UNIVERSITY OF CAPE COAST

DETERMINING THE GLYCEMIC LOAD OF BOILED YAM, CASSAVA AND PLANTAIN IN ABURA, CENTRAL REGION OF GHANA

ROSINA BONYAH ASANTE

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BY

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DECLARATION

Candidate's Declaration

I hereby declare that this Thesis is the result of my own original research and that no part of it has been presented for another degree in this university or elsewhere.

Candidate's Signature: ……………………. Date: …………………..

Name: Rosina Bonyah Asante

Supervisors' Declaration

We hereby declare that the preparation and presentation of the Thesis were supervised in accordance with the guidelines on supervision of Thesis laid down by the University of Cape Coast.

Principal Supervisor's Signature: ……….................. Date: ………………….

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Co- Supervisor's Signature: ……………................. Date: ………………….

Name: Mrs Christiana Nsiah-Asamoah

ABSTRACT

Glycemic load and index of local foods is becoming a topical issue in food science. Therefore, determining glycemic load and index of locally consumed foods in is necessary. The aim of this research was to determine the glycemic load of boiled yam, boiled cassava and boiled plantain among the people of Abura. In finding answers to the problem being investigated, three research questions and one research hypothesis were set to guide the study. Theoretical and empirical literature was reviewed to give better understanding and background to the study. True experimental design was adopted to be used for the study. A total of 10 participants were purposively and conveniently sampled and screened to meet the criteria needed before participating in the study. Ethical clearance was obtained from the Institutional Review Board of University of Cape Coast before conducting the study. The data obtained were analysed and tested with mean, standard deviation, graph and ANOVA. The study revealed that boiled plantain had the lowest glycemic load (12.62) followed by yam (20.39) and cassava (26.71) in order of magnitude. Again, boiled plantain had the least effect on blood glucose level; and had the least content of protein, fat/oil, fibre and carbohydrate as compared to boiled yam and cassava. Also, the moisture content in boiled plantain was higher than yam and cassava in order of magnitude respectively. The study recommended that the consumption of plantain and its related meals can be suggested more often to diabetic patients. In addition, more recipes from plantain should be developed by stakeholders in the hospitality industry and food product development.

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DEDICATION

To my lovely family and friends

TABLE OF CONTENTS

APPENDIX E: INTRODUCTORY LETTER

LIST OF TABLES

LIST OF FIGURES

CHAPTER ONE

INTRODUCTION

Background to the Study

Roots and tubers are the thickened underground starch storage organs of some plants, propagated vegetatively from the underground stems and their stem cuttings. These edible roots and tubers belong to several families and are formed by both monocotyledons (yams and cocoyams) and dicotyledons (cassava and sweet potatoes) (FAO, 1985). Food consumption is for the purposes of building the body, providing the body with energy and protection from diseases. The main source of energy in the diet of most people is carbohydrates and they play a very significant role in homeostasis and energy metabolism (Mann, Cummings, Englyst, Key, Liu, & Riccardi, 2007).

Yam, cassava and plantain in the boiled form are predominantly enjoyed by most Ghanaians due to its delicacy (Aidoo, 2009). These foods are traditional meals in the Ghanaian cuisine served with spicy gravy, vegetable stew, cocoyam leaves (kontomire), thick palm-nut soup or groundnut soup. Yam is the common name for some plant species in the genus *Dioscorea* (family *Dioscoreaceae*) that form edible tubers. Yams are perennial herbaceous vines cultivated for the consumption of their starchy tubers in many temperate and subtropical world regions.

The tubers themselves are also called "yams", having numerous cultivars. 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 (Food and Agriculture Organisation [FAO], ` 2008). Plantain belongs to the *Musacace* family and is cultivated in many tropics and sub-tropical countries of the world. It ranks third after yams and cassava for sustainability of life (Akomolafe & Aborisade, 2007). Plantain (*Musa paradisiaca*) is a rhizomatous perennial crop used as a source of starchy staple for millions of people (Adeniyi, Sanni, Barimalaa & Hart, 2006).

These foods (boiled yam, boiled cassava and boiled plantain) are not only rich in carbohydrate and serve as the major source of energy, but also contain vitamins, minerals, phytoestrogens, and trace elements (Mourey, 2015). Yam, cassava and plantain are considered as the main carbohydrate sources of food in Ghanaian diet. The energy contents and digestibility of different carbohydrates, however, differ. Some carbohydrate foods elicit a quicker response from insulin than others. This is due to differences in the rate at which they are metabolized into glucose.

The concept of glycemic index (GI) was introduced as a means of classifying different sources of carbohydrates (CHO) and CHO-rich diets. The classification is according to their effect on postprandial blood glucose level, different carbohydrate containing foods have different effects on blood glucose response (Jenkins, Wolever, Taylor, Barker, Fielden, Baldwin & Goff, 1981; Wolever, 1990; Brouns, Bjorch, Frayn, Gibbs, Lang, Slama & Wolever, 2005).

Low-GI CHO is the CHO that is digested and absorbed slowly and led to a low glycemic response, whereas high-GI CHO is rapidly digested and absorbed and shows a high glycemic response (Brouns *et al*., 2005). The rate of glucose entry into blood and the duration of the elevated blood glucose induce many hormonal and metabolic changes that may affect health and disease parameters (Hodge, English, O'dea & Giles, 2004).

Evidence from prospective studies shows the intake of low GI-diets are associated with reduced risk of diabetes (with specific reference to type 2 diabetes) (Hodge *et al*., 2004; Frost, Leeds, Trew, Margara & Dornhorst, 1998), cardiovascular disease (Liu, Willett, Stampfer, Hu, Franz, Sampson & Hennekens, 2000), cancer (Augustin, Polesel, Bosetti, Kendall, La Vecchia, Parpinel & Dal Maso, 2003; Augustin, Gallus, Franceschi, Negri, Jenkins, Kendall & Dal Maso, 2004), and the metabolic syndrome (Mckeown, Meigs, Liu, Saltzman, Wilson & Jacques, 2004). Low GI foods improve overall blood glucose control in people with type 2 diabetes (Wolever, Katzman-Relle, Jenkins, Vuksan, Josse, & Jenkins, 1994), reduce serum lipids in hypertriglyceridemia patients (Jenkins & Jenkins, 1987) and improve insulin sensitivity (Riccardi & Rivellesse, 2000; Augustin *et al.*, 2002; Slyper, 2004).

Also, the intake of a low GI-diet is associated with higher concentrations of high-density lipoprotein (HDL) cholesterol (Frost, Leeds, Dore, Madeiros, Branding & Dornhorst, 1999) and significant reduction in low density lipoprotein (LDL) cholesterol as well as total cholesterol (Opperman, Venter, & Oosthuizen, 2005). When low glycemic CHOs, get incorporated into an energy restricted diet, compared to higher glycemic CHOs, it leads to a reduction in insulin resistance that cannot be accounted for by weight loss alone (Slabber, Barnard, Kuyl, Dannhauser & Shall, 1994). Low-GI diets influence weight loss and resting energy expenditure independently of energy intake in young moderately overweight subjects (Agus, Swain, Larson, Eckert & Ludwig, 2000).

Modern life habits are characterized by low daily energy expenditure and by the excessive ingestion of foods rich in carbohydrates and lipids, making the positive energetic balance a reality. The consequence is the increase of the body mass index (BMI) and the prevalence of obesity, in developed as well as developing countries (Barreto, Pinheiro, Sichieri, Monteiro, Filho & Schimidt, 2005; Blair & Church, 2004).

The consumption of High glycemic load diet has its dire health consequences, this type of diet is responsible for the increase of the prevalence of obesity (Ebbeling, Leidig, Sinclair, Hangen & Ludwig, 2003; Ludwig, 2002; Silva & Alfenas, 2011), which might lead to the alteration of the oxidative state and inflammatory markers, besides favouring lipogenesis, hyperglycemia, hyperinsulinemia, reduction of insulin sensibility, hypertriglyceridemia and decrease the concentration of HDL-cholesterol in the blood (Frost, *et al.*, 1999).

The Joint FAO/WHO expert in 1998 endorsed GI usefulness in diet planning caption "Carbohydrates in Human Nutrition" due to its beneficial effects to health (Riccardi & Rivellesse, 2000). According to a report, eating habit characterized by the consumption of high glycemic index (HGI) and high glycemic load is a measure that incorporates both the quality and quantity of dietary carbohydrate (Hu, Stampfer, Manson, Grodstein, Colditz & Speizer, 2000). It takes into account the GI and its impact on body system (Wylie-Rosett, Segal-Isaacson & Segal-Isaacson, 2004).

According to Davis (2009), carbohydrates are broken down into glucose when they are eaten, and absorbed into the blood stream. As blood glucose levels rise, the pancreas produces insulin, a hormone that prompts cells to absorb blood glucose for energy or storage. Carbohydrate is the main nutrient that raises blood glucose levels. 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 (American Diabetes Association (ADA, 2015).

A study conducted in the UK concluded that a very good glucose control is paramount in the prevention of complications resulting from diabetes (Nazar, Bojerenu, Safdar & Marwat, 2016). Regulation of glucose in the blood is variably dependent on the type of food consumed. This is due to the varying effect of different carbohydrates on the blood glucose level. The rate at which particular carbohydrate food substances are converted into sugar in the body is thus an important parameter to consider in glycemic control.

The relative ranking of how fast or slow a carbohydrate food is converted to glucose after ingestion is a measure of its glycemic index (ADA, 2015). Carbohydrate foods that are quickly broken down into glucose after ingestion are considered to be high glycemic index foods while those with a relatively slower pace of conversion to glucose and thus elicit a slower insulin response are low glycemic index foods (Nazar, Bojerenu, Safdar & Marwat, 2016).

The glycemic index of foods is a categorization based on the effect of the content and type of carbohydrates of a food on blood glucose (Passos, 2012; Brand-Miller, Stockmann, AtkinsonPetocz, & Denyer, 2014). In addition to the glycemic index, the amount of carbohydrate in a food is also considered an important determinant of glucose tolerance on fasting and the postprandial glycemic response (Food and Agriculture Organisation (FAO) & World Health Organisation [WHO], 2001).

According to Liu and Willet (2002), glycemic index is not the optimum way of determining the effect of carbohydrate on blood glucose, as it does not take into account how much digestible carbohydrate; the total carbohydrate excluding fibre, it delivers. Thus, researchers established a related way to categorize foods that take into account both the amount of carbohydrate in the food with respect to its impact on blood glucose levels, therefore, a measure that involves the quantity and quality Glycemic Index (GI) of dietary carbohydrate known as the glycemic load (Willet, Manson & Liu, 2002).

The glycemic load of a typical serving of food is the product of the amount of available carbohydrate in that serving and the glycemic index of the food. The higher the glycemic load, the greater the expected elevation in blood glucose and in the insulinogenic effect of the food. The long-term consumption of a diet with a relatively high glycemic load (adjusted for total energy) is associated with an increased risk of type 2 diabetes and coronary heart diseases (Mathews, Liebenberg & Mathews, 2015). According to Burani (2006), glycemic load of 20 or more is high, 11 to 19 is medium, and 10 or less is low.

According to Bemiller (2010) several studies to analytically examine carbohydrates have been undertaken by numerous scientists; however, Rubner (1917) was the first person to provide a report of a detailed study on carbohydrates. Defined in the broadest sense, glycobiology is the study of the roles of carbohydrates in cellular life. Carbohydrates are the primary products of plant photosynthesis and the metabolic precursors of all other organic compounds. Often they are covalently bound to proteins (glycoproteins) and lipids (glycolipids) to form glycoconjugates.

Many glycoconjugates have structural roles (Kresge, Simoni & Hill, 2002). Kresge *et. al* (2002) however, noted that the carbohydrate groups of glycoconjugates also can be involved in cellular processes including adhesion, transformation, growth, endocytosis and fertilization. The concept was a very useful aid in nutritional counselling of diabetics in their choice of carbohydrates.

The available carbohydrate concept is however central to the determination of glycemic load since the glucose raising ability of a carbohydrate is by the glucogenic part of the carbohydrates and not the whole carbohydrate food. Although some work has been done to experimentally determine the glycemic index and load of foods and more specifically carbohydrate foods, the glycemic index of some foods as are known, are extrapolations from published glycemic values of closely related foods (Aston, Gambell, Lee, Bryant & Jebb, 2008).

In relation to the relevance of glycemic load, an extensive amount of work has been done on the effect of high blood glucose, measured as Fasting Blood Glucose (FBG) on the various organs of the body and general wellbeing of individuals. Some prospective studies done have shown that the protective effect of low glycemic load on people at risk of diabetes (Nazar, Bojerenu, Safdar & Marwat, 2016; Hasan, Sultana, Shill, Purba & Sultana, 2019).

Various studies have also linked low glycemic index with improvement in glucose control (Rizkalla, Taghrid, & Laromiguiere, 2004), sensitivity to insulin (Nazar, *et al.*, 2016; Hasan, *et al.*, 2019) and memory (Kaplan, Greenwood, Winocur, & Wolever, 2000). A comparative study conducted by Barona, Jones, Kopec, Comperatore, Andersen, Schwartz, and Fernandez (2012) is in consonance with current research findings that suggest the protective role of low glycemic load diet and in this case regulation of blood lipids. In their work they found a significant decline in the total and low-density lipoprotein cholesterol as well as triglycerides with the consumption of low glycemic load foods. A systematic review and meta-analysis conducted by Fan, Song, Wang, Hui and Zhang (2012) found a slight association between coronary heart disease (CHD) and dietary glycemic index.

In Ghana, there is some concern over the consumption of boiled yam, boiled cassava and boiled plantain, as some are of the view that such traditional starch-based diets could be detrimental to health, since the regular consumption of high carbohydrate contents may trigger hyper-postprandial glucose responses. Some people, especially diabetic patients, even exclude tubers from their diets (Kouamé, Kouassi, N'dri & Amani, 2015). This is largely because of a lack of knowledge of the glycemic index (GI) and glycemic load (GL) values for such foods. The weighted prevalence of diabetes among the adults aged 50 years and above in Ghana was 3.95% (95% Confidence Interval: 3.35–4.55) with the prevalence being insignificantly higher in females than males (2.16%, 95% CI: 1.69–2.76 vs. 1.73%, 95% CI: 1.28–2.33) (Gatimu, Milimo & Sebastian, 2016).

According to the World Health Organization (WHO), Diabetes is the 7th leading cause of death globally and the 6th commonest medical cause of death in Ghana (World Health Organization, 2017), accounting for 2.58% of total deaths with a death rate of 36.81 per 100,000 of the population (World Health Organization, 2017). Thus, the determination of the glycemic responses of these foods is required considering its role to maintain normoglycaemia and possibly also maintain insulin demand.

