

Research Article

An Evaluation of Glycaemic Load in the Assortments of Fufu in Ghana

Christabel Amponsah Adu-Gyamfi * 

Department of Family and Consumer Sciences, University for Development Studies. Tamale, Ghana

*Correspondence: Christabel Amponsah Adu-Gyamfi (bigkristal25@gmail.com)

Abstract: Knowledge about the glycaemic load of a food is very important in minimizing the prevalence of diabetes and other Non-Communicable Diseases. The purpose of this study was to determine the glycaemic load of the different varieties of fufu in the Wenchi municipality in Ghana. Quantitatively, the study adopted a crossover experimental research design. The research was carried out in Wenchi, the capital of the Wenchi Municipal Assembly, in the Bono Region. Convenience and purposive sampling techniques were used to select ten (10) healthy adults for blood glucose tests in this study. Materials used for the study were Fresh cassava, plantain, yam, and cocoyam. Descriptive analysis was used in analysing and interpretation of the data. Values were analyzed by one-way analysis of variance (ANOVA). Statistical significance was set at $p < 0.05$. Statistical analysis was performed using Statistical Package for Social Science (SPSS) 20.0. Proximate analysis of the study concluded that, plantain fufu contained the least carbohydrate content among the three fufu mixtures. The study also revealed that all fufu combinations had a high glycaemic load and this is as a result of the large portion size of fufu that is eaten at a serving. The glycaemic load of fufu combinations showed no significant difference, however, looking at the actual values, there are differences in them which should not be overlooked. It is recommended that consumers of fufu can eat any of the three mixtures of fufu, but there will be the need to take a smaller portion size of the fufu since a larger size can have adverse effects on their blood glucose level. It is also recommended that in other for fufu to be digested well and glucose to be absorbed easily, especially yam fufu, consumers should make sure to eat fufu at least about five hours before going to bed. It is recommended that nutritionists, dieticians, and diet therapists can as well recommend yam fufu and cocoyam fufu for diabetics and prediabetics, to bring about varieties in their diet.

Keywords: Evaluation, Glycaemic Load, Assortments, Fufu

How to cite this paper:

Amponsah Adu-Gyamfi, C. (2022). An Evaluation of Glycaemic Load in the Assortments of Fufu in Ghana. *Universal Journal of Food Science and Technology*, 1(1), 12–32.

Retrieved from

<https://www.scipublications.com/journal/index.php/ujfst/article/view/528>

Received: May 24, 2022

Accepted: August 21, 2022

Published: November 14, 2022



Copyright: © 2022 by the author. Submitted for possible open access publication under the terms and conditions of the Creative Commons Attribution (CC BY) license (<http://creativecommons.org/licenses/by/4.0/>).

1. Introduction

Fufu is one of the local foods mostly eaten in Ghana and other West African countries. In Ghana, it is commonly eaten among the Akans and it is made from cassava and/or plantain, cocoyam, or yam. Even though most people prefer the cassava and plantain combination, the cassava and yam or the cassava and cocoyam combination become an option for people, especially during seasons when plantain becomes scarce and expensive in the country. There are equally other people who prefer the other combination to the cassava and plantain combination. The main nutrient found in fufu is carbohydrate. This means that other nutrients can be found in fufu. Carbohydrates are broken down into sugar when they are eaten and absorbed into the bloodstream. According to Davis (2009), as blood sugar levels rise, the pancreas produces insulin, a hormone that prompts cells to absorb blood sugar for energy or storage. Carbohydrate is the main nutrient that will raise blood glucose [1]. Blood glucose is the amount of glucose in an individual's blood at a given time. Other factors that could cause a rise in blood

glucose include stress, medication, sickness and genetic factors [2]. Carbohydrate can be classified as simple or complex carbohydrate. However, grouping carbohydrates into simple and complex does not account for the impact they have on blood sugar and the chronic diseases associated with them [3]. To describe the direct effect different kinds of carbohydrate-rich foods have on blood sugar, the glycaemic index was developed and is considered a better way of classifying carbohydrates, especially starchy foods [4]. Glycaemic index is the measure of the relative ranking of how fast or slow a carbohydrate-rich food raises blood sugar levels after the food has been ingested [5]. Eating high glycaemic index foods can lead to powerful spikes in blood sugar. The outcome of this may lead to an increased risk of Type 2 diabetes, heart diseases and even overweight [6, 7-8]. A food's glycaemic index is not the optimum way of determining the effect of the carbohydrate on blood glucose. This is because it does not take into account how much digestible carbohydrate; the total carbohydrate excluding fibre, it delivers [4]. For this reason, researchers established a related way to categorize foods that take into account both the glycaemic index and the amount of carbohydrate in the food and its impact on blood sugar levels. This is known as the glycaemic [9, 10]. A food's glycaemic load is determined by multiplying its glycaemic index by the amount of carbohydrate present in the food. A glycaemic load of 20 or more is high, 11 to 19 is medium, and 10 or less is low [11]. A study conducted revealed that people who eat lower-glycaemic load diets are at a lower risk of developing type 2 diabetes than those who eat a diet of higher-glycaemic load foods [12]. A comparable analysis on Associations of glycaemic index and load with coronary heart disease events: a systematic review and meta-analysis of prospective cohorts shown that higher-glycaemic load diets are associated with an increased risk of coronary heart diseases.

Carbohydrate metabolism is vital in the development of Type 2 diabetes. This happens when the body cannot produce enough insulin or cannot properly use the insulin it makes. Type 2 diabetes usually develops progressively over years. It starts when muscles and other cells stop responding to insulin, a condition, known as insulin resistance [13]. This causes blood sugar and insulin levels to remain high over long periods after eating. With time, the hefty demands made on the insulin-producing cells wear them out, and insulin production ultimately stops [4]. This can also lead to a long-term damage to the body and the failure of various organs and tissues [14].

In 1997, an estimate of 124 million people worldwide had diabetes, 91% of whom were non- insulin dependent Diabetes mellitus (Type 2 diabetes). By the year 2010, the total number of people with diabetes was anticipated to reach 221 million. The regions with the highest potential increase are Asia and Africa, where the rate could rise 2 or 3 times what is experienced today [15]. A study indicated that the diabetes prevalence rate in Ghana is estimated to be 2.0% with a mortality rate of 13% [16]. In urban Ghana today, Type 2 Diabetes mellitus affects at least 6% of adults and is associated with age and obesity [17]. Even though there are other factors that can contribute to diabetes, foods that have a high glycaemic index, as well as high glycaemic loads, are the leading cause of diabetes

1.1. Different combinations of ingredients for making fufu

In Ghana, 'fufu' usually comes in three different varieties. It is either made with cassava and plantain, cassava and cocoyam or cassava and yam. Even though the cassava-plantain combination is most preferred, due to cultural influence or scarcity, patrons often go in for the other alternatives. The cassava-yam combination, for instance, is preferred in the Brong-Ahafo and Northern part of the country (personal knowledge). Below are pictures of the different combinations of 'fufu' eaten in Ghana.



Figure 1. Cassava-plantain fufu



Figure 2. Cassava-cocoyam fufu



Figure 3. Cassava-yam fufu

1.2. Cassava

Cassava is regarded as one of the most essential crops grown in the tropics and a principal carbohydrate staple. It is ranked third most important food source of calories in the tropics after cereal crops [18]. Ghana is recorded the third African producer, after Nigeria and the Democratic Republic of Congo with a yearly production of about 10 million tonnes representing 8% of overall cassava production on the continent [19]. The starch content in the root differs according to varieties and contains the highest amount of starch [20]. Cassava ranks 6th as the most essential source of energy in human diets on a global basis and the 4th supplier of energy after rice, sugar, and corn/maize [21]. It is very low in fats and protein compared to cereals and pulses. Nevertheless, it contains more protein than that of other tropical food sources like yam, potato, plantain etc. [4]. Cassava also has antinutrients, such as phytate, fibre, nitrate, polyphenols, oxalate, and saponins that can lessen nutrient bioavailability [22]. Cassava is considered a perishable commodity with a shelf life of fewer than 3 days after harvest. Processing offers a means of producing shelf-stable products (thereby reducing losses), adding value at a local rural level and reducing the bulk to be marketed [23]. Cassava, when processed, can be made into different kinds of food like 'gari', 'tapioca' and 'akyeke'. One common Ghanaian food, 'fufu', is prepared by boiling cassava and mixing with other boiled carbohydrate staples like plantain, yam or cocoyam. A 100 g of raw cassava contains 38 g carbohydrate, 1.8 g fibre, and 1.7 g sugar and could yield about 670 (kJ) of energy. Cassava has an amylose-amylopectin ratio of 30:70, which makes it more accessible to digestive amylases hence the more likely to stimulate higher glucose response when it is consumed [24]. Below is a picture of fresh and matured harvested cassava tubers.

