KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY KUMASI, GHANA

COLLEGE OF SCIENCE

DEPARTMENT OF BIOCHEMISTRY AND BIOTECHNOLOGY

GLYCEMIC INDEX OF FIVE CORN AND CASSAVA STAPLES IN GHANA

BY

EUNICE SERWAA YEBOAH

OCTOBER, 2017

KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY, KUAMSI
GHANA

COLLEGE OF SCIENCE
DEPARTMENT OF BIOCHEMISTRY AND BIOTECHNOLOGY

GLYCEMIC INDEX OF FIVE CORN AND CASSAVA STAPLES IN GHANA

BY

EUNICE SERWAA YEBOAH

A THESIS SUBMITTED TO THE DEPARTMENT OF BIOCHEMISTRY AND BIOTECHNOLOGY, COLLEGE OF SCIENCE IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF

MASTER OF PHILOSOPHY

IN

HUMAN NUTRITION AND DIETETICS

OCTOBER, 2017

DECLARATION

I Eunice Serwaa Yeboah hereby declare that this thesis titled: "*Glycemic Index of five corn and cassava staples in Ghana*" is my own work based on primary data collected. To the best of my knowledge, this work contains no material previously published by another person, nor material accepted for the award of any other degree of the university, except where due acknowledgement has been made in the text.

STUDENT NAME & ID No

Eunice Serwaa Yeboah	……..……..	……
(PG4429615)	**SIGNATURE**	**DATE**
Dr. Jacob K. Agbenorhevi	……..……..	……
(SUPERVISOR)	**SIGNATURE**	**DATE**
Dr. Peter Twumasi	……..……..	……
HEAD OF DEPARTMENT	**SIGNATURE**	**DATE**

ABSTRACT

Glycemic index (GI) is referred to as the grouping of foods based on their ability to raise blood glucose level after consumption. The objective of this study was to determine and assess the GI of some Ghanaian corn and cassava staples (*abolo, akple, kafa, locally made kokonte* and *processed kokonte*) and to investigate the effect of processing on them. Ten healthy subjects consisting of five males and five females were involved by means of a cross over trial. The study subjects were served 50 g of pure glucose dissolved in 200 ml of pure water on two different occasions. They were also served specific amounts of test foods which contained 50 g of available carbohydrate on specific days. The GI was assessed by quantifying the blood glucose level of study subjects at the fasting state and after consumption of reference food (glucose) and test foods within a period of 2 h at intervals 15, 30, 45, 60, 90, and 120th min. The GI value for the test food was calculated for each subject by dividing the blood glucose incremental area under the glucose response curve for the test food by the blood glucose incremental area under curve for the reference food and multiplying by 100. The GI value for each test food is the mean or average for the ten study subjects. Among the test foods that had their glycemic assessed, *locally made kokonte* had the least GI of 7 followed by *processed kokonte* which GI of 18 while *kafa* had low GI value of 29. *Abolo* and *akple* had medium GI value of 58 and 69, respectively. The mean age, BMI, weight, height and waist circumference were 23.1±2.60years, 24.39±3.1kg/m^2, 64.1±7.9kg, 161.40±6.04cm and 74.6±6.9cm, respectively. There was no significant difference between the GI of *locally made kokonte* and *processed kokonte* ($p > 0.05$) indicating that the form of processing had no significant effect on the GI of *kokonte*. The present findings should lead and assist health care professionals, diabetics and consumers in their selection of local staples and meal planning.

ACKNOWLEDGEMENT

My deepest gratitude goes to the almighty God for his faithfulness towards me throughout the programme and this research.

I greatly acknowledge the indispensable role of my supervisor Dr. Jacob Agbenorhevi of the Department of Food Science and Technology in not providing me with only guidance but the inspiration to make this project a possibility. My sincere appreciation also goes to the director of Sanford Hospital for his support and cooperation in my data collection. To all persons who agreed to take part in this study as research subjects, I'm eternally grateful.

Finally and importantly I thank my parents Mr. and Mrs. Owusu Yeboah for their support throughout the research and not forgetting siblings and friends whose names space will not permit me to mention.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

BMI = Body Mass Index

FAO = Food and Agriculture Organization

FBS = Fasting Blood Sugar

GI = Glycemic Index

GIT = Gastro Intestinal Tract

IAUC = Incremental Area Under the Curve

OGTT = Oral Glucose Tolerance Test

SD = Standard Deviation

WC = Waist Circumference

WHO = World Health Organization

CHAPTER ONE

1.1 INTRODUCTION

Carbohydrates are basically the main source of energy in human diets and they contribute to about 40-80% of our caloric intake. It plays enormous roles in the human physiology which includes energy provision, regulating of blood glucose and sparing the use of proteins for energy (Mann *et al.,* 2007). Most Ghanaian diets are carbohydrate based and most families plan their meals around them. Sources of carbohydrates include maize, cassava, rice, millet and yam. Carbohydrates vary in terms of their physical structure, chemical forms, particle size and fiber content which instigate different plasma glucose and insulin response (Jenkins *et al.,* 1981). In countering with the profound statement that, it is wealthy country's disease, diabetes mellitus is steadily a major problem in developing countries especially in sub-Saharan Africa (Gning *et al.,* 2007).

Data indicates that dietary management is a necessity in obtaining an improved glycemic control to lessen the possibility of diabetic complications and to lengthen life span (Kouassi *et al.,* 2009). An amelioration of glycemic control by equalizing dietary intake with insulin levels is a main focal point in the nutritional management of diabetes (Kalergris *et al.,* 2005). Therefore, the way forward to maintain a balance between blood glucose and insulin levels is glycemic index and glycemic load (Mash and Brand-Miller, 2008). The categorizing of how rapid or slow a carbohydrate food is transformed into glucose after eating is an estimation of its glycemic index (Eli-cophie *et al.,* 2016). This physiologic response to carbohydrate can be measured by GI index which match plasma glucose to distinct foods with the response instigated by the same quantity of carbohydrate source, usually white bread or pure glucose. Furthermore, elevated risk of type two diabetes has been correlated with an increased dietary glycemic load which can be defined as the product of the glycemic index of a precise food and its carbohydrate constitutes (Frost *et al.,* 1998).

Carbohydrate foods that are speedily degraded into glucose after eating are classified as a high glycemic index whereas those that take a long time to convert into glucose are also classified as low glycemic index (Eli-Cophie *et al.,* 2016). The glycemic indexes of foods are categorized on a scale of 0-100 with 100 assigned to foods with a high glycemic index and 0 assigned to foods with a low glycemic index. There are three main forms of carbohydrates based on the GI figures. Foods with GI ranges from 0-55, 56-69 and 70-100 are classified as low, medium and high GI foods (Eli-Cophie *et al*., 2016). Factors that can influence the GI of a food include processing, variety, methods of cooking, ripeness and storage time (Aston *et al.,* 2008).

Currently, there is much scientific and public interest in the function of low GI diets in both weight reduction and metabolic diseases risk (Aston *et al.,* 2008). However, both observational and intervention studies are affected by limited knowledge of GI and GL figures for many West Africa local foods including Ghana (Omoregie and Osagie, 2008). In Ghana, a study has been conducted by Eli-Cophie *et al.,* (2016) to determine the glycemic index of some Ghanaian stables.

Rubner was the first to initiate a study on the effect of carbohydrates on diabetes and other metabolic diseases (Nils-George, 1995). McCane and Lawrence (1929) initiated the idea of available and unavailable carbohydrates and this has been an important tool in nutritional counselling of diabetics in their selection of carbohydrates (Nils-George, 1995). Various relationships have been found to exist between dietary glycemic index and some medical conditions. A systematic review and meta-analysis undertaken by Fan *et al.* (2012) showed a slight link between coronary heart disease and dietary glycemic index. Jenkins *et al.* (1985) also found a positive relationship between low glycemic diet and its regulation of blood lipids.

The relationships that have been discovered to exist between GI and various medical conditions compelled the standardization of GI determining methods to make way for certainty and correctness (Wolever *et al.,* 2003).

1.2 PROBLEM STATEMENT

Globally, the glycemic index of carbohydrates has been proven to be beneficial in the management of diabetes. Most developed countries have the glycemic index of their staples determined making diabetes management flexible and easy for health professionals and their patients. The same cannot be said of Ghana and other developing countries where there is an increasing surge in the incidence of diabetes and other communicable diseases. With the high consumption of some of the processed forms of local staples, it is important to understand the pace through which these foods transform to sugar in the body which is a count of their glycemic index.

A report of a joint FAO/WHO Expert discussion emphasized the need to deduce the glycemic index of local staples locally due to contrast that could emerge from numerous methods of cooking and processing (Aston *et al.,* 2008).

The determination of the glycemic index of some Ghanaian staples by Eli-Cophie *et al.,* (2016) was a step in the right direction but they however worked on five staples out of the numerous ones in Ghana. This present study therefore aims at determining the glycemic index of *kokonte (locally made and processed), abolo, kafa and akple*.

1.3 AIM

To determine the glycemic response and the glycemic index of *kokonte (locally made and processed), kafa, abolo and akple*.

1.4 SPECIFIC OBJECTIVES

1. To determine the glycemic of index of *kokonte (locally made and processed), kafa, abolo and akple.*
2. To investigate the effects of processing on these local staples.

1.5 JUSTIFICATION

The study will provide information which would help diabetics in their selection of local staples based on their glycemic index.

The results from the research would give an understanding of the effect of some cooking and processing methods on the glycemic index of foods.

Healthy individuals will be benefited with information in healthy food choices and meal planning.

CHAPTER TWO

LITERATURE REVIEW

2.1 INTRODUCTION

Carbohydrates are classes of composites which consist of monosaccharides building units. They consist of structures such as monosaccharide, disaccharide and oligosaccharides and more complex ones such as starch and polysaccharides. Carbohydrates are grouped according to their level of chemical process. Simple carbohydrates consist of monosaccharides or disaccharides whiles complex carbohydrates are made up of polysaccharides or starches. The complex carbohydrate concept was introduced in a report by the US state-senate select committee on Nutrition and Human need in 1977 to denote various fruits, whole grains and vegetables (Stylianopoulos, 2005).

However, these groupings were centered on the compositions and properties of carbohydrates and do not inevitably depict the specific physiological attributes, nutritional and health implication (Cumming and Stephen, 2007).

The chemical groupings of carbohydrate into simple and complex carbohydrates was centered on the claim that all simple carbohydrates can cause a quick increase in the blood glucose level whiles complex carbohydrates cause a slow increase in the blood glucose level and hence it is very appropriate carbohydrate of choice for individuals with glucose intolerance and insulin malfunctions.

Carbohydrates consist of various important minerals and micronutrients which are very needful for healthy living. They also play an enormous role in sustaining gastrointestinal health and glycemic balance (Stylianopoulos, 2005). In 1939, Conn and Newburg conducted a research on how varied forms of carbohydrates with similar micronutrient constitute produce varying glycemic responses (Conn and Newburg, 1939). Otto and Niklas (1980),

spearheaded the systemic groupings of food or meals based on their glycemic responses. Jenkins *et al.* (1981), gave an account on how the carbohydrate exchange list that has been useful over decades for diabetes management was not dependent on the physiologic impact of food consumed. They also discovered that the health impact of carbohydrate can be best explained according to their physiological characteristics which include its capacity to increase glucose level. Augustin (2002), also found out that the physiological characteristics of carbohydrate are also affected by the components of the monosaccharides forms and physical constituents which includes their particle forms and level of hydration.

The glycemic index concept came about based on the positive contribution or impact of carbohydrates towards health. However, the difficulty linked in the conjunction with carbohydrate groupings necessitated the need for a straight forward or uncomplicated index centered on the glycemic impact of foods, to back or support data made available in food table obtained from calculations using their chemical constituents.

Glycemic index is referred to as the grouping of foods based on their glucose raising ability (Wolever *et al.*, 2003). Mendosa (2009), further explained that glycemic index is an estimation or computation of the quantity or worth of carbohydrate not the amount of carbohydrate consumed.

2.2 THE GLYCEMIC INDEX NOTION

Glycemic index is referred to as the categorizing of food based on how they are able to increase the blood glucose level (Wolever *et al.*, 2003). According to FAO/WHO (1998), glycemic index can be quantified or estimated by determining the area under the blood glucose response curve after consuming a test food or meal containing 50 g of available carbohydrate as a percentage of that induced by a reference which can either be white bread or pure glucose.

