UNIVERSITY OF CAPE COAST

DETERMINING THE GLYCAEMIC LOAD OF VARIETIES OF FUFU IN GHANA

CHRISTABEL AMPONSAH ADU-GYAMFI

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BY

CHRISTABEL AMPONSAH ADU-GYAMFI

Thesis submitted to the Department of Vocational and Technical Education of the College of Education Studies, University of Cape Coast, in partial fulfilment of the requirements for the award of Master of Philosophy degree in Home Economic Education

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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: ……………………………………………………..……………..

Supervisors' Declaration

We hereby declare that the presentation and preparation 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 ………………

Name: ……………………………………………………..……………….

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

Name: ……………………………………………………..……………………

ABSTRACT

Knowledge about the glycaemic load of a food is very important in minimizing the prevalence of diabetes and other Non-Communicable Diseases. This study seeks to determine the glycaemic load of varieties of fufu that are often eaten in Ghana. The study was a crossover experimental study which used 10 healthy participants, who were given 50 g of pure glucose and subsequently served with a measured amount of test foods; cassava – plantain fufu, cassava – cocoyam fufu and cassava – yam fufu, containing 50 g of carbohydrate. Fasting blood glucose was taken and after ingestion of test foods, capillary blood was also taken within a 2-hour period and assayed for postprandial glucose concentration. The glycaemic loads were determined using the GI values taking into account the typical portion size of fufu. Sensory evaluation was carried out to identify the most preferred variety. A proximate analysis was also carried out on all three varieties to assess their nutritional components. Findings from proximate analysis indicated that, cassava – plantain combination had the least amount of carbohydrate of 34.87%, followed by the cassava – cocoyam with an amount of 36.10% and the cassava – yam with an amount of 43.00%. All three varieties had low glycaemic index, however, they had high GL. Cassava- plantain fufu had GL of 40%, cassava – yam fufu had 22% and cassava - cocoyam fufu had 29%. This was attributed to the large portion sizes of fufu eaten. Results from sensory evaluation revealed that cassava – plantain fufu variety was much preferred among the three varieties. Culture was identified as the main reason why panelists preferred a particular fufu variety to the others. Consumers must take smaller portion sizes of any of the fufu variety in order to minimize the effect on their blood sugar level.

KEY WORDS

Fufu combinations

Glycaemic load (GL)

Glycaemic index (GI)

Glycaemic response

Portion size

Sensory evaluation

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To my parents, Rev. & Mrs. Adu-Gyamfi, my husband Mr. Adusei – Poku Afful, loved ones, friends and everybody who assisted me one way or the other in my education.

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LIST OF ACRONYMS

ADA	American Diabetes Association
CHDs	Coronary Heart Diseases
FAO	Food and Agriculture Organisations
GI	Glycaemic Index
GL	Glycaemic Load
HDL	High Density Lipoproteins
IAUC	Incremental area under curve
IOM	Institute of Medicine
LDL	Low Density Lipoproteins
MOFA	Ministry of Food and Agriculture
NCDs	Non-Communicable Disease
WHO	World Health Organization

CHAPTER ONE

INTRODUCTION

Background to the Study

The key purpose of eating food is to satisfy hunger. More importantly, the intake of food is very necessary for providing the body with energy, maintaining tissues as well as promoting growth and also for the protection of the body against diseases. To ensure all these, the need for a balanced consumption of food is very vital as this guarantees a healthy living. In Ghana, there are varieties of local foods which contain essential nutrients that are needed for a healthy living, however one may prefer a particular food to the other due to factors such as, cost, personal likes, and dislikes, religion, culture, food availability among others, with or without knowledge about the nutritional value of the food (Tull, 1996).

Fufu is one of the local foods mostly eaten in Ghana and other West African countries. In Ghana, it is commonly eaten among the Akans and it is made from cassava and/or plantain, cocoyam or yam. Even though most people prefer the cassava and plantain combination, the cassava and yam or the cassava and cocoyam combination become an option for people especially during seasons when plantain becomes scarce and expensive in the country. There are equally other people who prefer the other combination to the cassava and plantain combination.

The main nutrient found in fufu is carbohydrate. This means that there are other nutrients that can be found in fufu. Carbohydrates are broken down into sugar when they are eaten and absorbed into the bloodstream. According to Davis (2009), as blood sugar levels rise, the pancreas produces insulin, a hormone that prompts cells to absorb blood sugar for energy or storage. Carbohydrate is the main nutrient that will raise blood glucose (Davis, 2009). 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).

Carbohydrate can be classified as simple or complex carbohydrate. However, grouping carbohydrates into simple and complex does not account for the impact they have on blood sugar and the chronic diseases associated with them (FAO/WHO, 1998). To describe the direct effect different kinds of carbohydrate-rich foods have on blood sugar, the glycaemic index was developed and is considered a better way of classifying carbohydrates, especially starchy foods (The nutrition source, 2016). Glycaemic index is the measure of the relative ranking of how fast or slow a carbohydrate-rich food raises blood sugar level after the food has been ingested (Jenkins, Wolever, Kalmusky, Giudici, Giordano & Wong, 1985). Eating high glycaemic index foods can lead to powerful spikes in blood sugar. The outcome of this may lead to an increased risk of Type 2 diabetes (de Munter, Hu, Spiegelman, Franz & van Dam, 2007), heart diseases (Beulens, de Bruijne, Stolk, Peeters, Bots, Grobbee, & van der Schouw, 2007) and even overweight (Ebbeling, Leidig, Feldman, Lovesky & Ludwig, 2007).

A food's glycaemic index is not the optimum way of determining the effect of the carbohydrate on blood glucose. This is because it does not take into account how much digestible carbohydrate; the total carbohydrate excluding fibre, it delivers (The nutrition source, 2016). For this reason, researchers established a related way to categorize foods that take into account both the glycaemic index and the amount of carbohydrate in the food and its impact on blood sugar levels. This is known as the glycaemic load (Liu & Willet, 2002; Willet, Manson & Liu, 2002). A food's glycaemic load is determined by multiplying its glycaemic index by the amount of carbohydrate present in the food. A glycaemic load of 20 or more is high, 11 to 19 is medium, and 10 or less is low (Venn, Wallace, Monro, Perry, Brown, Frampton et al., 2006). A study conducted by Livesey, Taylor, Livesey, and Liu (2013) concludes that people who eat lower-glycaemic load diets are at a lower risk of developing type 2 diabetes than those who eat a diet of higher-glycaemic load foods. A comparable analysis by Mirrahimi, de Souza, Chiavaroli, Sievenpiper, Beyene, Hanley et al. (2012) have also shown that higher-glycaemic load diets are associated with an increased risk of coronary heart diseases.

Carbohydrate metabolism is vital in the development of Type 2 diabetes. This happens when the body cannot produce enough insulin or cannot properly use the insulin it makes. Type 2 diabetes usually develops progressively over years. It starts when muscles and other cells stop responding to insulin, a condition, known as insulin resistance. This causes blood sugar and insulin levels to remain high over long periods after eating. With time, the hefty demands made on the insulin-producing cells wear them out, and insulin production ultimately stops (The Nutrition Source, 2016). This can also lead to a long-term damage to the body and the failure of various organs and tissues (Centre for Disease Control, 2014).

In 1997, an estimate of 124 million people worldwide had diabetes, 91% of whom were non- insulin dependent Diabetes mellitus (Type 2 diabetes). By the year 2010, the total number of people with diabetes was anticipated to reach 221 million. The regions with the highest potential increase are Asia and Africa, where the rate could rise 2 or 3 times what is experienced today (Zimmet & Amos, 1997). In a study, Acheampong, Eho, and Boateng (1995) states that the diabetes prevalence rate in Ghana is estimated to be 2.0% with a mortality rate of 13%. In urban Ghana today, Type 2 Diabetes mellitus affects at least 6% of adults and is associated with age and obesity (Amoah, Owusu, & Adjei, 2002). Even though there are other factors that can contribute to diabetes, foods that have a high glycaemic indices, as well as high glycaemic loads, are the leading causes of diabetes.

Statement of the Problem

Willet et al. (2002) report that the consumption of high glycaemic indices and high glycaemic load diets for several years might result in increased postprandial blood glucose spikes and excessive insulin secretion. This could lead to the loss of insulin-secreting function of the pancreatic β-cells, resulting in irreversible Type 2 Diabetes mellitus. In addition to this assertion, Ludwig and Daniel (2002) in a study state that, sustained spikes in blood sugar and insulin levels may lead to increased diabetes risk. Diabetes mellitus Type 2 is currently one of the most prevailing chronic diseases in the world and the number of people with the disease is stated to be increasing in every country.

International Diabetes Federation (IDF) has estimated that 415 million adults globally, are presently living with the condition. Nonetheless, this is predicted that people having this condition would rise to 642 million by 2040. An estimated 14.2 million adults (aged 20-79) have diabetes in Africa, representing 6.7% (IDF, 2016). This prevalence can be minimized to a lower rate when people are made aware of the glycaemic indices and glycaemic loads of the foods they consume, as these play major roles in the development of this condition. When consumers are well informed on the rate at which the glucose in our local foods is released into the bloodstream, they will be very cautious about their choice of food and even the time they eat these foods as well as the amount they consume.

A study by Wormenor (2015) revealed that the fufu made from cassava and plantain has a low glycaemic index of 55, hence it has little impact on blood glucose level when ingested and digested. However, people do not only consume cassava-plantain variety of 'fufu' in Ghana. Some take the cassava and yam and the cassava and cocoyam combinations. The research did not focus on the glycaemic load of fufu. Little works appear to have been done on these other fufu varieties and their impact on the blood glucose. This study investigated all the possible varieties of fufu that is consumed in the country and to analyze the extent to which each of variety affects the blood glucose level.

Purpose of the Study

The purpose of this study was to determine the glycaemic load of the different varieties of fufu. To achieve this, the study sought to;

a. examine participants' glycaemic response to ingested carbohydrate.

b. determine the glycaemic load of all the varieties of fufu.

c. perform proximate analysis on all varieties of fufu.

d. sensorily analyze the three fufu varieties.

Research Hypothesis

H_0 = There is no significant difference in the glycaemic load of the different varieties of fufu.

H_1= There is a significant difference in the glycaemic load of the different varieties of fufu.

Significance of the Study

Essentially, the glycaemic load, which is the product of the glycaemic index and the carbohydrate content of a given food, may be more useful than only the glycaemic index. This is because the glycaemic load takes into account the portion size of the food as well as the carbohydrate content. Glycaemic load is a significant factor in dietary programmes aiming at the metabolic syndrome, insulin resistance, and weight loss.

When mixed meals containing carbohydrate foods of different glycaemic index are consumed, it is known that the difference in postprandial blood glucose response is maintained (Chew, Brand, Thorburn & Truswell, 1988). However, the extent of this differential blood glucose response may be dependent on the size of the meal consumed. It is hoped that this study will come up with the optimal size of fufu which when consumed will have no effect on the blood glucose level. Knowledge of the glycaemic load of the various fufu variety could serve as a guide to diabetics to choose the fufu variety with the best glycaemic load.

It may also inform nutritionists, dieticians and diet therapists on the optimal fufu variety to recommend to prediabetics and diabetics when they counsel their clients. Since fufu is widely eaten across Ghana, providing information on the nutritional value on fufu varieties would be worthwhile and helpful to consumers. It is anticipated that the findings from the study will provide literature on fufu and its nutritional value.

Delimitations

The study determined the glycaemic load of varieties of fufu. All the different fufu mixtures; cassava-plantain, cassava-cocoyam, and cassava-yam were analyzed. Findings cannot be easily generalized for other carbohydrate foods. The study focused on the effect fufu has on blood glucose level after it has been digested and so healthy individuals were used for the study. Diabetics already have elevated blood glucose levels and using them for the study may not be appropriate. The study was carried out in Wenchi in the Brong Ahafo region. Panel members used for sensory evaluation were only people who eat all three mixtures of fufu. However, those who were not fit or had any respiratory infection like cold were excluded.

Limitations

Even though the nature of the sensory analysis test used demands more panel members, the number of panel members used in the study had to be limited. This was because panelists were not given prior notice but were told instantly to participate in the sensory evaluation and since it was carried out on a weekday, it was difficult persuading them to spend few minutes of their time to undertake the test. Since sensory perception of a food is subjective, the texture of the food presented to them may not have been liked by some participants and hence affect their ranking choice. Again it is likely that fufu mixtures may not have been evenly mixed and so could affect the appearance as well.

Organisation of the Study

Chapter one of the study dealt with the background to the study. It gave a vivid explanation of the concept of glycaemic load and the important role it plays in minimizing the increasing rate of diabetes and other related diseases. It further explained the fact that most people choose to eat foods not necessarily thinking about its effect on their health. The chapter also includes the problems statement, objectives of the study, research questions and significance of the study.

In chapter two, an extensive review of relevant related literature was carried out. The researchers further explained the concept of glycaemic index and load as well as issues relating to them. It draws extensively from the work of other researchers which are published in journals and scholarly articles.

The third chapter dealt with Methodology which included the study design. The study design is purely experimental. It also dealt with the study area, sources and type of data, sampling technique, data collection procedure, data processing and analysis and limitations of the study.

In chapter four, data analysis and discussion of major findings were done. Quantitative content analysis was done and findings were presented in graphs and tables. The chapter five of the study which is the final chapter dealt with the summary of the major findings, conclusion, and recommendations of the study.

CHAPTER TWO

LITERATURE REVIEW

Introduction

This chapter deals with the review of existing literature which is related and also relevant to the study. It consists of empirical evidence on determining the glycaemic load of foods. Some studies carried out by earlier researchers provide empirical evidence on how the carbohydrate in food affects the blood sugar levels and overall well-being of the individual. The following paragraphs identified some of these studies and reported their findings.

Fufu

'Fufu' is a staple food of West and Central Africa. It is usually made by boiling starchy roots and pounded with a mortar and pestle until the preferred texture is achieved. Even though many countries eat 'fufu', it is not prepared in the same way. In Ghana 'fufu' is made by boiling raw cassava and yam, plantain or cocoyam. It is then pounded in a mortar with a pestle to a smooth consistency. In between blows from the pestle, the mixture is turned by hand and water added to it bit by bit till it becomes slurry and sticky. The mixture is then formed into a ball and served with a delicious soup. 'Fufu' is mostly served with light soup but people also prefer taking it with palm nut and groundnut soup (personal knowledge).

In Nigeria, 'fufu' is prepared differently. In a study, Hahn (1989) and Anon (1994) described fufu production in Nigeria. According to them, the cassava roots are peeled, washed and soaked in a drum or earthen pots of water for three days to undergo fermentation. When sufficiently soft, the roots are taken out, broken by the hand and the fibre is removed by sieving. The starch suspension is allowed to settle in a large container for about 24 hours. After sedimentation, the water is decanted while the fine, clean filtrate (mainly starch) is dewatered by putting it into a raffia or cotton bags, pressing with heavy stones and leaving it overnight to remove excess water.