**Figure 4.** Freshly harvested matured cassava tubers.

1.3. Plantain

It is projected that 60 million people in West Africa obtain more than 25% of their carbohydrate intake from plantain [25]. In Ghana, plantain contributes more to the Agricultural Gross Domestic Product (AGPD) than cereals [26]. Plantains serve as significant sources of food particularly in the Ashanti, Brong Ahafo and Eastern regions of Ghana. Numerous varieties of plantain are cultivated in West Africa. These are categorized as French Horn Plantain, False Horn Plantain, or the True Horn Plantain [27]. Locally in Ghana, names of the sub-varieties of French Horn plantain include 'Apempa', 'Oniaba' and 'Nyeretia apem'. That of the False Horn comprise 'Borodewuo', 'Apantu pa', 'Borode sebo' and 'Osoboaso' and the True Horn sub-varieties are 'Asamienu' and 'Aowin'. In Ghana, the variety that is mostly used in making 'fufu' is the 'Apantu

pa'. Raw unprocessed plantain contains 32 g of carbohydrate, 15 g sugar and 2.3 g fibre per 100 g [24]. Plantains, unlike banana, are often processed before eating. They are cooked, fried or roasted before eating. In Ghana, plantain can be boiled and pounded together with boiled cassava into 'fufu'. The slightly ripe boiled plantain could also be mashed into 'eto', a food common to the Akans. Plantain has a high fiber content, and therefore capable of lowering cholesterol and also helps to relieve constipation and hence prevention of colon cancer. Besides this, its low glycaemic index makes it the desirable carbohydrate staple that is mostly recommended for diabetics [24].

Potassium content in plantain is found to be beneficial in the prevention of raising blood pressure and muscle cramp. Plantain is identified to be low in sodium [29]. It has very little fat and no cholesterol; hence useful in managing patients with high blood pressure and heart disease.



Figure 5. Fresh fingers of plantain

1.4. Yam

The Food and Agriculture Organization of the United Nation ranks Ghana as second to Nigeria in the production of yam with a production of 6,638,867 tonnes [30]. A 100 g of raw yam provides the body with 110 calories with about 54% of glucose, and 21% dietary fibre which makes yam to have a lower glycaemic index [31]. Yam contains good levels of potassium, manganese, thiamine while being low in saturated fat and sodium [32]. The tuber is a good source of vitamin B-complex such as pyridoxine (vitamin B6), thiamine (vitamin B1), riboflavin, folate, pantothenic acid, and niacin. These vitamins are needed for metabolic functions in the body. Vitamin C which plays vital roles as anti-aging, immune function booster and wound healing is also present in fresh tubers of yam. It, however, contains a small amount of protein and vitamin A [4]. Nevertheless, a combination of yam and cassava provides a much better proportion of protein. Yam is widely consumed in Africa especially in Ghana. Boiled yam tubers are added to boiled cassava and are pounded into "fufu". This mixture of fufu is mostly found in the Northern and Brong Ahafo regions of the country. Yam can also be fried and roasted. Among the Akans, "bayire to", a dish similar to "eto" (mashed plantain) is prepared from mashed yam and palm oil with eggs. Below is a picture of some fresh mature yam.



Figure 6. Freshly harvested matured yam tubers

1.5. Cocoyam

Nutritionally, cocoyam has a higher value than most other root and tuber crops. Cocoyam is very rich in carbohydrates, ranging between 73 and 80% and 1.4% crude fibre [33]. Cocoyam contains greater amounts of vitamin B-complex than whole milk [34]. He also concludes that because of the ease in the assimilation of cocoyam, it can be used by persons with digestive problems. Cocoyam also has a higher value of proteins and amino acids than many other tropical root crops [35]. Additionally, cocoyam tubers contain minerals such as potassium, calcium, and magnesium but they are low in sodium [36]. Thus, cocoyam is one of the few major staple foods where both the leaf and the underground parts are equally important in the human diet. All part of the cocoyam may contain calcium oxalate hence it must be cooked to be eaten safely. Both the tuber and leaves of cocoyam have been used extensively as food in many countries. Poi is a Hawaiian dish, for babies from cocoyam [37]. In Ghana, cocoyam can be boiled and pounded with boiled cassava to make “fufu”, a Ghanaian food. A dish known as “mpoto mpoto” or “nuhuu” (cocoyam porridge) is made from boiled cocoyam with palm oil and other vegetables like pepper, onion, tomatoes. The tuber can be fried, roasted and boiled and eaten whole. Cocoyam can also be made into flour and used as a composite in flour products. Below is a picture of matured harvested cocoyam.



Figure 7. Matured harvested cocoyam

1.6. Determination of glycaemic index

The glycaemic response of a food is measured by taking blood samples for glucose test at timed intervals which start at the first bite of the test food [38]. In determining GI of a number of carbohydrate foods, the incremental area under the curve for the reference food is used as a denominator to each test food. According to the standard methodology, the reference food is repeatedly measured to allow for precision. Any differences in the glycaemic response from the reference food will have a great effect on the GI than variations in the test foods [39]. They recommend that the measurement of the reference food be repeated at least one in each participant of a GI determination research.

1.7. Glycaemic load concept

Although the GI can represent a carbohydrate-containing food's effect on blood glucose, the portion size is also an important factor that needs to be taken into consideration for glucose management as well as the management of weight. A study stated that both the quality and quantity of carbohydrate in a food determine an individual's glucose response to the food [40]. The glycaemic load is therefore the new way to evaluate the impact of carbohydrate consumption that takes into account the glycaemic index but provides a deeper picture than the GI does. Glycaemic load is defined as the product of a food's glycaemic index and its total available carbohydrate content [41].

1.8. Portion size and glycaemic control

The idea of portion size of foods consumed at a sitting and the serving sizes are important in the effective dietary intake and glycaemic control studies. This is because food's portion sizes have a major effect on the glycaemic index of the food, thereby increasing the glycaemic load of the food [42]. The United States Department of Agriculture (USDA) and Food and Drugs Administration and Control (Young & Nestle, 2003) have established standard serving sizes that guide Americans to select the right portion sizes of food to eat for sustained and improved health [43, 44].

1.9. Glycaemic Load and Health

The glycaemic load concept has widely been associated with various Non-Communicable Diseases (NCDs) by several [45, 46]. It has positive associations with the tenacity of either increasing the risk of acquiring them or reducing the risks. Foods that have high GL are linked to an increased risk of certain chronic diseases while low GL diets are seen to reduce the risk of acquiring these diseases.

1.10. Glycaemic load and diabetes

In a collection of studies, both the glycaemic index and the glycaemic load of the total diet have been associated with a greater risk of type 2 diabetes in both men and women [47]. Diabetes represents a group of metabolic disorders, categorized by hyperglycemia (high blood glucose) or hypoglycaemia (low blood glucose) as well as glucose intolerances [45]. Hyperglycaemia has been associated with loss of pancreatic β cell function that can result in glucose intolerance and eventually an irreversible state of diabetes [10].