A report of a joint FAO/WHO (1998) expert consultation stressed the need to determine the glycemic index and glycemic load of local staples due to differences that could arise from various cooking and processing methods

(Aston, Gambell, Lee, Bryant & Jebb, 2008). Willet, Manson and Liu (2002) reported that, the consumption of high glycemic index and high glycemic load diets for several years may result in increased postprandial blood glucose spikes and excessive insulin secretion. This could lead to the loss of insulin-secreting function of the pancreatic β-cells, resulting in irreversible Type 2 Diabetes mellitus. Ludwig and Daniel (2002) in a study stated that, sustained spikes in blood glucose and insulin levels may lead to increased diabetes risk.

Statement of the Problem

The glycemic index and glycemic load of foods have become important measure used by healthy individuals and mostly diabetics in their food choices to maintain good glycemic control (FAO, 2014). Food choices from intercontinental food lists using glycemic load are easier because it has been determined. However, the same cannot be said about most of our starchy foods in Ghana. With the increased consumption of some of the local foods comes a need to understand the rate of converting these foods to sugar in the body which is a measure of their glycemic load.

There is some concern over the consumption of some staple local foods as some are of the view that such traditional starch-based diets could be detrimental to health, since the regular consumption of high starch contents may trigger glucose responses. The clinical application of glycemic index and glycemic load is still a debatable topic for many scientists because of the confounding effect of fats, protein and other chemicals. Several studies showed that the glycemic index and glycemic load of the complete meal have negligible effects of fats and protein when consumed in usual dietary amounts (Brand-miller & Wolever, 2005). Despite these debates based on sufficient epidemiologic studies, glycemic index and glycemic load remain an interested topic for research for planning of many dietary interventions.

To the best of knowledge, there is scarcity of research work and data on the glycemic index and glycemic load of our local foods in Ghana. A study by Wormenor (2015) revealed that, fufu made from cassava and plantain has a low glycemic index, hence, a little impact on blood glucose level when ingested and digested. The research did not focus on the glycemic load of such foods. Nevertheless, no research seems to have been done on these and other combinations as related to their impact on the blood glucose level.

In Ghana, yam, cassava and plantain in the boiled form are some of the major foods consumed in large quantities on a daily basis. However, in the absence of information on the blood glucose response of these foods, physicians and dietitians may find it difficult to suggest meals prepared from these staple foods to patients with symptoms of hyperglycemia.

The determination of the glycemic responses of these foods therefore is required considering its role in the dietary management of sugar related disease conditions. This research study is therefore designed to determine the glycemic load of boiled yam, boiled cassava and boiled plantain. It is anticipated that the findings of the study will be of great use to diabetic patients and those caring for them with respect to the dietary management of the condition. In addition, health professionals will benefit from the findings as it will provide some evidence that can inform dietary counselling information given to diabetic patients.

Purpose of the Study

The study determined the glycemic load of boiled yam, boiled cassava and boiled plantain among the people of Abura.

Main Objective of the Study

The main objective of the Study was to determine the glycemic load of boiled yam, cassava and plantain.

Specific Objectives of the Study

The specific objectives of the study were to seek the following:

1. Determine the glycemic load of boiled yam, cassava and plantain.
2. Compare the effects of boiled yam, cassava and plantain on blood glucose level and;
3. Proximately analyse moisture, ash, protein, fat, fibre and carbohydrate contents of boiled yam, cassava and plantain.

Research Hypothesis

1. H_0: There is no statistically significant difference in the glycemic load of boiled yam, cassava and plantain.

Significance of the Study

Essentially, the glycemic load, which is the product of the glycemic index and the carbohydrate content of a given food, may be more useful than the glycemic index because the glycemic load takes into account the portion size of the food as well as the carbohydrate quantity. Glycemic load appears to be an important factor in dietary programmes aiming at the metabolic syndrome, insulin resistance, and weight loss.

It is hoped that findings from this study will make available the glycemic loads of these foods which are popular Ghanaian foods. Hopefully diabetics could do proper glycemic load counting rather than the conventional carbohydrate counting for proper monitoring of foods they eat.

When carbohydrate foods of different glycemic index are consumed, it is known that the difference in postprandial blood glucose response is maintained (Eleazu, 2016). However, the extent of this differential blood glucose response may be dependent on the meal size. It is hoped that findings from this study will come up with the optimal portion size which consumers will take. Determining the glycemic load of boiled yam, cassava and plantain could serve as a guide to diabetics to choose the starchy food with the best glycemic load.

It may also inform nutritionists, dieticians and diet therapists also to recommend to pre-diabetics and diabetics when they counsel them since these foods are widely eaten across Ghana, providing information on the nutritional value on boiled yam, cassava and plantain would be worthwhile and helpful to consumers. It is anticipated that the findings from the study will go to enrich the scarce literature on boiled yam, cassava and plantain with regard to their glycemic load in addition to other nutritional values.

Delimitations

The study was delimited to determining of glycemic load of boiled yam, plantain and cassava in Abura a suburb of Cape Coast Metropolis in Ghana. The yam, plantain and the cassava for the study were bought from the market women who were selling them at the Abura market. Also, the respondents (male = 5 and female = 5) used were those certified by medical officer to be healthy in terms of their body mass index (BMI). The blood samples from the respondents were only used to determine their glycemic load and their blood fasting sugar.

Limitations

The consumable materials (yam, cassava and plantain) were not freshly harvested from the farm since Abura community in the Cape Coast Metropolis is far from the farming communities where these food stuffs are planted. The food stuff takes a day or two before they are available at the marketing centres. In view of the food stuff not been freshly harvested may have a limitation on the chemical properties of the food stuff in a way. However, the probable limitation could have not affected the result of the glycemic index of the result.

Having access to respondents was a challenge. Most of the people were afraid of lancert pricking their fingers for their blood samples. Also, the issue of diverting their blood for other mischievous purpose like ‘blood money’. Organising the people in the Abura community was very difficult as most of them thought it was a waste of their time which could have been used for their personal work. Transporting those who agreed to participate in the study was difficult since they were coming from different places within the community. It took a lot of time to assembling them for the test each week.

Organisation of the Study

The first chapter of the study contains the introduction of the research. Sections within the chapter include background of the study, statement of problem, purpose of the study, objectives of the study, research questions, significance of the study, delimitation, limitation, and organization of study. The second chapter consists of the review of relevant literature. The third chapter describes the methodology used to carry out the research. Sample size, research instrument, tools for the data analysis and research design was clearly discussed. Chapter four of the research contains results whereas the last chapter spelt out conclusion and recommendations on the research, where major findings were presented.

CHAPTER TWO

REVIEW OF RELATED LITERATURE

Introduction

This chapter reviews literature relevant to the study. It consists of empirical evidence on determining the glycemic load of foods. The review covers the concept of glycemic load, the concept of glycemic index, yam, cassava plantain and carbohydrate. The effect of the carbohydrate on blood glucose level and glycemic load of those who consume them.

The concept of glycemic load

To provide a more accurate description of the quantity and quality of carbohydrate in a meal simultaneously, researchers developed the concept of the glycemic load (GL), which takes the concept of glycemic index (GI) a step further, accounting not only for how rapidly a food's carbohydrates are converted to glucose but also the relative amounts of carbohydrate the food contains in an average serving. Glycemic load is defined as the product of a food's glycemic index and its total available carbohydrate content (Nazar, Bojerenu, Safdar & Marwat, 2016). GL is generally held to be a more accurate measure of a food's overall effect on pancreatic insulin release and serum glucose levels.

$$\text{Glycemic Load (GL)} = \frac{\text{Glycemic Index (GI)} \times \text{Carbohydrate (g)}}{100}$$

The GL of a food is calculated by multiplying the GI value by the amount of carbohydrates in grams provided by a serving of food and dividing the total by 100. Therefore, the GL provides a summary measure of the relative glycemic impact of a "typical" serving of the food. In general, items with a low

GI tend to have a correspondingly low GL. However, foods with a high GI may vary as to whether their GL is low or high. For example, the carbohydrates in watermelon are rapidly converted to glucose, so watermelon's GI is high at 72. However, because watermelon is made up primarily of water and contains little absolute carbohydrate content, its GL is relatively low at a value of 4 (Foster-Powell, Holt & Brand-Miller, 2002).

The glycemic load examines the total impact of the dietary carbohydrate on postprandial glycemia. The glycemic load is the product of the glycemic index of the food or diet under study and the grams of available carbohydrate in that food or diet divided by 100 (Nazar, Bojerenu, Safdar & Marwat, 2016). For a meal, GL is calculated by multiplying the mean glycemic index weighted according to the grams of total available carbohydrate by the grams in the meal or diet.

Glycemic load accounts for carbohydrates in food and how much each gram of it will raise an individual's blood glucose level. This implies the GL provides a summary measure of the relative glycemic impact of a "typical" serving of the food. Foods with a GL less than or equal to 10 (< 10) are considered as low GL foods, those with a GL 11-19 are classified medium GL foods whereas foods with a GL greater than or equal to 20 (> 20) considered high GL foods (Venn, Wallace, Monro, Perry, Brown & Frampton, 2006).

To determine the GL of a food, there is the need to first determine the glycemic index of the food. It is instrumental to the calculation of the GL. The FAO/WHO recommends that the standard method for the determination of the GI of food is *in vivo*, where a test food containing 50g available carbohydrate is ingested and the rate at which the food is digested and absorbed into the blood stream is measured (FAO/WHO, 1998). The glycemic load is therefore the new way to evaluate the impact of carbohydrate consumption that takes into account the glycemic index but provides a deeper picture than the GI does.

The concept of glycemic Index

The concept of glycemic index (GI) was introduced as a means of classifying different sources of carbohydrates (CHO) and CHO-rich diets. The classification is according to their effect on postprandial blood glucose level, different carbohydrate containing foods have different effects on blood glucose response (Jenkins, Wolever, Taylor, Barker, Fielden, Baldwin & Goff, 1981; Wolever, 1991; Brouns, Brouns, Bjorck, Frayn, Gibbs, Lang & Wolever, 2005).

The glycaemic index (GI) concept is based on the difference in blood glucose response after ingestion of the same amount of carbohydrates from different foods, and possible implications of these differences for health, performance and well-being (Arvidsson-Lenner, Nils-Georg, Axelsen, Bryngelsson, Eliina Haapa, Ja¨rvi, Karlstrom, Raben & Sohlstrom, 2004). This concept was first proposed in 1981 by scientists led by Dr. David Jenkins, University of Toronto, Canada (Jenkins, Wolever, Kalmusky, Giudici, Giordano & Wong, 1985). This concept was proposed because they realized that the carbohydrate exchange list that was used over the years for controlling diabetes was not a true reflection of the actual physiologic effect of the food consumed. They also observed that, the health effects of carbohydrate can be better described with their physiological properties, like its ability to raise blood glucose. FAO/WHO (1998) defines GI as the area under the glucose response curve after ingestion of 50g of carbohydrates of a test food expressed as a response percentage to the same amount of carbohydrate from a standard food, in the same individual.

A high GI is generally accompanied by a high insulin response. The glycemic load (GL) is the GI × the amount (g) of carbohydrate in the food/100. Many factors affect the GI of foods, and GI values in published tables are indicative only, and cannot be applied directly to individual foods. Properly determined GI values for individual foods have been used successfully to predict the glycemic response of a meal, while table values have not (Arvidsson-Lenner, *et al.*, 2004).

An internationally recognized method for GI determination is available, and work is in progress to improve inter- and intra-laboratory performance. Some epidemiological studies and intervention studies indicate that low GI diets may favourably influence the risk of chronic diseases such as diabetes and coronary heart disease, although further well-controlled studies are needed for more definite conclusions (Arvidsson-Lenner, *et al.*, 2004).

Low GI diets have been demonstrated to improve the blood glucose control, LDL-cholesterol and a risk factor for thrombosis in intervention studies with diabetes patients, but the effect in free-living conditions remains to be shown. The impact of GI in weight reduction and maintenance as well as exercise performance also needs further investigation. The GI concept should be applied only to foods providing at least 15 g and preferably 20 g of available carbohydrates per normal serving, and comparisons should be kept within the same food group.

The standard food is glucose or white bread (FAO/WHO, 1998; Brand-Miller, Hayne, Petocz & Colaguiri, 2003). Glycemic index measurement is thus equi-carbohydrate (because equal quantities of available carbohydrate are involved) (Monro & Shaw, 2008) as compared to Glycemic impact which is a measure of “the weight of glucose that would induce a glycemic response equivalent to that induced by a given amount of food” (Miller-Jones, 2007). The glycemic index measures how quick or slow the rise in blood glucose occurs as a result of a carbohydrate food consumed. A joint report by FAO and WHO (1998) expert committee indicated that there were a number of factors that influenced the postprandial glycemic response of a food when ingested. Such of these factors were identified as;

1. The nature of monosaccharide components in the food (glucose, fructose, galactose).
2. The nature and proportion of starch in the food i.e. the ratio of amylose to amylopectin in the food as well as the starch-nutrient interactions.
3. Cooking or processing of the food (degree of starch gelatinization, particle size, food form and cellular structure).
4. Other food components like fat, protein, dietary fibre, anti-nutrient and organic acids.

According to a report of the Joint FAO and WHO Expert Committee in 1998, GI is a more established concept though it appears to be a simple index (FAO & WHO, 1998). A number of factors influence the postprandial glycemic response of a food when ingested. These factors range from extrinsic components such as composition of the whole meal and variations in the overall diet, to intrinsic properties such as the amylose to amylopectin ratio, presence or absence of viscous fibre and the length of the monosaccharide units (Bjorck, Granfledt, Liljeberg, Tover, & Asp, 1994). The defining standard of glycemic index determination, is that glucose has a value of 100. GI is expressed in percentages and commonly represented on an absolute scale where foods with values of 55 or less, 56 to 69, and 70 or more are classified as low, medium and High GI foods respectively (Brand-Miller, *et al*). GI measures postprandial glucose which can be manipulated by varying the amount and type of dietary carbohydrates consumed. Meals which have a low GI tend to slow insulin response and decrease postprandial glucose concentration (FAO & WHO, 1998).