The 'fufu' is collected and sold to consumers as a wet paste in a small unit packaged in plastic or polypropylene bags. To prepare the 'fufu' for consumption, a quantity of the slurry containing about 25% of 'fufu' solids is boiled directly in an open pan. After constant stirring using a wooden rod, a paste or dough is formed. Cooked 'fufu' is usually eaten warm with fish, meat, vegetable stew or soup.

In Liberia, it is known as 'Domboy'. 'Domboy' in Liberia is made only with boiled cassava roots. It is pounded in a mortar until a desired paste is attained and it is served immediately with soup (Swanson, 2014). There is a different cassava food known as 'fufu' but it is made from fermented cassava just like in the case of Nigeria.

Different processing forms of fufu

As stated in the previous paragraph, 'fufu' is originally made by boiling raw cassava and with either plantain, yam or cocoyam. It is then pounded together in a mortar with a pestle until a desirable paste is attained. However many people see this as a tedious and sweaty activity to do (Modern Ghana, 2008). This has influenced the initiation of other processing forms of 'fufu' that may help ease the stress in preparation and processing.

Instant fufu flour

Food manufacturers have come up with alternatives to help consumers to enjoy this delicacy no matter where they find themselves. 'Fufu' flour has been developed as a convenient form of the traditional pounded fufu as it needs a much shorter time for the preparation and has a long shelf-life (Kordylas, 1991). In Ghana, there are about three different varieties available in the market. Below are the steps involves in preparing 'fufu' from flour (Tropiway, 2014);

1. add water to the 'fufu' flour and stir into a paste in a saucepan.
2. place over heat and knead with a wooden spoon
3. check for thickness and consistency. If 'fufu' is too soft while cooking, add some more flour. On the other hand, if it is too stiff, add a little water.
4. serve with your desired soup.

The flour for making 'fufu' comes in all the combinations that are consumed in the country and so consumers can get any mixture of their choice. They are colorfully packaged and labeled and can be found everywhere in the country as well as in other Ghanaian communities abroad. People go in for it due to convenience and availability sake. The eruption of these fufu flour has indeed helped a lot especially when the mortar pestle stress, sweat, and accident are concerned (Anim-Mensah & Anim, 2016).

However, issues associated with the emergence of 'fufu' flour are that they are expensive due to the potato present in them. Their import volumes and bill can go a long way to put pressure on the economy of the country. Moreover, processing of these 'fufu' flour involves techniques that go a long way to affect the nutritive value of the food. This can be affirmed by a study made by Smith (2000) who established the fact that, factory processing methods used in processing foods can affect the digestibility of starch in these products, giving them a high glycaemic index. These foods, eaten constantly over time can affect the blood sugar control system of the body. He explained that during these processing methods, the fibre content, which is an essential part of the food is reformed from its natural state, and essential fatty acids are removed to increase shelf life.

Fufu machine

The stress one has to go through to make 'fufu' and the issues associated with instant fufu flour has made way for another innovation in making 'fufu' in the country; the 'fufu' machine. With this the cassava and plantain, yam or cocoyam are boiled as in the original method. These are then put into a funnel-like machine and stirred for few minutes after which the boiled substances pipe out of an opening just beneath the funnel-like it is done during corn milling. This machine is not used for only domestic purposes but also for commercial purposes.

Different combinations of ingredients for making fufu

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

Figure 1: Cassava-plantain fufu

Figure 2: Cassava-cocoyam fufu

Figure 3: Cassava-yam fufu

Cassava

Cassava (*Manihot esculenta* Crantz) was introduced from Brazil, where it originated from, 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 the18th century, cassava became the most commonly grown and used crop of the people of the coastal plains. The Akans name for cassava is 'Bankye' which perhaps maybe a deduction from 'Aban Kye' 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 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 6th as the most essential source of energy in human diets on a global basis and the 4th supplier of energy after rice, sugar, and corn/maize (Heuberger, 2005). It is very low in fats and protein compared to cereals and pulses. Nevertheless, it contains more protein than that of other tropical food sources like yam, potato, plantain etc. (Nutrition and You, 2016).

According to Ebuehi, Babalola, and Ahmed (2005), cassava also has antinutrients, such as phytate, fibre, nitrate, polyphenols, oxalate, and saponins that can lessen nutrient bioavailability. Cassava is considered a perishable commodity with a shelf life of fewer than 3 days after harvest. Processing offers a means of producing shelf-stable products (thereby reducing losses), adding value at a local rural level and reducing the bulk to be marketed (Phillips, Taylor, Sanni & Akoroda, 2004).Cassava, when processed, can be made into different kinds of food like 'gari', 'tapioca' and 'akyeke'. One common Ghanaian food, 'fufu', is prepared by boiling cassava and mixing with other boiled carbohydrate staples like plantain, yam or cocoyam.

A 100 g of raw cassava contains 38 g carbohydrate, 1.8 g fibre, and 1.7 g sugar and could yield about 670 (kJ) of energy. Cassava has an amylose-amylopectin ratio of 30:70, which makes it more accessible to digestive amylases hence the more likely to stimulate higher glucose response when it is consumed (United States Department of Agriculture, 2002). Below is a picture of fresh and matured harvested cassava tubers.

Figure 4: Freshly harvested matured cassava tubers.

Plantain

Plantain (*Musa paradisiaca*) is a major source of carbohydrate in diets of people from Latin America, through most of Africa as well as countries of South-east Asia (Marriott and Lancaster, 1983). It is projected that 60 million people in West Africa obtain more than 25% of their carbohydrate intake from plantain (Oritz & Vuylsteke, 1996). In Ghana, plantain contributes more to the Agricultural Gross Domestic Product (AGPD) than cereals (MOFA, 2006). Lescot (2000) reports that plantain's per capita yearly consumption is higher than maize and yam. Plantains serve as significant sources of food particularly in the Ashanti, Brong Ahafo and Eastern regions of Ghana.

Numerous varieties of plantain are cultivated in West Africa. These are categorized as French Horn Plantain, False Horn Plantain, or the True Horn Plantain (Ahiekpor, 1996; Hemeng & Bandful, 1996). Locally in Ghana, names of the sub-varieties of French Horn plantain include 'Apempa', 'Oniaba' and 'Nyeretia apem'. That of the False Horn comprise 'Borodewuo', 'Apantu pa', 'Borode sebo' and 'Osoboaso' and the True Horn sub-varieties are 'Asamienu' and 'Aowin'. In Ghana, the variety that is mostly used in making ‘fufu’ is the ‘Apantu pa’. Raw unprocessed plantain contains 32 g of carbohydrate, 15 g sugar and 2.3 g fibre per 100 g (United States Department of Agriculture, 2002).

Plantains, unlike banana, are often processed before eating. They are cooked, fried or roasted before eating. In Ghana, plantain can be boiled and pounded together with boiled cassava into ‘fufu’. The slightly ripe boiled plantain could also be mashed into ‘eto’, a food common to the Akans. Plantain has a high fiber content, and therefore capable of lowering cholesterol and also helps to relieve constipation and hence prevention of colon cancer. Besides this, its low glycaemic index makes it the desirable carbohydrate staple that is mostly recommended for diabetics (United States Department of Agriculture, 2002). According to Ng and Fong (2000), its potassium content is found to be beneficial in the prevention of raising blood pressure and muscle cramp

Plantain is identified to be low in sodium (Chandler, 1995). It has very little fat and no cholesterol; hence useful in managing patients with high blood pressure and heart disease. Plantain is, nonetheless, a seasonal and very perishable crop. Ogazi (1996), reports that over 80% of the crop is harvested in the period of September to February. However, there is much wastage during this period as some of the products do not store for a long period. The outcome of this is seasonal unavailability and limitations on the use by urban populations. Below is a picture of fresh fingers of plantain

Figure 5: Fresh fingers of plantain

Yam

The International Institute of Tropical Agriculture (IITA, 2009), describe yams 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 the plant from the genius of *Dioscorea.* A study by Coursey (as cited in 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 Portuguese adapted it and introduced it in Elmina and Sao Tome in West Africa. 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 dominant, especially in the forest zone. The second most cultivated species is the *Dioscorea alata* which of the 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 Organization of the United Nation (2012) ranks Ghana as second to Nigeria in the production of yam with a production of 6,638,867 tonnes.

A 100 g of raw yam provides the body with 110 calories with about 54% of glucose, and 21% dietary fibre which makes yam to have a lower glycaemic index (Harvard Health Publications, 2008). Yam contains good levels of potassium, manganese, thiamine while being low in saturated fat and sodium (Uwaegbute, Osho & Obatolu, 1998). The tuber is a good source of vitamin B-complex such as pyridoxine (vitamin B6), thiamine (vitamin B1), riboflavin, folate, pantothenic acid, and niacin. These vitamins are needed for metabolic functions in the body. Vitamin C which plays vital roles as anti-aging, immune function booster and wound healing is also present in fresh tubers of yam. It, however, contains a small amount of protein and vitamin A (Nutrition and You, 2016). Nevertheless, a combination of yam and cassava provides a much better proportion of protein.

Yam is widely consumed in Africa especially in Ghana. Boiled yam tubers are added to boiled cassava and are pounded into “fufu”. This mixture of fufu is mostly found in the Northern and Brong Ahafo regions of the country. Yam can also be fried and roasted. Among the Akans, “bayire to”, a dish similar to “eto” (mashed plantain) is prepared from mashed yam and palm oil with eggs. Below is a picture of some fresh mature yam.

Figure 6: Freshly harvested matured yam tubers

Cocoyam

Cocoyam (*Colocasia esculenta*) also known as taro is a herbaceous perennial plant belonging to the family Araceae and are grown primarily for their edible roots, although all parts of the plant are edible. Cocoyam is originated from Southeast and Central Asia. The skin of the tuber is hairy and its flesh varies in colour from purplish to white. The leaves of cocoyam can stand erect and reach a length of 1metre. The leaf blade is large and heart shaped (Plant village, 2014). It is also believed to be an important food staple of developing countries in Africa, the West Indies, the Pacific region and Asia (Lee, 1999).

Nutritionally, cocoyam has a higher value than most other root and tuber crops. Cocoyam is very rich in carbohydrates, ranging between 73 and 80% and 1.4% crude fibre (Jane, Shen, Chen, Kasemsuwan & Nip, 1992). Onwueme (1994), reports that because of its high carbohydrate content, it represents one of the basic sources of energy in many parts of the tropics and sub-tropics providing about a third of the food intake of more than 400 million people in these areas. A study by Miller (1971) shows that cocoyam has a small starch grain about a tenth of that of potato and this makes it more digestible. With a digestibility of about 98.8%, cocoyam is suitable for use in infant food, food for the elderly and the sick. People who are habitually allergic to cereals and babies or infants who are intolerant to milk can easily eat foods made of cocoyam without any complications.

Lee (1999), also reports that cocoyam contains greater amounts of vitamin B-complex than whole milk. He also concludes that because of the ease in the assimilation of cocoyam, it can be used by persons with digestive problems. Cocoyam also has a higher value of proteins and amino acids than many other tropical root crop (Kay, 1987). Additionally, cocoyam tubers contain minerals such as potassium, calcium, and magnesium but they are low in sodium (Wills, Lim, Greenfield & Bayliss-Smith, 1983). According to Lee (1999), the cooked leaves have similar nutritional value of spinach, therefore the leaves can be said to be an excellent source of vitamin K, vitamin A (in the form of carotenoids), manganese, folate, magnesium, iron, copper, vitamin B2, vitamin B6, vitamin E, calcium, potassium and vitamin C.

Thus cocoyam is one of the few major staple foods where both the leaf and the underground parts are equally important in the human diet. All part of the cocoyam may contain calcium oxalate hence it must be cooked to be eaten safely. Both the tuber and leaves of cocoyam have been used extensively as food in many countries. Poi is a Hawaiian dish, for babies from cocoyam (Darkwa & Darkwa, 2013). In Ghana, cocoyam can be boiled and pounded with boiled cassava to make "fufu", a Ghanaian food. A dish known as "mpoto mpoto" or "nuhuu" (cocoyam porridge) is made from boiled cocoyam with palm oil and other vegetables like pepper, onion, tomatoes. The tuber can be fried, roasted and boiled and eaten whole. Cocoyam can also be made into flour and used as a composite in flour products. Below is a picture of matured harvested cocoyam

Figure 7: Matured harvested cocoyam

Carbohydrate

Carbohydrates are a group of organic compounds comprising a ratio of one carbon atom to two hydrogen atoms to one oxygen atom. Carbohydrate compounds are made up of monosaccharide building units, and ranges from simple monosaccharides, 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 in (FAO/WHO, 1998). Hence, it was classified as 'simple' and 'complex' carbohydrate. Simple carbohydrate contains either monosaccharides or disaccharides whiles the complex contains either the polysaccharides or the starch. 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 mistaken 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 disorder, as well as glucose intolerance.

Dietary carbohydrate

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

The Joint FAO/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 subclasses 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 below

Table 1: The Major Dietary Carbohydrate

Group	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 are made up of multiple nutrients, including dietary fibre, sugars, and starches. According to a study by FAO/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 contains a number of non-carbohydrate components such as lignin, organic acids, tannins, waxes, and some maillard products. In addition to this fault, 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, 2003) 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. The joint FAO/WHO expert consultation on carbohydrate (1998) has also made a similar recommendation. An ideal diet for all ages (except for children under the age of two) should include at least 55% of total energy from a variety of carbohydrate sources. FAO/WHO (1998) emphasized that the minimal amount of carbohydrate in the human diet that is required 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 distinguish sugar as naturally incorporated into the cellular structure of a food (intrinsic), from those that are free or added to the food (extrinsic).

Intrinsic sugar

Sugars forming a fundamental 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 hence naturally occurring and are always complemented by other nutrients (The Department of Health, 1989)

Extrinsic sugar

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

Starch

Starch is the primary carbohydrate in most diets. It is stored in plants such as cereals, root, vegetable and legumes, and consist of more than two glucose molecules. It is made up of two polymers: amylose and amylopectin. The amylopectin starches are digested more quickly, probably because of the more effective enzymatic attack of the more open-branched structure. High amylose starches require high temperature for gelatinization and are more likely to retrograde and to form amylose-lipid complexes (Cummings et al., 2007). In their study, Cummings et al. (2007) report that starches can also be altered chemically to impart functional properties needed to yield certain qualities in foodstuffs such as a decrease in viscosity and to improve gel stability, mouth feel, appearance and texture, and resistance to heat treatment.

