fried plantain, boiled egg, or meat. Previous studies have reported that consumption of processed grains especially white rice has been associated with an increased risk of type 2 diabetes mellitus [33, 34]. However, this study showed that consumption of white rice as mixed meals has a lower glycemic response which could reduce the risk of type 2 diabetes mellitus. A lowering effect of boiled rice eaten with different sauces was also reported in a study in Cote D'Ivoire [35] which also agrees with the findings from this study. The GI values for the mixed meal of rice and beans, rice and plantain from this study are lower than the values reported by [28] though are consistent in terms of the categorization as a high glycaemic index meal. The difference in the GI values of rice mixed meals is associated with the varied glycaemic response of meals that changes significantly with heat utilized, cooking method, amount of water and the time of cooking [36, 37].

Previous studies by [31, 38] reported a lower GI value for boiled rice compared to the value obtained in this study. This could be attributed to specie variation, reference food and cooking method used. Different varieties of rice (FARO-52, FARO- 51, FARO-44, and NERICA-1) have been reported by [39] to have varying GI values when consumed with stew which is quite consistent with the values observed in this study. GI values published for rice vary widely. This is principally due to variety, with the ratio of amylose to amylopectin being important. High amylose rice such as basmati, has widely been found to have low GI values [17]. Also, the GI is not only based on the measure of absorption of carbohydrates in the small intestine but is indicative of the effect of other factors in the test meals that can have an influence on the carbohydrate absorption rate in the small intestine [28]. Fried rice and Jollof rice mixed meals also had a lower GI value as against when they are consumed as single meals. The glycaemic index of white bread consumed as single food was found to be higher than when it was consumed with either fried egg, *moin-moin* or beans. A high GI value for white bread was also reported by [17].

Mixed meals made from bean products in this study had high GI values. Boiled beans, *akara, moin moin* and beans porridge showed a high glycemic response when consumed as single foods compared to when consumed as mixed meals. Boiled beans when eaten with either stew or fried plantain or in combination had a lower GI while a higher GI was observed when it was consumed with garri soaked in water. The high GI value elicited when beans was consumed with *garri* soaked in water could be attributed to the increased surface area created by the soaking process which enhanced digestibility and absorption of the starch granules. The high GI values for bean products either as a single or mixed meal found in this study contradict the previous categorization of beans and its products as a low GI food. Previous studies in Nigeria on brown and white varieties of beans such as oloyin", "drum", and "sokoto white have reported a lower GI for bean products [40-42]. Pap (*Ogi* yellow) had a higher GI

when consumed as a single food compared to when it was consumed with either *akara, moin moin* or beans porridge. The variations in the GI values of beans could be attributed to the methodological differences. In this study, participants served as both control and experimental groups. Differences were observed in portion sizes, specie variation, cooking and preparation methods, blood sampling procedure, blood glucose measurement procedure and GI calculation methods of previous studies.

From the overall observed GI values of single and mixed meals, the GI of mixed meals is reduced when consumed with a meal containing protein, fibre or fat. A significant reduction in the glycaemic response of a mixed meal in the presence of large amounts of protein or fat increases insulin secretion and delays gastric emptying which was contributed by other ingredients in the test meal [43]. Co-ingestion of fat or protein lowers the glycaemic index of individual foods somewhat but does not change their hierarchical relationship with regard to glycaemic index [44].

A slight difference was observed when boiled plantain was consumed as a single food and mixed meal in this study. This slight variation can be attributed to a high starch gelatination and physiochemical characteristics of the starch in unripe plantain upon boiling and cooling which has inhibited the action of other nutrients thus insignificantly affecting the GI of the mixed meal [35]. The GI values observed in this study are close to the values reported by [32] for unripe plantain stew but entirely contrary to the findings reported by [41] who reported a very low GI value for boiled unripe plantain. The variations could possibly be due to differences in the methodology used whereby subjects did not serve as a control in the previous study.

In Summary, single, and mixed meals commonly consumed in Southwestern Nigeria analyzed in this study had high glycaemic Index values with the least GI value observed in boiled white rice+fried plantain+stew+meat while the highest GI was observed in Beans+Garri (soaked with Water). Overall, there is a difference between the glycaemic index of a single food and the mixed meals. However, there was no statistically significant difference in single and mixed meals of boiled yam, unripe plantain, white-bread, fried rice, jollof rice and beans. Statistically significant values of $p < 0.05$ was observed in single and mixed meals of boiled white rice and Ogi yellow. This can be attributed to several contributory factors such as protein, fat, and fibre in the mixed meals. The glycaemic index of a meal is determined mainly by the nature of consumed carbohydrates and other dietary factors that influence nutrient digestibility or insulin secretion [45]. This study therefore in alignment with the evidence discussed conforms with several studies that have shown that the addition of fat and protein to a carbohydrate food can significantly reduce the glycaemic response of foods. It also confirms that a mixed meal, which is, one that includes additional fat, protein, and fiber, produces a lower postprandial glycaemic response than that produced following a single meal with the same amount of available carbohydrate [46-49].

5. Conclusion

The Glycaemic Index of the single foods determined was reduced when eaten as a mixed meal. Therefore, this study has established a reducing association between single staple foods and their mixed meal forms as the mixed meals have an overall effect on reducing the blood glucose response when compared to single foods. This study has provided the GI values of 11 single foods and 24 mixed meals, which can be used for dietary recommendation and management of DM in Nigeria as consistent consumption should be limited to prevent the progression of DM and ultimately regulate blood glucose levels.

6. Recommendations

Dietary management is a key cornerstone modality in the attainment of good glycaemic control in diabetic patients. However, most of the commonly consumed single and mixed meals in Southwestern Nigeria are quite high in starch composition, it is suggested for further studies that mixed meals containing 25g of available carbohydrate and an increased amount of protein, fat, fiber and other dietary constituents be developed and tested in healthy respondents. This will enable the effective utilization of the glycaemic index tool in the dietary management of diabetes mellitus in Nigeria.

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