Modern life habits are characterized by low daily energy expenditure and by the excessive ingestion of foods rich in carbohydrates and lipids, making the positive energetic balance a reality. The consequence is the increase of the body mass index (BMI) and the prevalence of obesity, in developed as well as developing countries (Barreto, et al, 2005; Blair & Church, 2004). Several works by Roberts, (2000) and Gulliford et al (1989) have shown that glycemic CHO leads to hunger and CHO craving. Slyper, (2004) demonstrated increased satiety, delayed return of hunger, and decreased food intake, after ingestion of low-GI compared to high-GI foods. The consumption of High glycemic load diet has its dire health consequences, this type of diet is responsible for the increase of the prevalence of obesity (Ebbeling *et al.,* 2003; Ludwig, 2002; Silva and Alfenas, 2011), which might lead to the alteration of the oxidative state and inflammatory markers, besides favouring lipogenesis, hyperglycemia, hyperinsulinemia, reduction of insulin sensibility, hypertriglyceridemia and decrease the concentration of HDL-cholesterol in the blood (Frost, *et al.*, 1999).

Portion size and glycemic control

The idea of portion size of foods consumed at a sitting and the serving sizes are important in effective dietary intake and glycemic control studies. This is because food's portion sizes have a major effect on the glycemic index of the food, thereby increasing the glycemic load of the food (Azadbakht, Mirmiran & Azizi, 2005). The United States Department of Agriculture (USDA) as cited in Sanusi and Olurin, (2010) and Food and Drugs Administration and Control (Young & Nestle, 2003) have establish standard serving sizes that guide Americans to select the right portion sizes of food to eat for sustained and improved health.

These serving sizes are also important in monitoring portion sizes as part of weight loss and weight management programmes and has gone a long way to help dieticians to manage diet related chronic diseases better (Sanusi & Olurin, 2010). Fractions (quarter, half, two third), sizes (small, medium and large) and household measures (cups, spoons, and ladles) are mostly used in describing serving sizes of foods. Despite the fact that portion sizes have been proven to have a strong association with adequate nutrient intake, little studies seem to exist on portion and serving sizes especially in Ghana. To add to this assertion, Sanusi and Olurin raise similar concerns in Nigeria.

In Ghana, information on serving size of local Ghanaian foods are limited and the term 'serving' is even not clearly understood. The Ministry of Health (2009) has however come out with dietary recommended serving sizes for various foods that provide the body with macronutrients (carbohydrate, protein and fat) based on the individual's physical activity. According to them, children and adults need a minimum of 130 grams/day of carbohydrates for proper brain function. This means that a person can consume more depending on his/her physical activity level. The recommended amount of a serving of fufu is 211 grams which contains 76g of carbohydrate. Most dieticians and nutritionist use this guideline in managing diet related diseases.

Determination of glycemic index

The glycemic response is measured by taking blood samples for glucose test at timed intervals which start at the first bite of the test food (Wolever, et al, 2003). 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 glycemic response from the reference food will have a great effect on the GI than variations in the test foods (Brouns, et al, 2005). Brouns et al recommend that the measurement of the reference food be repeated at least one in each participant of a GI determination research.

Reference food

The use of a standard food against which the test food will be measured is very necessary in the determination of the GI of a food. According to Foster-Powell, Holt & Brand-Miller (2002) a number of foods have been used as reference foods in the determination of GI. An updated database of GI of some 1300 foods measurements involved about 10 different reference foods including: glucose, wheat chapatti, arepa (a Mexican carbohydrate food item) potato, rice, bread, white bread, whole barley bread and wheat. Glucose and white bread however have been the main reference foods used (Foster-Powell *et al*). The use of white bread as a reference food produces a relatively higher

GI value than glucose. The GI of white bread as determined in some studies produce a value of 73 constantly. White bread composition and preparation may however differ from one experimental setting to another as was reported in a study where white French bread produced a GI value of 97 (Brand-Miller *et al*).

The use of glucose as a reference food also raises some concerns such as its great sweetness. Some people also complain of a nauseating effect they feel when the glucose solution is taken in the morning after a 10-14 hour fast (Brouns *et al.*, 2005). Pure glucose is, however, more likely to be the same in most experimental settings. This makes it easier to compare results from other laboratories (Wormenor, 2015). Since the Incremental Area Under Curve (IAUC) of the reference food will be used as the denominator in calculating the test foods, differences in glycemic response to the glucose or white bread used will therefore produce significant difference in the GI of the test foods. Consequently, various theoretical assessment and replication studies have indicated that either three or two trials of the reference food are acceptable in order to reduce these variations (Brouns, *et al.*, 2005).

Blood sampling

Glucose concentrations can be measured from whole blood or plasma from various parts of the body. Blood samples could be obtained from the veins, arteries or capillaries. An assessment of the arterial blood could yield the truest reflection of the glucose concentration being delivered to the various body tissues, because they are the blood vessels that deliver blood from the heart to the tissues and will obviously be richer in nutritional composition. However, since the arteries are found deeper within the body than the capillaries and veins, drawing arterial blood could come with associated risks such as excessive bleeding, nerve damage and involuntary contraction. This notwithstanding, capillary blood approximates the composition of arterial blood and therefore a better alternative to the arterial blood (Brouns *et al.,* 2005).

Measured glucose concentration in the capillaries is fairly higher than in venous blood and thus makes it easier to detect very small changes in blood glucose concentrations over time. In the determination of GI, blood from the capillary taken from the fingertip or earlobe is therefore more suitable and better for the assessment of glycemic response (Wormenor, 2015).

Physiological characteristics of study Respondents

Since Glycemic Index (GI) determination measure the postprandial glucose response of a person, the physiological state of any person participating in GI studies must be considered. This is because the individual's insulin response and glucose tolerance can influence the body's glycemic response (Wormenor, 2015). According to Wolever, et al (1985) as cited in Wormenor (2015) "Prediction of the relative blood glucose response of mixed meals using the white bread glycemic index" confirmed that, normal healthy subjects showed intermediate intra-individual variation in glycemic response, whilst subjects with type II diabetes showed a less significant intra-individual variation as compared to subjects with type I diabetes. Brouns *et al.* (2005) hence recommends the use of healthy individuals in the determination of GI to increase precision.

Characteristics of Yam

Yam is an excellent source of starch, which provides caloric energy. Quality factors such as textural quality, appearance and taste are the main acceptability factors used by consumers to assess the quality of pounded yam; but the most important is textural quality (Otegbayo, et al, 2005). These sensory factors are influenced by the physico-chemical and functional properties of yam starch since it accounts for about 60-80% of the dry matter of yam tuber (on dry weight basis). The dominant factor in determining the physicochemical, rheological and textural characteristics of food products from different yam species (Amani, Buléon, Kamenan & Colonna, 2004).

Botanical and agronomic characteristics of yams

The term ‘yam’ refers to all members of the genus *Dioscorea*. Yams are climbing plants with glaborous leaves and twining stems, which coil readily around a stake. They include some 600 species (Amani, Buléon, Kamenan & Colonna, 2004) including *D. alata*, *D. abyssinia*, *D. batatas*, *D. cayenensis*, *D. esculenta*, *D. japonica*, *D. rotundata* (Hoover, 2001), *D. opposite* (Wang, et al, 2006b) and *D. dumetorum* (Afoakwa & Sefa-Dedeh, 2001). About 10 species are commonly cultivated for food, while a number of others are harvested from the wild in times of food scarcity (Bhandari, Kasai & Kawabata, 2003). Many wild yam species contain toxic or bioactive chemicals, and some of these are cultivated for pharmaceutical products (Coursey, 1967).

Yam though highly variable in appearance both between and within species, all yams share a common growth habit of thin, twining vines and a shallow, widely radiating root system, both of which die and are renewed each year. All economically important species are tuberous, producing one or more underground tubers, which are starch storage organs derived from stem tissue. The tubers provide a means of vegetative propagation from one season to the next. In most cases the tubers are annual and they shrivel at the start of the new growing season and are replaced by new tubers (O'Sullivan, 2010).

Classification of Yam

Yams are staple foods with cultural, economic and nutritional importance in many parts of Africa and Southeast Asia. They belong to the Dioscorea genus that produces edible starchy storage tubers. Yams are the third most important tropical root crop in Africa after cassava and sweet potatoes, with Nigeria reported as the leading producer (Ferraro, Piccirillo, Tomlins & Pintado, 2016). Yams contribute to more than 200 daily dietary calories per capita for more than 150 million people in West Africa. Furthermore, they serve as an important source of income (Abiodun & Akinoso, 2014).

The International Institute of Tropical Agriculture (IITA, 2009) posited that yam as starchy staples in the form of large tubers produced by annual and perennial vines grown in Africa, the Americas, the Caribbean, South Pacific and Asia. Yam is a common name for plant from the genus of *Dioscorea.* A study by FAO (1990), reports that yam is the only root crop that the Asian and African species developed independently from each other. This was due to the influence of the Portuguese explorers, who learned of the value of the *Dioscorea alata* from the Indian sealers, because of its storage and antiscorbutic properties.

The African species are the *Dioscorea rotundata* also known as the "white yam", and the *Dioscorea cayenensis* which is also known as "yellow yam". White yam is very important and dormant especially in the forest zone. The second most cultivated specie is the *Dioscorea alata* which is of Asia origin. It is also known as the "water yam" and it is widely distributed in the world (IITA, 2009). In 2007, worldwide estimated production of yam amounted to 52 million tonnes, of which Africa produced 96%. Most of the production came from West Africa, representing 94% (IITA, 2009). The Food and Agriculture Organisation (2012) ranks Ghana as second to Nigeria in the production of yam with a production of 6,638,867 tonnes.

A 100g 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 glycemic index (Harvard Health Publications, 2008). Yam contains good levels of potassium, manganese, thiamine, while being low in saturated fat and sodium (Uwaegbute, Osho & Obatolu, 1998 as cited in Alabi & Anuonye, 2007). 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 and contains small amount of protein and vitamin A (Carr & Maggini, 2017). 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 pounded into “fufu”. 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 matured yam.

Figure 1: Freshly harvested matured yam tubers

Classification of Cassava

Cassava (Manihot esculenta) is a major food crop in the humid and sub-humid parts of Africa and a major source of dietary energy for millions of people in these regions (Asiedu, et al, 1992). World production of cassava was 160 million tonnes of fresh roots, with 80 million tonnes produced in Africa, out of which 34 million tonnes is coming from Nigeria (FAO, 1994). Nigeria is the largest producer of cassava in the world going by this estimate. In nutritional terms, cassava is essentially a carbohydrate food with about 75-83% and less than 2% protein (Cock, 1985; Ukpabi & Dafe, 1999).

Cassava is emerging as a dominant staple of primary or secondary importance in many developing countries of the humid and sub-humid tropics in Africa and elsewhere. In Nigeria, it is the most important root crop in terms of food security, employment creation, and income generation for crop producing households (Ugwu & Ukpabi, 2002). In Nigeria, farmers earned more income from cassava production compared to most other major staples (Ugwu, 1996) and more than 85% of total cassava produced in Nigeria is processed into different products including gari, flour, fermented paste, starch or abacha, among others.

Cassava (*Manihotesculenta* crantz) was introduced from Brazil, where it was originated to the tropical areas of Africa, by the Portuguese during the 16th and 17th centuries. In Ghana, the crop was planted by the Portuguese around their trading ports, forts and castles and it was a major food eaten by both Portuguese and slaves. During the second half of the 18th century, cassava became the most commonly grown and used crop of the people of the coastal plains. The Akan name for cassava is 'Bankye' which perhaps maybe a deduction from 'Abankye' - Gift from the Castle (Korang-Amoakoh, Cudjoe & Adams, 1987). Cassava is regarded as one of the most essential crops grown in the tropics and a principal carbohydrate staple. It is ranked the third most important food source of calories in the tropics after cereal crops according to FAO (2008).

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 (FAO Food Outlook, 2009). The starch content in the root differs according to varieties and contains the highest amount of starch (Nanda, Sajeev, Sheriff & Hermasankari, 2005). Cassava ranks 6^{th} 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 (Heuberger, 2005). It is very low in fats and protein compared to cereals and pulses. Nonetheless, it has more protein than that of other tropical food sources like yam, potato, plantain etc. (Nutrition and You, 2016).

According to Ebuehi, Babalola and Ahmed (2006) cassava also contains anti-nutrients, such as phytate, fibre, nitrate, polyphenols, oxalate, and saponins that can reduce nutrient bioavailability. Cassava is a perishable commodity with a shelf life of less than 3 days after harvest. Processing provides a means of producing shelf stable products (thereby reducing losses), adding value at a local rural level and reducing the bulk to be marketed (Phillips, Taylor, Sanni & Akoroda, 2004). Cassava when processed can be made into a number 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 100g of raw cassava contains 38g carbohydrate, 1.8g fibre and 1.7g 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 (United States Department of Agriculture, 2002). Below is a picture of fresh and matured harvested cassava tubers.

Figure 2: Freshly harvested matured cassava tubers

Classification of Plantain

Plantain belongs to the Musacace family and is cultivated in many tropics and subtropical countries of the world. It ranks third after yams and cassava for sustainability in Nigeria (Akomolafe & Aborisade, 2007). Plantain (*Musa Paradisiaca*) is a rhizomatous perennial crop used as a source of starchy staple for millions of people in Nigeria (Adeniyi, Sanni, Barimalaa & Hart, 2006). Mature plantain pulp is very rich in iron, potassium, vitamin A and ascorbic acid but low in protein (Adegboyega, 2006). The proximate content, functional characteristics and properties of starch of ripe and unripe plantains have been evaluated (Izunfuo & Omuaru, 2006; Osundahunsi, 2009). The processing, utilization and effect of storage have been reported (Niba, 2004; Onwuka & Onwuka, 2005).

Plantain (*Musa paradisiaca*) is a major source of carbohydrate in diets of people from Latin America, through most of Africa and from countries of South-east Asia (Marriott & Lancaster, 1983). It is estimated that 60 million people in West Africa obtain more than 25% of their carbohydrate intake from plantain (Oritz & Vuylsteke, 1996). In Ghana, they have a higher contribution to the Agricultural Gross Domestic Product (AGPD) than cereals (MOFA, 2006). According to Lescot (2000), plantain's per capita annual consumption is higher than maize and yam. Plantains serve as important 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 (Ahiekpor, 1996; Hemeng & Bandful, 1996). The local names of the sub varieties of French Horn plantain include 'Apempa', 'Oniaba' and

‘Nyeretiaapem’. Sub varieties of the False Horn plantain include ‘Borodewuo’, ‘Apantu pa’, ‘Borodesebo’ and ‘Osoboaso’ while the True Horn sub varieties comprise ‘Asamienu’ and ‘Aowin’. In Ghana the variety that is mostly used in making fufu is the 'Apantu pa'. Raw unprocessed plantain contains 32g of carbohydrate, 15g sugar and 2.3g fibre per 100g (United States Department of Agriculture, 2002).