Dietary fibre

The original description of dietary fibre was made by Trowell in 1972. He described dietary fibre as that part of food which is obtained from cellular walls of plants and 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 related 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 involved. 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 partly 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 helps prevent glucose and insulin spikes. They also help lower cholesterol and reduce the occurrence of hemorrhoids and constipation. Mann, De Leeuw, Hermansen, Karamanos, Karlström, Katsilambros et al. (2004), confirm this in their study where they concluded that certain fibre-rich foods affect glycaemic 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 (as cited in FAO/WHO, 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 FAO definition of available carbohydrate as cited in Brouns, Bronus, Bjorck, Frayan, Gibbs, Lang 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). Thus FAO/WHO (1998) suggested that digestible carbohydrate should be described as glycaemic whereas the indigestible carbohydrate is described as non-glycaemic; which is closer to the original concept of McCance and Lawrence. Describing available carbohydrate is vital in understanding the part of carbohydrate which is measured in the determination of the Glycaemic Index of a food. This is because G. I measures the glycaemic response of subjects to 50g available carbohydrate comparative to 50g pure glucose or 50g available carbohydrate in a given portion of white bread.

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/WHO (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 (Institute of Medicine, 2002).
3. Dietary carbohydrate is important to maintain glycaemic homeostasis and for gastrointestinal integrity and function.
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.
5. Finally, diets high in carbohydrate as compared to those high in fat, reduce the likelihood of developing obesity and its co-morbid conditions.

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 increases 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, sucrase and maltase are 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.

Glycaemic index concept

This concept was first proposed in 1981 by scientists led by Dr. David Jenkins, University of Toronto, Canada (Jenkins, Wolever, Kalmusky, Giudici, Giordano & Wong, 1981). 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 by 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.

The standard food is glucose or white bread (FAO/WHO, 1998; Brand-Miller, Hayne, Petocz & Colaguiri, 2003). The glycaemic index measures how quick or slow the rise in blood glucose as a result of a carbohydrate food consumed. A report by the joint FAO/WHO expert committee in 1998 indicated that, there are a number of factors that influence the postprandial glycaemic 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, antinutrient and organic acids.

Golay, Coulston, Hollenbeck, Kaiser, Würsch and Reaven (1986), Haber, Heaton, Murphy and Burroughs (1977) and O'Dea, Nestle & Antonoff (1980) report in their studies that when the botanical structure of legumes are disrupted, the amount of available carbohydrates in them increase. These factors can also contribute to the unexpected differences in the GI values of different foods (Wolever, Jenkins, Jenkins & Josse, 1991). GI is expressed in percentages and it is represented on an absolute scale where foods with values of 55 or less have a low GI, foods with 56 to 69 have a medium GI and 70 or more are classified as foods with higher GI (Brand-Miller, et al., 2003). The GI of a food is mostly compared with a standard; pure glucose, which has a GI of 100. GI measures postprandial glucose which can be influenced by varying the amount and type of dietary carbohydrates consumed. Meals containing low GI foods reduce both postprandial blood glucose and insulin responses (FAO, 1998).

Glycaemic load concept

Although the GI can represent a carbohydrate-containing food's effect on blood glucose, the portion size is also an important factor that needs to be taken into consideration for glucose management as well as the management of weight. In a study by Sheard, Clark, Brand-Miller, Franz, Pi-Sunyer, Mayer-Davis et al. (2004) they made a statement that both the quality and quantity of carbohydrate in a food determine an individual's glucose response to the food. The glycaemic load is therefore the new way to evaluate the impact of carbohydrate consumption that takes into account the glycaemic index but provides a deeper picture than the GI does. Glycaemic load is defined as the product of a food's glycaemic index and its total available carbohydrate content (Salmeron, Manson, Stampfer, Colditz, Wing, Jenkins et al, 1997).

$$\textbf{Glycaemic Load (GL)} = \frac{\textbf{Glycaemic Index (GI) x Carbohydrate (g)}}{\textbf{100}}$$

Glycaemic load accounts for carbohydrates in food and how much each gram of it will raise an individual's blood sugar level. This implies the GL provides a summary measure of the relative glycaemic impact of a "typical" serving of the food. Foods with a GL less than or equal to 10 ($\leq$ 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 ($\geq$ 20) considered high GL foods (Venn, Wallace, Monro, Perry, Brown, Frampton et al, 2006).

To determine the GL of a food, there is the need to first determine the glycaemic index of the food in order to use for 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).

Portion size and glycaemic control

The idea of portion size of foods consumed at a sitting and the serving sizes are important in the effective dietary intake and glycaemic control studies. This is because food's portion sizes have a major effect on the glycaemic index of the food, thereby increasing the glycaemic load of the food (Azadbakht & Azizi, 2005). The United States Department of Agriculture (USDA) as cited in (Sanusi & Olurin, 2012) and Food and Drugs Administration and Control (Young & Nestle, 2003) have established standard serving sizes that guide Americans to select the right portion sizes of food to eat for sustained and improved health.

These serving sizes are also important in monitoring portion sizes as part of weight loss and weight management programmes and have gone a long way to help dieticians to manage diet related chronic diseases better (CDC as cited in Sanusi et al., 2012). 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 (USDA). 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 et al 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 a 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. The recommended amount of a serving of fufu is 211grams which contains 76g of carbohydrate. Most dieticians and nutritionist use this guideline in managing diet related diseases.

Determination of glycaemic index

The glycaemic response of a food is measured by taking blood samples for glucose test at timed intervals which start at the first bite of the test food (Wolever, Vorster, Björck, Brand-Miller, Brighenti, Mann 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 glycaemic response from the reference food will have a great effect on the GI than variations in the test foods (Brouns et al., 2005). They 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 for the determination of the GI of a food. According to Foster-Powell, Holt & Brand-Miller (2002), over the years, 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., 2002).

The use of white bread as a reference food produces a relatively higher GI value than glucose. Wolever et al (1999) report that 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 (Bornet et al., as cited in Brand-Miller et al., 2003).

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 10-14hour 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 IAUC of the reference food will be used as the denominator in calculating the test foods, differences in glycaemic response to the glucose or white bread used will, therefore, produce a 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. 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 sugar 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 glycaemic response (Wolever et al., 1991).

Physiological characteristics of study subjects

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

Glycaemic Load and Health

The glycaemic load concept has widely been associated with various Non-Communicable Diseases (NCDs) by several studies (Wang, Guo, Zhang, Zhou, He & Zhang 2013; Willett, et al., 2002; Goff, Lloyd-Jones, Bennett, Coady, D'Agostino, Gibbons et al., 2013; Mirrahimi et al., 2012; Bells and Sears, 2003; Ludwig, 2000). It has positive associations with the tenacity of either increasing the risk of acquiring them or reducing the risks. Foods that have high GL are linked to an increased risk of certain chronic diseases whiles low GL diets are seen to reduce the risk of acquiring this diseases.

Glycaemic load and diabetes

In a collection of studies, both the glycaemic index and the glycaemic load of the total diet have been associated with a greater risk of type 2 diabetes in both men and women (Sluijs, van der Schouw, Spijkerman, Hu, Grobee, & Beulens, 2010; Barclay, Petocz, McMillan-Price, Flood, Prvan, Mitchell, 2008). 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). Hyperglycaemia 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).

Since diabetes is primarily a condition of disordered glucose metabolism, it is important to bear in mind the type of dietary carbohydrate that can influence the risk and course of this disease (American Diabetes Association, 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 glycaemic load food would increase the risk of type 2 diabetes, Willet et al (2002) report 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 improve blood glucose control as well as reducing the incidence of hypoglycaemic events.

Glycaemic load and coronary heart diseases

Mathers, Boerma and Ma Fat (2009) reports that 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 glycaemic load increase the relative risk of CHDs (Mirrahimi et al., 2012; Fan, Song, Wang, Hui & Zhang, 2012). A study by (Jeppesen, Schaaf, Jones, Zhou, Chen & Reaven) as cited 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.

Glycaemic load and obesity

It has been observed by Bells et al. (2003) that the prevalence of obesity has increased instead of lowering. This concern has been raised when recommendations by Western Dietary Guidelines encouraged the consumption of carbohydrate in place of fat. This has been attributed to the fact that total diet calories have been consumed more from carbohydrate than fat (Bell, et al., 2003). Studies have confirmed that consuming a low GL diets reduce hunger and promote satiety (Ludwig, 2000; Roberts, 2000). 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. (Ludwig, Majzoub, Al-Zahrani, Dallal, Bianco & Roberts) as cited in (Bell, et al., 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 glycaemic load and health are summarized in the table below.

Table 2: Summaries of studies on glycaemic load and health

Author (s) and Year	Study Topic	Findings
Galani, Aguirre & Diaz (2006).	Acute effect of meal glycaemic index and glycaemic load on blood glucose and insulin response in human.	Glycaemic 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-glycaemic load diet on cardiovascular disease risk factors	An ad libitum low-glycaemic load diet may be more efficacious than a conventional, energy-restricted, low-fat diet in reducing cardiovascular disease risk.
Meinhold (2010)	Low glycaemic load diets: how does the evidence for prevention of these diseases measure up?	There is increasing evidence that low-glycaemic 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-glycaemic load diet provided it meets current dietary recommendations including those related to dietary fat content and portion control, seems prudent.

Table 2: Continued

Beulens, de Bruijne, Stolk, Peeters, Bots, Grobbee, et al. (2007)	High dietary glycaemic load and glycaemic index increased the risk of cardiovascular disease among middle-aged women.	Among women consuming modest glycaemic load diets, high dietary glycaemic load and glycaemic index increase the risk of CVD, particularly for overweight women
Livesey, Taylor, Livesey & Liu (2013)	Is there a dose-response of dietary glycaemic load to the risk of type 2 diabetes?	People who consumed lower-glycaemic load diets were at a lower risk of developing type 2 diabetes than those who ate a diet of higher-glycaemic load foods.
Mirrahimi, de Souza, Chiavaroli, Sievenpiper, Beyene, Hanley et al. (2012)	Associations of glycaemic index and load with coronary heart disease events: a systematic review and meta-analysis of prospective cohorts	Higher-glycaemic load diets are associated with an increased risk for coronary heart disease events

Factors Affecting Preference and Food Choice

Making food choices and decisions based on several criteria is a daily need. The choice of food is more complex than just liking or disliking a food product (Palojoki & Tuomi-Gröhn, 2001). Even though the main drive for eating is hunger, what one chooses to eat is not determined solely by physiological or nutritional needs. It is influenced by psychological factors, cultural, social, economic, availability, sensory appeal, religious, and health reasons among others (Hayford, Steiner-Aseidu & Sakyi-Dawson, 2015).

Food choices or preferences begin early in life and change as individuals interact with parents, friends, and peers.

Psychological factors

One reason for differences in food choices and preference is what we experience with food as we grow up. Peoples' liking for specific foods and food acceptance patterns are to a very large extent learned (Beauchamp & Mannella, 2009). Food preferences are distinctive examples of learned behaviours that occur unintentionally. In comparison to intentional learning, this type of learning does not deteriorate with age. We learn about food throughout our lives, but most food related learning occurs during the first 5 years of life (Köster, 2009). As young children, food experiences may have been severely limited by parents and other adults responsible for us.

The first most basic learning experience is mere exposure; that is repeated exposure and consumption of food which increases the liking of that particular food hence the preference for that food (Hausner, Hartvig, Reinbach, Wendin & Bredie, 2012). Secondly is the medicine effect that occurs when food associated with recovery from illness becomes preferred. On the other way around, when the consequence is negative leads to a dislike of that particular food (Capaldi, 1996).

Another learning experience is flavour-flavour learning which occurs when a new flavour is paired with an already liked flavour (Yeomans, 2007). This type of learning last longer and the food remains liked unless another learning experience counteracts the initial experiences. Yeomans (2007) gives an example that sweetness is naturally liked and therefore the addition of sweetness to foods increases their immediate acceptability.

Lastly, of the food learning experience is the flavour-nutrient learning which occurs when a food becomes associated with ingested nutrients or calories. Humans prefer foods with the highest energy density, such as food high in sugars or fat (Capaldi, 1996; Cooke & Wardle, 2005). A strong conclusion can be made from the above points that, several different learning mechanisms cause differences in food preferences and these differences are highly subjective.

Another psychological factor that plays a major role in consumers' perception and preference of food is personality characteristics (Jaeger et al.) as cited in (Vabø & Hansen, 2014). They indicated that Private Body Consciousness (PBC) is one characteristic that is related to food preference. According to them, PBC is an individual measure of inner body awareness and subjects might be classified as either high or low in PBC. These classifications are based on several factors such as sensitivity to changes in body temperature, internal tensions, heart rate, dryness of mouth and throat, and hunger sensations (Jaeger et al.). PBC theory predicts that some people are more sensitive to changes in their body than others, and this has been successfully linked to different aspects of human behaviour including preference for sensory characteristics (Jaeger, Andani, Wakeling & MacFie, 1998). Specifically, they revealed that how consumers' react to information given about a food product depend on whether they are high or low in PBC.

Other personality characteristics investigated by Goldberg & Strycker (2002) is that individuals who substitute low-fat food for high-fat food tend to describe themselves as dutiful, orderly and conscientious. Moreover, people who avoid foods flavoured with fat tended to describe themselves in terms of quickness, alertness and other aspects of intellect. Further, people who try to avoid non-meat types of fat describe themselves in respect of morality, cooperativeness, dutifulness, and purposefulness. People who avoid meat fats describe themselves in terms of imagination and reflection as contrasting to talkativeness and sociability. Finally, those who reported high consumption of fibre rich foods tended to describe themselves as open to experience which includes imagination, reflection, quickness, and poise. It is fascinating how differences in personality characteristics effect the types of food we prefer and how we perceive them, however, these issues cannot be overlooked.

Lastly on psychological factors affecting food preference is consumers' perception about how food products are marked and brand knowledge of products. Consumers might have expectations or experiences related to a certain brand and this can affect their food preferences (Lawless & Heymann, 2010). Additionally, consumers are mostly brand loyal and have a preferred brand that they continue to choose repeatedly. These brands are also loyal to produce positive associations for the consumers, and these associations determine the consumer's willingness to repeatedly buy the product (Jansson-Boyd, 2010).

Cultural factors

Food preferences have been proven to be closely related to cultural development throughout history (Wright, Nancarrow & Kwok 2001; Montanari, 2006). The cultural group we belong plays a major role when it comes to food preferences. Culture can be seen as a sort of collective memory that influences individual behaviours and the influence of culture is rooted in a combination of several factors (Franchi, 2012). One factor is the environment;

that is geography, climate, and availability of different plant and animal species. Another is ritual and belief systems, both religious and otherwise. Community and family structure is also a factor as well as the degree of innovation, mechanization, and experimentation in the society.

Finally, the historical, economic and political context within a culture also affect consumers' food choices and preferences (Mela, 1999 as cited in Vabø, et al., 2014; Wright, Nancarrow & Brace, 2000). Consumers use the categories and rules of their cultures, subcultures or ethnic groups to decide what is acceptable and preferable to eat (Nestle, Wing, Birch, DiSogra, Drenwnowski, Middleton et al., 1998). This supports the assumption that people from the same culture or region would have been affected in the same way culturally and therefore have similar food preferences. More so, in the contemporary world, it is common for people to eat the same food or ingredients, all over the world (Risvik, Rødbotten, & Veflen, 2006).