Monro and Shaw (2008), stated that the glycemic index measures equal amounts of available carbohydrates involved as compared to glycemic impact which measures the amount of glucose that would trigger a glycemic response parallel to that triggered by a given amount of food (Miller-Jones, 2007).

There are various indices that can affect the blood glucose level after consumption. These elements include the characteristics or nature of the overall diet. Other internal factors also include the presence or absence of viscous fibre, the length of monosaccharide units and the amylose to amylopectin ratio. Particle size, manufacturing methods, characteristics of starch and anti-nutrients are among such factors that are rarely available and present in food tables but play a very important role on physical properties and characteristics food. These factors must be considered in determining the glycemic index of various foods. Research conducted by Golay *et al.*,(1986), Haber *et al.*,(1977) and O'Dea *et al.*,(1980) on the botanical compositions of legumes, apples and rice pointed in the same direction. They found out that when these structures are deranged, the quantity of available carbohydrate in them increases. These are also the basic factors which account for the unpredicted and unforeseen variations in the glycemic of various foods (Wolever *et al.*, 1991).

The glycemic indexes of foods are categorized on a scale of 0-100. There are three main forms of carbohydrate base of their glycemic index figures. Foods with GI ranging from 0-55, 56-69 and 70-100 are classified as low medium and high GI foods respectively (Eli-cophie *et al.,* 2016). Carbohydrate foods that are speedily degraded into glucose after eating have a high glycemic index whereas those that take a long time to convert and transform into glucose have a low glycemic index (Eli-cophie *et al.,* 2016). The glycemic index helps in categorizing a particular food as either high, low or medium after digestion and absorption based on the extend at which blood glucose increases after consumption (Eli-cophie *et al.,* 2016).

2.3 DIETARY CARBOHYDRATE

Carbohydrates are basically the main source in human diets and they contribute to about 40-80% of our daily caloric intake. It plays enormous roles in the human physiology which includes energy provision, regulating blood glucose and sparing the use of protein for energy (Mann *et al.,* 2007). These essential functions of carbohydrates contribute in human diet and health generated the glycemic index concept. Dietary carbohydrates are normally grouped according to the functions they play as well as their chemical and physiological forms or properties.

FAO/WHO (1998), defined carbohydrates as polyhydroxy aldehydes, ketones, alcohol, acids, their simple derivatives and their polymer linkages of the acetal type. They went further to explain that carbohydrates can be grouped into three main domains namely sugars, oligosaccharides and polysaccharides. How carbohydrates are digested is mainly dependent on their level of amylose and amylopectin branches.

Table 2-1 The Major Dietary carbohydrates

Group	Sub group	Components
Simple Sugars (1-2 monosaccharide units)	Monosaccharides Disaccharides Sugar Alcohols	Fructose, galactose, glucose Maltose, lactose, sucrose Mannitol, sorbitol
Oligosaccharides (3-9 monosaccharide units)	Malto-oligosaccharides Other oligosaccharides	Maltodextrins Fruto-oligisaccharides, raffinose, staychose
Polysaccharides (>9 monosaccharide units)	Starches Non-starch polysaccharides	Modified starches, amylose, amylopectin, Cellulose, hemicellulose, hydrocolloids, pectins

Source: (FAO/WHO, 1998)

2.3.1 Total Carbohydrates

Total carbohydrates can be described based on two main concepts;

-by quantifying all constituents that make up carbohydrate and

-by deducting the total amount of ash, fat, protein, and moisture content from the total amount of a particular food (FAO/WHO, 1998).

2.3.2 Available Carbohydrates

McCane and Lawrence (1929), in order to improve and help the understanding of carbohydrates grouped them into available and unavailable carbohydrates. In the process of generating food tables for diabetic diets, it was discovered that some carbohydrates could not be broken down and absorbed. They further went on to discover that some carbohydrates escape digestion and assimilation in the small intestine but get to the large bowel where it is fermented. They defined available carbohydrates as starch and soluble sugars. FAO/WHO (1998), defines available carbohydrates as constituents of carbohydrates that are broken down to produce sugar which is further degraded to yield energy.

According to Eli-cophie *et al.*, (2016), paying more emphasis on available carbohydrates is very essential because it makes it clear which part of the carbohydrates are used to determine the glycemic index of a particular food. Glycemic index determination quantifies the glycemic response of subjects to 50 g of available carbohydrate relative to 50 g of pure glucose or white bread.

2.3.3 Unavailable Carbohydrate

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

2.3.4 Dietary Fibre

Trowel (1972), defined dietary fibre as that part of food obtained from the cellular walls of plants which cannot be digested by human beings. Vinik and Jenkins (1988), further described dietary fibre as roughage and are parts of carbohydrates that cannot be broken down by enzymes of the gut. Dietary fibre can also be classified as soluble and insoluble. Cellulose, hemicellulose, pectin, and lignin make up or constitute dietary fibre (FAO/WHO, 1998).

Dietary fibre has been found to affect the concentrations of insulin in the blood and upgrade postprandial glycemic response since they reserve water and control many metabolic hormones (Vinik and Jenkins, 1988). Other benefits discovered by Leeds (1987), showed that dietary fibre is not energy dense and the heavy feeling they elicit in the gastrointestinal tract results in increased satiety with a decreased caloric intake.

2.4 CARBOHYDRATE STAPLES IN GHANA

Some common carbohydrate staples in Ghana are described in the following sections.

2.4.1 Maize (*Zea Maize*)

It is an inexpensive type of starch and a main source of energy for animal consumption (Macrae *et al.*, 1993). The four main types of which are of important benefits to the economy and mostly used are: Dent Maize (it is identified by the dent in the crown of the kernel), Flint Maize (it has a hard and round kernels), Sweet Corn (it is the dent type maize) and Pop Corn (it is the flint-type maize which expands when heated) (Mckevith, 2004).

It is also known as corn in many English speaking countries. It is noted to account for about 55% of all grain output. Maize is the most predominant cereal in the Ghanaian market. Corn must be worked on to make them consumable. It can be roasted, boiled, or fried for consumption. Variety of Ghanaian dishes which can prepared from maize or corn include

banku, *akple*, *kafa*, *abolo*, *kenkey*, *tuozaafi*, *etsew*, and *appraprensa*. Per 100 g of a freshly cultivated maize or corn consists of 74 g of carbohydrates, 7.3 g of fibre and 0.64 g of sugar. Sweet corn which is one of the numerous types of maize has high sugar content. Matured corn has more starch whiles unmatured corn contains more sugar. Figure 2.1 shows a picture of grains of maize and maize cob.

Fig 2.1 (a) Corn removed from the cob **(b) Corn on the cob**

2.4.2 Cassava (*Manihot Esculenta*)

Cassava is cultivated in the southern part of Ghana especially in the non-forested sites. Cassava yields about 50% of the total crop production (Doku, 1965).

It is ranked the 3rd most consumed carbohydrate stable and is of a great importance to the economy (Food and Agriculture Organization of the United Nations, 2014).They are basically mulched or farmed for their tuberous root since they are rich in carbohydrate. Various products or food items such as *tapioca*, *gari* and *fufu* (when mixed with cocoyam, plantain and yam) are derived from cassava. A 100 g of unprocessed cassava comprises 38 g carbohydrate, 1.8 g fibre and 1.7g sugar and can produce or provide 670 KJ worth of energy. Cassava constitutes amylose-amylopectin quantities of 30:70 (United States Department of Agriculture, 2002). Cassava is presumably to induce an increased glucose response on

ingestion since it consists of a large size of amylopectin which is more branched and more available to digestives enzyme amylases. The nutrient content of cassava will differ depending on the type of cooking method. Figure 2.2 shows a picture of cassava tubers.

Fig 2.2 Tubers of cassava

2.5 CARBOHRATE DIGESTION AND ABSORPTION

In order to understand the important roles carbohydrates play in metabolism, the site, extent and the rate of digestion from the gastrointestinal tract must be clearly comprehended (Mann *et al.*, 2007). Digestibility and absorption are essential factors that are helpful in grouping carbohydrates based on their nature, properties and the roles they play. Carbohydrate digestion starts in the mouth with the help of salivary amylase an enzyme produced by the salivary gland. How well digestion occurs in the stomach and small intestine is dependent on how well food is masticated before swallowing.

2.5.1 Carbohydrate Digestion in the Stomach

The acidic condition denatures and renders the amylase enzyme which was introduced in the mouth in active in the stomach (Bender, 1997). Some carbohydrates are released during this phase as proteins are denatured and uncoiled, which disrupt various bonds. There is no carbohydrate splitting enzyme in the stomach but hydrochloric acid (HCl) hydrolyses the disaccharides, particularly sucrose into glucose and fructose.

2.5.2 Carbohydrate Digestion in the Small Intestine

Once food exits the stomach, it enters in to the small intestine which is responsible for most of the starch hydrolysis by amylase enzyme secreted by pancreas and also carbohydrate in the small intestine digested by hydrolases secreted by intestinal mucosal cells. Undigested food particles continue to the large intestine where water is absorbed and bacteria metabolize some undigested carbohydrates. The undigested contents are stored in the rectum prior to evacuation as faeces (Bender, 1997).

2.5.3 Absorption of Carbohydrates

The carbohydrate digestion is completed in the small intestine and by the time food bolus reaches the end of small intestine, all the complex carbohydrates have been converted into simpler monosaccharides. These monosaccharides are almost completely absorbed from the small intestine (Farrell *et al.*, 2010).

2.5.4 Spot of Absorption

The jejunum which is the upper part of the small intestine is involved in the absorption of carbohydrates. The rate of absorption decreases down the intestine i.e. proximal jejunum absorbs much more effectively than the distal portion. A very small amount is absorbed in the stomach or large intestine. In the small intestine various fluids and enzymes such as maltase, lactase, sucrose and isomaltase continue with the breakdown of carbohydrate. Some carbohydrates and other food substances including fibre are not digested in the large intestines. These substances can be broken into gas or serve as food for gut bacteria (FAO/WHO, 1998).

2.6 HOW GLYCEMIC INDEX IS DETERMINED

After Jenkins *et al.*, (1981), introduced the glycemic index idea; series of studies have been conducted to know the glycemic index of some foods. Even though the FAO/WHO (1998),

fully supports the glycemic index concept, most Ghanaian common staples have their glycemic index unknown or undetermined. This makes the application of glycemic index very uneasy. Also the glycemic indexes of some specific food were determined by a number of laboratories and their end results varied (Wolever *et al.*, 2003). Typical evidence is rice (Foster-Powell and Brand-Miller, 1995) and potato (Wolever *et al.*, 2003). In order to prevent differences in the glycemic index figures attained for the same food in different locations, a homogenized procedure has been used to determine the glycemic index of foods (Brouns *et al.*, 2005).

Based on the FAO/WHO commendation, the homogenized method to determine the glycemic index of food in an organism, where a test food holding 50 g of accessible carbohydrate is consumed and the extent at which the food is broken down and assimilated into the blood is measured (Brouns *et al.*, 2005). There is a great relationship that exist between the extend at which sugar is disseminated from starchy foods using digestive enzymes in vitro to raise the blood glucose levels in humans. Carbohydrate foods that are steadily broken down and assimilated and induce a slow increase in the blood sugar or glucose bring forth a low glycemic index figure and can be categorized as low glycemic index foods whilst foods that are broken down and assimilated speedily are also categorized as high glycemic index foods (Eli-cophie *et al.*, 2016). The measurement of glycemic response is normally done by taking blood samples for glucose at specific times which begins at the first bite of the test food (Wolever *et al.*, 2003). In calculating the amount of carbohydrate foods, the incremental area beneath the blood glucose response curve of a 50 g carbohydrate size or serving of a test food used as a denominator to the response of the same amount of carbohydrate food consumed by the same subjects.(FAO/WHO, 1998).

Based on the FAO/WHO recommended methods, to ensure clarity and accuracy, the reference food which is usually white bread or glucose must be measured severally or more

than once since any difference in the glycemic response from the reference food will greatly hamper the glycemic index than difference in the test foods (Brouns *et al.,* 2005).

2.6.1 Reference Food

Different types of foods have been used as a reference food in glycemic index determination for some years now. Some reference foods that were used include glucose, wheat chapatti, arepa, potato, rice, bread, white bread, whole barley, whole bread and wheat. However, the most widely used reference foods were glucose and white bread (Foster-Powell *et al.,* 2002).