Plantains unlike banana are often processed before eating. They are boiled, 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 high fiber content, and thus is capable of lowering blood cholesterol levels, helps to relieve constipation and hence prevents colon cancer. Besides this, its low glycemic index makes it the desirable carbohydrate staple that is mostly recommended for diabetics. Its potassium content is found to be useful in the prevention of raising blood pressure and muscle cramps (Ng & Fong, 2000).

Plantain is known to be low in sodium (Chandler, 1995). It contains very little fat and no cholesterol; therefore, it is useful in managing patients with high blood pressure and heart diseases. Plantain is however a seasonal and highly perishable crop. Ogazi (1996) reports that over 80% of the crop is harvested during the period of September to February, and that there is much wastage during this period as some of the harvested produce cannot be stored for a long period. This results in seasonal unavailability and limitations on the use by urban populations. Below is a picture of fresh fingers of plantain.

Figure 3: Fresh fingers of plantain

Classification of Carbohydrate

Carbohydrates are a group of organic compounds containing a ratio of one carbon atom to two hydrogen atoms to one oxygen atom. Carbohydrates compounds are made up of monosaccharide building units, and ranges from simple monosaccharide, disaccharides, and oligosaccharides to the more complex forms such as starch and non-starch polysaccharides (Wormenor, 2015). The classification of carbohydrate foods has been based on the structural conformation or degree of polymerization of the major carbohydrate that is present (FAO & WHO, 1998). Subsequently, the convention has been to classify carbohydrate food sources as "simple" if it contains mostly mono or disaccharides, and "complex" carbohydrates if it contains polysaccharides or starches. The complex carbohydrate idea was first introduced in a report by the US Senate Select Committee on Nutrition and Human needs in 1977 to denote various fruits, whole grains and vegetables (Stylianopoulos, 2005).

These classifications are, however, based on the chemistry of the carbohydrates and do not necessarily reflect their specific physiological properties, nutritional or health effects (Cummings & Stephen, 2007). The chemical classification of carbohydrate into simple and complex, started the fallacious assumptions that all simple carbohydrate would cause a rapid glucose response in the body whereas the complex carbohydrate rather stimulates a slower glucose response. This idea influenced the preference of complex carbohydrate by people with various insulin disorders, as well as glucose intolerance.

Carbohydrate foods contain important micro nutrients necessary for healthy living, and have also been found to play an important role in the maintenance of gastrointestinal health and glycemic homeostasis (Stylianopoulos, 2005). Studies by Conn and Newburgh (1939) showed how different carbohydrates with comparable micronutrient content yielded different glycemic responses. In 1980, Otto and Niklas cited in Wolever, (1991) pioneered the systemic classification of foods according to their glycemic responses.

Jenkins, et al (1981), reported that the carbohydrate exchange list that had been used over the years for controlling diabetes was not a true reflection of the actual physiologic effect of the foods consumed. It was also observed that the health effects of carbohydrate can be better described with their physiological properties (such as its ability to raise blood glucose). The physiological properties are also influenced by the constituent monosaccharide units and physical conformation which enclaves' particle size and extent of hydration (Augustin, *et al.*, 2002).

The importance of carbohydrates to health and yet the complexity associated with its classification informed the need for a simple index based on the glycemic effect of foods, to complement information provided in food tables derived from calculations using their chemical composition (Wolever, 1991). The Glycemic index was thus developed. Glycemic index is an empirical system of classification that measures how glucose rises in the blood after ingestion of a carbohydrate food. It is a measure of the quality of the carbohydrate and not the quantity ingested (Mendosa, 2009).

Dietary carbohydrate

Carbohydrates are the main energy source in most human diets, making up about 40 – 80% of our calorie intake. They are a primary fuel source for body cells especially red blood cells and cells of the central nervous system (Keim, 2006). Carbohydrates also provide muscle cells with the required energy during very intense physical activity. In the blood, carbohydrates are readily available as simple sugar (glucose) whilst available as glycogen (the storage form) in the liver and muscle (Carol, Gaile, Donna & Jacqueline, 2013).

Carbohydrates contribute massively on nature and human physiology and their complexity makes their classification also challenging (Mann, et al, 2007). Dietary carbohydrates are carbohydrate present in food, including sugar, starches, cellulose and gums. Carbohydrate serves as a major energy source of human diets. Classification of dietary carbohydrate involves a systematic approach that includes their functional, chemical and physiological properties (Englyst, Liu & Englyst, 2007).

The Joint FAO and WHO expert consultation committee on carbohydrates in human nutrition, defined carbohydrates principally as carbon compounds with ketones or aldehydes functional groups and can be found in their acid and alcohol forms as well as other derivatives (FAO & WHO, 1998).

They also added that carbohydrates can be grouped into a number of classes and sub-classes depending on their molecular size or structural composition. All starches contain amylose and amylopectin but in different ratios depending on the particular carbohydrate. For the same carbohydrate food item, the amylose/amylopectin ratios even differ with variety. Digestibility is greatly influenced by the ratio of amylose to amylopectin which is a more branched glucose chain (Wormenor, 2015). A typical representation of the various carbohydrate groups is shown in Table 1.

Table 1: The Major Dietary Carbohydrate classifications

Classification	Sub group	Components
Sugars (1-2 monosaccharide units)	Monosaccharides	Glucose, Galactose, Fructose
	Disaccharides	Maltose, Lactose, Sucrose
	Sugar Alcohols	Mannitol, Sorbitol
Oligosaccharides (3-9 monosaccharide units)	Malto-Oligosaccharides	Maltodextrins
	Other Oligosaccharides	Raffinose, stachyose, fructo-oligosaccharides
Polysaccharides (>9 monosaccharide units)	Starches	Amylose, amylopectin, modified starches
	Non-starch polysaccharides	Cellulose, hemicellulose, pectins, hydrocolloids

Source: (FAO/WHO, 1998)

Total carbohydrate

Total carbohydrates include all types of carbohydrate found in the food or beverage. Total carbohydrates consist of multiple nutrients, including dietary fibre, sugars and starches. According to a study by FAO and WHO (1998), total carbohydrate can be defined on two major principles: firstly, by direct measurement of all the components that form carbohydrates, and secondly the "difference" which is by subtracting the sum of ash, fat, protein, and moisture content from the total weight of the food. They however concluded that there are a number of problems with this approach to total carbohydrate analysis by the use of the "difference" concept in that the "by difference" figure includes a number of non-carbohydrate components such as lignin, organic acids, tannins, waxes, and some maillard products. In addition to this error, it combines all of the analytical errors from the other analyses.

Intake of total carbohydrate has been suggested to be from 55% to 70% of total energy. This was made by WHO (1990) in the recommended population nutrient intake goals, for the prevention of diet-related chronic diseases. This range was built on the remaining 10-15% protein energy and 15-30% fat energy. A similar recommendation has been made by the joint FAO and WHO (1998) expert consultation on carbohydrate. An optimum diet for all ages (except for children under the age of two) should consist of at least 55% of total energy from a variety of carbohydrate sources. FAO/WHO highlighted that the minimal amount of carbohydrate in the human diet that is needed to avoid ketosis is 50 g/day in adults.

Sugars

The term "sugar" is usually used to describe the mono and disaccharides. Sugar by contrast, is used to describe purified sucrose, just as the terms "refined" or "added sugar". The Department of Health (1989) classifies sugars as "intrinsic" and "extrinsic". These terms were established when they examined the role of sugar in diets. The terms were developed to distinguished sugar as naturally incorporated into the cellular structure of a food (intrinsic), from those that are free or added to the food (extrinsic). According to the report these are the definitions:

Intrinsic sugar

Sugars forming an integral part of certain unprocessed foodstuffs, that is enclosed in the cell, the most important being whole fruits and vegetables (containing mainly fructose, glucose and sucrose). Intrinsic sugars are therefore naturally occurring and are always accompanied by other nutrients (The Department of Health, 1989).

Extrinsic sugar

Sugars not located within the cellular structure of a food. Extrinsic sugars are mainly found in fruit juice and are those added to processed foods, as well as those sugars added to foods as a sweetener in cooking or at the table, as in hot drinks and breakfast cereal. Lactose in milk is also extrinsic in that it is not found within the cellular structure of food and has important nutritional benefits (The Department of Health, 1989).

Starch

Starch is the principal carbohydrate in most diets. It is stored in plants such as cereals, root, vegetable and legumes, and consist of only two glucose molecules. It is made up of two polymers: amylose and amylopectin. The amylopectin starches are digested more rapidly, presumably because of the more effective enzymatic attack of the more open-branched structure. High amylose starches require high temperature for gelatinization and are more prone to retrograde and to form amylose-lipid complexes (Cummings & Stephen, 2007). In their study, Cummings and Stephen reported that starches can also be modified chemically to impart functional properties needed to yield certain qualities in foodstuff such as decreased viscosity and improved gel stability, mouth feel, appearance and texture, and resistance to heat treatment.

Carbohydrate Preparation

Most Ghanaian carbohydrates (such as corn, rice, cassava, yam, and plantain) are subjected to quite a number of processing techniques during preparation for consumption. The processing of a particular carbohydrate food plays an important role in determining its overall properties (Englyst, Liu & Englyst, 2007) which also has a significant influence on physiological function in the human body. Glycemic index value is also directly influenced when the physiological effect of a carbohydrate is altered (Bahado-Singh, Riley, Wheatly & Lowe, 2011).

Generally, and for most foods, boiling is considered to increase GI due to increased gelatinization which improves starch digestibility and increased glucose response (Lin, Wu, Lu & Lin, 2010; Bahado-Singh *et al.*, 2011). For instance, the high GI obtained with *banku* which was low in fiber and had larger 50 g available carbohydrate portion. Also *banku* is prepared from corn dough and a small amount (20%) of cassava dough. The cassava could have influenced GI obtained. Cassava has a higher amylopectin to amylose ratio (United States Department of Agriculture, 2002). Amylopectin is more branched and more susceptible to digestive amylases and would thus increase glucose response (Arvidsson-Lenner *et al.*, 2004).

Insulin and metabolic processes

Insulin is a hormone secreted by the beta cells in the islet of Langerhans of the pancreas. It plays a major role in the metabolic processes of the body by controlling the storage and metabolism of the ingested metabolic energy. When insulin production ceases, the metabolism of carbohydrates in most tissues of the body becomes considerably depressed (Brunner & Suddath, 1980). Following a meal, the secretion of insulin facilitates the uptake, utilisation and storage of glucose, amino acids and fat. It promotes the storage of glucose in the liver and utilisation of glucose in the muscles and storage of fat in the adipose tissue by enhancing the transport of glucose across the cell membrane (Brunner & Suddath).

Insulin regulates the level of blood glucose which is formed from the ingested carbohydrates and from the conversion of amino acid to glucose by the liver (gluconeogenesis). Lack of insulin prevents insulin-sensitive cells from using glucose as a source of energy. Without insulin, the body enters into serious state of catabolism, glucose builds up in the body and hyperglycaemia results. Hyperglycaemia causes a series of fluid and electrolyte imbalances ultimately resulting in polyuria (excessive volume of urine), polydipsia (persistent thirst) and polyphagia (increased appetite). These are classic signs and symptoms of diabetes. Although diabetes may occur at any age, its prevalence rises dramatically in older populations from less than 2 cases per 1000 children to almost 200 in their sixties (Davidson, Passmore, Brock & Truswell, 1975).

Atherosclerosis is a leading complication of diabetes mellitus making coronary heart disease and cerebral vascular disease major causes of morbidity and mortality in diabetic patients. Davidson et al reported three methods of treatment and each involves an obligation for the patients to adhere to dietary regimen for the rest of their lives. These methods are dietary treatment, the use of diet and insulin and diet and hypoglycaemic drugs.

Classification of glucose tolerance status

According to the World Health Organization definition (Jia, et al, 2019, Alberti & Zimmet, 1998, WHO/IDF consultation, 2006), normal glucose tolerance (NGT) was defined as FPG < 6.1 mmol/L and 2-h plasma glucose < 7.8 mmol/L. Pre-diabetes was defined as having impaired fasting glucose (IFG) (Fasting Plasma Glucose (FPG): 6.1–6.9 mmol/L) and/or IGT (2-h plasma glucose: 7.8–11.0 mmol/L). Diabetes was defined as having FPG ≥7.0 mmol/l and/or 2-h plasma glucose ≥11.1 mmol/L.

Classification of glucose curve shapes

The shapes were classified in line with previous studies (Matthews, et al, 1985). A monophasic response curve was determined by a gradual increase in glucose concentrations until a peak was reached, followed by a subsequent decrease in glucose of ≥0.25 mmol/L. A biphasic response curve was defined by the second rise in glucose concentrations of ≥0.25 mmol/L. A triphasic response curve was defined by two complete peaks of the plasma glucose curve, with every rise and decrease in glucose concentrations of ≥0.25 mmol/L. The latter two were collectively called multiphasic response curve. This was done with a plasma glucose threshold of 0.25 mmol/L to minimize fluctuations in glucose concentrations, which may be caused by the method of glucose analysis rather than by physiological reasons.

Blood glucose response curves

Blood glucose response curves are generated by blood glucose readings versus time increments as seen below in Figure 4. When calculating GI, the incremental area under the blood glucose response curve (iAUC) for the test food is divided by the incremental area under the blood glucose response curve for the reference food. The result then, is multiplied by 100. The incremental area under the blood glucose curve is calculated for each blood glucose response curve geometrically by the trapezoid rule, disregarding the area below the baseline. The basic equation derived by Wolever *et al*., (1991) is

$$iAUC = (A + B + C + D/2)t + \frac{D^2}{2} t(D + |e|)$$

In view of now rule in dealing with outliers in the data, Wolever *et al.* (1991) proposed that if a test result is greater than two standard deviations from the mean, further testing can be done to replace the outlier given these tests prove more representative. Sample blood glucose time graph prosed by the University of Sydney is shown figure 4.