According to Ludy and Mattes (2012) to some degree culture determines what kind of foods children are exposed to, thereby influencing their preferences later in life. Adults may have introduced children to only small subsets of available foods because some excellent foods are often considered inappropriate for children (Wardlaw, 2000). In support of this Dindyal and Dindyal (2003) stat that different cultures may inspire or frown upon consumption of different foods by individuals who belong to their groups. Also, the consumption of different foods at different stages of life may be actively encouraged or discouraged.

Social factors

Social influences can have an effect on food choices as well as healthful dietary change (Devine, Connors, Sobal & Bisogni, 2003). Social influences on food intake refer to the impression that one or more persons have on the eating behaviour of others, either direct (buying food) or indirect (learn from peer's behaviour), either conscious (transfer of beliefs) or subconscious (Feunekes, de Graaf, Meyboom & van Staveren, 1998). The closest social reference groups that provide several chances for modelling and reinforcing the common food choices, as well as sensory likes and dislikes, are family and peers (Mela, 1999). In the line of this reasoning (Anderson, Cox, McKellar, Reynolds, Lean, & Mela, 1998) inscribe that the family is widely recognised as being significant in food decisions and that shaping of food choices takes place in the home.

Nevertheless, research indicates that both food choice and intake can be influenced by the behaviour of others present during an eating occasion (Herman, Roth & Polivy, 2003; Robinson, Tobias, Shaw, Freeman & Higgs, 2011). In as much as the present of an eating, companion can influence food choice and intake, other researches also back the notion that normative social influence can transform food intake, and inform typical food choice (Roth, Herman, Polivy & Pliner, 2001; Pliner & Mann, 2004). Likewise, studies of social norms in young adult humans have shown that supposed social norms are predictive of habitual food choice (Lally, Bartle & Wardle, 2011). From these studies, it can be deduced that social influence on eating behaviours may be obvious even when one has already acquired a preference for a particular food.

Economic factors

Economic factors have a strong influence on the type of food people eat as well as how they are prepared, served and eaten. There is no doubt that the cost of food is a primary determinant of food choice (De Irala-Estevez, Groth, Johansson & Oltersdorf, 2000). The cost of food is a much more important element in selection of food among people with low incomes compared with those that are better off (Steptoe as cited in Vabø & Hansen, 2014). However, whether the cost is expensive depends basically on a person's income and socio-economic status. Low-income groups have a greater propensity to consume unbalanced diets. On the other hand, Kwakye (2010) strongly believes that poor people spend a higher proportion of their income on food, although the actual amount of money spent may be small. Nevertheless, access to more money does not automatically guarantee a better quality diet but the range of foods from which one can choose should increase (De Irala-Estevez et al., 2000).

Availability

Availability and accessibility to food are important factors that influence food preference. Even though availability and accessibility are sometimes used interchangeably, they do not mean the same thing. Cullen, Baranowski, Owens, Marsh, and Rittenberry (2003) clarify this by explaining that availability refers to whether the foods of interest are present in an environment, whiles accessibility means whether these foods are available in a form, location, and time that facilitates their consumption (e.g., ready-to-eat foods). Nestle et al. (1998) distinguished between overall availability and immediate availability.

Overall availability refers to the range of food options accessible that are accepted and affordable by the consumer. Immediate availability, on the other hand, refers to the readiness and convenience of the food product, for example, if it can be stored for a long time, preparation time and whether it can be eaten anywhere. This is dependent on geographical location.

Our diets are one way or the other, limited to the types of food and amounts of food allotted by the food supply. Depending on where you live you may find certain kinds of foods you may not find in another part of the world (Morland, Wing & Diez Roux, 2002). Donkin, Dowler, Stevenson, & Turner (2000) also reports that certain foods tend to be more expensive when available within towns and cities compared to the rural areas.

According to Mela, there are some basic global rules related to the understanding of food choice. Availability is included in the rules as follows: *"If it is not available, it will not be eaten. If it is available, it is likely to be eaten. If there is no alternative, it will be eaten."*(Mela, 1999). Subsequently, foods may be comparatively unavailable, or available as a small percentage of total volume, or only available at a higher cost.

Religious reasons

According to Dindyal et al. (2003), various religions of the world have a profound influence on man's dietary practices and customs. Over the centuries many religions have decreed what food man could eat or could not eat on certain days of the year. Many of these dietary habits have become symbolic of the religion itself. An example was given that, in the Hindu and Buddhist religions the consumption of both pork and beef is frowned upon. This is because it is considered to not be clean meat. Equally only the consumption of pork and not beef is prohibited for the same reasons in the Islamic religion and Judaism. However, all other meats taken in these religions must be 'halal' and 'kosher' respectively. This means that special prayers are performed in order to make the eating of these animals acceptable (Dindyal et al).

In the same way, Katz and Weaver (2010) mark that in Christianity, Catholics are required to abstain from eating meat on Fridays during lent seasons, in remembrance of the sacrificial death of Christ. Moreover, most Seventh-Day Adventists are lacto-ovo vegetarian. They believe that the vegetarian diet prescribed by God is the diet for health; therefore, they reject flesh foods for many reasons. The Seventh-Day Adventists as their name implies observe Saturday, the seventh day of the week as a Sabbath - a day of rest and prayer. Due to this, they prepare the Sabbath meal on Fridays and wash the Sabbath dishes on Sundays. That means that, on Saturday, preparation of food becomes a taboo hence in the selection of food, they will prefer already prepared foods and not raw foods which need further preparation (Katz, et al.).

Health reasons

Health is valued by everybody as one of the essential drivers of human behaviour. It attempts to change eating patterns by informing consumers about the link between diet and health (Grunert & Wills, 2007). A prediction was made by the World Health Organization (WHO) that by the year 2020, chronic non-communicable diseases will account for approximately three-quarters of all deaths in the developing world (WHO, 2002). WHO further recommended that in order to prevent such nutrition related diseases, there should be a reduction in sugars, fat, saturated fats and trans fats in processed foods, in order to improve the nutritional value of food products (WHO, 2002). This has influenced most people to be concerned about the food choices they make.

McCluskey (2015) supports this assertion that consumers are increasingly demanding nutrition and ingredient claims on the products they buy. Kubberødet, Ueland, Rødbotten,Westad and Risvik (2002) finds that in order to maintain an ideal weight, females tend to avoid eating red meat but rather prefer to eat more fresh fruit than males, who eat more crisps, fried foods and processed meat. Simply put men are less interested in health when it comes to food than females (Wardle, Hasse, Nillapun, Jonwuitwes & Bellisle, 2004).

Dindyal et al. (2003) also include that allergy to food influences a person's choice of food. A person's physical needs also affect what he/she chooses to eat. People who participate in athletics or strenuous work obviously need more kilocalories than others do. In choosing their meals they will prefer to choose food of high carbohydrate content to produce the energy needed for them to work (Jones, Dewar, & Donaldson, 2005). Likewise, Sedentary workers will require choosing food of lees carbohydrate content or even small quantity of carbohydrate food.

Sensory appeal

According to Lawless et al. (2010), understanding a person's opinion about the senses such as taste and olfaction is very important in understanding food preferences. There are some characteristics of foods that make people eat because their senses are influenced. These sensory characteristics influence consumers, particularly in spontaneous food choices. Characteristics such as aroma and the appearance of the food first attract people and later the taste of the food influences people to eat (Kwakye, 2010).

Sensory Evaluation

Determining how food products affect consumers' senses, is one of the most vital goals of the food industry. It also serves as a major concern for nutritionists and dieticians who develop a healthier recipe. Obtaining the benefits of a healthy food can be achieved only if our senses accept it (Choi, 2013). Consumers' reaction as perceived by the five senses is hence considered essential. Sensory evaluation is a scientific discipline used to evoke measure, analyse and interpret reactions to those characteristics of foods and materials as they are perceived by the senses of sight, smell, taste, touch, and hearing (Stone and Sidel, 2004). The qualities of a food acknowledged by these senses are called sensory characteristics of the food. These include the taste, odour, appearance, mouth feel, and the sound of the food.

The human senses

Sight

The eyes see the initial quality of food such as the colour, size, shape, texture, and constituency. Choi (2013) indicates that colour is used to evaluate a food's desirability and acceptability and also can indicate ripeness, the strength of dilution and degree to which food has been heated. Therefore a change in the original colour of a food (cooked or uncooked), can alter a person's choice and desirability. Colour mostly generates certain anticipations in the mind e.g. the creamy colour of vanilla ice cream evokes an expectation of richness. However, it can also be deceptive since the quality of a food can be masked by changes in colour (Choi). Sizes, shapes, and texture likewise provides information on food quality and thus affects its acceptability and preference.

Smell

Our sense of smell factors much in our evaluation of food quality. The volatility of odours is related to temperature and because of this, only volatile molecules in the form of gas carry an odour. This makes it easier to smell hot foods than cold foods (Choi, 2013). According to Brown (2008), molecules that are volatile are detected by the olfactory epithelium in the nasal cavity, through one or two pathways;

1. directly through the nose or
2. after entering the mouth and flowing retro-nasally or forward the back of the throat and up into the nasal cavity.

Choi (2013) describes the gradual decrease in the ability to distinguish between odours over time as adaptation, and this helps to prevent sensory overload. Human subjects have fluctuating sensitivities to odours conditional to hunger, satiety, mood, concentration, presence or absence of respiratory infections and gender (Maruniak, as cited in Choi). Since different people smell a particular odorant differently, it is essential to use a large panel as possible when identifying a new odour from a food product to get valid results.

Taste

Taste is the most significant factor in a person's selection of a particular food. A substance should be dissolved in the water, oil, saliva to make it possible for it to be tasted (Choi, 2103). Taste buds found on the surface of the tongue, by the mucosa of the palate and in areas of the throat is responsible for a person's ability to taste. Variation in taste by individuals is associated with a genetic component of the individual (Kim, Jorgenson, Coon, Leppert, Risch, & Drayna, 2003).

Aside from genetic component, variation in the taste perception also depends on how noticeable sweet, fatty and bitter component is in the food or beverages (Duffy & Bartoshuk, 2000). Duffy, Peterson, Dinehark, and Bartoshuk (2003) also added that variation depends on the value a consumer place on factors such as health and convenience. Taste can be categorised as follows;

1. sweet: sweet taste includes sugar, glycols, alcohols and alternative sweeteners (Godshall, 1997).
2. salty: salty taste comes from ionized salts like ions in sodium chloride (NACL) and other salts found naturally in some foods (Choi, 2013).
3. sour: sour taste comes from the natural acids found in foods, fruits, vinegar and certain vegetables (Choi).
4. bitter: bitterness is imparted by compounds such as caffeine in tea and coffee, theobromine in cocoa and phenolic compounds in grapefruits (Brown, 2008).
5. umami: this a most lately defined component of taste. It is a Japanese word meaning "delicious". It is induced by glutamate compounds which are commonly found in meats, mushrooms, soy sauce, fish sauce and cheese (McWilliams, 2008).

Touch

The sense of touch conveys an impression of a food's texture to us through oral sensations or skin (Choi, 2013). Texture is the sensory manifestation of the structure or inner makeup of products in terms of their feel which are measured as mechanical properties in the muscles of the hand, fingers, tongue, jaw or lips; or by the tactile nerves in the surface of the skin, hand, lips or tongue (Meilgaard, Civille & Carr, 2007). Choi explains that the greater surface sensitivity of the lips, tongue, face, and hands makes easy discovery of small differences in particle size, thermal and chemical properties possible among food products.

Sensory evaluation is normally carried out by designed experiments under proper environmental conditions. Trained and untrained panels are used in sensory evaluation and the degree of training panels depends on the type of sensory analysis to do, thus panels with different degree of training are required for different types of sensory analysis (Ayeh, 2013). The level of training required depends on factors, such as the degree of differences to be detected, the number of panellists required for the tests, and time and value of the analysis to the product type.

Sensory evaluation is conducted in the food industries for various reasons (IFT as cited in Ayeh, 2013) such of which includes:

1. New product development
2. Product matching
3. Product improvement
4. Process change
5. Cost reduction

6. Selection of a new source of raw material supply
7. Quality control
8. Consumer acceptance and opinions
9. Product grading and rating
10. Consumer preference
11. Sensory panel selection and training
12. Correlation of sensory properties

Sensory evaluation tests can be group into two major types. These are the Product-Oriented or Analytical tests and the Consumer-Oriented or Affective tests (Choi, 2013).

Analytical tests (or Product-Oriented Tests)

These are used to discriminate between products (Discriminative tests) or to describe sensory characteristics of the product (Descriptive tests).

Descriptive test

Descriptive methods are used to provide more-comprehensive profiles of a product by asking panelists to provide information on the specific sensory characteristics of food samples and to quantify the sensory differences. Here the use of 10-12 highly trained and/or experienced panelists are required (Choi, 2013). Examples of the descriptive test are, Flavour Profile Analysis®, Quantitative Descriptive Analysis®, Texture Profile Analysis® and Sensory Spectrum®. (Lawless et al., 2010)

Discriminative test

According to Stone and Sidel (2004), the discriminative test also known as difference test is used to determine if products are different from each other. It is aimed at evaluating specific attribute of products e.g.

sweetness. A number of 25-50 trained panelists are used. Examples of discriminative tests are; triangle test, paired comparison test, and duo-trio test (Lawless, et al, 2010).

Affective tests (consumer-oriented tests)

Affective tests are used to either evaluate consumer preference or acceptance of the product. Large numbers of untrained panelists are required for these tests (Choi, 2013).

Preference tests

These tests are used to allow consumers to make a choice between samples. It answers the question "which of the sample do you prefer?" Examples of preference test are the paired preference test; where two samples are presented for consumers to indicate the one they prefer most and the ranking preference test; where more than two samples are presented (Lawless, et al., 2010).

Acceptance tests

Acceptance tests are used to determine consumer acceptance of a product. A degree of liking a product is rated by the use of the hedonic scale. The scale is a category-type scale with an odd number (five to nine) categories ranging from "dislike extremely" to "like extremely." A neutral midpoint (neither like nor dislike) is included (Choi, 2013).

Panel selection

Usually, two types of panels are used in the sensory evaluation. These are the descriptive and consumer panels (Choi, 2013). The author further explains that descriptive panels are commonly used to determine differences between food samples. A descriptive panelist is experienced in the type of food being tested and goes through extensive training before the test. A consumer panel, on the other hand, is selected from the public according to the demographics necessary to test a product (Choi). When selecting a panel, it is best to use an equal number of men and women. The age distribution of the panelists must also be considered since it can affect the results (Brown, 2008). She also adds that people to be selected must be committed to the time and should also know what is expected of them during the test. Choi recommends certain criteria to follow in selecting panel members. These are;

1. panel members should be in good health and free from illness related to sensory properties such as chronic colds, food allergies or diabetes.
2. they should not be smokers
3. they should not be colour blind
4. they should not have strong likes or dislikes for the food to be tested.