Since diabetes is primarily a condition of disordered glucose metabolism, it is important to bear in mind the type of dietary carbohydrate that can influence the risk and course of this disease [2]. A diet that produces higher blood glucose concentration and greater demand for insulin would increase the risk of type 2 diabetes. To evaluate the hypothesis that high dietary glycaemic load food would increase the risk of type 2 diabetes, women with a high intake of high cereal fibre and low GL foods were at a lower risk of diabetes as compared with those with low cereal fibre and high GL diets [10]. A study reports that increasing the consumption of low-GL and fibre-rich foods, possibly

improve blood glucose control as well as reducing the incidence of hypoglycaemic events [48].

1.11. Glycaemic load and coronary heart diseases

A scientific research reports that CHDs have become the largest cause of deaths globally [49]. Cholesterol has normally been associated with CHDs and as a result of that, people should focus on the reduction of saturated fatty acids. Consequently, there has been the embracement of low-fat, high carbohydrate diet. However, studies have shown that these high carbohydrate diets, having high glycaemic load increase the relative risk of CHDs [13]. A study found that high GL diets can affect changes in lipid profile regardless of the cholesterol, protein or fat content [50]. In a similar study postulate that high GL diets were found to produce a decrease in HDL and increased in LDL [51].

1.12. Glycaemic load and obesity

The prevalence of obesity has increased instead of lowering. This concern has been raised when recommendations by Western Dietary Guidelines encouraged the consumption of carbohydrate in place of fat. This has been attributed to the fact that total diet calories have been consumed more from carbohydrate than fat [52]. Studies have confirmed that consuming low GL diets reduce hunger and promote satiety [53]. This will mean that people who consume high GL diet will find it difficult to lose weight since these high GL foods incite the onset of hunger, few hours after eating. This supports the assumption that GL of a food is significant in the management of obesity [52, 53].

However, the consumption of high glycaemic indices and high glycaemic load diets for several years might result in increased postprandial blood glucose spikes and excessive insulin secretion [10]. This could lead to the loss of insulin-secreting function of the pancreatic β - cells, resulting in irreversible Type 2 Diabetes mellitus. In addition to this a study state that, sustained spikes in blood sugar and insulin levels may lead to increased diabetes risk [53]. Diabetes mellitus Type 2 is currently one of the most prevailing chronic diseases in the world and the number of people with the disease is stated to be increasing in every country.

International Diabetes Federation (IDF) has estimated that 415 million adults globally, are presently living with the condition. Nonetheless, this is predicted that people having this condition would rise to 642 million by 2040. An estimated 14.2 million adults (aged 20-79) have diabetes in Africa, representing 6.7% [54]. This prevalence can be minimized to a lower rate when people are made aware of the glycaemic indices and glycaemic loads of the foods they consume, as these play major roles in the development of this condition. When consumers are well informed on the rate at which the glucose in our local foods is released into the bloodstream, they will be very cautious about their choice of food and even the time they eat these foods as well as the amount they consume.

A study revealed that the fufu made from cassava and plantain has a low glycaemic index of 55, hence it has little impact on blood glucose level when ingested and digested [55]. However, people do not only consume cassava-plantain variety of 'fufu' in Ghana. Some take the cassava and yam and the cassava and cocoyam combinations. Little works appear to have been done on these other fufu varieties and their impact on the blood glucose. This study investigated all the possible varieties of fufu that is consumed in the country and to analyze the extent to which each of variety affects the blood glucose level. The purpose of this study was to determine the glycaemic load of the different varieties of fufu in the Wenchi municipality in Ghana. The study was guided by these objectives (1) examine participants' glycaemic response to ingested carbohydrate. (2) determine the glycaemic load of all the varieties of fufu. (3) perform proximate analysis on all varieties of fufu. The study was also guided by a research hypothesis - H_0 = There is no significant difference in the glycaemic load of the different varieties of fufu. H_1 = There is a significant difference in the glycaemic load of the different varieties of fufu.

2. Materials and Methods

Quantitatively, the study adopted crossover experimental research design. The research was carried out in Wenchi, the capital of the Wenchi Municipal Assembly, in the Bono Region. Wenchi is a town that is made up of people of different tribes and cultures due to the schools and other companies found there. Convenience and purposive sampling techniques were used to select participants for the study. Ten apparently healthy adults were purposively sampled from public places like church, schools, and market places for the blood glucose test. All the participants were grouped together three days prior to the day of the test for an orientation. They were made known of the importance of undertaking such an experiment and its importance to the researcher as well. They were again instructed to stay away from alcohol and smoking within the periods of the experiment.

2.1. Materials

Fresh cassava, plantain, yam, and cocoyam were purchased from the local market in Wenchi. Below is the procedure involved in the preparation of the fufu used for the blood glucose test. The fufu was served with light soup and 30 g salmon fish. The calculation for each quantity of test food served was based on a proximate analysis done earlier by the researcher.

2.2. Plantain fufu

A ratio of 80:20 percent of cassava to plantain was used. They were then peeled and boiled together. After boiling, they were pounded in a mortar with pestle individually before they were mixed together until a soft texture was attained. The fufu was then divided into a portion size of 143 g, which contained 50 g of carbohydrate.

2.3. Cocoyam fufu

Cocoyam fufu was prepared from a ratio of 80:20 percent of cassava to cocoyam. They were boiled together until it well cooked, and then pounded separately. They were then mixed and pounded together to a soft texture. The final product was divided into sizes of 138 g containing 50 g of carbohydrate.

2.4. Yam fufu

The third test food which is yam fufu was prepared with a combination of cassava and yam. The ratio of the cassava to the yam was 80:20 percent. After being cooked together, the fufu was made by pounding each staple separately and then mixed together and pounded. The end product was then divided in sizes of 116 g which had 50 g of carbohydrate.

2.5. Proximate analysis

A quantity of 100 g of each fufu combination was taken, milled and proximately analyzed. The following individual nutrients were determined.

2.6. Moisture content

An amount of 10 g was taken from each fufu and weighed into cleaned beakers. They were oven-dried at a temperature of 105°C for 48 hours. The samples were removed from the oven and put in a desiccator to cool for 30 minutes. The dry weights of the fufu were determined after cooling. The percentage moisture content of the fufu samples was determined using the formula:

$$\text{Moisture content (\%)} = \frac{\text{Weight of fresh sample} - \text{weight of dried sample (g)}}{\text{weight of oven dried sample (g)}} \times 100$$

2.7. Ash content

Approximately 3 g of the milled fufu samples were weighed into a pre-weighed empty crucible. The crucibles containing the samples were placed in the oven at 100°C for 24 hours. The crucibles were removed from the oven and transferred to a furnace where the temperature was raised to 550°C. The crucibles were then removed from the furnace to a desiccator and allowed to cool for 30 minutes and weighed. The percentage ash content of the samples was calculated using the formula below:

$$\text{Ash content (\%)} = \frac{\text{Ash weight}}{\text{weight}} \times 100$$

2.8. Protein content (Kjeldhal protein)

Protein content was determined by weighing 0.2 g of the milled samples into different digestion flasks, followed by the addition of 4.5 mL of digestion mixture. The samples in the flask were digested for two hours on a digester. After digestion, the flasks were removed and allowed to cool. Each flask was then washed with distilled water and the solution poured into a 100 mL conical flask. The solution was then made to the mark with distilled water. Twenty (20) mL aliquot of the solution was pipetted into the distillation apparatus followed by 10 mL of NaOH solution. Five (5) mL of boric acid was also pipetted into 50 mL conical flask. Each conical flask containing the boric acid was successively placed under the funnel of the unit to collect 50 mL of the distillate. The distillate turned from green to red wine using 1/140 MHCl.

The percentage of nitrogen in the sample was calculated using the formula below:

$$\%N = \frac{(S - B) \times M \times 14.007}{\text{weight of sample (mg)}} \times 100 \times 100/2$$

where

S = sample titre (mL) B = blank titre (mL) M = molarity of HCl

The protein content in the sample was calculated using the formula:

$$\% \text{ protein} = \% N \times 6.25,$$

where 6.25 is the protein-nitrogen factor.