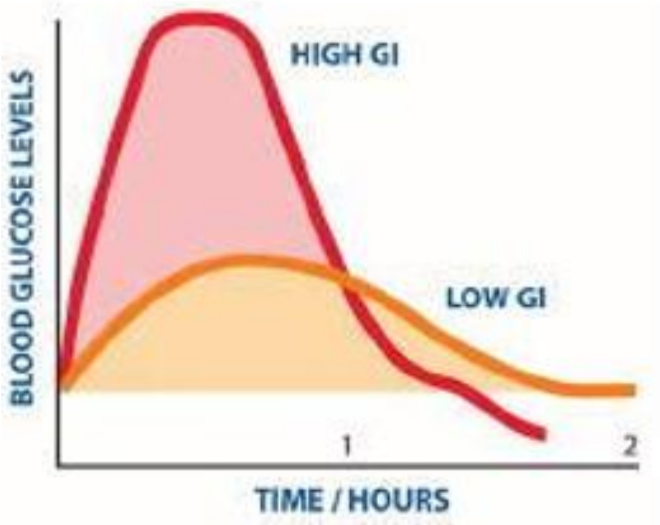

Figure 4: Blood Glucose Time Graph

Source: University of Sydney, 2012

The GI has also been considered in the food industry when developing new products. Kraft Foods Inc. currently has a patent pending in vitro method of quickly predicting the GI of foods. Kraft intends on using this as a screening tool for products, but not for labelling purposes (Nutraceuticals World, 2010).

Another company who has done substantial work on GI is Kellogg's company. Kellogg's Australia has a page on their website dedicated to GI information and classification of their products (Kellogg, 2010).

Dietary fibre

The original description of dietary fibre was made by Trowell in 1976. He described dietary fibre as that portion of food which is derived from cellular walls of plants which is digested very poorly by human beings. Report of the Dietary Fibre Definition Committee to the Board of Directors of the American Association of Cereal Chemist (AACC, 2001) also describes Dietary Fibre as the edible parts of plants or analogous carbohydrates that are resistant to digestion and absorption in the human small intestine with complete or partial fermentation in the large intestine. Dietary fibre constitutes the cell wall of plant material, cellulose, hemicellulose and pectin. Lignin, a non-carbohydrate component of the cell wall is also often included. Dietary fibre can be divided into two types: the soluble and the insoluble fibre.

1. Soluble fibre absorbs water to form a gel-like substance and swells. It has major effects on glucose and lipid absorption in the small intestines.
2. Insoluble fibre does not absorb water. It passes through the digestive system in its original form. They are slowly and incompletely fermented and has a profound effect on bowel habit.

Dietary fibre is important in our diets because they slow the absorption of glucose into the blood stream which help to prevent glucose and insulin spikes. They also help lower cholesterol and reduce the occurrence of hemorrhoids and constipation. Mann, et al (2004) confirms this in their study where they concluded that certain fibre-rich foods affect glycemic control and lipid levels and have been extensively used in the management of diabetes particularly the legumes and pulses rather than high bran products.

Available carbohydrate

A foremost step to understanding the concept of carbohydrate was primarily made by McCance & Lawrence (1929) as cited in FAO (1998) who divided dietary carbohydrate into available and unavailable. It was in an attempt to prepare food table for diabetic that they comprehended that not all carbohydrate could be utilized and metabolized. The Food and Agriculture Organisation (FAO) definition of available carbohydrate as cited in Brouns et al, (2005) is basically soluble sugars and starch in total carbohydrate minus dietary fibre. This definition is what is presently commonly applied in countries. Available carbohydrate is the part of the carbohydrate that is digested to provide the sugar that is metabolised for energy.

The portion of the carbohydrate considered "unavailable" (hemicellulose and true cellulose) passes into the large intestines and fermented to produce energy for the body (Wormenor, 2015). FAO (1998) suggested that digestible carbohydrate should be described as glycemic whereas the indigestible carbohydrate should be described as non-glycemic. FAO (1998) suggested this based on the concept of McCance and Lawrence (1929).

Describing available carbohydrate is vital in understanding the part of carbohydrate which is measured in the determination of the Glycemic Index of a food. This is because GI measures the glycemic response of subjects to 50g available carbohydrate comparative to 50g pure glucose or 50g available carbohydrate in a given portion of white bread.

Unavailable Carbohydrate

The size of carbohydrate that escapes digestion and metabolism in the small intestines and passes through the large intestine to ferment and produce energy is referred to as unavailable carbohydrates. It consists of true cellulose, hemi-cellulose and lignin. Available carbohydrates can be referred to as digestible carbohydrates whiles unavailable carbohydrates can also be referred to as indigestible carbohydrates. It is thus appropriate to describe the digestible carbohydrates as glycemic and the indigestible ones as non-glycemic carbohydrates (FAO/WHO, 1998).

Roles of carbohydrate in the body

Carbohydrates are an essential source of energy in human diets comprising of about 40 – 80% of total energy intake.

1. The principal role of carbohydrate in the body is to provide the body with energy. FAO (1998) indicated several reasons why it is desirable that carbohydrate should be the main source of energy. It was explained that, in addition to providing readily available energy for oxidative metabolism, carbohydrate-containing foods are vehicles for important micronutrients and phytochemicals.
2. Another important role of carbohydrate (sugars and starches) is to deliver energy to the brain which is the only carbohydrate-dependent organ in the body (Hermann, 2019).
3. Dietary carbohydrate is important to maintain glycemic homeostasis and for gastrointestinal integrity and function (Keim, 2006).

4. Unlike fat and protein, high levels of dietary carbohydrate, provided it is obtained from a variety of sources, is not associated with adverse health effects (Keim, 2006).
5. Finally, diets high in carbohydrate as compared to those high in fat, reduce the likelihood of developing obesity and its co-morbid conditions (Keim, 2006).

Carbohydrate digestion

Digestion and absorption are vital components in the characterization and functional classification of carbohydrates. Mann, et al (2007) indicated that to define the functionality of carbohydrates in metabolism, there is the need to understand the site, extent and rate of digestion and absorption from the gastrointestinal tract. The digestion of carbohydrate begins in the mouth where salivary amylase act on the amylose and amylopectin in the food. How well a food is chewed in the mouth before swallowing could affect the rate of digestion in the stomach and small intestines.

Chewing would increase the surface area for enzyme activity and thus increase the rate of digestion and absorption (Wormenor, 2015). The food (chyme) then passes through the stomach into the small intestines. No digestion takes place in the stomach. In the small intestines, the pancreas releases the pancreatic amylase which breaks polysaccharide to disaccharide. The enzymes lactase, sucrose and maltase is then released to further break down the disaccharide into monosaccharides; the simplest form of carbohydrate.

The end product of the digestion of carbohydrate is glucose, which is then absorbed. Absorption takes place in the gastrointestinal tract with the help of certain fluids and enzymes (Kaiser, 2016). Some carbohydrates and other food substances like fibre may escape digestion into the large intestines where they could undergo fermentation into gases.

Glycemic Response of local foods

Glycemic response of local foods especially those that have been determined help in several aspect of life. Knowing glycemic response of local foods has been on the search mostly in Africa since the local foods are of more starch base. Glycemic responses to eight Nigerian foods have been determined which includes roasted yam, boiled cocoyam, boiled yam, and boiled unripe plantain were found to have high glycemic responses (Oli, Ikeakor & Onwuameze, 1982).

The study of Oli *et al* further revealed that boiled beans had a low glycemic response, while "eba" (cassava flour) and rice had intermediate responses (Oli, *et al*). Ohwovoriole and Johnson (1983) reported the glycemic responses to five Nigerian meals and found high glycemic responses to rice, yam, and "dodo" (fried ripe plantain), intermediate response to "eba," and low glycemic response to beans.

In a similar study to determine the glycemic responses of other local foods, Balogun (1992) also reported high glycemic responses to boiled yam, rice, "amala" (yam flour); "eba" had an intermediate response while beans and the rice/bean mixture had low glycemic responses. In determining glycemic indices of processed unripe plantain (Musa paradisiaca) meals in Nigeria, the result indicated that the Glycemic Indices (GI) of boiled plantain (Bp), fried plantain (Fp), roasted plantain (Rp), boiled and pounded plantain (BPp) and plantain flour (Pf) did not show any differences at ($p < 0.05$). However, roasted plantain gave the lowest glycemic index and the value was significantly lower than the other test foods. The processed plantain meal elicits low postprandial rise of blood glucose (Ayodele & Godwin, 2010).

Glycemic Load and Health

The glycemic load concept has widely been associated with various Non-Communicable Diseases (NCDs) by several studies (Ludwig, 2000; Willett, Manson, & Liu, 2002; Bells & Sears, 2003; Mirrahimi, et al 2012; Wang, et al 2013; Goff, et al, 2013). 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 increase risk of certain chronic diseases whiles low GL diets are seen to reduce the risk of acquiring these diseases.

Glycemic load and diabetes

In a collection of studies, both the glycemic index and the glycemic load of the total diet have been associated with a greater risk of type 2 diabetes in both men and women (Barclay, et al, 2008; Sluijs, et al, 2010). Diabetes represents a group of metabolic disorders, categorized by hyperglycemia (high blood glucose) or hypoglycaemia (low blood glucose) as well as glucose intolerances (Wang *et al*., 2013). Hyperglycemia has been associated with loss of pancreatic β cell function that can result in glucose intolerance and eventually an irreversible state of diabetes (Willett, *et al*., 2002).

So far as 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 (ADA, 2001). 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 glycemic load food would increase the risk of type 2 diabetes, Willet et al (2002) reports that 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.

Similarly, Riccardi, Rivellese & Giacco (2008) reports that increasing the consumption of low-GL and fibre-rich foods, possibly improves blood glucose control as well as reducing the incidence of hypoglycemic events. Several works by Roberts, (2000) and Gulliford *et al* (1989) have shown that glycemic of CHO leads to hunger and CHO craving (Slyper, 2004) demonstrated increased satiety, delayed return of hunger, and decreased food intake, after ingestion of low-GI compared to high-GI foods.

Glycemic load and coronary heart diseases

Mathers, Boerma and Ma Fat (2009) reports that coronary heart diseases (CHDs) have become the largest cause of deaths globally. Cholesterol has normally been associated with CHDs and as a result of that, Mirrahimi *et al* (2012) recommend 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 glycemic load increase the relative risk of CHDs (Mirrahimi et al., 2012; Fan, et al, 2012). A study by Mathews, Liebenberg and Mathews (2015), found that high GL diets can affect changes in lipid profile regardless of the cholesterol, protein or fat content. In a similar study by Tsimikas and Hall (2012) high GL diets were found to produce a decrease in HDL and increased in LDL.

Glycemic load and obesity

It has been observed by Hui and Bell (2003) that the prevalence of obesity has increased instead of lowering. This concern was 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 (Hui & Bell, 2003).

Studies have confirmed that consuming low GL diets reduce hunger and promote satiety (Brand-Miller, Holt, Pawlak & McMillan, 2002). 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 (Hui & Bell, 2003). This supports the assumption that GL of a food is significant in the management of obesity. A review of published researches done on the glycemic load and health is summarized in the table below.

Table 2: Summaries of studies on glycemic load and health

Author (s) and Year	Study Topic	Findings
Galani, Aguirre & Diaz (2006).	Acute effect of meal glycemic index and glycemic load on blood glucose and insulin response in human.	Glycemic load was found to be useful in predicting the acute impact on blood glucose and insulin responses within the context of mixed meals.
Ebbeling, Leidig, Sinclair, Seger-Shippee, Feldman & Ludwig (2005).	Effects of an ad libitum low-glycemic load diet on cardiovascular disease risk factors	An ad libitum low-glycemic load diet may be more efficacious than a conventional, energy-restricted, low-

Table 2 Continued

		fat diet in reducing cardiovascular disease risk.
Meinhold (2010)	Low glycemic load diets: how does the evidence for prevention of these diseases measure up?	There is increasing evidence that low-glycemic load diets could prevent diabetes, cardiovascular diseases, and some cancers, including endometrial cancer and oesophageal adenocarcinoma. In light of these findings, adherence to a low-glycemic load diet, provided it meets current dietary recommendations including those related to dietary fat content and portion control, seems prudent.
Beulens, de Bruijne, Stolk, Peeters, Bots, Grobbee, et al. (2007)	High dietary glycemic load and glycemic index increased risk of cardiovascular disease among middle-aged women.	Among women consuming modest glycemic load diets, high dietary glycemic load and glycemic index increase the risk of CVD, particularly for overweight women
Livesey, Taylor, Livesey& Liu (2013)	Is there a dose-response of dietary glycemic load to risk of type 2 diabetes?	People who consumed lower-glycemic load diets were at a lower

Table 2 Continued

		risk of developing type 2 diabetes than those who ate a diet of higher-glycemic load foods.
Mirrahimi, de Souza, Chiavaroli, Sievenpiper, Beyene, Hanley et al. (2012)	Associations of glycemic index and load with coronary heart disease events: a systematic review and meta-analysis of prospective cohorts	Higher-glycemic load diets are associated with an increased risk for coronary heart disease events

Definition and measurement

GI is defined as the blood glucose response measured as area under the curve (AUC) in response to a test food consumed by an individual under standard conditions expressed as a percentage of the AUC following consumption of a reference food consumed by the same person on a different day (FAO/WHO, 1998). The test food and reference food (usually 50 g glucose) must contain the same amount of available carbohydrate. It is important to standardize GI testing conditions, and the procedure for the measurement of GI is described in detail in the 1998 FAO/WHO report on carbohydrates in human nutrition (FAO/WHO). Hundreds of foods have been tested for GI with the aim of ranking foods within and between food categories. A GI classification system is in common use in which foods are categorized as having low (<55), medium (55–69) or high GI (>70) (Brand-Miller, Wolever, Foster-Powell & Colagiuri, 2003a).

Summary of Literature

From the literature review, there is evidence that numerous studies have been done earlier by researchers on how carbohydrate foods affect our blood glucose levels and our general wellbeing. It was revealed that, the traditional way of classifying carbohydrate as simple and complex has been ruled out that, they do not necessarily reflect their physiologic effect on the food consumed. That is the ability to raise blood glucose. As a result of this, the glycemic index concept was propounded (Jenkins, et al 1981).

The GI (which is the area under the glucose response curve after ingestion of 50g of carbohydrates of a test food expressed as a response percentage to the same amount of carbohydrate from a standard food, in the same individual), measures how quick or slow the rise in blood glucose levels occurs as a result of consuming a carbohydrate food item. A number of factors were seen to influence the glycemic response of a food that can affect its GI. Such factors include the nature and proportion of starch in the food, dietary fibre content on the food, fat and protein content, processing, effect of previous meal (FAO & WHO, 1998). Foods with values of 55 or less indicates a low GI, foods within 56-69 have a medium GI and those with values of 70 or more are considered high GI foods.