Other factors to consider so as to enhance panelists performance during a sensory evaluation includes;

1. sensory evaluation of certain products should be organized at the time of the day these products are typically consumed (Meilgaard, et al., 2007).
2. midmornings or midafternoons (such as 11 am or 3 pm) are considered the appropriate times for testing because at these times people are not usually too hungry or full (Brown, 2008).
3. panelists should not eat any food for at least an hour before testing and should not chew gum immediately before testing (Brown).

Chapter Summary

From the literature review, there is an evidence that numerous studies have been done earlier by researchers on how carbohydrate foods affect our blood sugar levels and our general wellbeing. The review showed that fufu being a commonly consumed staple food in the West and Central Africa, is prepared differently and in Ghana, three different varieties of fufu are consumed. The staples that are used in preparing fufu (cassava, plantain, cocoyam, and yam) contain carbohydrate but in different quantities and proportions. 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 glycaemic index concept was propounded (Jenkins et al., 1981).

The GI (which 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 as a result of a carbohydrate consumed. A number of factors were seen to influence the glycaemic 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, the effect of a previous meal (FAO/WHO, 1998). Foods with values of 55 or less indicate a low GI, foods within 56-69 have a medium GI and those 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 glycaemic load (Salmeron, et al, 1997). The glycaemic load (which is the product of a food's glycaemic index and its total available carbohydrate content), evaluates the impact of carbohydrate consumption and how much each gram of it affects blood sugar level. It measures the relative glycaemic 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; Bells, et al., 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. It is influenced by psychological factors, cultural, social, economic, availability, sensory appeal, religious, and health reasons among others (Hayford, et al, 2015). Sensory evaluation was also perceived to be an important factor in the food industry and a major concern for dieticians and nutritionists in developing a healthier recipe.

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

CHAPTER THREE

RESEARCH METHODS

Introduction

In this chapter, the method that was used in conducting the research is discussed. It includes the research design, study area, study subjects and panel members, methods and materials, data collection procedure, how data collected was analyzed and interpreted, ethical consideration and limitations of the study.

Research Design

The research was an experimental research and the research design used was the crossover experimental design. 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.

The researcher manipulated the independent variables. 'Fufu' which is the independent variable was made in three different combinations. This was done in order to assess the effect each combination has on the glucose response of the individual. Other relevant variables such as time participants used in eating and their movement after eating were also controlled in order to achieve the desired results that were needed.

A crossover design is a research design in which study participant receives all treatments that are being investigated, but at different times

(Stoney & Johnson, 2012). According to Liu (2015), in this design the same subjects are used for both test and control treatments, thereby diminishing the influence of inter individual variability and allowing a smaller sample size. A crossover design was appropriate for this study because, same participants were used to assay for blood glucose of reference foods, as well as test foods

Study Area

The research was carried out in Wenchi, the capital of the Wenchi Municipal Assembly, in the Brong Ahafo Region. Wenchi is a town that is made up of people of different tribes and cultures due to the schools and other companies found there. Most people come there to either school or work. The major occupation for the native inhabitants, however, is farming. The research was done there because it was easy to get people who eat all the three types of fufu mixtures.

Sampling Procedure

The convenience and purposive sampling technique were used in the study for the selection of panel members for the sensory evaluation and the selection of participants for the blood glucose test respectively. Convenience sampling, also known as haphazard sampling or accidental sampling is a type of non-probability or non-random sampling where members are selected, 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).

Lewis-Beck, Bryman, and Liao (2003) explain purposive sampling (also known as judgment, selective or subjective sampling) as a nonprobability sampling technique in which researcher relies on his or her own judgment when choosing members of the population to participate in the study. According to them, it is deliberately seeking out for participants with particular characteristics, according to the needs of the developing analysis and emerging theory. Employing these two sampling techniques were appropriate in other to achieve the objectives of this study.

Panel Members

In sensory evaluation, respondents are called Panel members. Panel members were conveniently sampled from public places like the market place, church places, schools, and banks. Sixty (60) untrained panel members were selected for the sensory evaluation test. This was because, in the affective test, large numbers of not less than 50 untrained panelists are required (Choi, 2013). Since the preference test, (a type of affective test) was used, the number and nature of panelists used in this study were in accordance with the requirement. Sixty panelists were used because they were available during the time of the sensory test and also they made up of people who eat all the three varieties of fufu. Panelists involved were not trained, however; they were oriented on the sensory evaluation test to be done. Prior to the selection of these panel members, they were asked whether they were allergic to any of the ingredients used in preparing the test foods. Also, anyone with respiratory infections like a cold was not included.

Study Subjects

Ten apparently healthy adults were purposively sampled from public places like church, schools, and market places for the blood glucose test. These 10 subjects were selected based on the FAO/WHO (1998) recommendation of glycaemic index determination. According to FAO/WHO this type of test can be repeated in six more subjects. Despite the high cost component, using more subjects will provide more accurate results. This is in agreement with Wolever, Vuksan and Jenkins (2011) and Bronus et al. (2005) who recommended the use of ten subjects in the determination of glycaemic index for a significant degree of precision. Purposive sampling was used because participants were to meet certain inclusion criteria prior to participating in the study.

Inclusion criteria

1. Participants were between 18- 60 years
2. They were not diabetic
3. They were not on any medication of any kind and would be available throughout the duration of the study.
4. They should be people who eat all three varieties of 'fufu'

All the participants were grouped together three days prior to the day of the test for an orientation. They were made known of the importance of undertaking such an experiment and its importance to the researcher as well. They were again instructed to stay away from alcohol and smoking within the periods of the experiment.

Methods and Materials

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

Plantain fufu

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

Cocoyam fufu

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

Yam fufu

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

Proximate analysis

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

Moisture content

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

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

Ash content

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

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

Protein content (Kjeldhal protein)

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

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

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

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

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

Fibre content

Fibre content was determine by weighing approximately 0.5 g of the milled samples into separate pre-dried crucibles. The crucibles were placed into a fibretec Hot Extraction Unit. Hundred (100) ml of concentrate H_2SO_4 (1.25%) solution were added to the samples and allowed to boil for exactly 30 minutes exactly. After boiling, the samples in the crucibles were washed with hot distilled water followed by 100 ml of 1.25 NaOH and then boiled for another 30 minutes. The crucibles were transferred to the fibretec cold extraction unit and then washed with methanol. The crucibles were later removed and dried at 105°C overnight and weighed after cooling. The samples in the crucibles were ashed for about 3 hours at 500°C, cooled in the desiccator and weighed.

The percentage fibre content in the fufu was calculated using the formula below;

$$\text{Fibre content (\%)} = \frac{\text{weight loss through ashing}}{\text{weight of oven−dry sample}} \times 100$$

Soluble carbohydrates content

Soluble carbohydrate content in the samples were determined using standard laboratory procedure of Brown, Young and Steraile (1957) as outline in Stewart, Grinshaw, Parkinson and Quarnby (1974). Step one involved the extraction of material while step two involved colour development.

Extraction of materials

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

Colour development

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

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

Data Collection Instrument

A sugar profile sheet was used to assess participants' glycaemic response and the glycemic load to all varieties of fufu. Sugar profile sheet included participants' background information and the individual test food profile. A sensory evaluation questionnaire form was used in collecting data for the sensory evaluation of all three test foods.

To perform proximate analysis on the varieties of fufu, the following apparatus were used:

i. Moisture content: beakers, desiccators,

ii. Ash content: crucibles, furnace, desiccators.

iii. Protein content: conical flask, pipette,

iv. Fat content: Soxhlet extractor, Soxhlet extraction thimbles, round bottom flask, desiccators, heating mantle

v. Fibre content: crucible, fibertec hot extraction unit, desiccators

vi. Soluble carbohydrate content: conical flask, glass bubble, hot plate, volumetric flask, No.44 Whatman filter paper, pipette, boiling tubes, ice bath, spectrophotometre

Data Collection Procedure

For the proximate analysis, a letter from the Department of Vocational and Technical Education was obtained 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 blood glucose test was carried out at the Wenchi Methodist Hospital. Prior to the test, ethical clearance was obtained from the University of Cape Coast for approval to carry out the test. All subjects 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. Subjects reported to the laboratory of the Wenchi Methodist Hospital between 7:00 – 8:00 am on the day of test. Upon arrival participants' age, gender, weight (kg) and height (m) and waist circumference was taken and recorded.

Fasting blood glucose test (FBGT)

The FBG of each subject was taken each day of the test before administering the test and reference foods. This was done by wiping the forth left finger of each subject with alcohol. Their fingers were then pricked with a lancet to draw a drop of capillary blood. The ONE TOUCH Select glucometer with a strip inserted inside was used to collect the drop of blood to assay for the FBG.

Oral glucose tolerant test (OGTT)

Each subject was given a glucose solution (reference food) prepared from 50 g glucose and 200 ml water to take within a five minute period. A timer was used to ensure that subjects took the glucose solution within five minutes. Thirty minutes after drinking the glucose solution, a drop of capillary blood was taken from all the subjects and assayed for glucose. Afterwards, samples were taken from subjects at the 60th, 90th and 120th minutes as well and assayed for the glucose concentration. Subjects were given lunch before leaving. The OGTT was done twice on different days to ensure accuracy and precision.

Test foods

The first test food was given a week after the second OGTT. All subjects were given 143 g of fufu made from cassava and plantain, with 30 g of salmon fish and two ladles of light soup. The night prior to the day of test, they were made to do a 10- 12 hours fast and their FBGs taken. The time subjects started eating was recorded and they were asked to finish eating within a period of five minutes. After eating, drops of capillary blood were taken from subjects at 30th, 60th, 90th and 120th minutes to assay for glucose. This was done by wiping subjects' finger tips with alcohol. They were pricked with a lancet and a glucometer with a strip inserted was used to collect the drop of blood. Results were recorded in mmol/L.

On subsequent days for the second and third foods, the same processes as of the first test food was followed. However, the quantity for each test food was different even though the quantity of fish and soup were the same for all test foods. Subjects were given 138 g of cocoyam fufu and 116 g of yam fufu. Subjects were monitored throughout the study so as to ensure that they did not take in any other food or involved in strenuous activities that may affect the results of the study. Subjects were always given lunch at the end of each session. They were also always informed on the day of the next test and were remembered to do a 10-12 hours fast each night prior to the day of test. Subjects were also advised to stay away from alcohol and smoking until the duration of data collection was over.

Sensory Evaluation

The type of sensory test used was affective test. Precisely, the preference test was carried out to know the most preferred among the three combinations of fufu. Panelists ranked their preference based on the sensory characteristics; appearance, texture, aroma and taste. An overall preferred combination as well as the reason for that choice were provided for panelist to choose from. Reasons included cultural, religion, availability, sensory appeal, health and finance. Sensory evaluation test started in the morning around 11:30 am. Panelists were seated as and when they arrived. They were provided with all three food samples coded as PLF, COF and YAF for plantain fufu, cocoyam fufu and yam fufu, respectively.

They were made to observe, touch, smell and taste all three food samples and then ranked them in ascending order of their preference, in all sensory characteristics (appearance, texture, aroma and taste). Ranks were in order of 1, 2 and 3, with 1 being the most preferred and 3 being the least preferred. With regard to taste, panelists were made to rinse their mouth before taking any sample. This was to ensure that, the taste of the previous sample does not affect the result of the next one. Panelists were all asked not to communicate with each other.

Data Processing and Analysis

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

The Incremental Area under the Curve of both reference and test foods were calculated separately for each participant by using the trapezoid rule, to show the rise in glycaemic response after consumption of foods. The percentage GI for each participant was calculated as the IAUC of each test food over the mean IAUC of the reference food, multiplied by 100. The formula used was;

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

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

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

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

Limitations

Even though the nature of the sensory analysis test used demands more panel members, the number of panel members used in the study had to be limited. This was because panelists were not given prior notice but were told instantly to participate in the sensory evaluation and since it was carried out on a week day, it was difficult persuading them to spend few minutes of their time to undertake the test. Since sensory perception of a food is subjective, the texture of the food presented to them may not have been liked by some participants and hence affect their ranking choice. Again it is likely that fufu mixtures may not have been evenly mixed and so could affect the appearance as well.

Ethical Consideration

Due to the nature of this research which involved the feeding of participants with food and the drawing of blood from the figure tips, it was very necessary to seek for ethical clearance in order to proceed. Ethical clearance from the Institutional Review Board (IRB) of the University of Cape Coast, was sought and approved before data collection. Furthermore consent was sought from participants for their willingness to partake in the study (Sample shown in Appendix A). No participant was compelled in any way to participate in the study. Moreover, issues regarding confidentiality, anonymity and privacy were given a priority.

Chapter Summary

This chapter presented the method that was used in conducting the research. It focused on the research design, study area, study subjects and panel members, methods and materials, data collection procedure, how data collected was analyzed and interpreted and limitations of the study. Ethical consideration was also spelt out in this chapter.

CHAPTER FOUR

RESULTS AND DISCUSSION

Introduction

This chapter covers the results of the study as well as the discussion. The results are presented in graph and table forms. The results include the general anthropometric characteristics of subjects, glycaemic response graph of the reference food and the test foods, incremental area under the curve of the reference and test foods, glycaemic index of test foods, glycaemic load of test foods, the nutrient content of the different varieties of 'fufu', the demographic characteristics of panel members, results from the sensory evaluation of the 'fufu' mixtures including the most preferred, association of panelists' demographics on their preferences, descriptive statistics of the overall preference and multiple regression analysis of the reasons for the most preferred combinations. Results and Discussion were presented based on the objectives.

General Anthropometric Characteristics of Participants

The general anthropometric characteristics of participants included weight, height, BMI, age and the waist circumference. These were the attributes that were measured to determine the health status of participants. Results are presented in Table 3.

Table 3: General Anthropometric characteristics of participants

Statistic	Height (cm)	Weight (kg)	Age (years)	BMI (kg/m^2)	waist circumference (inch)
Minimum	150	49.5	18	20.6	26
25% Percentile	155	52.05	20.75	21.25	27.75
Median	162.	59.25	22.5	22.9	30
75% Percentile	167.5	71.18	30.75	24.5	31.63
Maximum	175	74.4	48	26	33
Mean	162	60.71	27	23.01	29.65
Std. Deviation	8.56	9.09	10.55	1.84	2.36
Std. Error	2.70	2.87	3.34	0.58	0.75
Coefficient of variation	5.29%	14.97%	39.08%	8.01%	7.95%

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

Ten participants were selected for the study. They were made up of five males and five females. Measurement of their height, weight, age, body mass indexes (BMIs) and waist circumference were all in the normal ranges as shown in Table 3. WHO (2006), classifies an adult with a BMI range of 18.5-24.9 as healthy, therefore looking at the mean BMI for the participants (Table 3) and considering the mean age, their status could be determined. The waist circumference of participants were also taken and the results were within the healthy adults' category of calculated waist circumference, as stated by Bhahd (2016). The average fasting blood glucose (FBG) level for both reference and test foods (Figures 8 & 9), as well as postprandial blood sugar levels were also found to be in the normal range as recommended by ADA (as cited in Niedziocha, 2011). Looking at the participants' measurements for Body Mass

Index and waist circumference, they were taken to be healthy individuals and their blood glucose levels also confirmed that they are not diabetics.