Limited research has been conducted on the glucose raising effect of the widely used white bread. However, the use of white bread has proven a substantial level of stability and uniformity in the determination of different test meals. Using white bread as a reference food yields a higher glycemic index value than using glucose as a reference food. When the glycemic index of white bread was assessed and determined in some studies, it produced a figure of 73 uniformly. The content and processing of white bread varies from various experimental sites. This was discovered in a research where white French bread yielded a glycemic index figure of 97 (Bornet *et al.,* 1987).

The use of pure glucose makes it easy to compare data from different laboratories. Pure glucose also remains unchanged in different or various experimental sites. However, there has been a report on the nauseating effect of glucose when it is taken in the morning after the 10-14hr fast (Brouns *et al.,* 2005).

If there is a difference in the glycemic response to the glucose or white bread (reference foods), there will be a remarkable difference in the glycemic index of the test foods (Brouns *et al.,* 2005). Wolever *et al.,* (2003), disclosed that to reduce the difference the glycemic index of the test food, the mean of the three trial of the reference food must be used (Wolever

et al., 1991). Even though there was no meaningful or considerable data to back this view. Some studies have proven that three or two trial of the reference food can be used.

2.6.2 Test Foods

Glycemic index is expressed as the incremental area beneath the blood glucose response curve of a 50 g of available carbohydrate of a test food expressed as a percentage of the response to the same quantity of carbohydrate from a reference food taken by the same subjects.

The quantity of food tested should contain 50 g of glycemic or available carbohydrate and it is often measured or quantified as total carbohydrate excluding dietary fibre (FAO/WHO, 1998).

2.6.3 Pathophysiology of Study Subjects

No variations have been noted in the glycemic response between males and females (Wolever *et al.,* 2002). Also there are no reasons to avoid the addition of both sexes in various studies conducted to determine the glycemic indexes of various foods. Some characteristics of participants which include insulin sensitivity and glucose tolerance have a great impact on the glycemic response to a food. It is therefore necessary to consider the pathophysiology of the study participants in order to ensure accuracy in glycemic index values.

Brouns *et al.,* (2005), stated that participant's physiology does not seem to have a great impact on the mean glycemic index values. Difference in figures may vary in various group but great changes was noted among diabetics (type 1). They therefore recommended that healthy subjects must be included in the study (Brouns *et al.*, 2005).

2.6.4 Number of Subjects

Numerous studies done on the glycemic index of food used different number of study participants. This variation was dependent on the number of food been tested for their glycemic index. However, the larger the number of study subjects involved, the more accurate the results (Eli-cophie *et al.,* 2016).

Based on the FAO/WHO joint expert report, for the glycemic index of a food to be known, it must be redone in six or more participants.

In a report for the determination of Hand-stretched Pizza, (2011) compiled by Jenkins, using the standard ISO method (ISO/FDIS 26642), ten (10) subjects were studied. According to the report, "using the t-distribution and assuming an average coefficient variation within individual variation of incremental area under curve values of 25%, n=10 subjects has 80% power to detect a 33% difference in IAUC with 2 tailed $p<0.05$" (Wolever *et al.*, 2011).

In Brouns *et al.,* (2005), it was stated that involving ten healthy subjects in the study yields concrete results.

2.6.5 Time Test Should Take Place

In order to differentiate test foods with foods on the glycemic index table, it has been recommended by Brouns *et al.,* (2005), that the test should take place in the morning at breakfast time. It was discovered that there was a vast difference between glycemic responses that was generated from a test during lunch time after a standard breakfast. This was due to the fact that the 10-14hr fast helps in stabilizing intra individual difference due to time of the day and meal influence.

The glycemic index of two breakfast cereals were studied after a 10-14hr fast and lunch time after a standardized breakfast. There was a vast difference noted between the glycemic

responses of cereals when tested at breakfast time than that at lunch time (Wolever and Bolognesi, 1996c). It has therefore been recommended that test must commence in the morning or at breakfast time after a 10-14hr overnight fast (Brouns *et al.*, 2005).

2.6.6 Blood Sampling

Glycemic index was dependent on quantifying the glucose responses in the entire capillary blood since it is a desirable and unharmful form of blood sampling which ensures an ample sampling and assessing of foods (Wolever *et al*,. 1991).

Since glycemic responses in the capillary blood are larger than that of the venous blood, it may yield a little variation in the glycemic responses to various foods to be tested (Brouns *et al.,* 2005). According to Frayn *et al.,* (1989), venous blood which can be sampled from the visible parts of the body including the forearm has a greater and larger concentration than capillary blood. Quantified glucose concentration in the capillaries is relatively higher than in venous blood and this makes it easy to detect or determine variations in the blood sugar concentrations over time.

It has therefore been approved to use capillary or arterialized venous blood and avoid the use of normal blood due to factors such as fluctuation and ambient temperature which can result in variations in the glycemic index response. Fingertip or ear lops capillary blood gives the greatest sensitivity hence must be used to generate a better assessment of glycemic response (Wolever *et al.,* 1991).

2.6.7 Blood Sampling Time

Blood sampling time varies in non-diabetics and diabetics. In non-diabetics blood samples are usually taken after the 10-14hr fasting before test food is given and at the 15, 30, 45, 60, 90, and 120th min after consumption of the test meal. In diabetics, samples are taken after 10-14hr fasting before the test food is given and the 30, 60, 90, 120, 150 and 180th min after

consumption of the test meal. According to Wolever *et al.*, (2004b), when blood is sampled below 30min rather than 15 min in healthy individuals, it affects the mean glycemic index values and differences in their incremental area under curves.

There has been no research or analysis done to verify if the lengthen of blood sampling above 2hrs has an impact on the glycemic index values but however they may likely be an effect which may differ with various types of foods.

It has been approved that blood sampling in non-diabetics should commence at the fasting state and at the 15, 30, 45, 60, 90 and 120th min after consuming the test meal since sticking to a homogenized timing of blood sampling is an essential contributing factor in getting a concrete or frequent glycemic index figures (Brouns *et al.*, 2005).

2.6.8 STUDIES CONDUCTED ON THE GLYCEMIC INDEX OF SOME FOODS

Table 2-2 A Summary of findings of studies on the Glycemic index (GI) of foods

INSTIGATORS	STUDY DESIGN	NUMBER OF PARTICIPANTS INVOLVED	TEST FOODS ASSESSED	RESULTS
Wolever *et al.*, 2003	Experimental (Inter laboratory study	Ten non diabetics	Oat biscuits, cheese balls, fruit leather	Glycemic index assessed by homogenized controlling ways depicted no essential variations from the different laboratories. The differences that arised was based on the analytical or mathematical errors.
Chlup *et al.*, 2004	Experimental	eleven healthy participants	White bread and juicy cereal bars	There was variation found between the glycemic figures in the morning and evening hours or times
Fajkusova *et al.*, 2007	Experimental	Ten healthy participants	Ten test foods	Essential inter individual variations were seen between the glycemic indexes of meals that were assessed.
Aston *et al.*, 2008	Experimental	Forty-two healthy participants(adults)	Thirty three test foods	The glycemic of 33 diets was assessed with much attention placed on the need to quantify the glycemic index of each diet separately instead of basing values on earlier published figures of a meal with an equivalent brand or kind.
Chlup *et al.*, 2008	Observational	Twenty healthy subjects	Chocolate, apple	The spread sheet software used

			baby food, rice squares yoghurt	together with the continuous glucose monitoring (CGM) could be used in the daily quantifying of glycemic index.
Aston *et. al.,* 2008	Experimental	Forty six healthy adults.	Breads, breakfast cereals, pasta, rice	Various internal indices in meals influence their glycemic index. The glycemic index of various meals should be quantified rather than making predictions based on figures published for similar meals.
Chlup *et al.,* 2008	Experimental (Extended post prandial)	Healthy subjects	Mixed foods Honey, tomato soup, white bread, potatoes and fish, wafers, and others	120 mins glycemic some meals differed from their respective glycemic index at 120 mins.
Omoregie and Osagie, 2008	Experimental	Fifty healthy subjects (16-40yrs, 23 males and 27 females)	Starch, eba garri, amala, agidi, tuwo dawa, tuwo masara, semovita, semolina and tuwo shinkafa	Various processing methods had an effect on the glycemic response and glycemic index of test food. Variety of test foods with similar amount and type of carbohydrate yielded varied glycemic response
Lin *et al.,* 2010	Experimental (2hr post prandial	Ten subjects	Taro, brown rice, yam, mung bean noodles, adlay	Glycemic index figures assessed in reducing or descending order. Brown rice, taro, adlay, yam, mung beans noodles
Alkaabi, 2011	Experimental	Thirteen healthy participants and ten diabetics	Five Varieties of dates (Tamer	The different variety or types of dates did not have different glycemic

			stage)	index. The glycemic index of dates when tested in both diabetics and nondiabetics. There was no great difference found between glycemic index figures of healthy participants and diabetics.
Itam *et al.*, 2012	Experimental	Ninety subjects (forty five diabetics and forty five non diabetics)	Cassava flour, cassava eba, cassava starch, baked sweet potato, roasted sweet potato, fried sweet potato, boiled sweet potato, yam flour and yam amala	There were variations found between the glycemic index figures of both diabetic and nondiabetic subjects. Processing had an effect on the glycemic index of test foods.
Camille *et al.*, 2014	Experimental	Ten healthy participants (seven males and three females)	Pounded yam with eggplant stew, cassava paste with granulates palm nut sauce and rice with groundnut sauce	Based on the glycemic loads and glycemic index figures of the test meals, they must be eaten moderately in a diet.
Adam *et al.*, 2015	Experimental	Ten healthy participants (seven males and three females)	Pounded yam, pounded plantain, cassava paste fermented and maize meal stiff or maize	Food indices such as processing, preparation and cooking methods, the physical form of food, type of sugars and starch in the food, presence of macronutrients

			porridge	affected the glycemic index of test foods.
Eli-cophie *et al.*, 2016	Experimental (cross over trial)	Ten healthy participants (eight males and two females)	Banku, ga kenkey, tuo zaafi, locally prepared fufu (plantain) and industry processed neat fufu	The research showed that the five major Ghanaian staples had low to moderately high Glycemic index. Processing and cooking methods had an effect on the glycemic index of foods.

2.7 FOOD FACTORS THAT AFFECT GLYCEMIC RESPONSE OF A FOOD

Food factors that affect the glycemic response of a foods glycemic index are linked to the differences which are sometimes centered on the physical form of food. Some of these factors include the following in table 2-3 below.

Table 2-3 Findings of food factors that affect the Glycemic index (GI) of foods

FOOD RELATED FACTOR	EXAMPLES
The nature and quantity of digestible carbohydrate available in the food.	The physical form of the carbohydrate (particle size, degree of hydration) The nature of starch (amylose, amylopectin) or starch hydrolysis products The content of monosaccharides (glucose, fructose, galactose, mannose, tagatose) The content of disaccharides (sucrose, isomaltulose, trehalose, lactose) The content of oligosaccharides (maltodextrins)
The nature and amount of other food components	Fat Protein Dietary fibre Organic acids Phytochemicals
The type of food and the impact of processing and type of cooking method.	Degree of cooking Physical form (solid versus liquid) Particle size of food

Source: Sadler, (2011).

2.8 FACTORS THAT AFFECT GLYCEMIC INDEX

2.8.1 Physical Form Of Food

Transforming the content particle size of food changes their glycemic indexes. (Collier and O'Dea, 1982). An example of a 1-inch cube potato can increase by 25% just by mashing the cube (Wolever *et al.*, 2001).

2.8.2 Processing Effects

How food is processed affects and influences its glycemic index. More milling, beating, mixing, mashing and refining increase the glycemic index of that particular food.

Grinding, rolling processing or even thoroughly chewing a kernel or other starch food can disrupt the granules. Same procedure is applied in processing many grains and this disrupts their outer germ layer and granules. This in turn increases their glycemic index (ASP NG, 1987). Carbohydrates undergo different forms of processing throughout the course of preparation to make them edible. How a particular carbohydrate meal is processed plays an essential role in discovering its general characteristics or nature (Englyst *et al.*, 2007). Highly processed foods are broken down faster and tend to have a high glycemic index rating. Unprocessed grains have a lower glycemic index rating since they take a long time to be broken down.