2.9. Fat content

Approximately 10 g of the milled samples were weighed into 50 x 10 mm Soxhlet extraction thimbles. The samples were then placed into a 50 mL capacity Soxhlet extractor. A clean, dry 250 mL round-bottom flask was placed under the Soxhlet extraction unit. Fifty (50) mL of petroleum ether was measured and poured into the Soxhlet extraction thimbles that contained the samples and extracted for 6 hours using a heating mantle. The round bottom flask was later removed and placed in an oven. The samples were left in the oven at 60°C for 3 hours. The round bottom flask containing the oil was removed and put into a desiccator to cool and then weighed. The fat content of the samples were calculated as follows:

$$\text{Fat content (\%)} = \frac{\text{Weight of fat}}{\text{weight of sample}} \times 100$$

2.10. Fibre content

Fibre content was determined by weighing approximately 0.5 g of the milled samples into separate pre-dried crucibles. The crucibles were placed into a fibretec Hot Extraction Unit. Hundred (100) ml of concentrate H₂SO₄ (1.25%) solution were added to the samples and allowed to boil for exactly 30 minutes exactly. After boiling, the samples in the crucibles were washed with hot distilled water followed by 100 ml of 1.25 NaOH and then boiled for another 30 minutes. The crucibles were transferred to the fibretec cold extraction unit and then washed with methanol. The crucibles were later removed and dried at 105°C overnight and weighed after cooling. The samples in the crucibles were ashed for about 3 hours at 500°C, cooled in the desiccator and weighed. The percentage fibre content in the fufu was calculated using the formula below:

$$\text{Fibre content (\%)} = \frac{\text{weight loss through ashing}}{\text{weight of oven - dry sample}}$$

2.11. Soluble carbohydrates content

Soluble carbohydrate content in the samples were determined using standard laboratory procedure [56]. Step one involved the extraction of material while step two involved colour development.

2.11.1. Extraction of materials

Approximately 0.01g of the milled samples were weighed into different 50ml conical flasks and 30ml of distilled water were added. A glass bubble was placed in the neck region of the flasks and allowed to simmer gently on a hotplate for two hours. The conical flasks were periodically topped up to the 30ml mark distilled water. The samples were allowed to cool and the solutions poured into 50ml volumetric flasks fitted with No. 44 Whatman filter paper. The solution was diluted to the 50ml mark with distilled water. Blank solution was also prepared using distilled water.

2.11.2. Colour development

Two (2) ml each of standard solution was pipetted into different sets of boiling tubes. 2 ml of the extracts were also pipetted into another set of boiling tubes. 10ml of anthrone reagent was added to the boiling tubes containing the sample solutions and the blank and then mixed thoroughly in an ice bath. They were placed in a beaker of boiling water and kept boiling for 10 minutes. The tubes were removed from the boiling water and transferred into cold water in the dark. The optical density of the sample and the blank were measured at 625 nm using the spectrophotometre (CE 1000 series). A calibration graph will be obtained by plotting absorbance against concentration for the standard solution. The glucose content (mg) in the milled fufu will be determined using the formula below:

$$\text{Soluble carbohydrates (\%)} = \frac{C \text{ (mg)} \times \text{extract volume}}{10 \times \text{aliquot volume} \times \text{sample weigh}}$$

2.12. Data analysis

Calculations from the nutrient analysis were done using standard equations. Descriptive analysis was used in analysing and interpretation of the data. Nutrient determinations were done in triplicate. The average values of the glycaemic responses before and after consumption of test and reference foods were used to draw a blood glucose curve for a 2-hour period. The blood glucose concentration against time was plotted on a graph sheet.

The Incremental Area under the Curve of both reference and test foods were calculated separately for each participant by using the trapezoid rule, to show the rise in

glycaemic response after consumption of foods. The percentage GI for each participant was calculated as the IAUC of each test food over the mean IAUC of the reference food, multiplied by 100. The formula used was;

$$GI (\%) = (IAUC \text{ test food} / IAUC \text{ reference food}) \times 100$$

The GI of each test food was then calculated as the mean value of all 10 participants. The GL of a typical serving of each test food was then calculated using the formula below:

$$GL = \frac{(GI \times \text{grams of carbohydrate in a serving})}{100}$$

The IAUC and GI were calculated using Excel 2013. Data was presented as means and standard deviations. Values were analyzed by one- way analysis of variance (ANOVA). Statistical significance was set at $p < 0.05$. Statistical analysis was performed using Statistical Package for Social Science (SPSS) 20.0.

3. Results and Discussion

Ten participants were selected for the study. They were made up of five males and five females. Measurement of their height, weight, age, body mass indexes (BMIs) and waist circumference were all in the normal ranges as shown in Table 3. WHO, classifies an adult with a BMI range of 18.5-24.9 as healthy, therefore looking at the mean BMI for the participants (Table 3) and considering the mean age, their status could be determined [57]. The waist circumference of participants were also taken and the results were within the healthy adults' category of calculated waist circumference [58]. The average fasting blood glucose (FBG) level for both reference and test foods (Figures 8 & 9), as well as postprandial blood sugar levels were also found to be in the normal range. Looking at the participants' measurements for Body Mass. Index and waist circumference, they were taken to be healthy individuals and their blood glucose levels also confirmed that they are not diabetics. Using healthy people was important because it made it easier for participants to show intermediate intra-individual variation in the glycaemic response to foods [59]. A study looked at "Prediction of the relative blood glucose response of mixed meals using the glycaemic index of white bread" reports that to obtain precise result using "Glycaemic index methodology" [60] It is appropriate to use healthy individuals as seen in this study [60].

3.1. Participants' Glycaemic Response to Ingested Carbohydrate

Participants' glycaemic response to reference and test foods are shown in Figure 8 and 9. The fasting blood glucose level of participants before ingestion of reference and test foods were plotted on a blood glucose-time graph. Furthermore, fluctuations in participants' response to carbohydrate is seen.

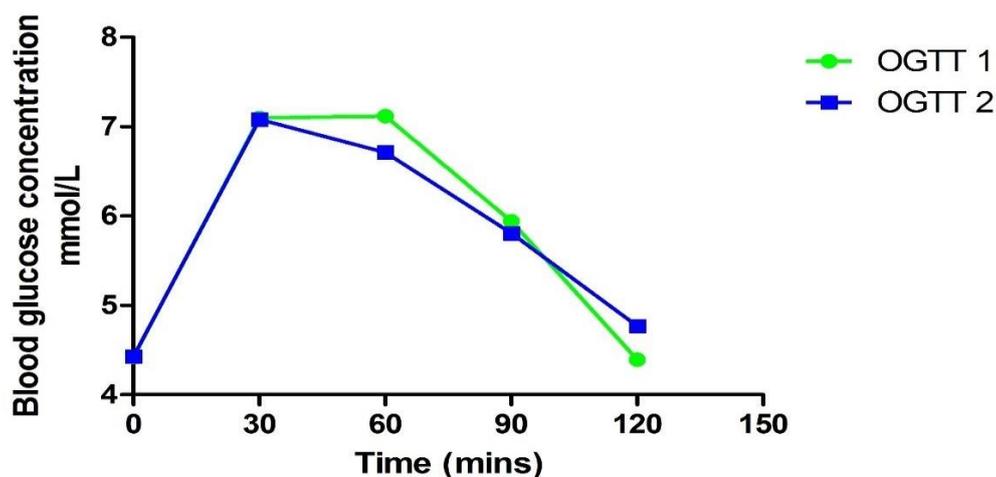


Figure 8. Participants' glycaemic responses to ingested carbohydrate (OGTT) Source: Field data, Adu-Gyamfi (2017).