Using healthy people was important because it made it easier for participants to show intermediate intra-individual variation in the glycaemic response to foods. This finding is similar to that reported by Wolever, et al. (as cited in Wormenor, 2015). They looked at “Prediction of the relative blood glucose response of mixed meals using the glycaemic index of white bread”. Bronus, et al (2005) reports that to obtain precise result using “Glycaemic index methodology”, it is appropriate to use healthy individuals as seen in this study.

Participants’ Glycaemic Response to Ingested Carbohydrate

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

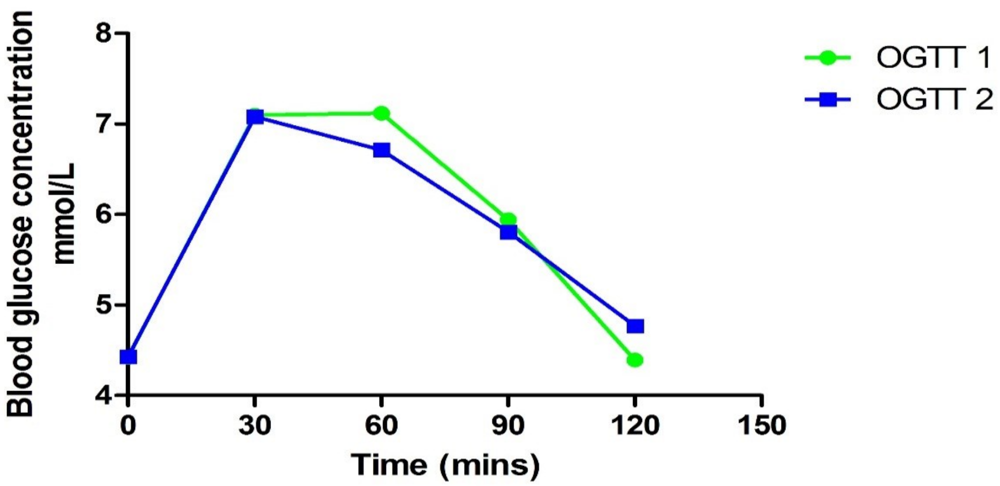

Figure 8: Participants’ glycaemic responses to ingested carbohydrate (OGTT)
Source: Field data, Adu-Gyamfi (2017).

The Oral Glucose Tolerance Test (OGTT), was carried out in duplicate as seen in figure 8. The average FBG (4.4 mmol/dl) was the same in both tests. The graph shows that, upon administration of the glucose solution, the average peak of the glycaemic response among all participants was observed at the 30th minutes after consumption, and dropped at the 120th minutes. Glucose stood out to be the preferred material for a reference food than white bread, because of the likely variations that may occur had in the preparation of white bread; as earlier stated by Bornet, et al. (as cited in Brand-Miller, et al., 2003) in a study on "Low–Glycaemic Index Diets in the Management of Diabetes". In a study on "Glycaemic index methodology", Bronus, et al. (2005) reports of participants complains about the nauseating feeling they had after drinking glucose solution. In this study too participants complained of the same nauseating feeling after they had consumed the glucose solution.

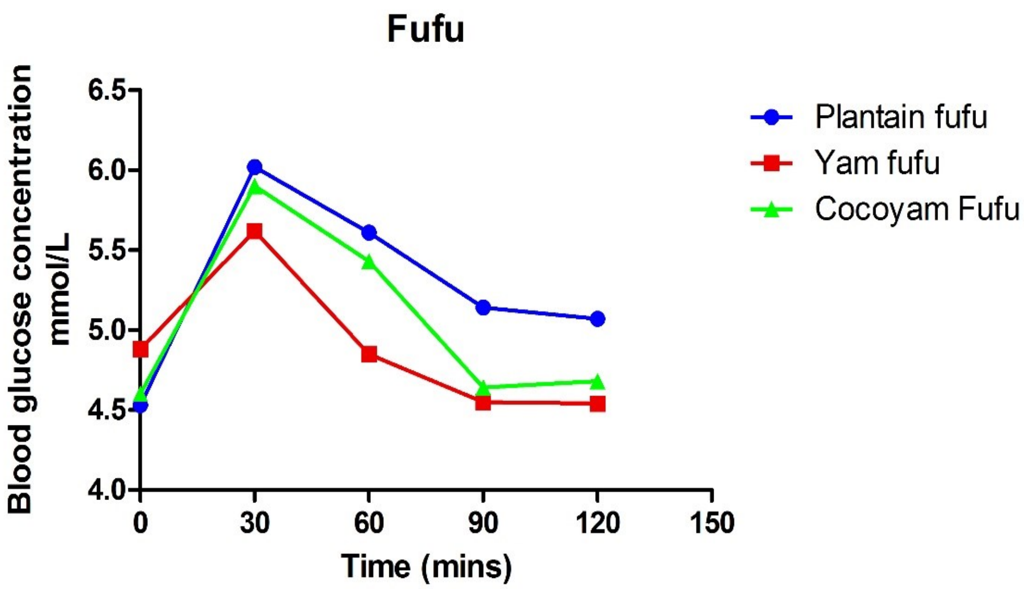

Figure 9: Participants' glycaemic responses to ingested carbohydrate (test foods).

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

Unlike the reference food, the average Fasting Blood Glucose (FBG) before the consumption of the test foods was different, however, the difference was not significant since it was in the normal range. Figure 9 illustrates that, the average peak of response for all test food was observed at the 30th minute after eating and this reduced to normal blood glucose levels at the 120th minutes after eating. The glycaemic response by participants after eating the plantain fufu was high (6.2mmol/L). This was followed by cocoyam fufu (5.8mmol/L) and yam fufu was reported to have a low glycaemic response (5.6mmol/L) by participants as seen in figure 9.

In figures 8 and 9, it can be observed that, there were differences in the glycaemic response of the reference food and the test foods. Postprandial glucose level of the reference food was high at each time interval as compared to the test foods when they were ingested. This could result from the high GI (100) of glucose, as reported by Foster-Powell, et al. (2002) when they studied "International table of glycaemic index and glycaemic load values". Brouns, et al. (2005) states in their study: "Glycaemic index methodology" that, glycaemic response among participant varied and even with the same participant, there are variations in each test food. The variations in the post-prandial blood glucose levels at different time interval could be attributed to this.

Proximate Analysis of Fufu Combinations

Proximate analysis of the fufu is the determination of the major nutrients in the 'fufu'. The moisture, ash, protein, fat, fibre and soluble carbohydrate contents were determined. Results are presented in table 4

Table 4: Nutrient content of the different combinations of fufu

Sample	Moisture (%)	Ash (%)	Protein (%)	Fat (%)	Fibre (%)	Soluble Carbohydrate (%)
Plantain fufu	71.77	0.76	2.99	0.06	2.29	34.87
Cocoyam fufu	68.28	0.89	3.62	0.07	2.70	36.10
Yam fufu	72. 15	0.82	4.30	0.06	2.80	43.00

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

From table 4, proximate analysis of the different combinations showed the carbohydrate content as well as other nutrients in the different combinations of 'fufu'

Glycaemic Load of the Different Fufu Combinations

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

Incremental area under the curve (IAUC)

The incremental area under the curve (IAUC), is the area under the curves from the reference and test foods (Figures 8 and 9). The trapezoid rule was used in calculation. Results are presented in Table 5.

Table 5: Incremental Area under the Curve of Reference Food and Test Foods

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

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

In table 5, the IAUC of reference food which is glucose was seen to be significantly different from the test foods at ($p<0.05$). However, there was no significant difference between the IAUC of the test foods ($p>0.05$). The values with the same superscript alphabets in the same row are not significantly different at ($p>0.05$).

Glycaemic index of test foods

Analysis of Variance (ANOVA) was used in comparing the glycaemic index of test foods. Results are presented in table 6. The values with the same superscript alphabets in the same row are not significantly different at ($p>0.05$).

Table 6: Glycaemic Index of Test Foods

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

Source: Field data, Adu-Gyamfi (2017)

The Glycaemic Indices of the test foods were classified as low, medium or high based on the following GI value ranges stated by Brand-Miller, et al. (2003).

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

Table 6 shows that, The GI of all test foods measured were low; plantain fufu was 53%, yam fufu was 30% and cocoyam fufu was 39%. Moreover, there was no significant difference (p>0.05) among them. The postprandial glycaemic response of each combination of fufu when ingested was influenced by a number of factors, including digestion, the nature and proportion of starch in the food, dietary fibre content on the food, fat and protein content, the effect of digestion on the test food, processing and effect of previous meal (FAO/WHO, 1998). These factors probably affected the digestibility of the fufu and the absorption of glucose, hence the differences in the GI.

The effect of dietary fibre in the food

Results from proximate analysis (Table 4) showed that yam fufu had the highest amount of fibre content of 2.8%. This level of fibre could have affected the lower postprandial glucose response of participants to yam fufu. Mann et al. (2004) also confirmed this in a similar study on the "Evidence-based nutritional approaches to the treatment and prevention of *Diabetes mellitus*", that, a diet rich in fibre slows down digestion which in turn slows down the absorption of glucose into the blood stream. A publication by Harvard Health Publications (2008) reports that, yam provides the body with 110 calories and dietary fibre provides 21% of the 110 calories, adding to the argument that yam is rich in dietary fibre.

Even though the average peak of glycaemic response to all test foods was observed at the 30th minute after ingestion, the glycaemic response to yam 'fufu' was around 4.6 – 5.9mmol/dL (Figure 9), which was lower compared to the other test foods. Plantain 'fufu' contained the least fibre of 2.3% and cocoyam had 2.7% as shown in Table 4. Similar comparison could be made to explain the high GI value of plantain fufu among the three test foods.

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

Crago, Reaven and Olefsky (as cited in Foster-Powell, et al., 2002) state in their study: "postprandial plasma glucose and insulin responses to different complex carbohydrate diseases" that, the nature and proportion of starch present in a food influence the rate of digestion and finally the glycaemic response to the food. This could be attributed to plantain 'fufu' having the highest GI amongst the three. Cassava according to USA Department of Agriculture (2002), has an amylose –amylopectin ratio of 30-70%, however, since plantain has an amylose to amylopectin ratio of 17-83% (Ogazi, 1996) it probably affected the digestion of the plantain 'fufu'.

Plantain 'fufu' having a highest GI among the three as illustrated in Table 6, could be attributed to the fact that, it was easily digested by participants and glucose was absorbed faster. In the case of yam 'fufu', a similar conclusion can be made to explain the reason for its low GI. Yam has an amylose –amylopectin ratio of 38-62% (Ogunmolasuyi, Egwim, Adewoyin & Awoyinka, 2016). When combined with cassava, digestion of yam 'fufu' was seen to be very slow hence a lower glycaemic response. This could have also contributed to its low GI value.

Effect of fat and protein in the food

The fufu was served with light soup made with salmon fish. Salmon fish having a reasonable amount of fat and protein probably contributed to the three test foods having a low GI. A study by Wolever, Mehling, Chiassan, Josse, Leiter, Maheux et al. (2008) on "Low glycaemic index diet and disposition index in type 2 diabetes (the Canadian trial of carbohydrate in diabetes): a randomized controlled trial", reports that fat slows the rate at which dietary carbohydrate are digested in the intestines.

Furthermore Eleazu (2016) in a study on "The concept of low glycaemic index and glycaemic load foods as panacea for type 2 Diabetes mellitus; prospects, challenges and solution", states that foods that contain protein increase insulin secretion and could contribute to the reason why the starch in such foods are not easily hydrolysed, giving them low GI.

Effect of digestion on food

Studies have indicated that, in carbohydrate digestion chewing is an important factor as this affects the rate of digestion and absorption (Mann et al., 2007; Wormenor, 2015; Kaiser, 2016). In these studies, researchers further explained that chewing breaks large chunks of food into smaller particles in the mouth. This increases the surface area of the food for salivary amylase found in the saliva, to breakdown the complex carbohydrate in the food before it enters the stomach and small intestines.

Test foods recording lower GI could probably be attributed to the fact that there is no chewing of fufu in the mouth during ingestion. It is swallowed and directly enters the stomach through the oesophagus. As a result of this salivary amylase could not break complex carbohydrate in the fufu before it entered the stomach. Digestion was probably slow in the small intestines hence lower glycaemic responses of test foods.

Effect of processing on food

Cooking of the test foods could have contributed to the GI of the test foods being low. This result can be supported by Foster-Powell, et al. (2002) report in a study on “International table of glycaemic index and glycaemic load values: 2002”, that different processing methods of foods affect their glycaemic indices. Cooking of the plantain, cocoyam, yam and cassava to make ‘fufu’ resulted in the difference in the degree of starch gelatinization by softening the starch which probably speeded up the rate of digestion and in the long run absorption of glucose. Hence different processing methods could have resulted in a different GI of the test meals.

Mixing the individual food items to form a meal (fufu), also probably influenced the GI of the food. The individual food items of the different combinations of fufu, that is; cassava, plantain, yam and cocoyam, may have a lower glycaemic index values than in a mixed constituent. This finding is consistent with the findings by Bornet et al, (as cited in Brand-Miller, et al., 2003) when they studied "Insulinemic and glycaemic indexes of six starch-rich foods taken alone and in a mixed meal by type 2 diabetics". In this study they report that, mixing the meal significantly affects the glycaemic index of the food.

Effect of previous meal on breakfast meal

Studies have confirmed that the previous meal a person takes prior to taking breakfast can affect the glycaemic response of the breakfast meal (Thorburn, Muir & Proitte, 1993; Grandfeldt, Wu, & Björck, 2006). However, in this study, variations in the GI of the reference and test foods could not be attributed to the effect of the previous meal, even though the possibility exists. This is because, the previous evening's meal taken by participants was not controlled and there was not much difference in the FBG levels of participants before ingestion of tests and reference foods.

Glycaemic load of test foods

The glycaemic load was calculated from the results obtained from the glycaemic index of the fufu combinations. The calculation for the glycaemic loads of the 'fufu' is shown in the Appendix C. Results are presented in table 7

Table 7: Glycaemic Load of test foods

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

Source: Field data, Adu-Gyamfi (2017)

The Glycaemic Loads of the test foods were classified as low, medium or high based on the following ranges stated by Venn, et al. (2006).

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

Even though the GI of the test foods were low, they all had high glycaemic loads. This could be as a result of the portion sizes of 'fufu' that were eaten as servings. The portion size of fufu as recommended by The Ministry of Health: Ghana (2009), is 211grams which contains 76g of carbohydrate.