2.8.3 Cooking Methods

The type of cooking method affects the glycemic index of a diet as well as glycemic response. The amount of heat applied, quantity of water and the length of cooking have a vast impact on the glycemic index of a food. When a food containing a large amount of carbohydrate is heated, moisturized, ground or pressed, the more it will be digestible apart from the portions that are not digestible. Cooking usually increases the digestibility of food and increases its glycemic index. It swells starch molecules and softens food making it faster to digest (Vaaler *et al.*, 1984, Collins *et al.*, 1981). During boiling, some simple sugars are lost and since resistant starches are not broken down, they limit glycemic response. Frying which is one of the methods of cooking hampers the rate at which food is broken down. The oil used in frying reduces starch degradation and lengthens gastric emptying and hence limits glycemic response. Bahado- Singh *et al.*, (2011), conducted an experimental research on how roasting, baking, frying, and boiling affect the glycemic index sweet potatoes. He discovered

that varied methods of preparation affects the glycemic index of sweet potatoes in varied ways. Boiling lowered the glycemic index of the sweet potatoes whereas roasting and baking increased it significantly. Ramadath (2004), also conducted an experiment on some Caribbean staples. He discovered that boiling affected the glycemic index of these staples. Aston *et al.,* (2008), discovered in his experimental research that the glycemic index of easy cook basmati rice was increase than normal basmati rice.

2.8.4 Variety Within Food Classes

The glycemic figures of foods can be differentiated based on its type, way it is processed and prepared. Different types of foods have different glycemic index. Example includes different types of rice which have different glycemic index. The glycemic index of rice can be influenced by the size or portion of amylose and amylopectin found in them. Amylopectin has booth (I-4) and (I-6) linkages there having a branched structure whiles amylose has a linear molecule with D-glucose units linked in an (I-4) (Annison and Topping, 1994)**.** The larger the portion of amylopectin, the more it raises glycemic index since it is made up of branched starch molecules. Starch molecules which are double stranded are easy to hydrolyze in the gut than amylose single stranded (Van and Weststrate, 1992). Fifty grams of the same type of rice yielded different glycemic index figures starting from 68 to 103 (Foster-Powell and Miller, 1995). Varieties of pasta which include macaroni, star pastina and spaghetti also yielded different glycemic index figures or values 68, 54 and 45 respectively (Wolever *et al.,* 1986). Thin linguini has a glycemic index of 87 whiles thick linguini has a glycemic index of 68 (Grandfeldt *et al.,* 1991).Long grain white rice also has a low glycemic index whiles brown rice has a high glycemic index. An experimental study conducted by Henry *et al.,* (2005), on different varieties of potatoes yielded wide variations in their glycemic indexes. Aston *et al*., (2008), conducted an experimental research on different varieties of rice and some porridge. He discovered the glycemic of easy cook basmati rice was increase than

normal basmati rice whiles porridge meal made with jumbo oats had a low glycemic index than meal made with firmly processed oats.

2.8.5 Ripeness

The more ripe a fruit or vegetable is, the higher its glycemic index value. The ripeness of a fruit influences its glycemic index. As a fruit starts to ripe, the starch content in it is converted and transformed into sugar. The starch basically has a high glycemic index than sugar so as ripening progress the glycemic index reduces. An example is banana (Englyst, 1982).

2.8.6 Chemical Modification

Chung *et al.,* (2008), conducted an experimental research on the chemical modification (oxidation, hydropropylation, acetylation, crosslinking) of normal corn. It was discovered that oxidation, hydropropylation and acetylation resulted in a reduced amount of fastly digestible starch and this lowered glycemic index. Glycemic index of cross-linked starch was similar to unmodified starch.

2.8.7 Micronutrients

An experimental study conducted by Su-Que (2013), on the micronutrients of two varieties of wheat bread revealed that adding micronutrients to wheat bread reduced their glycemic index drastically.

2.8.8 Dietary Fibre Content

Differentiation between white and brown rice, white and brown spaghetti, and whole wheat and white bread depicted a small variation in their glycemic indexes even though they contained different amounts of fiber. Jenkins *et al.,* (1981), did a research on the glycemic index and the fibre content of some foods but found no relation.

Holt *et al.,* (1997), found no relation between the postprandial insulin responses to the fiber content of foods. In persons with type two diabetes, no effect has been found on the effect of fiber on glucose concentrations. Long term studies have not been made in non-diabetic subjects too. (Nuttall, 1993, Tattersall and Mansell, 1990). Foods containing soluble fibers such as oats and legumes have a low glycemic index since they delay gastric emptying. Insoluble fiber does not have any impact on digestion and absorption of carbohydrate hence they have a high glycemic index. Another experimental study conducted by Jenkins (2010), on the novel fiber viscous polysaccharide in cornflakes, rice, and turkey dinner revealed that foods that were incorporated with NVP had their glycemic index reduced drastically.

2.8.9 Acid Supplementation

A meal that has high acidity content tends to have a lower glycemic index. Increasing the acid content in a meal affects its glucose response (Lilijeberg and Bjorck, 1996). Acids present in foods or diets slow down its digestion in the body. The slower the digestion rate the slower it raises the blood glucose level. Addition of lemon juice to a food reduces or lowers its glycemic index. Ostman *et al.,* (2008), conducted an interventional study on acetic supplementation (vinegar) in white bread. It was discovered that the glycemic response to bread meal reduced or decreased with high vinegar amounts.

2.8.10 Macro Nutrients

Protein rich foods tend to increase insulin secretion without affecting glucose concentration (Simpson *et al.,* 1985, Nuttal *et al.,* 1984, Krezowski *et al,.* 1986), but where glucose response decrease, insulin response rises. When more protein is taken with carbohydrate foods, the insulin response raises whereas postprandial glucose does not change much. Also adding fat to diet containing carbohydrate lowers plasma glucose. All macronutrients release many gut peptides but fat and protein enhances mostly the release of gut peptide which have little effect on glucose (Nuttal *et al.,* 1985; Collier *et al.;* 1984; Gannon *et al.,* 1993). Hence

insulin response to carbohydrate differs with the quantity of fat, protein or both it is eaten with.

2.8.11 Presence of Antinutrients

The presence of phytates, lectins, tannins, phytic acid and polyphenols normally slow down digestion and thereby lowering the glycemic index of a food (Rea *et al.,* 1985; Thompson *et al.,* 1984; Yoon *et al.,* 1983).

2.9 IMPORTANCE OF GLYCEMIC INDEX IN FOOD CHOICE

Carbohydrate diets consist of vitamins and minerals and other compounds such as phytochemicals and antioxidants which influence human health in varied ways. Since carbohydrate diets contain most food nutrients which contribute to healthy leaving, it is therefore appropriate to increase intake of their varieties (Hodgson *et al.,* 1994).

Selection of diets is not solely based on their health and nutrient but also individual choice, local availability, needs and cultural acceptability. Food choice cannot be based on just a single factor. The chemical makeup of a diet with fat, sugars and dietary fiber content play important roles in food choice. Knowing the chemical composition of carbohydrate diets does not depict their physiologic impacts. Individuals have varying factors that influence their choice of a food (FAO/WHO, 1998).

Two indices of carbohydrate foods based on their physiological function have been proposed. A recent study conducted by Holt *et al.,* (1996), on satiety index quantified the satiety figures of the same energy sizes of meals relative to white bread. The conditions which control food consumption are usually complicated and therefore satiety has been differentiated from satiation. Delving deeper into the satiety indices of food in future may help in the choosing of appropriate carbohydrate meals which can have a positive impact on energy balance.

Glycemic index is one of the concrete indexes that can be used to group food according to how they are able to increase blood glucose level (FAO/WHO, 1998).

2.9.1 Effects of Glycemic Index on Health

The glycemic index and glycemic index load has broadly been backed as tool for showing diets that may prevent long lasting diseases or ensure their control. Mann *et al*., (2007), discovered in his research the ability of glycemic index and glycemic load in the protection against diabetes and cardiovascular disorders. Consumption of a low glycemic index diet gives rise to numerous health advantages. These advantages consist of lowered insulin use and demand, enhanced glucose management and lowered blood lipid levels. These indices go a long way to play significant roles in the controlling and protection against several long lasting diseases and malfunctions such as diabetes, coronary heart disease as well as cancer. Diets that have a high glycemic index cause an increase in blood glucose rates which result in a high insulin use. In an environment noted for stationary behavior, excess eating and obesity, increase circulating blood glucose caused by eating meals that have a high glycemic index, could result in a high dependency for an already stressed metabolism due to obesity, lack of exercise, insulin resistance and metabolic syndrome can result in hyperinsulinemia or complicate existing conditions (Ludwig, 2002).

2.9.2 Glycemic Index and Obesity

The incidence of obesity is on the rise in most developed and developing countries. There has been a public interest in the incidence of obesity since it can result in diabetes, coronary heart disease and long lasting diseases which comes about as a result of life style factors. Certain factors or indices which includes genetic, environmental and lack of exercise contributes to obesity. Consumption of a high carbohydrate diets improves or enhances satiety. Fat is mostly stored in the body than surplus carbohydrate hence the consumption of high carbohydrate diets have the tendency in limiting the likelihood of obesity. Obesity comes

about as a result of surplus energy which comes from consumption of high fatty diets which promotes fat accumulation (FAO/WHO, 1998).

Consuming meals or diets that have a high glycemic index result in obesity since it make people eat more than necessary or accepted (Ludwig *et al.,* 1999). There are varied ways foods with a low glycemic index paly an essential role in obesity and weight control. Extended blood glucose reaction enhances satisfaction or satiety and this can be attributed to a prolonged absorption rate.

Also carbohydrate foods that are high in fibre tend to have a low glycemic index and they also improve and enhance satiety (Arvidsson-Lenner *et al.,* 2004).

2.9.3 Glycemic Index and Diabetes

The medical term diabetes can be referred to as a group of metabolic disorders that is marked by a high blood sugar level (hypoglycemia) or a low sugar level (hypoglycemia) and also glucose hypersentivity. Some medical conditions cardiovascular, cerebrovascular and peripheral vascular disorders have been associated with diabetes (Wang *et al.,* 2013). Type two diabetes which can also be referred to as non-insulin dependent diabetes which is on the rise has resulted in the reviewing of ways on how to prevent and treat this condition (Deville-Almond *et al.,* 2011). Consumption of high glycemic index diet has been discovered to relate to the existence of type two diabetes based on results from various research.

The metabolic consequences of low and high glycemic index meals are assumed to be associated with speed or pace at which glucose is absorbed from or in the small intestines (Jenkins *et al.,* 2002). The speed at which glucose is absorbed after eating a meal of a high glycemic index results in an increase blood glucose concentration (Meyer *et al.,* 2004). Hyperglycemia normally comes about when there is a problem with the role insulin plays in the body. Insulin is a hormone in the body produced by the beta cells in the islets of the

langerhans in the pancreas which is responsible for the uptake of blood glucose after digestion and absorption. Consumption of a diet with a low glycemic index has been found to enhance the glycemic control among individuals with type one diabetes as well as individuals with controlled metabolism (Wolever *et al.,* 2009).

According to Brand-Miller *et al.,* (2003), low glycemic index diets have a great importance in the management of diabetes than medicines used to control elevated or increased post-prandial glucose levels. In the Nutrition Recommendations and Intervention for Diabetes, a position statement by the American Diabetes Association recommended that low glycemic index foods that are high in fibre and other essential nutrients should be encouraged in the controlling and nutritional therapy of diabetes (American Diabetes Association, 2008). The joint FAO/WHO Expect Consultation on carbohydrate, The European Association for the study of diabetes, Canadian Diabetes Association, Diabetes UK and Diabetes Australia also supported the use of glycemic index in the prevention, controlling and treatment of diabetes (American Diabetes Association, 2008, Canadian Diabetes Association, 2008, Diabetes and Nutrition Study Group (DSNG), 2000, Wolever *et al.*, 2000, Diabetes Australia, 2006).

2.9.4 Glycemic Index and Cardiovascular Health

Numerous factors including genetic and lifestyle factors increase the occurrence of cardiovascular disease. Dietary factors are among the factors that increase the chances of cardiovascular disease. When obesity centered in the body it raises the risk of coronary heart disease. Other factors or indices which include consumption of high saturated fats can result in coronary heart disease (FAO/WHO, 1998).

A research conducted by Jakobsen *et al.,* (2009), revealed that the rate cardiovascular health occurrence can be attributed to high intake of refined carbohydrates rather than saturated fats.

Ludwig (2002), affirmed the duty of carbohydrate quality in cardiovascular health in a review on glycemic index prevention and treatment of cardiovascular disease, obesity and diabetes. It has been noted that consumption of high glycemic index foods increase the chances of coronary heart disease risk by elevating plasma glucose whiles reducing HDL cholesterol.