Nonetheless, other studies also brought up concerns that, the portion size of a food is a very vital factor to be taken into consideration for glucose management as well as weight management. This brought about the concept of glycemic load (Nazar, *et al*, 2016). The glycemic load (which is the product of a food's glycemic index and its total available carbohydrate content and dividing the total by 100), evaluates the impact of carbohydrate consumption and how much each gram of it affects blood glucose level. It measures the relative glycemic impact of a typical serving of a food. Foods considered low GL are foods with a value of 10 or less, values within 11-19 are classified medium and foods with 20 or more are considered high GL foods.

Both GI and GL has been proven to be associated with an increase or decrease risks of chronic NCDs (Wang et al., 2013; Willett, et al, 2002; Goff, *et al.,* 2013; Mirrahimi, *et al.,* 2012; Hui & Bell, 2003; Ludwig, 2000). Studies also showed that even though the main reason why people eat is to satisfy hunger, what one chooses to eat is not determined solely by physiological or nutritional needs.

This key point reviewed relevant information that was beneficial in this study. However, there seems to be a gap in literature that needs to be filled and this study has ensured that these gaps are addressed. It was discovered from the literature available that little work has been documented on determining the GI of Ghanaian local foods and no work seems to have been done on the glycemic load of our local foods. Also few studies seem to exist on portion and serving sizes of foods especially in Ghana.

CHAPTER THREE

RESEARCH METHODS

Introduction

This chapter presents the methods for the study. The methods include the research design, study area, study subjects, methods and materials, data collection procedure, how data collected was analyzed and interpreted and ethical consideration.

Research design

Research design describes the basic structure of a study, the nature of the hypothesis and the variables involved in the study (Bist, 2014). Babbie and Mouton (2002) also defined a research design as a plan or blueprint of how one intends conducting the research. It provides procedural outline for the conduct of any investigation. It thus reflects the plan that specifies how data relating to a given construct should be collected and analysed.

True experimental research design was used for this study. According to Amedahe (2009), an experimental study is where the researcher manipulates at least one independent variable, controls other relevant variables and observes or sees what will happen to the subjects as a result. It is the only type that can really test hypotheses about cause and effect relationship. Experimental design is the blue-print of the procedures that enable the researcher to test hypotheses by reaching valid conclusions about relationships between independent and dependent variables. Thus, it provides the researcher an opportunity for the comparison as required in the hypotheses of the experiment and enables him to make a meaningful interpretation of the results of the study.

Experimental research design is a basic, but efficient type of research. With experimental research groups, the people conducting the research have a very high level of control over their variables. By isolating and determining what they are looking for, they have a great advantage in finding accurate results. Since there is such a high level of control, and only one specific variable is being tested at a time, the results are much more relevant than some other forms of research. The main difficulty of experimental research design is, just like anything, errors can occur. This is especially true when it comes to research and experiments. Any form of error, whether systematic (error with the experiment) or random error (uncontrolled or unpredictable), or human errors such as revealing who the control group is, can all completely reduce the validity of the experiment. By having such deep control over the variables being tested, it is very possible that the data can be skewed or corrupted to fit whatever outcome the researcher needs. True experimental research design was deemed the most appropriate design for this study and was carried out to determine the glycemic load of boiled yam, cassava and plantain.

Study Area

The research was carried out in Abura a suburb of Cape Coast Metropolitan area in the Central Region of Ghana. Abura is located along the Pedu high way at the Eastern part of the Cape Coast North district. It is about three kilometres from the Pedu junction on the Accra-Takoradi highway. Abura is mostly comprised of different tribes but dominated by the Fantes (Ghana Population and Housing Census [GPHC], 2010). The community has different working class from different sectors of the Ghanaian economy. Trading is the dominant work of the people in the community. Cape Coast had a settlement population of 169,894 people in 2010 (Ghana Population and Housing Census, 2010).

Population

The total population of Abura community were 17,500 people in 2010 population census (Ghana Population and Housing Census, 2010). The target population for the study were adult from 18 years and above. The target population was 5,200. The population below 20 years and those above 60 years was not considered appropriate for the study per FAO/WHO (1998) regulation on determining glycemic index of foods.

Sampling procedure

Multi-stage sampling technique was used for the study. The multi-stage samplings were purposive and convenient sampling techniques. The convenient sampling technique was used for the study and in selecting of participants for the study. Convenience sampling also known as haphazard sampling or accidental sampling is a type of non-probability or non-random sampling where members of the target population that meet certain practical criteria, such as easy accessibility, geographical proximity, availability at a given time, or the willingness to participate are included for the purpose of the study (Dornyei, 2007).

Convenience samples are sometimes regarded as 'accidental samples' because elements may be selected in the sample simply as they just happen to be situated, spatially or administratively, near to where the researcher is conducting the data collection. Convenience sampling is also affordable, easy and the subjects are readily available (Battaglia, 2008). By adopting convenient sampling, the study had 10 people who were willing and ready to participate in the study process.

Convenience sampling was done by visiting home in Abura community and had briefing with residents about the research work and its criteria in selecting the participants. The names of adults without health issues and medication problems were listed from house to house. The people willing to take part in the study have been further screened to get a handful. Ten volunteers were finally picked to part take in the study.

The purposive sampling technique is the deliberate choice of a participant due to the qualities the participant possesses but it has vast array of inferential statistical. It is a non-random technique that does not need underlying theories or a set number of participants (Bernard, 2002). Purposive sampling was used to select only healthy people to participate in the study.

Study Participants

Based on the FAO/WHO (1998) recommendation of glycemic index determination, ten (10) healthy participants were willingly selected and used for the blood glucose level determination. According to Wolever, et al, (2003), Brouns, et al (2005), the use of ten subjects in the determination of glycemic index for a significant degree of precision is recommended. Thus, participants between the ages 20- 60 years who were not diabetic and not on any medication of any kind. In making sure the participants were not diabetic or have BMI not good for the study, medical doctor assisted me in doing the screening of the volunteered participants.

The participants were grouped together two days prior to the date of experiment for an orientation. During the orientation, the importance of undertaking such an experiment was made known to the participants. Again, they were informed of the importance of adhering to the rules of engagement in the experiment. Participants were also informed of a strict abstinence from smoking or drinking within the period of the study, as well as not engaging in any strenuous activity prior to the experiment.

Inclusion criteria of Participants

The following inclusion criteria were used:

- Normal or healthy subject with no history or complain of diabetes, CVDs or any illness or uneasiness through a thorough medical assessment.
- People within the age group between 20 - 60 years.
- People who were not morbidly obese and also with the normal BMI measure that is between 18.5 - 24.5 kg/m^2.
- People who are capable or willing to take the test meal.

Exclusion criteria of Participants

The following exclusion criteria were used:

- Subjects aged 20 - 60 years but have histories or complain of diabetes, metabolic disorders, or any illness or uneasiness through a thorough medical assessment.
- Obese individuals with or without diabetes since they have a problem with glucose metabolism.
- Subjects who for one reason or the other could not take any one of the test meals.
- Persons with any known cardiovascular disease to whom such a work might pose a health risk or stress to as well as individuals on medications that can interfere with results in any way.

Methods and materials

The consumable for the study were yam, cassava and plantain. The yam, cassava and plantain for the study were bought from market women in a local market in the Cape Coast Metropolis called Kotokuraba Market. The cost in purchasing yam, cassava and plantain were GHC 16.00, GHC 5.00 and GHC 16.00 respectively. The serving meal for boiled yam, boiled cassava and boiled plantain alongside with "palava" sauce weighed 210 g. The calculation for each quantity of boiled yam, boiled cassava and boiled plantain was based on a proximate analysis.

Proximate analysis

A quantity of 100g was taken from all three samples (boiled yam, cassava and plantain) and proximately analyzed. The following nutrients were determined.

Moisture content

An amount of 10g was taken from each of the samples and weighed into cleaned beakers. The boiled yam, cassava and plantain were oven-dried at a temperature of 105^{o}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 samples were determined after cooling. The percentage moisture content of the samples were determined using the formula below:

Moisture content (%) =

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

Ash content

Approximately 3g of the samples (boiled yam, cassava and plantain) were weighed into a pre- weighed empty crucible. The crucible containing the samples were placed in the oven at 100^{o}C for 24 hours. The crucible were removed from the oven and transferred to a furnace where the temperature was raised to 550^{o}C. The crucible was 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:

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

Protein content (Kjeldhal protein)

Protein content was determined by weighing 0.2g of the samples into different digestion flasks, followed by the addition of 4.5ml 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 100ml conical flask. Twenty (20) ml aliquot of the solution was pipetted into the distillation apparatus followed by 10ml of NaOH solution. Five (5) ml of boric acid was also pipetted into 50ml conical flask. Each conical flask containing the boric acid was successively placed under the funnel of the unit to collect 50ml of the distillate. The distillate turned from green to red wine using 1/140 MHCL. The percentage nitrogen in the sample was calculated using the formula below:

% N = (S – B) x M x 14.007 x 100 x 100/2

Weight of sample (mg)

Where

S = sample titre (ml)

B = blank titre (ml)

M = molarity of HCI

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

% protein = % N x 6.25, where 6.25 is the protein-nitrogen factor.

Fat content

Approximately 10g of the samples (boiled yam, cassava and plantain) were weighed into a 50 x 10mm Soxhlet extraction thimble. The sample was then transferred into a 50ml capacity Soxhlet extractor. A clean, dry 250ml round-bottom flask was placed under the Soxhlet extraction unit. Fifty (50) ml of petroleum ether was measured and poured into the Soxhlet extraction thimble that contained the sample and was extracted for 6 hours using a heating mantle. The round bottom flask was later removed and placed in an oven. The sample was left in the oven at 60^oC 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 sample was calculated as follows:

Fat content (%) = Weight of fat x 100

weight of sample

Fibre content

Fibre content was determined by weighing approximately 0.5g of the samples into separate pre-dried crucible. The crucible was inserted in the fibretec Hot Extraction Unit. Hundred (100) ml of concentrate H_2SO_4 (1.25%) solution was added to the sample and allowed to boil for 30 minutes exactly from the onset of boiling. After boiling, the sample in the crucibles was washed with hot distilled water followed by 100ml 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 crucible was later removed and dried at 105^{o}C overnight and weighed after cooling. The samples in the crucibles were ashed for about 3 hours at 500^{o}C, cooled in the desiccator and weighed. The percentage fibre content was calculated using the formula below;

Fibre content (%) = weight loss through ashing x 100

weight of oven – dry sample

Soluble carbohydrates content

Soluble carbohydrate content in the sample was determined using standard laboratory procedure as outlined in FAO (2008); and Page, Miller and Keeney (1982). Step one involved the extraction of material while step two involved colour development.

Extraction of materials

Approximately 0.01g of the samples were weighed into different 50ml conical flasks and 30ml of distilled water was then 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 solution poured into 50ml volumetric flask 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.

Colour development

Two (2) ml each of standard solution was pipetted into different sets of boiling tubes. Two (2) ml of the extract was also pipetted into another set of boiling tubes. Ten (10) ml of anthrone reagent was added to the boiling tubes containing the sample solutions and the blank and then mixed thoroughly in an ice bath. The boiled yam, cassava and plantain were placed in a beaker of boiling water, kept in a dark cupboard and boiled 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 was obtained by plotting absorbance against concentration for the standard solution. The glucose content (mg) in the samples was determined using the formula

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

Data Collection Procedure

For the proximate analysis, an introductory letter was obtained from the Department of Vocational and Technical Education, and a formal permission was sought from the research and teaching farm of the School of Agriculture, University of Cape Coast-Cape Coast (UCC). The copy of the permission letter could be found at Appendix C. The blood glucose test was carried out at the Abura medical laboratory. Prior to the test, ethical clearance was obtained from the University of Cape Coast for approval to carry out the test. The Institutional Review Board (IRB) letter for clearance is at Appendix D. All participants were made to undergo a 10-12 hour fast from the time of their last meal of the previous night to the morning of the test. Participants were told to report at Abura medical laboratory between 8:00 – 9:00 am on the day of the test. Participants' age, gender, weight (kg) and height (m) were taken and recorded.

Procedure for Anthropometry of Participants

The participants in the study have their anthropometric vitals taken on the first day of visiting the laboratory for the fasting blood glucose test. The height, weight and waist circumference were measured for each participant. The age of the participants was collected. In view of ethical consideration and privacy of the individuals, other participants were not allowed to know or see the anthropometric record of the other person.

Fasting Blood Glucose Test (FBGT)

The Fasting Blood Glucoe (FBG) of each participant was taken each day before administering the test. This was done by wiping the forth left finger of each participant with alcohol. Their fingers were then pricked with a lancet to draw a drop of capillary blood. The OneTouch Verio Flex glucometer with a strip inserted inside was used to collect the drop of blood to test for the FBS. The reliability of OneTouch Verio Flex glucometer is 95% of individual glucose test results falling within $\pm$15mg/dl (0.83mmol/litre) over the glucose range 20-600mg/dl (13.3 – 33.1 mmol/litre).

Oral Glucose Tolerant Test (OGTT)

Each participant was given a glucose solution prepared from 50g glucose and 200ml water to take within a period of five minutes. A timer was used to ensure that participants take the glucose solution within five minutes. An hour after drinking the glucose solution, a drop of capillary blood was taken from all the participants and tested for glucose. Samples were taken from participants at the 60th, 90th and 120th minutes as well and tested for the glucose concentration. The OGTT was done on Tuesdays every week at 8am prompt to ensure accuracy and precision.

Test foods

All the test foods weigh 210 g for each participant. The first test food sample (boiled yam and palava sauce) was given five days after the second OGTT. The night before the test, participants were made to fast within 10 - 12 hours and their FBS were taken. Participants' time spent for eating was recorded. After eating, drops of capillary blood were taken from participants at the 60^{th}, 90^{th} and 120^{th} minutes to test for glucose. This was done by wiping participants' finger tips with alcohol. A glucometer with a strip inserted was used to collect the drop of blood and results were recorded in mmol/L. The same process was followed on later days for the other food samples. Participants were monitored throughout the test so that they do not take in any other food or participate in any active activities. They were also advised to stay away from alcohol and smoking until the duration of the test was over.

Ethical Consideration

Ethical clearance was sought from the Institutional Review Board (IRB) of the University of Cape Coast before collecting data for the study (See Appendix D for detail). Again, informed consent was sought from participants for their willingness to partake in the study. Participants were not compelled in any way to participate in the study. Issues regarding confidentiality, anonymity and privacy were given a priority in this study. Once approval was obtained from the IRB of UCC, all potential study participants were individually approached to seek for their consent to voluntarily participate in the study.

The consenting process involved explaining the purpose of the study, confidentiality procedures, risks, benefits and the freedom to opt out of the study at any time without any penalty. After the study had been thoroughly explained to the prospective participants, they were recruited to participate in the study after they gave their consent by signing an informed consent form. To ensure participant's data confidentiality, they were identified with identity numbers.