The Oral Glucose Tolerance Test (OGTT), was carried out in duplicate as seen in Figure 8. The average FBG (4.4 mmol/dl) was the same in both tests. The graph shows that, upon administration of the glucose solution, the average peak of the glycaemic response among all participants was observed at the 30th minutes after consumption, and dropped at the 120th minutes. Glucose stood out to be the preferred material for a reference food than white bread, because of the likely variations that may occur had in the preparation of white bread on "Low-Glycaemic Index Diets in the Management of Diabetes" [61]. In a study on "Glycaemic index methodology", participants complain about the nauseating feeling they had after drinking glucose solution [60]. In this study too participants complained of the same nauseating feeling after they had consumed the glucose solution.

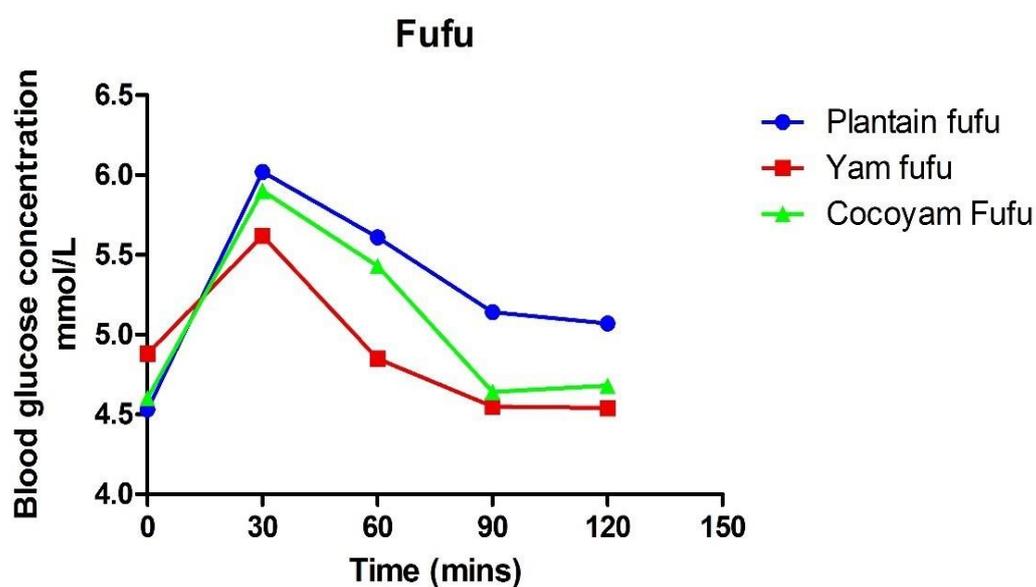


Figure 9. Participants' glycaemic responses to ingested carbohydrate (test foods); Source: Field Data, Adu-Gyamfi (2017).

Unlike the reference food, the average Fasting Blood Glucose (FBG) before the consumption of the test foods was different, however, the difference was not significant since it was in the normal range. Figure 9 illustrates that, the average peak of response for

all test food was observed at the 30th minute after eating and this reduced to normal blood glucose levels at the 120th minutes after eating. The glycaemic response by participants after eating the plantain fufu was high (6.2mmol/L). This was followed by cocoyam fufu (5.8mmol/L) and yam fufu was reported to have a low glycaemic response (5.6mmol/L) by participants as seen in [Figure 9](#).

In figures 8 and 9, it can be observed that, there were differences in the glycaemic response of the reference food and the test foods. Postprandial glucose level of the reference food was high at each time interval as compared to the test foods when they were ingested [61]. A similar research states in their study: “Glycaemic index methodology” that, glycaemic response among participant varied and even with the same participant, there are variations in each test food [60]. The variations in the post- prandial blood glucose levels at different time interval could be attributed to this.

3.2. Proximate Analysis of Fufu Combinations

Proximate analysis of the fufu is the determination of the major nutrients in the ‘fufu’. The moisture, ash, protein, fat, fibre and soluble carbohydrate contents were determined. Results are presented in [Table 1](#).

Table 1. Nutrient content of the different combinations of fufu

Sample	Moisture (%)	Ash (%)	Protein (%)	Fat (%)	Fibre (%)	Soluble Carbohydrate (%)
Plantain fufu	71.77	0.76	2.99	0.06	2.29	34.87
Cocoyam fufu	68.28	0.89	3.62	0.07	2.70	36.10
Yam fufu	72.15	0.82	4.30	0.06	2.80	43.00

Source: Proximate analysis data, Adu-Gyamfi (2017).

From [Table 1](#), proximate analysis of the different combinations showed the carbohydrate content as well as other nutrients in the different combinations of ‘fufu’.

3.3. Glycaemic Load of the Different Fufu Combinations

In order to determine the glycaemic load of the fufu combinations, the Incremental Area under the Curve as well as the glycaemic indices of the foods were determined.

3.4. Incremental area under the curve (IAUC)

The incremental area under the curve (IAUC), is the area under the curves from the reference and test foods (Figures 8 and 9). The trapezoid rule was used in calculation. Results are presented in [Table 2](#).

Table 2. Incremental Area under the Curve of Reference Food and Test food

	Glucose	Plantain Fufu	Yam Fufu	Cocoyam fufu
Mean	187.62 ^a	101.35 ^b	52.29 ^b	72.7954 ^b
Standard Error	21.31	21.48	17.26	12.63
Standard Deviation	67.38	67.91	54.58	39.93
Range	218.08	232.7	143.25	130.286
Minimum	107.22	0	2.25	1.714
Maximum	325.3	232.7	145.5	132
Confidence Level (95.0%)	48.20	48.58	39.04	28.57

Source: Field Data, Adu-Gyamfi (2017).

In [Table 2](#), the IAUC of reference food which is glucose was seen to be significantly different from the test foods at (p<0.05). However, there was no significant difference

between the IAUC of the test foods ($p>0.05$). The values with the same superscript alphabets in the same row are not significantly different at ($p>0.05$).

3.5. Glycaemic index of test foods

Analysis of Variance (ANOVA) was used in comparing the glycaemic index of test foods. Results are presented in Table 3. The values with the same superscript alphabets in the same row are not significantly different at ($p>0.05$).

Table 3. Glycaemic Index of Test Foods

Statistic	Plantain Fufu	Yam fufu	Cocoyam fufu
Mean	53.2 ^a	30.2 ^a	39.4 ^a
Standard Error	10.4	10.0	7.2
Standard Deviation	32.9	31.6	22.7
Range	101.2	90.5	81.4
Minimum	2.1	0.9	1.5
Maximum	101.2	91.4	82.9
Confidence Level (95.0%)	23.6	22.6	16.3

Source: Field data, Adu-Gyamfi (2017)

The Glycaemic Indices of the test foods were classified as low, medium or high based on the following GI value ranges [61].

Glycaemic index range	Class
Less than 55%	Low
Between 56 – 69	Medium
More than or equal to 70%	High

Table 3 shows that, The GI of all test foods measured were low; plantain fufu was 53%, yam fufu was 30% and cocoyam fufu was 39%. Moreover, there was no significant difference ($p>0.05$) among them. The postprandial glycaemic response of each combination of fufu when ingested was influenced by a number of factors, including digestion, the nature and proportion of starch in the food, dietary fibre content on the food, fat and protein content, the effect of digestion on the test food, processing and effect of previous meal [3]. These factors probably affected the digestibility of the fufu and the absorption of glucose, hence the differences in the GI.

3.6. The effect of dietary fibre in the food

Results from proximate analysis (Table 4) showed that yam fufu had the highest amount of fibre content of 2.8%. This level of fibre could have affected the lower postprandial glucose response of participants to yam fufu. A similar study on the "Evidence-based nutritional approaches to the treatment and prevention of *Diabetes mellitus*", revealed that, a diet rich in fibre slows down digestion which in turn slows down the absorption of glucose into the blood stream [63]. A publication by Harvard Health Publications reports that, yam provides the body with 110 calories and dietary fibre provides 21% of the 110 calories, adding to the argument that yam is rich in dietary fibre [64]. Even though the average peak of glycaemic response to all test foods was observed at the 30th minute after ingestion, the glycaemic response to yam 'fufu' was around 4.6 – 5.9mmol/dL (Figure 9), which was lower compared to the other test foods. Plantain 'fufu'

contained the least fibre of 2.3% and cocoyam had 2.7% as shown in Table 4. Similar comparison could be made to explain the high GI value of plantain fufu among the three test foods.