Low glycemic index diets can be essential in cardiovascular health by limiting factors that causes it (Eli-Cophie *et al.,* 2016). A study conducted by Mirrahimi *et al.,* (2012), discovered a positive role a low glycemic index meal play in coronary heart disease in a systematic review of 473 studies.

2.9.5 Glycemic Index and Dental Health

The causes of dental carries can be related to numerous indices. Diets that are rich in starch or sugar are easily degraded by α-amylase in the mouth which results in the production of some acids which can increase the chances of acquiring dental caries.

Effects of carbohydrate on dental caries can be based on certain factors such as type of diet, how often food is consumed, extent of oral hygiene, presence of salivary function and genetic factors (FAO/WHO, 1998). Starches that have a high glycemic index causes more changes in plaque pH than starches with a low glycemic index when combined with sugars (FAO/WHO, 1998).

2.9.6 Glycemic Index and Cancer

After heart disease been the leading the cause of death in many developed countries, cancer has been ranked the second causes of death and the third in developing countries resulting in 7.6 million deaths and more than 12 million cases been identified in the year 2007 only (American Cancer Society, 2007). Research suggests that the cause of cancer can be attributed some environmental or dietary factors (Rastogi *et al.,* 2008). Dietary facets linked with western or foreign lifestyles which include high consumption of processed or refined

carbohydrate, saturated fat, red meat, and high intake consumption have been identified to raise the possibility or menace of long lasting conditions such as cancer (Willett, 1995). Carbohydrate is one of the dietary compounds that have been found to cause cancer in various areas (Giovannucci, 1999b).

McKweon-Eyssen (1994) and Giovannuci (1995) each revealed that insulin resistance and hyperinsulinemia may include some of the essential factors that can enhance cells to grow or enlarge from tumor to malignant. Insulin resistance, hyperinsulinemia, obesity, sedentary life styles, excess intake of energy, clinical conditions related to insulin resistant and hyperinsulinemia (type two diabetes and polycystic ovary syndrome) and high circulating insulin and insulin like growth factor-1 have been linked with high cancer chances at various sites (Le Roith and Roberts, 2003, Augustin *et al.,* 2002).

Numerous epidemiological researches revealed that a diet with a high glycemic index results in colon, breast, and prostate cancers (Franeschi *et al.*, 2001; Augustin *et al.,* 2001 b, 2002).

It has been discovered by Augustin *et al.,* (2002), that diets which have a low glycemic index reduce the rate at which absorption occurs in the small intestines which results in the efficient use of insulin reduces cancer risk as compared with a diet that has a high glycemic index.

2.10 GLYCEMIC INDEX LABELLING

Discretionally tagging of meals according to their glycemic index by producers exist in many countries and locations. Products must be the same as the nutritional content demands to be qualified for the glycemic index assessing and tagging, which includes limit on the quantity of fat available in a diet. Content requirements are not uniform in a country where numerous laboratories may give a glycemic testing assistant or within countries worldwide. A uniform permitted yard stick would provide consumers, health professionals, and regulators a more appropriate glycemic index status of food on sale or offered for sale (Veen and Green 2007).

According to the FAO/WHO (1998), tagging of food commodities enable buyers know the nutritional composition of a diet in order to make appropriate selections of diets for healthy living. A lot of studies and articles have been published as a result of the glycemic index theory according to Brouns *et al.,* (2005) and has resulted to much attention been emphasized on its importance and usage. A possibility to label foods with GI would serve interested consumers and may be an incentive for producers to develop products suitable for low-GI labelling. GI values of certain products, e.g. bread and breakfast cereals, may vary widely. Low-GI alternatives and tools to identify them may be helpful for diabetic patients. However, for healthy people, the significance of GI is still unclear, and it cannot be judged at present to what extent labelling may contribute to overall public health (Arvidsson-Lenner, 2004).

According to Arvidsson-Lenner (2004), some essential considerations are required if foods are tagged or labeled with glycemic index values as part of nutrition information.

Three basic are requirements accounted for the support of such labelling or tagging and they include the following;

Glycemic index has to be tested for a particular food commodity to be tagged or labelled by a well-endowed laboratory or clinic.

Glycemic index is only accepted in the application to foods or diets that are rich in carbohydrate.

Differentiation of glycemic index should be restricted to food in the same food class. Mitchell (2008), also stated that the addition of glycemic index of diets on labels is seen to be one of the significant things on the food table. Numerous countries including Australia and the United Kingdom have appreciated and instigated some length of glycemic index tagging on their diets. Hence the notion of glycemic index theory in on the increase and also in Australia

and United Kingdom (Mitchell, 2008). However, the same cannot be said about Ghana since numerous of our diets are prepared at home and how they are made available for sale and consumption does not demand any type of labelling. Most Ghanaians do not check and consider the nutrient composition of a food tag before selecting because most of our staples are sold and marketed without their labels. According to the Ghana Food and Drugs Board, packaged diets which are hermetically sealed must be tagged or labelled. Basic things demanded by the food and drugs board before an item can be accepted or registered in Ghana exclude the glycemic index. Much of the glycemic notion or idea is not known or understood by the average Ghanaian even though dietitians in Ghana use the glycemic notion in medical nutrition therapy in numerous health care centers. It is therefore essential to make citizens aware of the glycemic index concept through education. Also, numerous researches must be conducted on most Ghanaian staples to know their glycemic index. This will help in providing enough knowledge on nutritional counselling when using the local diets (Eli-Cophie *et al.,* 2016).

2.11 GLYCEMIC INDEX CONTROVERSIES.

Even though a lot of research has been conducted and still ongoing on the functions glycemic index play in selecting healthy or appropriate foods, a lot of controversies or arguments came up in the latter 90's. Some arguments made ground and others were not in line with the important or crucial role glycemic index played in the prevention and controlling of diabetes and other diseases (Wolever *et al.,* 2002). Individuals and groups against the glycemic index concept discussed that it was an insignificant gist which entangles or muddles dietary constrains in the controlling of diseases (Coulston, 1997). The other idea was that glycemic index stands as the only asset to yield varied carbohydrate diets that a buyer may have not paid attention to (Jenkins *et al.,* 2002). Addition of glycemic index in food tags have been supported and promoted by advocates of the glycemic index notion. Eventhough various

higher bodies or organizations which includes the Canadian Diabetes Association, WHO (Mann *et al.,* 2007), Diabetes UK and the American Diabetes Association (Sheard *et al.,* 2004) have supported the use of the glycemic index concept or notion. A dissemination of data from the Health Canada revealed that glycemic index was not an essential or significant idea that should be included in food tags. Considerations involving inter and intra individual differences in the glycemic response to a distinct diet have also been highlighted in assessing the glycemic index by quantifying the glycemic response of a distinct diet or meal as a percentage of 50 g of either white bread or glucose. It has been indicated that the difference is lowered to about 10% (Wolever *et al.,* 2003, Sheard *et al.,* 2004).

Clarity and validity of glycemic index figures have been queried. The disfigurement of glycemic index verifications including other scientific verifications does not discredit the essentialness of the glycemic index. The verification of the glycemic index of a diet or meal is normally emphasized on the size of meal that is glycemic or digestible carbohydrate. It is normally documented on food tags by producers or schools. How to assess or verify the carbohydrates and fiber constituent of a diet or meal differ from places and can sometimes cause a high error in the final or last analysis. This including glycemic index verification ensures an admissible level of error below 15%, whilst allowable or admissible error for nutritional analysis on diet tags is below 20%. This affirms that GI determination is measured to a higher standard of precision and accuracy than everyday nutritional analysis on food labels (International Carbohydrate Quality Consortium (ICQC, 2014).

The data from a study or research conducted by the Stanford group resulted into the annotation of the glycemic index concept. Based on their findings, their anticipated glycemic responses from meals or diets were at odds in mixed diets (Wolever, 2002).

Glycemic index is a very essential notion or idea that is not used without dietary counselling. Controversies that glycemic index does not take into consideration saturated fats and fiber make up of a diet has lost its importance in the face of the notion that glycemic index is a yielded tool in diet selection and not a solution to all food associated problems, overriding professional dietetic counselling (Eli-Cophie *et al.*, 2016).

CHAPTER THREE

METHODOLOGY

3.1 STUDY DESIGN

This study was performed experimentally and the design used was a cross over trial. A cross over trial was suitable to the study since subjects used in the data collection procedure were the same subjects who were given both the test foods and the reference food. The homogenized method demanded that the test must be carried out in human beings due to some conditions that influence the metabolism of food in the human body.

3.2 STUDY SUBJECTS

After the research was approved by the Committee on Human Research Publication and Ethics of the Kwame Nkrumah University of Science and Technology School of Medical Sciences/Komfo Anokye Teaching Hospital, 10 healthy individuals were enrolled into the clinical trial. They consisted of 5 males and 5 females. These individuals agreed to take part in the research and were also enrolled in line with the FAO/WHO (1998), recommended procedure for the determination of the glycemic index. All subjects were oriented before the data collection procedure began. They were informed and made aware about what the research entailed. They were also asked to stay away from smoking and drinking, any tough or fatiguing activity before and during the period of study. This was ensured through an orientation that was done before data collection commenced.

3.2.1 Inclusion Criteria

The following inclusion criteria were used:

- Apparently, healthy people with no complain of ill health or uneasiness through a thorough medical assessment.
- Both male and female who are not obese based on their calculated body mass index.
- Subjects aged 20 to 50 years.

3.2.2 Exclusion Criteria

The following exclusion criteria were used:

- Subjects aged 20 to 50 years but have histories of hepatitis or any known metabolic disorders.
- Obese individuals with or without diabetes since they have a problem with glucose metabolism.
- Subjects who could not take any of the test meal.
- Persons with any known cardiovascular disease to whom such a work might pose a health risk or stress as well as individuals on medications that can interfere with results in any way.

3.3 DATA

Some basic and simple information such as age, sex, history of diabetes, metabolic disease or any cardiovascular disease, last meal eaten the previous night and time eaten gathered from the subjects. Weight and height were taken to calculate their Body Mass Index as well their waist circumference.

3.4 PROTOCOL

All ten individuals who took part in the data collection were made to undergo a 10-14h fast from the time they took their last meal the previous night to morning of testing. All subjects reported to the Sanford Hospital, Madina at 6:45 to 7:00am. The reporting time and venue was the same for both reference and test foods.

The subjects had their weight and height taken using a bathroom scale and a stadiometer without their shoes or any heavy material on such as watch and wallet. The average weight and heights were taken and used for analysis.

3.4.1 Fasting Blood Glucose

After the weights and heights were checked, the time each subject took their last meal was taken. This was done to know if participants had undergone the 10-14h prior to testing. Capillary blood was taken from each participant to test or check for the FBS using a One Touch glucometer.

3.4.2 Oral Glucose Tolerance Test

After the FBG was done, a glucose solution made from 50 g glucose and 200 ml of water was given to each participant. Stop watches were started when subjects started to drink the glucose solution. The glucose solutions were taken within a 5-minute period. The time each participant began to drink the glucose solution was recorded. Fifteen (15) min after consuming the glucose solution the reference sample, participants had their thumps pricked to check or test for blood glucose level. After that, samples were taken from all subjects at the 30th, 45th, 60th, 90th and 120th min as well to check or test for the glucose concentration in mmol/l. This lasted for 2h. Participants were given lunch and asked not to engage in any strenuous or stressful activity within the data collection period. They were also reminded of the dos and don'ts of the research work. Such as, no smoking, alcohol and strenuous activities.

3.4.3 Test Foods

The foods used for the research were *Neat konkonte, locally made konkonte, Akple, Kafa* and *Abolo*. The first test food which was *abolo* was given two days after the reference food (glucose) was given. As with the reference food, participants or subjects were made to undergo a 10-14 h fast prior to the day of testing. Just as with the reference food, subjects reported at 6:45 – 7:00 am at the same venue. The last meal and time of meal of each participant was asked and recorded. All participants had their thumbs or index fingers cleaned with alcohol and wiped with cotton to disinfect them. They were then pricked with lancet. A

rounded drop of blood was obtained by squeezing the fingers gently. A glucometer with an inserted strip was used to pick the drop of rounded blood to determine the fasting blood glucose in mmol/L. Their FBS was measured and appropriately recorded.