This indicates that the amount of carbohydrate in a serving of 'fufu' is greater than 50g. This probably explains why the test foods had high glycaemic loads. Theoretically, it can be said that there is no significant difference in the glycaemic load of the test foods considering the class under which the all fall. Based on this, the null hypothesis (H_0) was accepted. The H_0, states that "there is no significant differences in the glycaemic loads of the different combinations of fufu". However, the difference in the actual values as illustrated in Table 7, makes one higher than the other.

Sensory Evaluation on Fufu Combinations

Sensory evaluation was performed on the three fufu varieties in terms of appearance, texture, aroma and taste. Results are presented in the tables and figures below. Multiple regression analysis was done to determine the factor that influenced panelists' choices the most.

Table 8: Demographic characteristics of sensory evaluation panelists

Variable	Frequency	Percentage
AGE		
20-29	43	71.7
30-39	9	15.0
40-49	2	3.3
50 and Above	6	10.0
GENDER		
Male	39	65.0
Female	21	35.0
ETHNICITY		
Ashanti	29	48.3
Brong	19	31.7
Fanti	7	11.7
Dagarti	3	5.0
Kasena	2	3.3
EDUCATIONAL LEVEL		
Basic	10	16.7
Secondary	4	6.7
Tertiary	46	76.7
OCCUPATION		
Employed	36	60.0
Unemployed	5	8.3
Student	19	31.7

Source: Field Data, Adu-Gyamfi (2017)

Sensory evaluation of the three different varieties of fufu was carried out using 60 untrained panel members to determine the most preferred fufu combination in terms of appearance, texture, aroma and taste. The number of the panel members used for the evaluation was appropriate because in sensory preference test, a large number of untrained panelists could be used, as stated by Choi (2013). However, due to the geographical nature of the area and the time of the sensory test, only 60 people agreed to participate.

All the 60 panelists were people who ate all the three varieties of fufu. This was very necessary because panelists' familiarity to the test food affected the choice they made in all sensory parameters, as well as their overall preference. This finding is consistent with report by Hetherington, Bell and Rolls (2000) in a study; "Effects of repeated consumption on pleasantness, preference and intake". From Table 8, most of the panelists were males and between the ages of 20-29years. Majority of them were Ashantis and were also employed. In terms of education, the highest educational level among the panelists is tertiary.

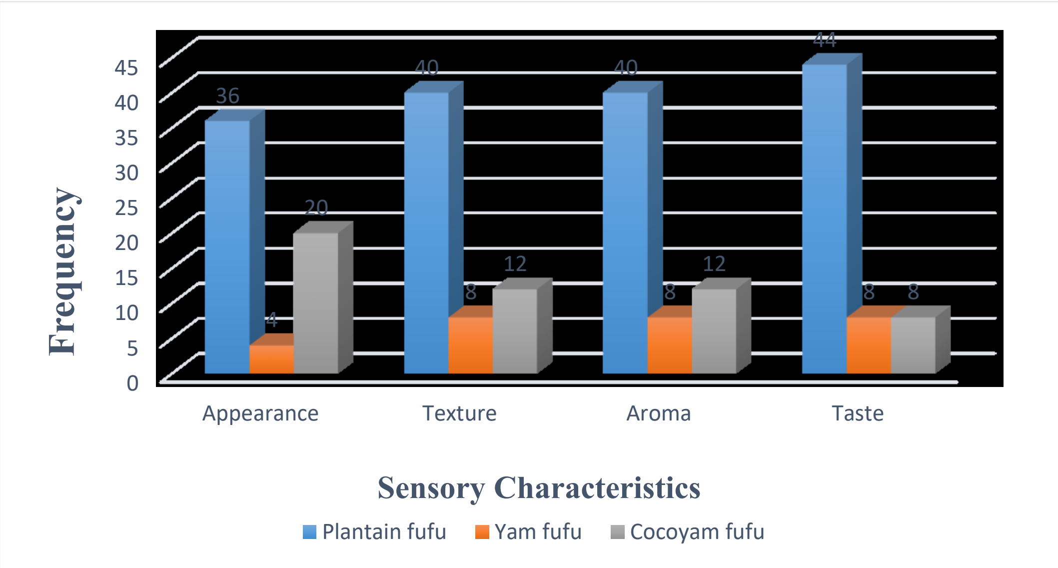

Figure 10: Sensory evaluation of the different combinations of fufu.
Source: Field Data, Adu-Gyamfi (2017).

Results from the sensory evaluation as shown in figure 10 revealed that, there were differences in the preference of the three varieties of 'fufu', in all of the sensory characteristics. With respect to the appearance, 36 panelists preferred plantain 'fufu', 20 preferred cocoyam 'fufu' and 4 preferred yam 'fufu'. Regarding the texture, plantain 'fufu' was the most preferred with 40 panelists going for that, 12 chose cocoyam 'fufu' and cassava – yam 'fufu' had the least of 8. In terms of the aroma of the 'fufu', most panelists 40 preferred the aroma of plantain 'fufu', followed by 12 panelists preferring the cocoyam fufu and then lastly 8 panelists preferring yam fufu. Regarding the taste, 44 panel members preferred the plantain fufu with cocoyam and yam fufu having equal numbers of 8 panelists preferring them. This result indicated that cassava – plantain 'fufu' was preferred in all the sensory characteristics.

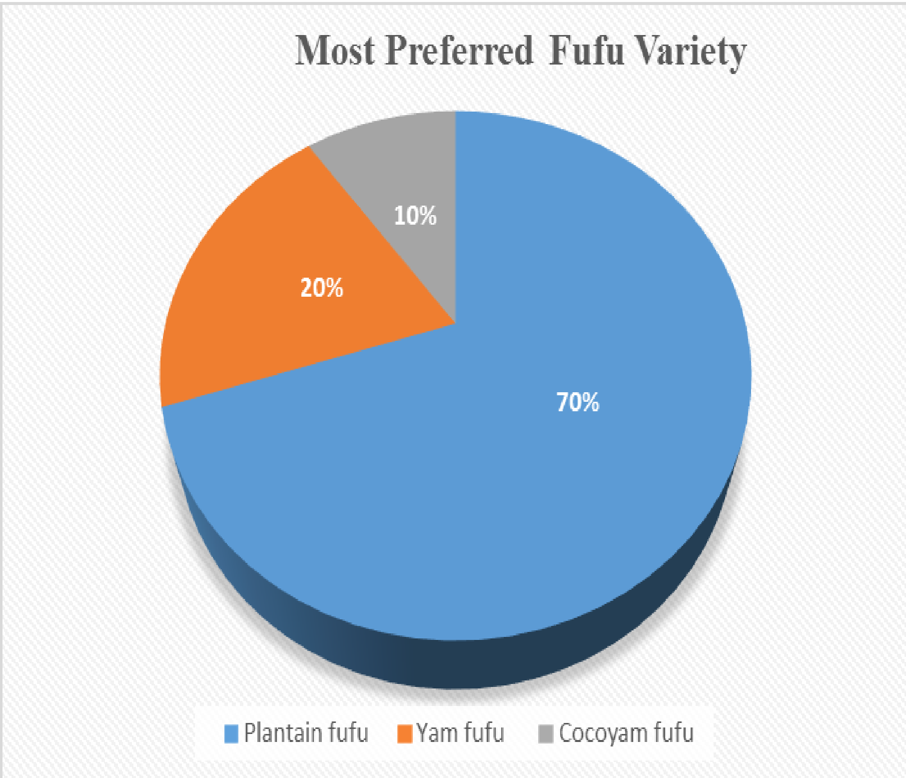

Figure 11: Most preferred fufu variety

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

Panelists were asked to rank samples in terms of overall preference (most preferred) among the three fufu samples. From figure 11, it was seen that, a majority of 70% of panelists chose plantain fufu, 20% chose yam fufu and 10% went for cocoyam fufu.

A multiple regression was perform on each demographic characteristics of panel members to see if they could have any effect on the choices panelists made in the sensory evaluation. Results are reported and discussed below. The multiple regression table can be seen at the Appendix D. A study by Meilgaard, Civille & Carr (2007) on "Sensory Evaluation technique", reports that in consumer testing it is appropriate to select panelists, considering their demographic categories such as gender, age, ethnicity, occupation and educational level, among others as these characteristics affect the choices consumers make. There have been a wide range of studies supporting this statement. A study by Mielby, Nøryaard, Edeĺenbos and Thybo (2012) on "Affective response of adolescents towards fruit and vegetables based snacks and the role of Neophobia, Gender and Age", states that, gender has the propensity to affect choices made by sensory panelists. Contrary to this study, gender was seen not to be significant (p= 0.659) in the choices panelists made during the sensory analysis of the food sample as well as their overall preference.

Age showed no significance (p=0.544) effect on the choices made by panelists in the sensory evaluation as well as the overall preference of the food samples. This results conflict with results from studies by Michon, O'Sullivan, Sheenan, Delahundy and Kerry (2010); on the "Investigation of the influence of age, gender and consumption habits on the liking of jam-filled cakes, and

"Study on the influence of age, gender and familiarity with the product on acceptance of vegetable soups" (Michon, O'Sullivan, Sheenan, Delahundy & Kerry, 2010) which reveal that age has a strong influence on the liking, acceptance, preference and /or perception of food.

Ethnicity as a demographic characteristic showed significant influence (p=0.047) on the choices made by panel members in the sensory evaluation (appearance, texture, taste and aroma) and in the overall preference of the food samples. This results is in agreement with findings made by Dindyal et al., (2003), who reports in a study on "How personal factors, including culture and ethnicity, affect the choice and selection of food we make", that different ethnic groups will chose and select different foods because people who belong to same ethnic group behave in similar manner even in their selection of foods.

Report made by Dindyal et al. (2003) in a study that, a person's occupation is a personal factor that affects food preference. Similarly in this study panelists' occupation showed significant (p=0.020), effect on their preferences.

In a study by Kearney, Kearney, Dunne and Gibney (2000) on "Sociodemographic determinants of perceived influences on food choice in a nationally representative sample of Irish adults", it was reported that, a person's level of education can influence dietary behaviour and food preference. In this study this was observed that, the educational level of panel members were insignificance (p=0.407), when it comes to the choices they made on sensory characteristics of the test food and the overall preference of the food.

Table 9: Descriptive Statistics of the reasons of overall Preference

Reasons for preference	Mean	Std. Deviation	N
Cultural	21.2	7.8	60
Health	20.0	7.0	60
Availability	12.4	4.4	60
Sensory Appeal	9.5	2.6	60

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

Table 9 presents the results of the descriptive statistics of reasons why panelists preferred plantain fufu to the other. Panelists were asked to give the reason for their overall preference or the most preferred fufu combination. Variables presented to them to select from were cultural reasons, health reasons, availability, sensory appeal, cost and religious reasons. Considering the means (Table 9), cultural reason recorded the highest reason why panelists preferred plantain fufu. This was followed by health reason, availability as a reason recorded the third and finally sensory appeal recorded least.

No panelist indicated that cost or religion to be the reasons for their choice of food. However, this does not imply that cost and religion cannot influence someone's preference for a particular food. Studies proved that, cost and religion strongly affect people's food choice and preference. Kwakye (2010) in a study on "Food and food related practices of cultural groups in Southern Ghana", reports that cost as well as culture determine what one accept as food. Furthermore, in a study done by Onuorah and Ayo (2003), results showed that religion has a positive impact on food choice and preferences. From this descriptive analysis (table 9), culture was the main reason why most people preferred the plantain fufu to the others. However, multiple regression analysis was done (table 10) to give a more statistical evidence on reasons panelist preferred cassava – plantain 'fufu'.

Table 10: Multiple Regression Analysis of the reason for the most preferred fufu variety

	Unstandardized Coefficients		Standardized Coefficients		
Model	B	Std. Error	Beta	t-value	Sig.
(Constant)	82.586	9.069		6.617	.000
Cultural	5.367	6.104	13.318	5.73	.000
Health	2.425	3.134	9.946	6.20	.000
Availability	2.249	2.133	4.747	7.69	.000
Sensory Appeal	3.276	1.003	3.06	9.46	.000

Dependent Variable: Most preferred fufu combination

Source: Field survey, Adu-Gyamfi (2017)

Table 10 presents the results of the multiple regression analysis. From the results, it is evident that all the four independent variables (Health, Cultural, Availability and Sensory Appeal) are statistically significant ($p<0.05$) showing that they are all reasons why people preferred plantain fufu. However, when evaluating the standardized beta values, it shows that Cultural reason had the highest beta value, followed by health, then availability and lastly sensory appeal (table 10). The above therefore, denotes that among all the reasons given, cultural reason is the dominant reason why people preferred plantain fufu, followed by health, availability next and then the least reason being sensory appeal.

Culture being the highest reason for panelists who preferred plantain fufu to the others could be as result from the fact that, most of the panel members were Ashantis. Ethnicity as a demographic characteristic was seen to have a significant effect on panelists' sensory evaluation of food samples. Even though fufu is consumed among most ethnic groups in Ghana, Ashantis are noted for eating plantain fufu. A study by Fisher, Mitchell, Smiciklas-Wright and Birch (2002) on "Parental influence on young girl's fruit and vegetable, micronutrient and fat intake", indicate that, ethnic and racial groups differ in how they identify foods and how they prepare them, the condiments they use, and the timing and frequency of meals.

Similarly in this study culture played a major role in the reason why plantain fufu was most preferred. Looking at the next most preferred fufu combination which was yam fufu, a conclusion can also be drawn to the fact that the second largest ethnic group of panelist was the Brongs who are also noted for eating yam fufu as well as the northerners. This can be supported by Montanari (2006) who states in his study on "Food is culture", that since people grow up in different societies, there is a distinctive differences in food tradition and cuisines.

The second reason why most panelists preferred plantain fufu was health. Various studies (Brakohiapa, Quaye, Amoah & Offei, 1997; Ayodele & Godwin, 2010; Ogbuji, Odom, Nudlaka & Ogbodo, 2013) report that plantain has a low GI as compared to other carbohydrate rich foods. Again, a study by Wormenor (2015) on "Determination of the glycaemic index of local staples in Ghana and the effect of processing on them", have contributed to the fact that fufu made with plantain and cassava has a low GI (55). As a result of this, dieticians and other health workers in Ghana educate the public to as much as possible, consume fufu made with plantain or even only plantain fufu in the case of diabetics. This could have been the reason why most panelists, being concern about their health, preferred plantain fufu to the other combinations. This findings is consistent with other findings in other countries. For instance, Ayodele et al (2010) in a study on "Glycaemic indices of processed unripe plantain (Musa paradisiaca) meals", made a statement that unripe plantain meal is usually consumed by Nigerian diabetics to reduce postprandial glucose level.