3.7. The effect of the nature and proportions of starch in the food

Research on postprandial plasma glucose and insulin responses to different complex carbohydrate diseases" indicated that, the nature and proportion of starch present in a food influence the rate of digestion and finally the glycaemic response to the food [61]. This could be attributed to plantain 'fufu' having the highest GI amongst the three. Cassava, has an amylose –amylopectin ratio of 30- 70%, however, since plantain has an amylose to amylopectin ratio of 17-83, it probably affected the digestion of the plantain 'fufu' [24, 65].

Plantain 'fufu' having a highest GI among the three as illustrated in Table 6, could be attributed to the fact that, it was easily digested by participants and glucose was absorbed faster. In the case of yam 'fufu', a similar conclusion can be made to explain the reason for its low GI. Yam has an amylose –amylopectin ratio of 38-62% [66]. When combined with cassava, digestion of yam 'fufu' was seen to be very slow hence a lower glycaemic response. This could have also contributed to its low GI value.

3.8. Effect of fat and protein in the food

The fufu was served with light soup made with salmon fish. Salmon fish having a reasonable amount of fat and protein probably contributed to the three test foods having a low GI. A study similar study on "Low glycaemic index diet and disposition index in type 2 diabetes (the Canadian trial of carbohydrate in diabetes): a randomized controlled trial", reports that fat slows the rate at which dietary carbohydrate are digested in the intestines [67]. Furthermore, in a study on "The concept of low glycaemic index and glycaemic load foods as panacea for type 2 Diabetes mellitus; prospects, challenges and solution", states that foods that contain protein increase insulin secretion and could contribute to the reason why the starch in such foods are not easily hydrolysed, giving them low GI [68].

3.9. Effect of digestion on food

Studies have indicated that, in carbohydrate digestion chewing is an important factor as this affects the rate of digestion and absorption [62, 63]. In these studies, researchers further explained that chewing breaks large chunks of food into smaller particles in the mouth. This increases the surface area of the food for salivary amylase found in the saliva, to breakdown the complex carbohydrate in the food before it enters the stomach and small intestines. Test foods recording lower GI could probably be attributed to the fact that there is no chewing of fufu in the mouth during ingestion. It is swallowed and directly enters the stomach through the oesophagus. As a result of this salivary amylase could not break complex carbohydrate in the fufu before it entered the stomach. Digestion was probably slow in the small intestines hence lower glycaemic responses of test foods.

3.10. Effect of processing on food

Cooking of the test foods could have contributed to the GI of the test foods being low. This result was supported in a study on "International table of glycaemic index and glycaemic load values: 2002", that different processing methods of foods affect their glycaemic indices. Cooking of the plantain, cocoyam, yam and cassava to make 'fufu' resulted in the difference in the degree of starch gelatinization by softening the starch which probably speeded up the rate of digestion and in the long run absorption of glucose. Hence different processing methods could have resulted in a different GI of the test meals [62].

Mixing the individual food items to form a meal (fufu), also probably influenced the GI of the food. The individual food items of the different combinations of fufu, that is; cassava, plantain, yam and cocoyam, may have a lower glycaemic index values than in a mixed constituent. This finding is consistent with the findings on Insulinemic and glycaemic indexes of six starch- rich foods taken alone and in a mixed meal by type 2 diabetics" [61]. In this study they report that, mixing the meal significantly affects the glycaemic index of the food.

3.11. Effect of previous meal on breakfast meal

Studies have confirmed that the previous meal a person takes prior to taking breakfast can affect the glycaemic response of the breakfast meal [69]. However, in this study, variations in the GI of the reference and test foods could not be attributed to the effect of the previous meal, even though the possibility exists. This is because, the previous evening's meal taken by participants was not controlled and there was not much difference in the FBG levels of participants before ingestion of tests and reference foods.

3.12. Glycaemic load of test foods

The glycaemic load was calculated from the results obtained from the glycaemic index of the fufu combinations. The calculation for the glycaemic loads of the 'fufu' is shown in the Appendix C. Results are presented in Table 4.

Table 4. Glycaemic Load of test foods

Test Food	Glycaemic Load	GL Class
Plantain Fufu	40.28%	High
Yam	22.08%	High
Cocoyam Fufu	29.64%	High

Source: Field data, Adu-Gyamfi (2017)

The Glycaemic Loads of the test foods were classified as low, medium or high based on the following ranges [11].

Glycaemic load range	Class
Less than 10%	Low
Between 11 – 19%	Medium
More than or equal to 20%	High

Even though the GI of the test foods were low, they all had high glycaemic loads. This could be as a result of the portion sizes of 'fufu' that were eaten as servings. The portion size of fufu as recommended is 211 grams which contains 76g of carbohydrate [37].

This indicates that the amount of carbohydrate in a serving of 'fufu' is greater than 50g. This probably explains why the test foods had high glycaemic loads. Theoretically, it can be said that there is no significant difference in the glycaemic load of the test foods considering the class under which the all fall. Based on this, the null hypothesis (H₀) was accepted. The H₀, states that "there is no significant differences in the glycaemic loads of the different combinations of fufu". However, the difference in the actual values as illustrated in Table 4, makes one higher than the other.

4. Conclusions and Recommendations

Proximate analysis findings in this study concluded that, plantain fufu contained the least carbohydrate content among the three fufu mixtures, however after determination of their glycaemic indices, it was seen that plantain had the highest amongst them and yam which had the highest carbohydrate content per the proximate analysis had the lowest GI amongst the three. Factors such as the nature and proportion of starch in the food, dietary fibre content on the food, fat and protein content in the food, the processing method used, the previous meal taken prior to eating test foods, contributed to this. The study also revealed that all fufu combinations had a high glycaemic load and this is as a result of the large portion size of fufu that is eaten at a serving. The glycaemic load of fufu combinations showed no significant difference, however, looking at the actual values, there are differences in them which should not be overlooked. It is recommended that consumers of fufu can eat any of the three mixtures of fufu, but there will be the need to take a smaller portion size of the fufu since larger size can have adverse effect on their blood glucose level. It is also recommended that in other for fufu to be digested well and glucose to be absorbed easily, especially yam fufu, consumers should make sure to eat fufu at least about five hours before going to bed. It is recommended that nutritionists, dieticians and diet therapists can as well recommend yam fufu and cocoyam fufu for diabetics and prediabetics, to bring about varieties in their diet. However, they should be more concerned about the portion size. This is because the portion size to take is of more importance than the type to eat. It is also recommended that much attention should be placed on researching into the glycaemic loads of our local dishes than the glycaemic indices since the glycaemic load of a food gives a comprehensive information about much the carbohydrate in a food consumed as a serving affects the blood glucose.

Author Contributions: Conceptualization; methodology; formal analysis; investigation; Resources; data curation; writing-original draft preparation; writing-review and editing; visualisation; supervision; project administration; Author has read and agreed to the published version of the manuscript.

Funding: "This research received no external funding"

Data Availability Statement: Data is available on request from the corresponding author.

Acknowledgments: I acknowledge respondents for their time with us.

Conflicts of Interest: "The author has declared no conflict of interest." "No funders had any role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript, or in the decision to publish the results".