A quantified amount (174g) of abolo, with 30 g of anchovies was given to each participant. The time each participant started the meal was recorded. Participants were made to consume the food in 10 min. The timer was started when each participant commenced eating of the food. The first sample was taken 15 min after the start time. Samples were taken again at the 30th, 45th, 60th, 90th, and 120th min and the glucose concentration recorded in mmol/L. On the assigned days, participants gathered at the same venue and times. Similarly, measured quantities of the other test foods, containing 50 g available carbohydrate was given to each participant and eaten within a 10 min period. The timer was started when each participant commenced eating of the food. The first sample was taken 15 min after the start time. Samples were taken again at the 30th, 45th, 60th, 90th, and 120^{th} min. Capillary blood was taken to measure the fasting blood glucose and appropriately recorded before any test food was given. Subjects were served lunch after the day's work.

Different varieties of test foods which include *abolo, kafa, akple, locally made konkonte* and *processed konkonte* had their glycemic index tested for under the same conditions.

3.5 PREPARATION OF TEST MEALS

The procedures that were followed or involved in the preparation of each test food explained below.

3.5.1 Industry Made or Processed Kokonte

An amount of 1kg of neat *kokonte* powder was purchased from the mall. The *kokonte* product or powder was poured in boiling water and stirred continuously to prevent it from becoming lumpy on a coal pot. More hot water was added to the *kokonte* to achieve the desired thickness. The *kokonte* was pressed against the side of the pot and was allowed to cook for about 15 min. The cooked product was taken from fire and moulded into sizes containing 50 g of available carbohydrate with the help of a food scale.

Fig 3.1 Pack of processed kokonte

3.5.2 Locally Made Kokonte

Cassava was cut into desirable sizes and dried continuously for about a month till there was no moisture. It was pounded and milled into a fine powder. It was continuously sieved to get rid of all unwanted particles. The *kokonte* product or powder was poured in boiling water and stirred continuously to prevent it from becoming lumpy on a coal pot. More hot water was added to the *kokonte* to achieve the desired thickness. The *kokonte* was pressed against the side of the pot and was allowed to cook for about 15 min. The end product was taken from fire and moulded into sizes containing 50 g of available carbohydrate with the help of a food scale.

Fig 3.2 locally made kokonte

3.5.3 Akple

Akple was prepared from corn flour which was dissolved in cold water and added to boiling water. Water was allowed to boil and divided into two parts. The corn flour was added to the boiling water on the fire and mixed very well. The remaining water was added to the mixture on fire. It was kneaded very well to prevent lumps and allowed to cook for about 25 min. The end product was moulded into sizes containing 50 g of available carbohydrates with the help of a food scale. The 50 g available carbohydrate was calculated using a nutrient analysis table.

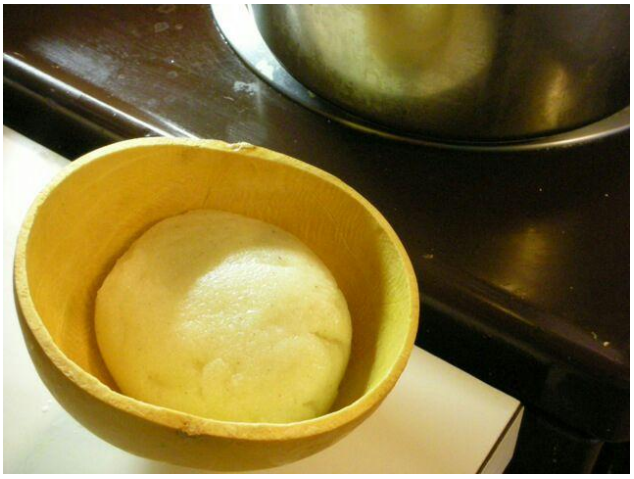


Fig 3.3 Akple

3.5.4 Abolo

The *abolo* was prepared from half-cooked corn dough (aflata) and raw corn dough with little sugar and flour. These ingredients were mixed together with water to form dough. The dough was allowed to rise overnight. The cooked product was moulded into about 180 g wrapped in leaves and steamed for about 45 min.

Fig 3.4 Abolo

3.5.5 Kafa or Agidi

Kafa or *agidi* was prepared from corn flour and cold water. Cold water was added to the corn flour bit by bit and stirred continuously to prevent lumps. Low heat was applied to the mixture and stirred continuously in one direction with a wooden spatula to prevent the formation of lumps. After mixture was completely thickened, it was moulded into about 200 g in dry leaves and left to cool completely at room temperature.

Fig 3.5 Kafa or Agidi

Due to the nature of *abolo* and *kafa*, their sizes containing 50 g of available carbohydrate were measured at the data collection site with the help of a food scale whiles with the *locally made konkonte*, *processed konkonte* and *apkle*, their sizes containing 50 g of available carbohydrates were measured right after preparation with the help of food scale and sent to the data collection site. Each food item was served with about 140 g of groundnut soup and 30 g of beef except *abolo* which was served with 30 g of anchovies.

Nutrient analysis was done on test foods as well as determining the quantities that contain 50 g of available carbohydrate of *locally made kokonte, abolo, kafa, akple*, groundnut soup, anchovies and beef was based or centered on the proximate analysis done by Eyeson *et al.*, (1975). The nutritional analysis outlined for *neat kokonte* was verified based on the nutritional information made available on the package by the manufacturer. However, the package did not have information on the nutritional composition of end product after cooking or preparation.

The portion of 60 g of *locally made kokonte* comprising of 50 g of available carbohydrate portion was quantified for *neat kokonte* and assessed. This was done so that the glycemic index could be differentiated on weight for weight since they are the same type food manufactured differently. This was done based on the idea that being the same of food they contain the same amount or quantity of available carbohydrate per 100 g of their processed form.

TABLE 3-1 NUTRIENT CONTENT OF TEST MEALS

Test meal	Amount (g)	Protein (g)	Fat (g)	Total Carbohydrate (g)	Dietary Fiber (g)	Energy (kcal)	Available Carbohydrate (g)
Neat Konkonte	60	0	1.02	48	0	47.79	50
Local Konkonte	60	0.84	0.24	50.58	0.66	207.6	50
Akple	238	3.80	1.19	50.694	0.71	224.11	50
Abolo	174	6.79	0.17	51.04	1.04	226.50	50
Kafa or Agidi	359	5.39	0.71	51.07	1.07	226.96	50

Source: Eyeson *et al*., (1975)

This nutrient analysis was to done to obtain the accurate quantities of test foods which contained 50 g of available or glycemic carbohydrate.

TABLE 3-2 NUTRIENT CONTENT OF GROUNDNUT SOUP WITH BEEF AND ANCHOVIES

Test meal (g)	Amount (g)	Protein (g)	Fat (g)	Total Carbohydrate (g)	Dietary Fiber (g)	Energy (kcal)
Groundnut Soup	140.0	7.98	21.14	0.28	0.14	205.7
Beef (cow meat)	30.0	5.64	3.09	0.00	0.00	51.90
Anchovies	30.0	5.52	0.45	0.00	0.00	27.60

Source: Eyeson *et al*., (1975)

3.7 DATA ANALYSIS

The incremental area under the glucose response curves (IAUC) were calculated using the trapezoid rule as recommended by FAO/WHO (FAO/WHO, 1998). The areas under the fasting baseline were ignored in the calculation. The Glycemic index of each test food was calculated as the mean GI as obtained by each subject in the study that consumed the test food. All GIs that were 2 SD above or below the mean GI value for a given test were ignored as an outlier (Wolever *et al.,* 2011). The IAUC for each test food was expressed as a percentage of the mean IAUC of the glucose which was the reference food used. The glucose response curves were plotted with the Graph Pad Prism software version 5.00. Data was analysed using Microsoft Excel and Statistical Package for Social Sciences (SPSS) software version 20. 45. The SPSS software was used to know and compare differences between the IAUC of test foods as well as their glycemic index values at ($p=0.05$).

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 GENERAL CHARACTERISTICS OF SUBJECTS

Ten Ghanaian subjects were enrolled in the research for the selected test meals. They consisted of 5 males and 5 females. The mean age, weight, height, waist circumference and body mass index were 23.10±2.6years, 64.16±7.9kg, 161.40±6.0cm, 74.6±6.9cm and 24.39±3.1kg/m^2, respectively.

The anthropometries of subjects are illustrated in table 4-1.

Table 4-1 ANTHROPOMETRY CHARACTERISTICS OF STUDY SUBJECTS.

Subjects	Age(yrs)	Weight(kg)	Height(cm)	BMI(kg/m^2)	WC(cm)
CC11	23	52.0	154.0	21.9	67.0
LA20	23	54.5	170.0	18.8	69.0
OF30	23	75.0	165.0	27.5	74.0
JE40	24	68.0	154.0	28.6	72.0
PK50	24	72.0	169.0	25.2	85.0
JA60	20	65.0	160.0	25.3	69.0
AB70	20	56.2	163.0	21.1	69.0
SA80	27	60.8	160.0	23.7	87.0
BE90	27	72.0	165.0	24.0	77.0
JN10	20	66.1	154.0	27.8	77.0
MEAN	23.1	64.2	161.4	24.4	74.6
SD	2.6	7.9	6.0	3.1	6.9

4.2 STUDY SUBJECTS AND THEIR HISTORY OF DIABETES, CARDIOVASCULAR OR ANY METABOLIC DISEASE.

Table 4-2 Study subjects, their history of diabetes, cardiovascular or any metabolic disease.

SUBJECTS	HISTORY OF DIABETES	HISTORY OF CVD	OTHERS
CC11	No	No	No
LA20	No	No	No
OF30	No	No	No
JE40	No	No	No
PK50	No	No	No
JA60	No	No	No
AB70	No	No	No
SA80	No	No	No
BE90	No	No	No
JN10	No	No	No

From the table above, none of the study subjects has a history of diabetes, cardiovascular disease and any metabolic disorder.

4.3 STUDY SUBJECTS, LAST MEAL OF THE DAY AND TIME MEAL WAS TAKEN.

Table 4-3 Study subjects, their last meal of the day and the time meal were taken.

SUBJECT	DAYS	LAST MEAL OF THE DAY	TIME MEAL WAS TAKEN
CC11	1	Porridge + bread	6:30pm
	2	Fufu + light soup	5:00pm
	3	Banku + okro stew	5:00pm
	4	Fufu +light soup	7:00pm
	5	Yam +egg stew	5:30pm
	6	Fufu + light soup	6:30pm
	7	Banku + okro stew	5:00pm
LA20	1	Banku + fried fish	6:30pm
	2	Jollof	5:00pm
	3	Rice + gravy	6:05pm
	4	Mpotompoto	7:00pm
	5	Banku + okro soup	6:30pm
	6	Kenkey + fried fish	6:00pm
	7	Yam + light soup	6:30pm
OF30	1	Banku + fried fish	5:30pm
	2	Fufu + light soup	5:00pm
	3	Banku + okro stew	5:00pm
	4	Fufu +light soup	7:00pm
	5	Kelewele	5:30pm
	6	Fufu + light soup	7:10pm
	7	Banku + okro stew	5:00pm
JE40	1	Milo + bread	8:20pm
	2	Jollof rice	7:00pm
	3	Jollof rice	7:00pm
	4	Kenkey + fried fish	7:30pm
	5	Kenkey + okro stew	9:00pm
	6	Kelewele	8:45pm
	7	Jollof rice	8:00pm
PK50	1	Banku + fried fish	6:30pm
	2	Jollof rice	5:00pm
	3	Rice + gravy	6:05pm
	4	Mpotompoto	7:00pm
	5	Banku + okro soup	6:30pm
	6	Kenkey + fried fish	6:00pm
	7	Yam + light soup	6:30pm
JA60	1	Fried yam + egg	5:20pm
	2	Tampico	6:00pm
	3	Yam +egg stew	4:20pm
	4	Jollof + chicken	7:20pm
	5	Rice + fish stew	5:20pm
	6	Rice + fish stew	8:30pm