A theoretical review made by Vabø and Hansen (2014) on the relationship between food preference and food choice; reports that availability is an important moderator when it comes to food choice and preferences. Similarly in this study, panelists indicated that availability played a major role in the choice they made about the most preferred fufu combination. Considering the geographic location where the sensory evaluation took place, plantain and yam are always available in the market and less expensive than cocoyam. Hence it was not surprising when most panelist preferred plantain fufu, followed by yam fufu.

It was also observed among some panelists; especially students and workers who had been transferred to the town, that the choice they made were not actually their favourite but it is because that is what they have been exposed to for a period of time. This can be supported by a statement made by Mela, *"if it is not available, it will not be eaten. If it is available, it is likely to be eaten. If there is alternative, it will be eaten"*. Due to the nature of their job (those who were employed), some of them get home late, and may not be able to prepare fufu on their own and so they end up buying from restaurants. Most often these restaurants may not present them with all the different mixtures and so they buy what is presented to them. As a matter of this, some panelists probably were somehow limited to always patronize what is available hence their preferences.

Sensory appeal has been proven to be an important factor affecting a person's food choice by various studies (Scheibehenneet, Miesler & Todd, 2007; Wądołowskaet, Babicz-Zielińska & Czarnocińska, 2008; Costellet, Tárrega & Bayarri, 2010). Findings from this study do not deviate from this fact, when it comes to reasons why panelists preferred one 'fufu' combination to the other. Some of panel members may not have had any favourite fufu combination, but the fact that a particular combination looked nice, had a pleasant smell, had good texture and tasted good; they decided to choose that as the most preferred. Even though only a few people selected this reason. It is still very significant as far as food choice and preference are concerned.

Chapter Summary

1. The study made use of 10 participants who underwent a blood glucose test for glycaemic index determination and 60 untrained panel members who took part in a sensory evaluation of the three fufu combinations
2. Proximate analysis made on the three fufu samples showed that per 100 g of fufu, plantain fufu had the least amount of carbohydrate (34.8 g), followed by cocoyam fufu (36.0 g) and yam fufu had the highest (43.0 g).

3. Result showed that, there was a significant differences ($p<0.05$) in the glycaemic response to the reference food and test foods. Glycaemic response varied from each participant in the reference food as well as the test foods.
4. All the fufu combinations had a low glycaemic indices, however, the glycaemic load for all fufu combinations were high. This indicates that a serving of fufu can lead to a powerful spike in the blood sugar.
5. The null hypothesis (H_0), which states; there is no significant difference in the glycaemic load of the different combinations of fufu, was not rejected.
6. Sensory evaluation performed on the three fufu samples revealed that, most panelists preferred plantain fufu in all the sensory attributes (appearance, texture, aroma and taste). In terms of the most preferred, plantain fufu was the most preferred. Four different reasons affected their choice, but cultural reason was seen to be the major reason for their choices.

CHAPTER FIVE

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

Introduction

This chapter provides the summary, conclusions and recommendations of the study. The summary briefly presents an overview of the research problem, objectives, methods and findings of the study. The conclusions encompasses the overall findings of the study with respect to the study hypotheses. The chapter lastly presents recommendations made by the study as well as suggestions for future research.

Summary of Study

This study generally determined the GL of the different combinations of fufu that are consumed in Ghana. Specifically, the study was carried out to study participants' glycaemic response to ingested carbohydrate, determine the glycaemic load of all the different combinations of fufu, perform a proximate analysis on all varieties of fufu and to sensorily analyse the most preferred choice among the combinations. The hypothesis was also tested. Experimental research method was employed and data was computed using SPSS version 20 and Graph Pad Prism Software version 5.

Key findings

a. Findings revealed that the glycaemic response to each test food and reference food was different among participants.
b. Proximate analysis was done on the three fufu samples and result showed that plantain fufu has the least carbohydrate content amongst

the three fufu mixtures, followed by cocoyam fufu and yam fufu with the highest.

c. Determining their glycaemic indices of the three fufu combinations showed that yam fufu had the least amongst them with plantain fufu having the highest amongst them. The glycaemic indices of all three fufu mixtures were low.

d. Despite the low glycaemic indexes, all fufu combinations had high glycaemic loads.

e. The null hypothesis (H_0) was accepted, meaning there are no differences in the glycaemic loads of the different combinations of fufu.

f. Sensory evaluation conducted on the three fufu samples showed that, plantain fufu was ranked best or first in all sensory attributes, followed by cocoyam fufu with yam fufu ranked last or third. With respect to the overall preference, plantain fufu was most preferred, followed by yam fufu and then cocoyam fufu. Culture was the major reason for panelists' choices. Moreover, certain demographic such like ethnicity and occupation had significant effects on the choices panelists made.

Conclusions

From the proximate analysis findings, plantain fufu contained the least carbohydrate content among the three fufu mixtures, however after determination of their glycaemic indices, it was seen that plantain had the highest amongst them and yam which had the highest carbohydrate content per the proximate analysis had the lowest GI amongst the three. Factors such as the nature and proportion of starch in the food, dietary fibre content on the food, fat and protein content in the food, the processing method used, the previous meal taken prior to eating test foods, contributed to this.

All fufu combinations had a high glycaemic load and this is as a result of the high portion size of fufu that is eaten at a serving. The glycaemic load of fufu combinations showed no significant difference, however, looking at the actual values, there are differences in them which should not be overlooked.

From the sensory evaluation, it can be concluded that most people do not really pay much attention to the effect the combination of fufu eaten has on their blood glucose level as they do for what they have been exposed to since childhood, in the name of culture.

Recommendations

As a result of the above findings, the following recommendations are suggested;

1. Consumers of fufu can eat any of the three mixtures of fufu, but there will be the need to take a smaller portion size of the fufu since larger size can have adverse effect on their blood glucose level.
2. In other for fufu to be digested well and glucose to be absorbed easily, especially yam fufu, consumers should make sure to eat fufu at least about five hours before going to bed.
3. Nutritionists, dieticians and diet therapists can as well recommend yam fufu and cocoyam fufu for diabetics and prediabetics, to bring about varieties in their diet. However, they should be more concerned about the portion size. This is because the portion size to take is of more importance than the type to eat.

4. Much attention should be placed on researching into the glycaemic loads of our local dishes than the glycaemic indices since the glycaemic load of a food gives a comprehensive information about much the carbohydrate in a food consumed as a serving affects the blood glucose.

Suggestions for further research

1. The effect of different soups on the GI and GL of fufu can also be researched into.
2. A similar study can be done on diabetics on medication to determine whether eating fufu alongside the medication affect blood glucose spikes.

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APPENDICES

APPENDIX A

CONSENT FORM

I am an MPhil student of the Department of Vocational and Technical Education, University of Cape Coast. I am conducting a study on "Determining the Glycaemic Load of the Different Combinations of Fufu in Ghana". Your participation in this study is paramount to the success of the study. If you agree to participate, you will be required to have a blood glucose test taken. You will be expected to do a 10-12hr fasting thus would not eat after 6pm from the night prior to the day of the test, this is to ensure accuracy in the fasting blood sugar test.

A period of one month covering four sessions 3 hours each will be required for the four different foods to be tested (glucose solution, cassava plantain fufu, cassava yam and cassava cocoyam). After eating, capillary blood will be drawn from your figure tips at the 30th, 60th, 90th and 120th minutes and tested for blood glucose. Care will be taken in pricking participants' fingers to minimize possible pain/discomfort since professional laboratory technicians will be doing the pricking. You will be provided lunch at the end of each test session and your transportation fares will be catered for.

Participation is strictly voluntary and hence you have the right to discontinue anytime without penalty. This research has been reviewed and approved by the Institutional Review Board of the University of Cape Coast (UCCIRB). If you have any questions about your rights as a research participant you can contact the Administrator at the IRB Office between the hours of 8:00 am and 4:30 p.m. through the phones lines 0332133172 and 0244207814 or email address: irb@ucc.edu.gh.

Your signature below indicates your willingness to participate in this study

Participant's Signature: ………………………. Date: ………………………..

Name (*Initials*): ………………… Telephone number: ……………………

E-mail: ………………………………………………………………………..

My signature below indicates my willingness to abide by all the terms and conditions stated in this document.

Researcher's Signature: …………………… Date: …………………………

Name: Miss Christabel Amponsah Adu-Gyamfi

MPhil Home Economics (Food and Nutrition)

Telephone number: 0203198499

SUGAR PROFILE SHEET

Background Information

Code: …………………………… BMI: …………………………

Age: ……………………………. Waist circumference: ………..

Sex: ……………………………... Last meal: …………………...

Weight: ………………………….. Time of last meal: …………...

Height: ……………………………

Oral Glucose Tolerance Test (OGTT) 1

Date: ………………………. Time: ……………………………

Fasting Blood Sugar: ………………………………………..

Time interval	30mins	60mins	90mins	120mins

Oral Glucose Tolerance Test (OGTT) 2

Date: ………………………. Time: …………………………

Fasting Blood Sugar: …………………………………………………..

Time interval	30mins	60mins	90mins	120mins

Plantain Fufu Test

Date: ……………………………. Time: ………………………………..

Fasting Blood Sugar: …………………………………

Time interval	30mins	60mins	90mins	120mins

Cocoyam Fufu Test

Date: ……………………………. Time: ………………………………

Fasting Blood Sugar: ………………………………

Time interval	30mins	60mins	90mins	120mins

Yam Fufu Test

Date: ……………………………….. Time: ……………………………….

Fasting Blood Sugar: ……………………………….

Time interval	30mins	60mins	90mins	120mins

APPENDIX B

SENSORY EVALUATION FORM

I am an MPhil student in the Department of Vocational and Technical Education in the University of Cape Coast. I am conducting a sensory evaluation on the three different combinations of fufu in Ghana; that is plantain fufu, yam fufu and cocoyam fufu; to find out the one that is most preferred in the sensory attributes (**appearance, taste, texture and aroma)**. Your contribution will help towards the success of this research project. Ingredients used in preparing these samples include cassava, plantain, yam, cocoyam, tomatoes, pepper, salmon fish, onion and garden eggs. If you are allergic to any of these ingredients you are advised to discontinue with this test. If you agree to continue with participating in this test, please sign below

Panalist's signature: ……………………… Date: ………………………….

Panalist's code (to be provided by researcher): ……………………………….

SECTION A

BACKGROUND CHARACTERISTICS

1. Gender

   Male { }

   Female { }

2. Age

   20-29 { }

   40-49 { }

   40-49 { }

   50 and above { }

3. Ethnicity

   ……………………….

4. Occupation

   Employed { }

   Unemployed { }

   Student { }

5. Level of Education

   JHS { }

   SHS { }

   Tertiary { }

SECTION B

Read the instructions carefully before you start the test. Please take note that, talking among panelists during testing is prohibited. Thank you.

Appearance

Please observe the appearance of each of the coded sample in the set in the sequence presented from left to right. Rank the three samples in ascending order of preference. Remember the most preferred sample should be ranked 1. No ties are allowed.

Sample Code: __________ __________ __________

1 2 3

Texture

Please feel the texture of each of the coded sample in the set in the sequence presented from left to right. Rank the three samples in ascending order of preference. Remember the most preferred sample should be ranked 1. No ties are allowed.

Sample Code: __________ __________ __________

1 2 3

Aroma

Please smell the aroma each of the coded sample in the set in the sequence presented from left to right. Rank the three samples in ascending order of preference. Remember the most preferred sample should be ranked 1. No ties are allowed.

Sample Code: __________ __________ __________

1 2 3

Taste

Please taste each of the coded sample in the set in the sequence presented from left to right. Rank the three samples in ascending order of preference. Remember the most preferred sample should be ranked 1. No ties are allowed.

Sample Code: __________ __________ __________

1 2 3

Overall preference

Indicate the overall preferred sample by writing the code of that sample in the space provided below

Sample code: ________________

Why do you prefer that sample?

Religious reasons { }

Health reasons { }

Cultural reasons { }

Availability reasons { }

Financial reasons { }

Other reasons (specify) ……………………………………………………

APPENDIX C

Calculations of the Glycaemic Loads of the Different Fufu Combinations

Formular for calculating the GL of a food is;

$$\frac{\text{Glycaemic index} \times \text{Carbohydrate (g)}}{100}$$

The available carbohydrate in atypical serving of fufu is 76g. Therefore the GL of the different fufu combinations are as follows;

$$\text{GL of plantain fufu} = \frac{53 \times 76}{100}$$

$$= \frac{4028}{100}$$

$$\text{GL} = 40.28$$

$$\text{GL of yam fufu} = \frac{30 \times 76}{100}$$

$$= \frac{2280}{100}$$

$$\text{GL} = 22.08$$

$$\text{GL of cocoyam fufu} = \frac{39 \times 76}{100}$$

$$= \frac{2964}{100}$$

$$\text{GL} = 29.64$$

APPENDIX D

Multiple regression of the demographic characteristics of panelists on their preferences.

Characteristics	Unstandardized Coefficients B	Std. Error	Standardized Coefficients Beta	T value	Sig.
(Constant)	1.347	.761		1.70	.082
Gender	.087	.197	.052	.443	.659
Age	-.076	.124	-.090	-.611	.544
Ethnicity	.212	.104	.273	2.04	.047
Occupation	-.312	.131	-.354	-2.39	.020
Educational level	.114	.137	.107	.836	.407

Dependent Variable: Most preferred fufu combination

Source: Field data, Adu-Gyamfi (2017)

APPENDIX E

ETHICAL CLEARANCE

UNIVERSITY OF CAPE COAST

INSTITUTIONAL REVIEW BOARD SECRETARIAT

TEL: 03321-33172/3 / 0207355653/ 0244207814
E-MAIL: irb@ucc.edu.gh
C/O Directorate of Research, Innovation and Consultancy

OUR REF: UCC/IRB/A/2016/100
YOUR REF:
OMB NO: 0990-0279
IORG #: IORG0009096

23RD APRIL, 2017

Ms Christabel Amponsah Adu-Gyamfi
Department of Vocational and Technical Education
University of Cape Coast

Dear Ms Adu-Gyamfi,

ETHICAL CLEARANCE –ID :(UCCIRB/CES/2016/17)

The University of Cape Coast Institutional Review Board (UCCIRB) has granted **Provisional Approval** for the implementation of your research protocol titled **'Determining of glycemic load of the different combinations of fufu in Ghana.'**

This approval requires that you submit periodic review of the protocol to the Board and a final full review to the UCCIRB on completion of the research. The UCCIRB may observe or cause to be observed procedures and records of the research during and after implementation.

Please note that any modification of the project must be submitted to the UCCIRB for review and approval before its implementation.

You are also required to report all serious adverse events related to this study to the UCCIRB within seven days verbally and fourteen days in writing.

Always quote the protocol identification number in all future correspondence with us in relation to this protocol.

Yours faithfully,

Samuel Asiedu Owusu
Administrator

ADMINISTRATOR
INSTITUTIONAL REVIEW BOARD
UNIVERSITY OF CAPE COAST
Date:..............................