References

- [1] Davis, N. J. (2009). Comparative study of the effect of a 1- year Diabetes intervention of a low-carbohydrate diet versus a lot- fat diet on weight and glycaemic control in type 2 diabetes. *Diabetes Care*, 32(7), 1147- 1152.
- [2] American Diabetes Association. (2015). Factors affecting blood glucose. Retrieved from <http://www.diabetes.org>treatment-and-care>
- [3] F. A.O & World Health Organization. (1998). Carbohydrates in human nutrition: report of a joint FAO/WHO expert consultation. *FAO Food Nutrition Paper*, 66, 1-140.
- [4] Nutrition-and-you. (2016). *Taro roots nutrition facts*. Retrieved from www.nutrition-and-you.com
- [5] Jenkins, D. J., Wolever, T. M., Kalmusky, J., Giudici, S., Giordano, C., & Wong, G.S. (1985). Low glycaemic index carbohydrate foods in the management of hyperlipidemia. *The American Journal of Clinical Nutrition*, 42 (4), 604-617.
- [6] de Munter, J. S., Hu, F.B., Spiegelman, D., Franz, M., & van Dam, R. M. (2007). Whole grain, bran, and germ intake and risk of type 2 diabetes: a prospective cohort study and systematic review. *PLoS Medicine*, 4(8), 261 – 288
- [7] Beulens, J. W., de Bruijne, L. M., Stolk, R. P., Peeters, P. H., Bots, M. L., Grobbee, D. E., & van der Schouw, Y. T. (2007). High dietary glycaemic load and glycaemic index increase risk of cardiovascular disease among middle-aged women: a population-based follow-up study. *Journal of the American College of Cardiology*, 50(1), 14-21.

- [8] Ebbeling, C. B., Leidig, M. M., Sinclair, K. B., Seger-Shippe, L. G., Feldman, H. A., & Ludwig, D. S. (2005). Effects of an ad libitum low-glycaemic load diet on cardiovascular disease risk factors in obese young adults. *The American journal of clinical nutrition*, 81(5), 976-982.
- [9] Liu, S. & Willett, W. C. (2002). Dietary glycaemic load and atherothrombotic risk. *Curr. Atheroscler. Rep.*, 4(6), 454-461.
- [10] Willett, W., Manson, J., & Liu S. (2002). Glycaemic index, glycaemic load, and risk of type 2 diabetes. *The American Journal of Clinical Nutrition.*, 76(1),274 - 280.
- [11] Venn, B. J., Wallace, A. J., Monro, J. A., Perry, T., Brown R., Frampton, C., & Green, T. J. (2006). The glycaemic load estimated from the glycaemic index does not differ greatly from that measured using a standard curve in healthy volunteers. *The Journal of Nutrition*, 136(5), 1377-1381
- [12] Livesey, G., Taylor, R., Livesey, H., & Liu, S. (2013). Is there a dose-response relation of dietary glycaemic load to risk of type 2 diabetes? Meta analysis of prospective cohort studies. *The American journal of clinical nutrition*,97(3), 584-596.
- [13] Mirrahimi, A., de Souza, R. J., Chiavaroli, L., Sievenpiper, J. L., Beyene, J., Hanley, A. J., Augustin, L. S. A., Kendall, C. W.C., & Jenkins, D. J. A. (2012). Associations of glycaemic index and load with coronary heart disease events: a systematic review and meta-analysis of prospective cohorts. *Am J Heart Assoc.*, 1(5), 110-752.
- [14] Centre for Diabetes Control and Prevention. (2014). *Health implication of diabetes*. Retrieved from <http://www.cdc.gov/diabetes/consumer>
- [15] Zimmet, M. P., & Amos, A. F. (1997). The rising global burden of diabetes and its complication, estimate and projection to 2010. *Diabetes Medicine* 14 supplement, 5: 51-55
- [16] Acheampong, J. W., Eho, P., & Boateng, A. (1995). Improved diabetes care in Kumasi Ghana. *International Diabetes Digest. Middle East Africa Edition*, 6 (1), 11.
- [17] Amoah, A. G., Owusu, S. K., & Adjei, S. (2002). Diabetes in Ghana: a community-based prevalence study in Greater Accra. *Diabetes Research and Clinical Practice*, 56(3) 197-205.
- [18] FAO, (2008). Cassava. Retrieved from <http://www.fao.org/ag/agp/agpc/gcdfs/>
- [19] FAO Food outlook. (2009). *IFAD Consultation on Cassava as a Potential Bioenergy crop*. FAO/IFAD Food Outlook, 2006.
- [20] Nanda, S.K., Sajeev, M.S., Sheriff, J.T. & Hermasankari, P. (2005). Starch extraction Machinery for tuber Crops. *Technical Bulletin.40*.
- [21] Heuberger, C. (2005). Cyanide content of cassava and fermented products with focus on attiéké and attiéké garba (Doctoral dissertation, Swiss federal institute of technology Zurich). Retrieved from <https://www.researchcollection.ethz.ch/bitstream/handle/20.500.11850/74635/eth-28660-01.pdf>
- [22] Ebuehi, O. A. T., Babalola, O., & Ahmed, Z. (2005). Phytochemical, nutritive and anti-nutritive composition of cassava (*Manihot esculenta* L) tubers and leaves. *Nigerian Food Journal*, 23(1), 40-46.
- [23] Phillips, T., Taylor, D. S. Sanni, L., & Akoroda, M. (2004). A Cassava Industrial Revolution in Nigeria. *The potential for a new industrial crop*. IFAD/FAO: Rome
- [24] United States Department of Agriculture. (2002). Nutrient Database for Standard Reference. Retrieved from <http://ndb.nal.usda.gov/ndb/nutrients/report/nutrients>
- [25] Oritz, R., & Vuylsteke, D. (1996). Improving plantain and banana-based systems. In R. Ortiz, & M. O. Akorada (Eds), *Plantain and Banana Production and Resaerch in West and Central Africa*, International Institute of Tropical Agriculture (pp 2-7). Ibadan, Nigeria.
- [26] Ministry of Food and Agriculture (MOFA). (2006). *Agriculture in Ghana, facts and figures*. Issued by the Statistics, Research and Information Directorate MOFA, Accra.
- [27] Ahiekpor, E. S. (1996). Plantains in Ghana. In R. Oritz & M. O. Akorada (Eds), *Plantain and Banana Production*, (p.43). Of a Regional Workshop, held in International Institute of Tropical Agriculture, High Rainfall station, Onne, Nigeria, September 1996.
- [28] Ng, S. P., & Fong, C. S. (2000). *Banana enhances your anti-cancer power: in health discovery*. Petaling Jaya: Malaysia
- [29] Chandler, S. (1995). The nutritional value of bananas. In *Bananas and Plantains* (pp. 468-480). Springer, Netherlands.
- [30] Patel, R. C. (2012). Food sovereignty: power, gender, and the right to food. *PLoS medicine*, 9(6), e1001223.
- [31] Harvard Health Publications. (2008). *Glycaemic index and glycaemic load for 100+ foods*. Retrieved from www.health.harvard.edu/diseases-and-conditions/glycaemic_index_and_glycaemic_load_for_100_foods
- [32] Uwaegbute, A. C., Osho, S.M., & Obatolu. V. A. (1998). Postharvest technology and commodity marketing: Proceedings of a postharvest conference. *International Institute of Tropical Agriculture* (p. 172).
- [33] Jane, J., Shen, L., Chen, J., Kasemsuwan, T., & Nip, W. K. (1992). Physical and chemical studies of taro starch and flours. *Cereal. Chem.*, 69, 528- 535.
- [34] Lee, W. (1999). Taro (*Colocasia esculenta*). *Ethnobotanical Leaflets*. 1(4). [35] Kay, D. E. (1987). Crop and Product Digest No. 2-Root Crops. *Tropical Development and Research Institute London*, 12-13.
- [35] Owusu-Darko, P. G., Paterson, A., & Omenyo, E. L. (2014). Cocoyam (corms and cormels)—An underexploited food and feed resource. *Journal of Agricultural Chemistry and Environment*, 3(01), 22.
- [36] Wills, R.B., Lim, J.S., Greenfield H., Bayliss-Smith T. (1983). Nutrient composition of taro (*Colocasia esculenta*) cultivars from Papua New Guinea Highlands. *Journal of the Science of Food and Agriculture*, 34(10), 1137-1142.