	7	Indomie	5:30pm
AB70	1	Jollof rice + chicken	6:00pm
	2	Fufu + light soup	5:00pm
	3	Banku + pepper	6:00pm
	4	Mango	6:30pm
	5	Light soup	7:00pm
	6	Fried yam	4:00pm
	7	Fried rice	5:00pm
SA80	1	Jollof rice + chicken	7:00pm
	2	Rice + salad	6:00pm
	3	Fanta + chicken	7:30pm
	4	Banku + okro stew	6:20pm
	5	Fufu + light soup	5:40pm
	6	Plantain + pepper	9:00pm
	7	Indomie	10:30pm
BE90	1	Sandwich + coke	7:00pm
	2	Jollof rice	7:00pm
	3	Fufu + light soup	6:20pm
	4	Fufuf + light soup	6:30pm
	5	Fufu + light soup	8:00pm
	6	Fanchoco + bread	8:30pm
	7	Fufu + light soup	5:45pm
JN10	1	Oats + bread	7:00pm
	2	Jollof rice + coke	7:00pm
	3	Potatoes + gravy	7:00pm
	4	TZ + green soup	6:44pm
	5	Banku+ fried fish	4:30pm
	6	Oats and bread	5:00pm
	7	Banku + okro stew	7:40pm

4.4 INCREMENTAL AREA UNDER THE CURVE OF TEST FOODS AND REFERENCE FOOD OF PARTICIPANTS.

Table 4-4 Incremental Area under the curve of the test and reference foods by the study subjects

SUBJECTS	INCREMENTAL AREA UNDER THE GLUCOSE RESPONSE CURVE (IAUC)					
	Glucose mean	**Abolo**	**Apkle**	**Kafa**	**Processed Kokonte**	**Locally made kokonte**
CC11	161.6	141.8	90.2	50.4	23.5	0.2
LA20	223.1	100.5	163.6	75.4	24.7	0
OF30	248.3	139.5	123.0	73.3	69.8	43.7
JE40	250.6	209.3	219.0	143.3	182.3	57.0
PK50	226.9	203.3	111.4	147.5	21.9	40.6
JA60	210.1	162.0	108.8	41.4	45.8	8.3
AB70	343.6	104.3	234.8	89.5	113.3	72.0
SA80	118.8	51.3	104.2	8.80	0	25.0
BE90	221.9	57.3	65.4	38.6	3.4	10.6
JN10	237.4	141.8	374.3	123.0	88.2	10.9
MEAN	225.1±58.6	131.1±53.8^{BC}	165.5±99.2^{CD}	79.1±46.7^{AB}	57.27±57.4^{AB}	26.85±25.2^{A}

^{ABCD}*Values in the same row having different superscripts differ significantly (p<0.05).*

Even though the glycemic index of both *locally made kokonte* and *processed kokonte* are low, a multiple comparison between their incremental areas under their curves revealed that there was no significant difference between the incremental areas under the curve (AUC) for both *locally made kokonte* and *processed kokonte* at (p=0.873).

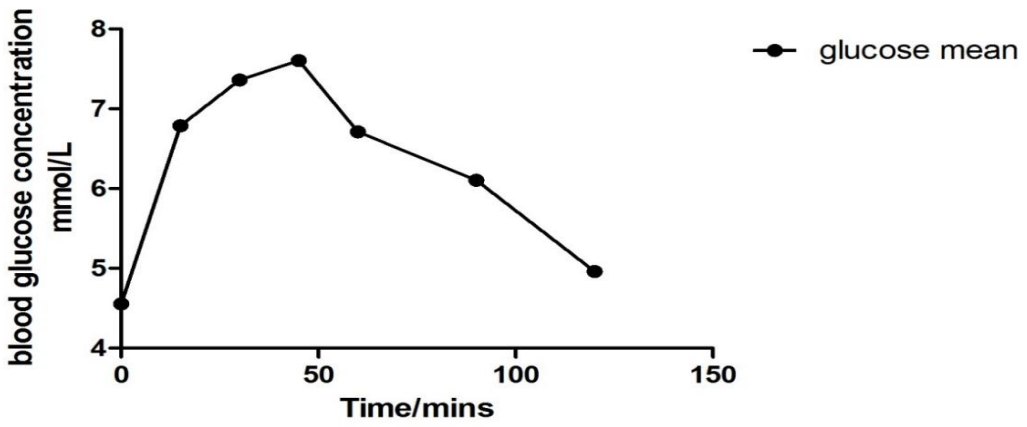


Fig 4.1. Mean glycemic responses of study subjects after consuming 50 g of glucose in duplicate.

The average peak after consumption of glucose solution (reference food) was noted at 45th min from glucose consumption.

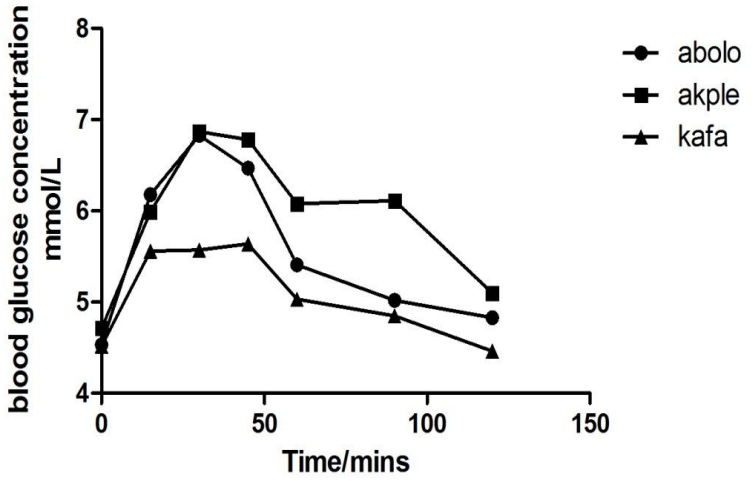


Fig 4.2. Mean glycemic responses after consuming the corn staples in their specific quantities containing 50 g of available carbohydrate.

The average fasting blood sugar leveels before the consumption of the test foods(corn staples) were similar. The average peaks after consumption of abolo and akple was seen at the 30th min where the average peak after consumption of kafa was also seen at the 45th min from consumption of the test foods.

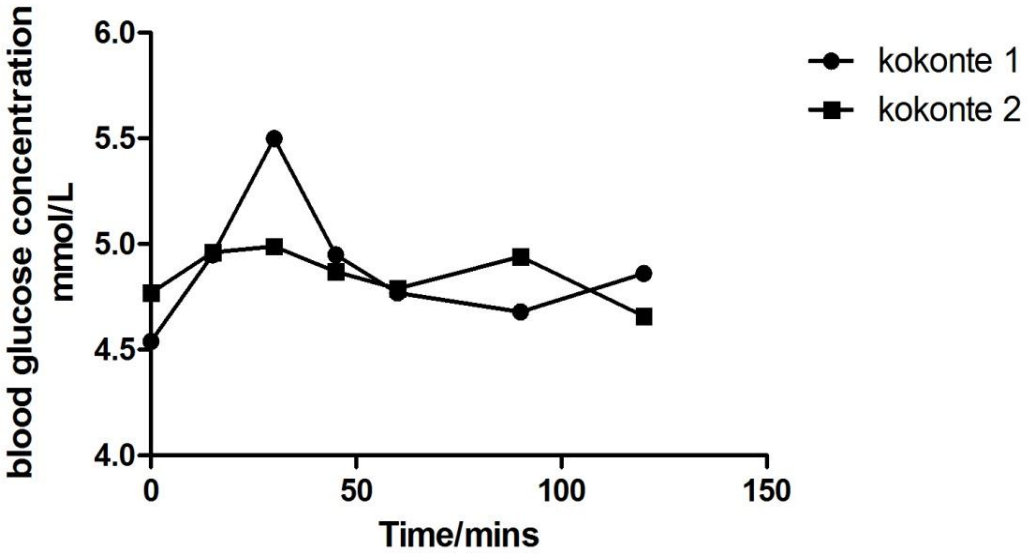


Fig 4.3 Mean glycemic responses of the study subjects after consuming the cassava staples in their specific quantities containing 50 g of available carbohydrate

The average peak after consumption of the two cassava staples (*locally made kokonte* and *processed kokonte*) was seen at the 30th min.

.

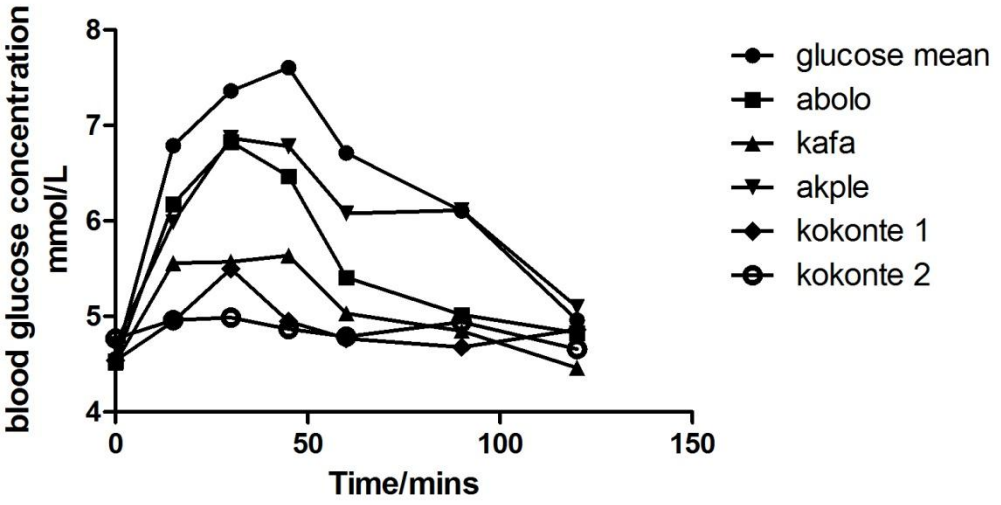


Fig 4.5 Mean glycemic response of both test foods and reference food (glucose duplicate) elicited by study subjects after consuming their specific quantities containing 50 g of available carbohydrate.

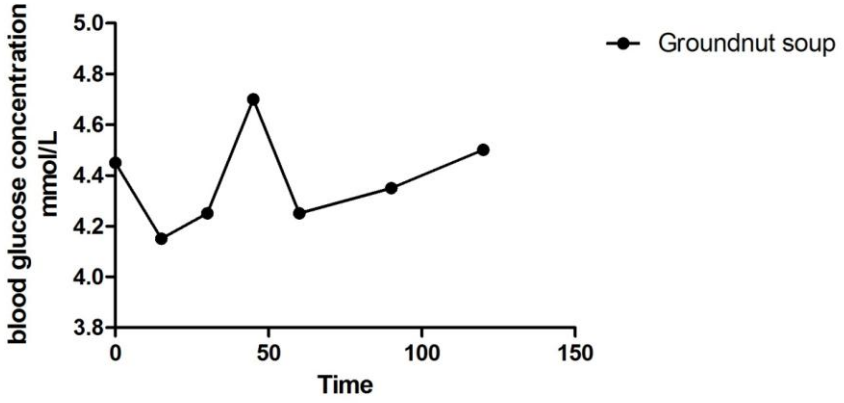


Fig 4.6 Mean glycemic response of 140 g of groundnut soup with 30 g of beef (cow meat) after been consumed by study subjects.

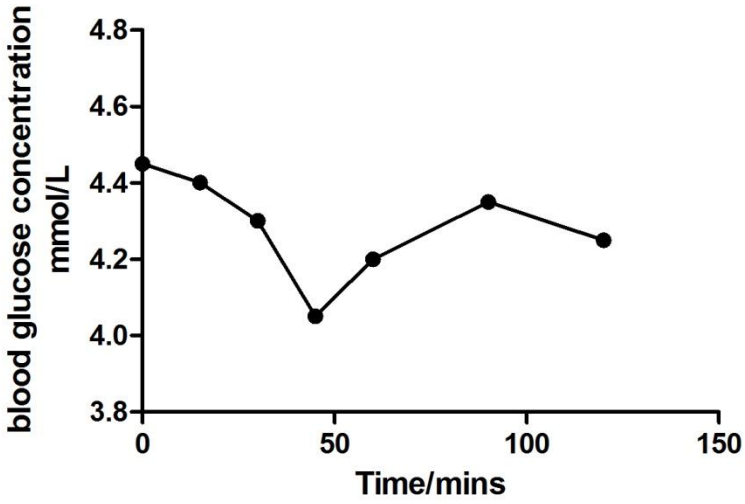


Fig 4.7 Mean glycemic response of 30 g of Anchovies (one man thousand) after been consumed by study subjects.

4.5 THE GLYCEMIC INDEX OF TEST MEALS

Glycemic index is a number associated or assigned to a test food that shows its influence on individual blood glucose level. A figure of 100 represents the standard and equivalent amount of pure glucose. It is normally ranked on scale of zero (0) to hundred (100). Glycemic index figures from 0-55 or below 55 are classified as low glycemic index. Figures ranging from56-69 are also categorized as medium glycemic index and finally, 70-100 are classified as high glycemic index.