Most importantly on the ethical issues of the study, pieces of information that were cited from earlier studies to support the review of related literature was duly acknowledged through both citation and referencing in order to avoid academic dishonesty otherwise known as plagiarism.

Data Processing and Analysis

Calculations from the nutrient analysis were done using standard equations as outlined by experts in the area (FAO, 2008; Page, Miller & Keeney, 1982). Descriptive statistics was also used in the analysis and interpretation of the data. The anthropometric data was analysed by using statistical tools like percentile, median, mean, standard deviation and coefficient of variance. Nutrient determinations were done in triplicate and the averages of the glycemic responses were used to draw a blood glucose curve for a 2-hour period.

The blood glucose concentration against time was plotted on a graph (x-axis for time and the y-axis for glucose concentration). The IAUC of the test foods was calculated separately for each participant by using the trapezoid rule, to show the rise in glycemic 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 reference food, multiplied by 100. The formula below was used:

GI (%) = (IAUC test food/ IAUC reference food) x 100

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

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

The IAUC and GL were calculated using Excel 2016. The data was presented as means and standard deviations. The research objectives were analysed using statistical tools with the aid of IBM-SPSS version 21 for Windows. The statistical tools (means and standard deviations) were used to determine the glycemic load of boiled yam, cassava and plantain. The research hypothesis was tested by using One-way Analysis of Variance (ANOVA) at 0.05 level of significance ($p<0.05$).

CHAPTER FOUR

RESULTS AND DISCUSSION

Introduction

This chapter presents the results from the field on the demographic information, general anthropometric characteristics of respondents, glycemic load of boiled cassava, yam and plantain. The glycemic response graph of the reference food and the test foods is presented. Incremental area under the curve of the reference and test foods and glycemic index of test foods is also presented in this chapter. Others include the proximate analysis of the boiled cassava, yam and plantain which are presented on bar graphs. The results and discussion are presented based on the objectives and the hypothesis guiding the study.

Demographical information of Participants

The demographical information of the participants in the study is presented in Table 3 for discussion.

Table 3: Demographical information of Participants

Variable	Frequency (N)	Percentage (%)
Gender		
Male	5	50.0
Female	5	50.0
Age (years)		
20 – 30	6	60.0
31 – 40	4	40.0

Source: Field data, Asante (2018).

The participants that took part in the study were five males and five females. Most of the participants (60%) were in the age range of 20 to 30 years and 40% were in the age range of 31 – 40 years. The participants were in their active and productive years. These groups of people use a lot of energy in doing their works. This implies that a lot of energy is needed for their day to day activities.

General Anthropometric characteristics of Participants

The general anthropometric characteristics of the participants with regard to the measurements of their height, weight, body mass indexes (BMIs) and waist circumference is presented in Table 4 for a detail analysis.

Table 4: General Anthropometric characteristics of Participants

Statistic	Height (cm)	Weight (kg)	Age (years)	BMI (kg/m^2)	Waist circumference (inch)
Minimum	145.94	57.00	25	19.79	30.00
25% Percentile	154.94	58.38	25	22.46	31.75
Median	173.99	64.50	25	23.60	34.50
75% Percentile	173.99	64.50	35.50	22.46	31.75
Maximum	177.80	78.00	36	25.00	37.00
Mean	167.25	65.95	29.20	23.31	33.80
Std. Deviation	12.03	8.27	5.42	1.56	2.25
Std. Error	3.80	0.17	1.72	0.49	0.71
Coefficient of variation	1	0.15	0.23	0.08	0.08

Source: Field data, Asante (2018).

The result in Table 4 indicated that the height and weight of the participants are normal since their BMI figure ranges from 19.79 – 25.0Kg/m^2.

According to WHO (2006) classification, the BMI of an adult must be in the range of 18.5 Kg/m^2– 24.5 Kg/m^2 to be described as being healthy or normal and figures below or above the recommended range is described as underweight or overweight respectively. Per the results in Table 4 with regard to BMI, it can therefore, be concluded that all the ten participants that took part in the study were all normal.

In considering the age of the participants, their mean age was around 29 years. The mean and standard deviation of the age were 29.20 and 5.42 respectively. The median age of the participants was 25. This was an indication that the participants in the study were all around the same age range. The participants were neither too young nor too old. The waist circumference of the participants was also taken and the results were also within the healthy adults' category of calculated waist circumference (33.80 inch), as indicated in the study of Bhahd (2016).

Assessment of the average fasting blood glucose (FBG) level for both reference and test foods is a means to determine if an individual or group of individuals is diabetic or not (Niedziocha, 2011). In the present study, the WHO (2006) criteria for determining healthy participant in terms of diabetic or otherwise were used in selecting the participants for the study. The glycemic response to boiled cassava, yam and plantain were used to draw glucose time graph (Figure 4) and the graph indicated that all the participants were normal and not diabetics. Using healthy people was important because it made it easier for participants to show intermediate intra-individual variation in the results. This finding is similar to what was reported by Wolever, et al, (1985) (as cited in Wormenor, 2015). They looked at the "Prediction of the relative blood glucose response of mixed meals using the glycemic index of white bread". Brouns, et al (2005) reported that to obtain precise results using the "Glycemic index methodology", it is appropriate to use healthy individuals in a study like this. Having this concept in mind, it was used in recruiting participants that were healthy to take part in this study.

Glycemic load of boiled Yam, Cassava and Plantain

The glycemic load of the test foods (boiled yam, cassava and plantain) has been presented in Table 5 for analysis and discussion.

Table 5: Glycemic load of boiled Yam, Cassava and Plantain

Description	Yam	Cassava	Plantain
GI	86.08	108.43	60.70
GL	20.39	26.71	12.64

Source: Field data, Asante (2018).

The calculated glycemic load (GL) of the test foods under consideration showed that plantain had the lowest GL, followed by yam and cassava in that order of high magnitude for GL. According to the scale of classifying GL, plantain fell within the range of moderate while the other two test food items (yam and cassava) were in the high scale (Burani, 2006).

Response of boiled yam, cassava and plantain on blood glucose level

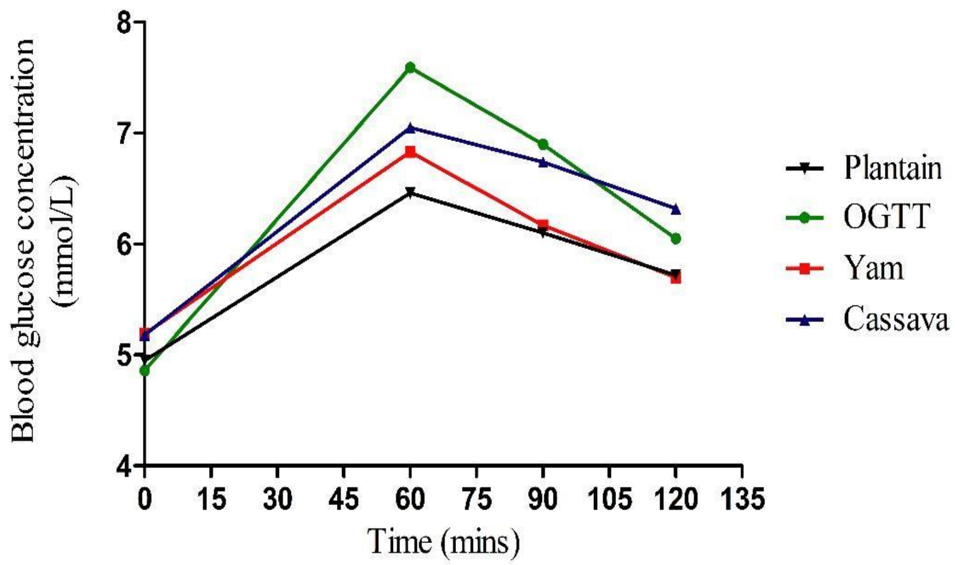

Figure 5: Graph showing the glycemic response of Test Foods

Source: Field data, Asante (2018).

The reference food, the average Fasting Blood Glucose (FBG) before the consumption of the test foods, were different after the test result. However, the difference in the result was not significant since it was in the normal range. The average peak response of the reference food was observed at the 60^{th} minute at about 7.6mmol/L and reduced to 7.0 mmol/L at the 120^{th} minutes. The average peak of response for all the test foods were observed at the 60^{th} minute after eating and this reduced to almost FBS levels at the 120^{th} minutes after eating. The glycemic response by participants after eating the boiled cassava reach its peak at the 60^{th} minute at about 7.0 mmol/L of Fasting Blood glucose (FBG) and reduced to about 6.5mmol/L in the 120^{th} minute just as the first test food. The next test food was boiled yam (6.6mmol/L) and this also reduced to 5.5mmol/L at the 120^{th} minute. The last was boiled plantain (6.2mmol/L) which also reduced to 5.5mmol/L at the 120^{th} minutes.

There were differences in the glycemic response of the reference food and the test foods as shown in Figures 4. Postprandial glucose levels of the reference food were high at each time interval as compared to the test foods when they were ingested except cassava at the 120th min. This could have resulted in the high GI (100) of glucose, as reported by Foster-Powell, Holt, and Brand-Miller (2002) when they studied the “International table of glycemic index and glycemic load values”. Brouns, et al (2005) states in their study, that glycemic response among participants varied and even with the same participant, there are variations in each test food. The variations in the post-prandial blood glucose levels at different time interval could be attributed to this. It can therefore, be concluded that plantain as a boiled food has the lowest GI with reference to the food types that were investigated.

Proximate Analysis of boiled Cassava, Yam and Plantain

The proximate analysis of the boiled cassava, yam and plantain is presented in Table 6.

Table 6: Proximate Analysis of boiled Cassava, Yam and Plantain

Meal type	DM %	Moisture %	Ash %	Protein %	Fat/Oil %	Fibre %	CHO %
Cassava	36.01	63.99	1.39	17.49	18.55	2.69	24.63
Yam	33.55	66.45	1.53	17.09	19.64	2.70	23.69
Plantain	30.65	69.35	1.38	15.43	19.27	2.21	20.83

Source: Field data, Asante (2018).

The result from the proximate analysis as summarized in Table 6 has shown that the Dry Matter (DM) for the boiled cassava, yam and plantain varied. The highest value was recorded for cassava and the least value was for the boiled plantain. The moisture content in the three samples was two times higher as recorded for the DM. The moisture quantity was higher in plantain and the least for cassava. The values determined with respect to ash, protein, fat/oil and fibre seems to be low as compared to what was recorded for DM and moisture quantities. The ash and protein quantities were low for plantain and it was high in yam. The fat/oil quantity was almost the same (a difference of 0.37) for yam and plantain. The fibre quantity in the three food items were in the range of 2.21 – 2.70 and this seems small. Meanwhile, the carbohydrate quantity in cassava and yam has a difference of 0.94 between the two higher values.

Hypothesis

H_0: There is no statistically significant difference in the glycemic load of boiled yam, cassava and plantain

Table 7: Mean and Std. Deviation of Glycemic Load of boiled foods

Food type	N	Mean	Std. Deviation
Cassava	3	26.7133	.30665
Yam	3	20.3933	.20008
Plantain	3	12.6467	.11060
Total	**9**	**19.9178**	**6.10448**

Source: Field data, Asante (2018).

The result in Table 7 indicated that the low mean score was for the boiled plantain which was in the moderate scale, while cassava and yam were in the high scale (Burani, 2006; Venn, et al, 2006). The difference in the mean value of cassava and yam was not so wide as compared to that of plantain.

Table 8: ANOVA of Glycemic Load for boiled Yam, Cassava and Plantain

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	297.824	2	148.912	3053.565	.000
Within Groups	.293	6	.049		
Total	**298.117**	**8**			

Source: Field data, Asante (2018).

The ANOVA result of the GL as indicated in Table 8 shows that there is a significant ($p<0.05$) difference between the food groups (cassava, yam & plantain). The Post- Hoc test of homogeneous subsets also revealed that plantain has the lowest value of GL and this was followed by yam and cassava in that order of magnitude as shown in Table 9. The analysis has therefore showed that plantain has low GL when used for meal. The p-value of 0.00 thus showed that there is a statistical difference at $\alpha = 0.05$ (alpha value at 0.05). The null hypothesis is therefore rejected in favour of the alternative hypothesis which states that there is a statistically significant difference in the glycemic load of boiled yam, cassava and plantain.

Table 9: Post Hoc Tests of Homogeneous Subsets of GL

		Subset for alpha = 0.05		
Food type	N	1	2	3
Plantain	3	12.6467		
Yam	3		20.3933	
Cassava	3			26.7133

Source: Field data, Asante (2018).

Discussion of Results

The result indicates that boiled plantain takes time to digest hence its lowest GI. This therefore means that consuming such a food item consistently may not increase the blood glucose level of the individual. Meanwhile, the opposite is the case for yam and cassava consumption. The risk of type two diabetes has been correlated with an increased dietary glycemic load which can be defined as the product of the glycemic index of a precise food and its carbohydrate constitutes (Hasan, et al, 2019).

The carbohydrate content is slightly low in yam and cassava. However, their fibre and protein content has contributed to their high GI. FAO/WHO (1998) has identified a number of factors that could influence the glycemic response of a given food that can affect its GI. The factors include the nature and proportion of starch in the food, dietary fibre content on the food, fat and protein content, processing, effect of previous meal. These factors according to FAO/WHO (1998) may be the cause of the GI increase in the cassava and yam. All the earlier mentioned factors actually have higher amounts of the quantities as compared to that of plantain.

The value for some of the factors identified to contribute to the increase in the GI value (FAO/WHO, 1998) were all low in the case of the boiled plantain hence, its low GI. The study of Sanusi and Olurin (2010) in Nigeria revealed that dieticians and other medical staff might have had some knowledge on the low GI status for plantain and as such were found to be recommending plantain as an alternative food for hypertensive patients. Consumption of meals prepared from plantain could help individuals to either reduce or maintain their blood glucose levels and its related side effects.

Constipation is largely attributed to the consumption of foods that are low in fibre content such as polished food items on the market. Cassava and yam fall in this context of having high fibre quantity though their GI might be contributing to something else when consumed. Nutritional approaches to the treatment and prevention of *Diabetes mellitus* is premised on the fact that a diet rich in fibre slows down digestion which in turn slows down the absorption of glucose into the blood stream (Mann, et al, 2004).