- [37] Darkwa, S., & Darkwa, A. A. (2013) Taro “Colocasia esculenta”: It’s Utilization in Food Products in Ghana. *Journal of Food Processing & Technology*, 4, 1-7.
- [38] Wolever, T. M. S., Vorster, H. H., Björck, I., Brand-Miller, J., Brighenti, F., Mann, J. I. & Venter, C. (2003). Determination of the glycaemic index of foods: interlaboratory study. *European Journal of Clinical Nutrition*, 57(3), 475-482.
- [39] Brouns, F., Brouns, F., Björck, I., Frayn, K. N., Gibbs, A. L., Lang, V., & Wolever, T. M. S. (2005). Glycaemic index methodology. *Nutrition research reviews*, 18(1), 145-171
- [40] Sheard, N. F., Clark, N. G., Brand-Miller, J. C., Franz, M. J., Pi-Sunyer, F. X., Mayer-Davis, E. & Geil, P. (2004). Dietary carbohydrate (Amount and Type) in the prevention and management of diabetes a statement by the American diabetes association. *Diabetes care*, 27(9), 2266-2271.
- [41] Salmeron, J., Manson, J. E., Stampfer, M. J., Colditz, G. A., Wing, A. L., & Willet, W. C. (1997). Dietary fibre glycaemic load and risk of non- insulin-dependent diabetes mellitus in women. *Jama*, 277(6), 472-477.
- [42] Azadbakht, L., Mirmiran P., & Azizi, F. (2005). Dietary diversity Score is favorably associated with the metabolic syndrome in Tehranian adults. *International Journal of Obesity*, 29 (11), 1361 – 1367.
- [43] Sanusi, R. A., & Olurin, A. (2012). Portion and serving sizes of commonly consumed foods, in Ibadan, Southwestern Nigeria. *African Journal of Biomedical Research*, 15(3), 149-158.
- [44] Young, L. R. & Nestle, M. (2003). Expanding Portion Sizes in the US Marketplace: Implications for nutrition counselling. *Journal of the American Dietetic Association*, 103(2), 231-234.
- [45] Wang, L., Guo, L., Zhang, L., Zhou, Y., He, Q., Zhang, Z. (2013). Effects of glucose load and nateglinide intervention on Endothelial function and Oxidative stress. *J Diabetes Res*, 8492 -8495.
- [46] Kettleborough, R. N., Busch-Nentwich, E. M., Harvey, S. A., Dooley, C. M., De Bruijn, E., Van Eeden, F., ... & Stemple, D. L. (2013). A systematic genome-wide analysis of zebrafish protein-coding gene function. *Nature*, 496(7446), 494-497.;
- [47] Sluijs, I., van der Schouw, Y. T., Spijkerman, A. M., Hu, F. B., Grobbee, D. E., & Beulens, J. W. (2010). Carbohydrate quantity and quality and risk of type 2 diabetes in the European Prospective Investigation into Cancer and Nutrition–Netherlands (EPIC-NL) study. *The American journal of clinical nutrition*, 92(4), 905-911.
- [48] Riccardi, G., Rivellese, A. A., & Giacco, R. (2008). Role of glycaemic index and glycaemic load in the healthy state, in prediabetes, and in diabetes. *The American Journal of Clinical Nutrition*, 87(1), 269-274.
- [49] Mathers, C. D., Boerma, T., & Ma Fat, D. (2009). Global and regional causes of death. *British medical bulletin*, 92(1), 7-32.
- [50] Mathews, M. J., Liebenberg, L., & Mathews, E. H. (2015). How do high glycaemic load diets influence coronary heart disease? *Nutrition & metabolism*, 12(1), 6
- [51] Tsimikas, S., & Hall, J. L. (2012). Lipoprotein (a) as a potential causal genetic risk factor of cardiovascular disease. *Journal of the American College of Cardiology*, 60(8), 716-721.
- [52] Bell, S. J., & Sears, B. (2003) Low-Glycaemic-Load Diets: Impact on Obesity and Chronic Diseases. *Critical Reviews in Food Science and Nutrition*, 43(4), 357-377
- [53] Ludwig, D. S. (2000). Dietary glycaemic index and obesity. *The Journal of nutrition*, 130(2), 280S-283S.
- [54] Maiorino, M. I., Bellastella, G., Petrizzo, M., Scappaticcio, L., Giugliano, D., & Esposito, K. (2016). Mediterranean diet cools down the inflammatory milieu in type 2 diabetes: the MÉDITA randomized controlled trial. *Endocrine*, 54(3), 634-641.
- [55] Wormenor, D. (2015). *Determination of the glycaemic index of local staples in Ghana and the effect of processing on them.* (Master’s thesis, Kwame Nkrumah University of Science and Technology). Retrieved from <http://ir.knust.edu.gh/bitstream/123456789/7451/1/DIVINE%20WORMENOR.pdf>.
- [56] Brown, Young and Steraile (1957)
- [57] World Health Organization. (2006). *BMI classifications*. Retrieved from apps.who.int/bmi/index.jsp?introPage=intro_3.html on 15th April, 2017.
- [58] Bhaht, W. (2016). Calculating your waist circumference. Retrieved from www.webmd.com/diet/guide/calculating-your-waist-circumference
- [59] Asante, R. B. (2019). *Determining the glycemic load of boiled yam, cassava and plantain in Abura, Central Region of Ghana* (Doctoral dissertation, University of Cape Coast).
- [60] Imel, Z., Baldwin, S., Bonus, K., & MacCoon, D. (2008). Beyond the individual: Group effects in mindfulness-based stress reduction. *Psychotherapy Research*, 18(6), 735-742.
- [61] Brand-Miller, J., Hayne, S., Petocz, P., & Colagui, S. (2003). Low– Glycaemic Index Diets in the Management of Diabetes. *Diabetes Care*, 28 (8), 2261-2267.
- [62] Foster-Powell, K., Holt, S. H., & Brand-Miller, J. C. (2002). International table of glycaemic index and glycaemic load values. *American Journal of Clinical Nutrition*, 76, 5 – 56.
- [63] Mann, J. I., De Leeuw, I., Hermansen, K., Karamanos, B., Karlström, B., Katsilambros, N., & Toeller, M. (2004). Evidence-based nutritional approaches to the treatment and prevention of diabetes mellitus. *Nutrition, Metabolism and Cardiovascular Diseases*, 14(6), 373-394.
- [64] Reedy, J., & Krebs-Smith, S. M. (2008). A comparison of food-based recommendations and nutrient values of three food guides: USDA’s MyPyramid, NHLBI’s Dietary Approaches to Stop Hypertension Eating Plan, and Harvard’s Healthy Eating Pyramid. *Journal of the American dietetic association*, 108(3), 522-528.

-
- [65] Ogazi, P.O. (1996). Plantain Utilization and Nutrition. In B. Mba, N. D. O. Nnayelugo, *Food Crops Production, Utilization Nutrition*. Eds. (pp. 135-144). Dotan Publications Ltd: Nigeria.
- [66] Ogunmolasuyi, A. M., Egwim, E. C., Adewoyin, M. A., & Awoyinka, O. (2016). A comparative study of functional and structural properties of starch extracted from *Dioscorea rotundata* and *Colocasia esculenta*. *Starch-Stärke*, 68(7-8), 771-777.
- [67] Wolever, T. M., Mehling, C., Chiasson, J. L., Josse, R. G., Leiter, L. A., Maheux, P. & Ryan, E. A. (2008). Low glycaemic index diet and disposition index in type 2 diabetes (the Canadian trial of carbohydrates in diabetes): a randomised controlled trial. *Diabetologia*, 51(9), 1607-1615.
- [68] Eleazu, C. O. (2016). The concept of low glycaemic index and glycaemic load foods as panacea for type 2 diabetes mellitus; prospects, challenges and solutions. *African health sciences*, 16(2), 468-479.
- [69] Thorburn, A., Muir, J., & Proitto, J. (1993). Carbohydrate fermentation lowers hepatic glucose output in healthy subjects. *Metabolism*, 42, 780-785.