The participants were labour intensive workers (hard labour) and they need a lot of energy so that they could go about doing their daily works. The energy required for their daily works would come from more carbohydrate contained foods like the test foods (cassava, yam and plantain). In line of this argument, this might have informed the participants and the people in Abura to probably eat cassava, yam and plantain. A study conducted on yam in Harvard Health centre had showed that it provides the body with 110 calories and dietary fibre provides 21% of the 110 calories (Harvard Health Publications, 2008). This has added to the argument that yam is rich in dietary fibre. The finding in the current study has attested to the fact that yam and cassava contain high proportions of fibre per the proximate analysis results presented in Table 4.

The findings might suggest that frequent consumption of yam and cassava would increase the GL since it is influenced by the percentage of GI with a reference to food (glucose) and the carbohydrate quantity in test food types (Plantain, Yam & Cassava). The higher the glycemic load, the greater the expected elevation in blood glucose and in the insulinogenic effect of the food. The long-term consumption of a diet with a relatively high glycemic load (adjusted for total energy) is associated with an increased risk of type 2 diabetes and coronary heart diseases (Mathews, Liebenberg & Mathews, 2015).

The finding pre-suggests that households or individuals should be feeding more on boiled plantain foods. The cost of plantain on the market of late is high compared to yam and cassava especially in the dry season. Perhaps the high demand of plantain might have contributed to the rise in the cost of plantain on the market. This has therefore made the purchase of plantain for consumption at homes probably by an average earner a bit difficult. Plantain is now processed into varied food products. These reasons could be attributed to the soaring prices of plantain on the market.

Obesity has been associated with GL and it has been increasing instead of lowering (Hui & Bell, 2003). Higher GI and carbohydrate have been the driving force in the increase of GL of some selected food types. The result in this study actually buttresses the point that the GL of boiled yam and cassava fall in the high classification scale according to Burani (2006).

The high cost of food items on the market upshot to people buying food types at less cost which unfortunately have high amount of carbohydrate in them. Enjoying balanced food is believed to be costly and only meant for the rich who can afford. Due to the apparent judgements about balanced food, most people eat to satisfy their hunger. Young adults and especially men are developing 'pot bellies' and according to medical reports, taking in heavy foods for instance carbohydrate foods late at night are some of the predisposing factors.

CHAPTER FIVE

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

Introduction

This chapter summarises findings of the study, conclusions and recommendations. The purpose of the study was to determine the glycemic load of boiled yam, cassava and plantain in Ghana. The relevant literature about the topic was reviewed to unearth the existing work done on the topic at hand.

True experimental research design was employed to guide the entire study. Multi-stage sampling technique was adopted for the study. Purposive and convenient samplings were used to sample healthy participants and those who were willing to participate in the study at Abura. Abura is a suburb of the Cape Coast Metropolis in the Central Region of Ghana. Convenience sampling approach was adopted to get the sample size for the study. The sample size for the study was ten (5males and 5 females) adults who were screened to be healthy by a medical doctor with the assistance of laboratory technicians per their Body Mass Index (BMI) status. Four days was used to collect the data from the participants for the study at the Abura Medical Laboratory in Cape Coast.

Frequencies and percentages were used with the help of SPSS to analyse the demographical information of the participants. The general anthropometric characteristics of the participants were also analysed using descriptive statistics with the aid of MS Excel. Research question one was achieved using MS Excel and the glucose time graph was drawn with GraphPad Prism 5. Means were computed and used to present the results for the proximate analysis. One-way ANOVA was used to test the hypothesis with the help of SPSS at 0.05 of alpha.

Summary of Key Findings

The result from the study revealed a lot of information per the research objectives and the hypothesis. However, the key findings have been summarised as follows:

1. Boiled plantain had the lowest glycemic load followed by yam and cassava in order of magnitude (boiled plantain < boiled yam < boiled cassava).
2. Boiled plantain had the least effect on blood glucose level.
3. Boiled plantain had the least content of protein, fat/oil, fibre and carbohydrate as compared to the values of boiled yam and cassava. However, the moisture content in boiled plantain was higher than yam and cassava in order of magnitude respectively.
4. There is a statistically significant difference in the glycemic load of boiled yam, cassava and plantain.

Conclusions

The glycemic load of the test foods (cassava, yam and plantain) indicated that plantain has the lowest glycemic load confirmed the importance of eating more plantain and also being recommended to diabetic patients. According to the findings, plantain is a food item that has a low glycemic load. This implies that digestion of plantain could be easier for the human system and it would not contribute to the elevation of blood glucose levels which can consequently lead to obesity.

The findings also suggest that the consumption of plantain by hypertensive patients may not aggravate their health condition but rather it may enable them to manage their condition better and even lower their risk of becoming diabetic. Excess fat and oil in the human body is reported to have negative effects on the human system. The low fat and oil in plantain is therefore good for the healthy functioning of the body. The high fibre content of cassava and yam could help in reducing constipation among adults as well.

Recommendations

The following recommendations are made based on the finding from this study.

1. The consumption of plantain and its related meals can be recommended to be eaten more since it does not help in increasing blood glucose level as compared to cassava. Cultivation of plantain should be encouraged among households that have land around their houses and can be used to pound 'fufu' since its effect on the blood glucose level is better than that of yam and cassava.
2. More recipes from plantain should be developed by stakeholders in the hospitality, food product development or food manufacturing sectors such as the department of VOTEC, (UCC) so that several varieties of meals prepared using plantain can be made available to consumers to choose from. This will help to reduce the intake of monotonous meals that are usually prepared from plantain such as "fufu" and boiled or roasted plantain.

Suggested Area for Further Studies

The current study was on the glycemic load of yam, cassava and plantain. A further study is suggested to be done in assessing the glycemic load of plantain and its influence on hypertensive patients in the Cape Coast

Metropolis. Another area for further investigation is assessing the glycemic load of other staple roots and tubers foods that are locally available in Ghana such as cocoyam, taro and various potato varieties. Again, the effect of the intake of plantain can be experimentally investigated on diabetic patients to provide more evidence on its efficacy or effectiveness in reducing their blood glucose levels.

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APPENDICES

APPENDIX A

PROXIMATE ANALYSIS

Sample	% DM	% Moist	% Ash	% Protein	% Fibre	% Fat/Oil	% CHO
Cassava	35.3980	64.6020	1.4494	17.8025	2.7727	18.9865	24.6670
Cassava	36.0852	63.9148	1.4107	17.8511	2.6096	18.2155	24.8967
Cassava	36.5566	63.4434	1.3018	16.8188	2.6958	18.4529	24.3360
Yam	34.2676	65.7324	1.5093	17.1191	2.8924	19.2155	23.6959
Yam	33.3527	66.6473	1.5183	17.0046	2.5372	20.0120	23.4578
Yam	33.0246	66.9754	1.5496	17.1452	2.6652	19.6987	23.9215
Plantain	30.4568	69.5432	1.3609	15.4920	2.2777	19.7854	20.6352
Plantain	30.6666	69.3334	1.3742	15.1550	2.1472	18.9325	21.0013

Plantain	30.8301	69.1699	1.4029	15.6328	2.1975	19.1005	20.8624

Source: Fieldwork 2018

APPENDIX B

TEST INSTRUMENT

Age ………………………… 20 yrs-30yrs ( ), 31yrs-40yrs ( ), 51yrs-60yrs

Sex …………………………… Female ( ), Male ( )

Weight ………………………………………… [ ]

Height ………………………………………….. [ ]

Blood pressure …………………………….…… [ ]

Waist circumference …………………………… [ ]

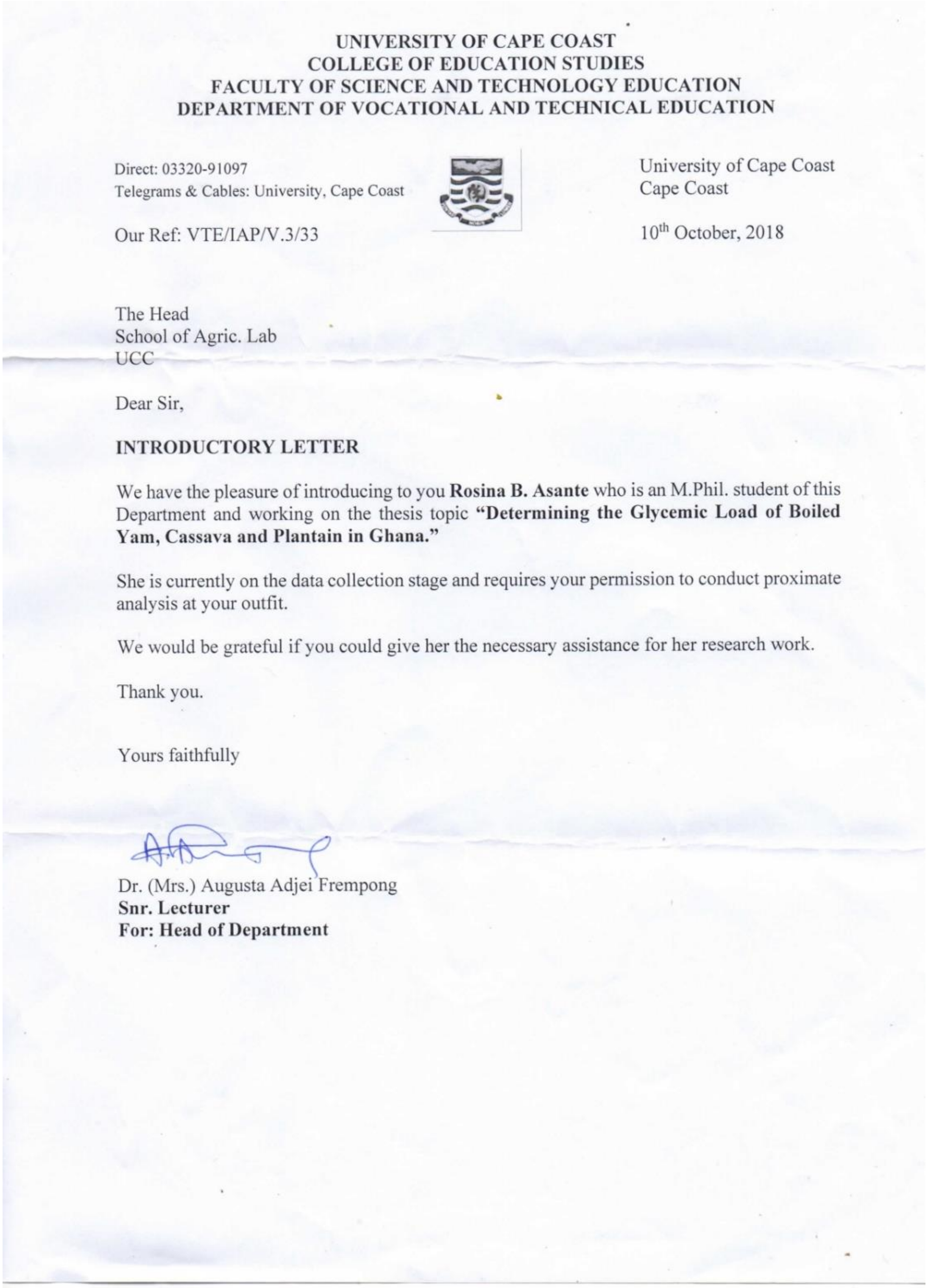
Body mass index ……………………………… [ ]

TEST RECORD

Time	Test 1	Test 2	Test 3	Test 4
Fasting blood glucose				
30 mins				
1 hour				
1 hour 30 mins				
2 hours				

APPENDIX C

PERMISSION LETTER TO UNIVERSITY OF CAPE COAST CHEMICAL LABORATORY



UNIVERSITY OF CAPE COAST
COLLEGE OF EDUCATION STUDIES
FACULTY OF SCIENCE AND TECHNOLOGY EDUCATION
DEPARTMENT OF VOCATIONAL AND TECHNICAL EDUCATION

Direct: 03320-91097
Telegrams & Cables: University, Cape Coast

Our Ref: VTE/IAP/V.3/33

University of Cape Coast
Cape Coast

10th October, 2018

The Head
School of Agric. Lab
UCC

Dear Sir,

INTRODUCTORY LETTER

We have the pleasure of introducing to you **Rosina B. Asante** who is an M.Phil. student of this Department and working on the thesis topic **"Determining the Glycemic Load of Boiled Yam, Cassava and Plantain in Ghana."**

She is currently on the data collection stage and requires your permission to conduct proximate analysis at your outfit.

We would be grateful if you could give her the necessary assistance for her research work.

Thank you.

Yours faithfully

Dr. (Mrs.) Augusta Adjei Frempong
Snr. Lecturer
For: Head of Department

APPENDIX D

CLEARANCE LETTER FROM INSTITUTIONAL REVIEW BOARD

VOTEC Department
University of Cape Coast
Cape Coast
1st June, 2018.

The Chairman
Institutional Review Board
University of Cape Coast
Cape Coast

Dear Sir,

<u>ETHICAL CLEARANCE: MS. ROSINA B. ASANTE</u>

We write in support of the above named student's application for ethical clearance to enable her undertake her thesis research. She is currently an M. Phil. Student in the VOTEC department, University of Cape Coast. She has completed all required taught courses and is in the process of conducting her thesis research.

I am co-supervising the work with Dr. Christina Buxton of Science and Technology Department, University of Cape Coast. We have both read through her proposal and do approve it. Since it involves human subjects, efforts have been made to minimize negative effects on the respondents or participants as much as possible the inclusion of sensitive issues.

We hope she will be granted Ethical Clearance to enable her undertake the study.

Thank you.

Yours faithfully,

Prof. (Mrs.) Sarah Darkwa

APPENDIX E

INTRODUCTORY LETTER

UNIVERSITY OF CAPE COAST
COLLEGE OF EDUCATION STUDIES
FACULTY OF SCIENCE AND TECHNOLOGY EDUCATION
DEPARTMENT OF VOCATIONAL AND TECHNICAL EDUCATION

Direct: 03320-91097
Telegrams & Cables: University, Cape Coast

Our Ref: VTE/IAP/V.3/34

University of Cape Coast
Cape Coast

10th October, 2018

The Head
Abura Medical Lab
Cape Coast

Dear Sir,

INTRODUCTORY LETTER

We have the pleasure of introducing to you **Rosina B. Asante** who is an M.Phil. student of this Department and working on the thesis topic **"Determining the Glycemic Load of Boiled Yam, Cassava and Plantain in Ghana."**

She is currently on the data collection stage and requires your permission to conduct blood glucose test at your outfit.

We would be grateful if you could give her the necessary assistance for her research work.

Thank you.

Yours faithfully

Dr. (Mrs.) Augusta Adjei Frempong
Snr. Lecturer
For: Head of Department