Table 4.5 below shows the glycemic index figures of test food, their mininmum and maximum values as well as their standard errors. The two cassava staples, locally made kokonte and processed kokonte both had a low glycemic index of 7 and 18, respectively. Among the corn staples, kafa had the lowest glycemic index figure whereas abolo and akple had medium glycemic index figures 29,58 and 69, respectively.

Table 4-5 Glycemic Index Figures and GI groups

FOOD ITEM	GI MIN (%)	GI MAX (%)	GI %	SE	MEAN	GI CLASS
GLUCOSE	100	100	100	0.0	0.0	High
ABOLO	25	89	58^{BC}	7.5	59.6	Medium
AKPLE	29	157	69^{C}	11.8	73.1	Medium
KAFA	7	65	29^{AB}	5.8	33.7	Low
LOCALLY MADE KOKONTE	0.0	22	7^{A}	2.9	11.3	Low
PROCESSED KOKONTE	0.0	72	18^{A}	6.8	22.9	low

^{ABC}*Values in the same row having different superscripts differ significantly ($p<0.05$).*

Table 4-6 Glycemic Index Figures of Groundnut soup with Beef and Anchovies

Food Item	Glycemic Index value	Glycemic Index Class
Groundnut soup with beef	4	low
Anchovies	0.9	low

Since test foods were eaten some accompaniments, the glycemic index of these accompaniments were tested for separately in other to get the accurate glycemic index figures of test foods. To get the actual glycemic index figures for the test foods, the glycemic index of the accompaniments were subtracted from the test foods. The glycemic index figure of groundnut soup with beef was subtracted from the glycemic index figures of *akple, kafa, locally made* and *processed kokonte* whereas the glycemic index figure of anchovies was subtracted from the glycemic index figure of *abolo*.

Table 4-7 Glycemic index of test meals with and without accompaniments

TEST FOODS	GLYCEMIC INDEX OF TEST FOODS WITH ACCOMPANIMENTS	GLYCEMIC INDEX OF TEST FOOD WITHOUT ACCOMPANIMENTS
Abolo	59	58
Akple	73	69
Kafa	33	29
Locally made kokonte	11	7
Processed kokonte	22	18

4.6 DISCUSSION

The FAO and WHO (1998) suggested that individuals in modern and developed countries should plan and center their meals that have a low glycemic index to avoid chronic diseases which include coronary heart disease, obesity and diabetes. (Bruns *et al.*, 1989; Gannon *et al.*, 1986; Jenkins *et al.*, 2002; Jenkins *et al.*, 2002; Liu and Willet 2002; Ludwig 2002; Raben 2002; Spraul *et., al* 1988). The three main groups of GI are, foods with low GI (GI ≤ 55% or less), foods with medium GI (GI 56-69%) and foods with high GI (GI ≥ 70%).

In this study, some of the subjects complained about the nauseating feeling after ingesting the reference food (glucose). This was in line with what was stated by Brouns *et al.*, (2005), which highlighted that when both white bread and glucose were studied as reference foods. According to a study conducted by Bornet *et al.*, (1987), even though glucose has a nauseating effect after it has been ingested, it remains the reference material that has no variation in its preparation as compared to white bread which showed different mode of preparation in different study areas.

Basic anthropometry such as weight, height, body mass index and waist circumference was checked to select subjects who deemed fit for the study. This study required an inclusion of subjects who are not obese, diabetic or any form of metabolic disorder. Body mass index as well as waist circumference which was measured helped in the selecting of subjects appropriate for the study. Subjects who were obese based on the calculation of their BMI were not selected since they may be predisposed to diabetes, cardiovascular diseases and may also have poor glucose metabolism. According to WHO 1995, for men, a waist circumference of 94cm or more indicates an increased risk of chronic disease and a measurement of 102cm or more indicates a higher increased risk of chronic disease.

For women, a waist circumference of 80cm or more indicates an increased risk of chronic disease and a measurement of 88cm or more indicates a higher increased risk of chronic disease. Therefore, the larger your waist circumference, the higher your risk of developing chronic diseases such as type two diabetes, heart diseases and some cancers. Subjects that were involved in this study were not those ranges.

The relationship between obesity and the risk of developing type two diabetes has been repeatedly observed in the both cross sectional studies (Hartz *et al*., 1983; Shaten *et al*., 1993 and Skarfors *et al*., 1991) and in prospective studies (Cassano *et al*., 1992, Colditz *et al*., 1990 and Ohlson *et al*., 1985). This factor accounts for the reason why individuals who are obese are not included in this study.

A body mass index of 30kg/m^2 and above indicates the presence of obesity. Even though waist circumference and body mass index are good predictors of obesity, waist circumference is effective and correlates more closely to abdominal adipose tissue than body mass index.

The relation between basic anthropometry and glycemic index exist in the sense that, it helps in selecting appropriate and required subjects for the study. Body mass index and waist

circumference are good indicators of obesity, cardiovascular and other metabolic diseases and individuals with such disorders cannot be included in the study since they may have poor glucose metabolism, decreased glucose tolerance, reduced insulin sensitivity and adverse lipid profile which when included in the study can affect study results.

The Ghanaian staples which had their glycemic index assessed and tested were *Abolo, Akple, Kafa, Locally made kokonte* and *Processed kokonte*. 140 g of groundnut soup and 30 g of beef (cow meat) were served with the test food except *Abolo* which was served with 30 g of anchovies (one man thousand). The glycemic index of beef and groundnut soup and the anchovies were tested differently to check and verify if they had any effect or impact on the test foods they were consumed with. Among the foods, *Akple* had the highest glycemic index figure of 69 followed by *Abolo* which had a medium glycemic index figure of 58, whereas *Kafa, Locally made kokonte* and *Processed kokonte* had low glycemic index figure of 29, 7 and 18 respectively. Groundnut Soup had a low glycemic figure of 4 whereas Anchovies had a glycemic index of 0.9.

In order for plant foods and other food sources to be ready for human consumption, they undergo some series of processing methods. These processing methods include cooking (boiling, roasting, frying, steaming, baking), drying, mashing, grinding into flour and fermentation (Omoregie and Osagie, 2008). In this study all test foods were boiled except *Abolo* which was further fermented and steamed.

Basically for most foods, boiling is noted to raise glycemic index as a result of a higher rate of gelatinization which enhances starch break down (digestibility) and raise glycemic response. Boiling disrupts the amylose and amylopectin structures of the starch by making it more available and easily broken down by digestive enzymes (Lin *et al.*, 2010, Bahado-Singh *et al.*, 2011). In this study, the ingredients (corn and cassava), were dried, ground into flour

and then sieved to remove unwanted particles. Among the corn staples, *kafa* had the lowest glycemic index figure of 29, whiles *Abolo* had a medium glycemic index figure of 59 and *Akple* also having a medium glycemic index figure of 69. Comparing their fibre contents per 100g, *Abolo* had the highest fibre content of 0.6g followed by *Akple* and *Kafa* which had the lowest amounts of fibre of 0.3 g but their specific quantities that contained 50 g of available carbohydrates, *kafa* had the highest fibre content of 1.07 g followed by *Abolo* which also had a fibre content of 1.04 g whiles *Akple* had the lowest fibre content of 0.71 g. Of all the corn products, *kafa* had the lowest glycemic index value. The lowest glycemic index figure obtained by *Kafa* among the three corn staples wasn't surprising because it had the lowest available carbohydrate per 100g and had the highest amount of fibre of it specific quantity aside other underlying factors.

The function of fibre in the breaking down of food and gastric emptying has deeply been delved into in numerous researches depicting its role in lengthening gastric emptying. The lengthening of gastric emptying also has an effect on glucose response by the body (Lin *et al.,* 2010). Fibre is referred to as a non-digestible starch and together with other non-starch polysaccharides, they go through the large intestines through the process of fermentation into short chain fatty acid constitutes such as butyrate, propionate and acetate. The end product butyrate has been discovered to help in preventing colon cancer (Silvester *et al.,* 1995). This therefore implies that, large amounts of dietary fibre may not reduce glycemic response but also prevent colon cancer. Hence it can be stated that foods that have a low glycemic index with high amounts of fibre could be capable of preventing colon cancer.

Another factor that resulted in *Kafa* having a low glycemic index is that, right after boiling it, when the mixture was completely thicken without lumps, it was divided into sizeable portions in dry leaves and left to cool completely at room temperature. On cooling starch which has undergone gelatinization will retrograde. This will result in amylose portion been poorly

digested by digestive enzyme amylase as result of the existence of stronger hydrogen bonds. Furthermore, when starches are cooked and cooled, the crystalline form within the food transforms into resistant starch which is more difficult to be broken down. Gelatinization is what occurs when heat is applied to starch followed by a disruption of the granules. If starch is then left to stand so that it cools, starch transforms into a gel which can differ in form depending on the quantity of moisture, the amylose to amylopectin ratio, time and temperature of storage (Annison and Topping, 1994). Crystallinity to the gel can occur and it is normally referred to as retrograded starch. These structures that are formed are insoluble ant not susceptible to hydrolysis in the small intestine (Sievert *et al.*, 1991).

Akple medium glycemic index value of 69 can be related to the fact among all the three corn staples, it had the lowest amount of dietary fibre of 0.3 g per 100 g and even with its specific amount that contained the 50 g of available carbohydrate, it still had the lowest dietary fibre content of 0.71 g. In the processing of corn to make *Akple*, it was grounded, milled into a fine powder and sieved to remove all unwanted particles. These processing methods could be contributing factors to the reason why it had the lowest quantity of dietary fibre both per 100 g and its specific quantity which contained 50 g of available carbohydrate. The presence of small amount of dietary fibre could be a reason why *Akple* had a medium glycemic index figure.

In the preparation of *Akple*, the corn flour was mixed with some amount of cold water and added to boiling water on fire. This mixture was divided into two parts and the rest was left on fire to boil again. The other half was left to cool for some few minutes. Corn flour was added to the boiling mixture on fire and mixed very well to prevent the formation of lumps. The remaining mixture was left to cool and added to the mixture on fire and kneaded. Gelatinization of starch occurred when heat was applied to the mixture on fire in the process of boiling. When the mixture was divided into two half's and the second part was left to cool

for some few minutes, retrogradation occurred. Since mixture did not cool completely, few amounts of resistant starches were introduced and are very difficult to be broken down by digestive enzymes since they are less susceptible to them. This could account to the reason why *Akple* had a medium glycemic index figure.

The preparation of *Abolo* differed from the other corn staples from all the three corn staples. Aside that, *Abolo* had the highest amount of fibre content of 0.6 g per 100 g and the second highest amount of fibre content of 1.04g per its specific quantity that contained 50 g of available carbohydrate.

Abolo was prepared from half-cooked corn dough (*aflata*) and raw corn dough with little sugar and flour. These ingredients were mixed together with water to form dough. The dough was allowed to rise overnight. Fermentation occurred as a result of soaking the corn in water and leaving the mixture to rise overnight. Through the fermentation process, some by products such as organic acids were produced. Acetic acid which is formed during the process of sourdough fermentation. Acetic acid is normally classified as part of a normal diet (Ostman *et al.*, 2005). The preparation of *Abolo* demands a partial cooking of fermented dough, followed by cooling to mix with uncooked dough, flour and sugar, leaving mixture overnight to rise, molding into desirable sizes and then finally steamed.

Acid which was produced during the process of fermentation accounted for the taste and flavor of *Abolo*. This explains why *Abolo* has a sour taste. These acids which are produced affect the glycemic response of the test food. A study conducted by Liljeberg and Bjorck (1998), revealed that acetic acid and addition of fermented products to foods enhances glycemic control. They also discovered that the presence of acetic acid in foods lowers glycemic response by prolonging gastric emptying. The acetic and other acids which are produced in the fermentation of corn and dough during the preparation of *Abolo* could have

reduced its glycemic response by prolonging gastric emptying. Also allowing the half cooked dough to cool before it was mixed with other substances enhanced retrogradation of starch which could introduced some amounts of resistant starches which are normally difficult to be digested or broken down by the digestive enzymes. This could have influenced the glycemic response and glycemic index of *Abolo*.

The addition of flour could have also affected the glycemic index of the tested food. Flour was produced as a result of milling of corn into a fine powder. The product was then sieved to remove unwanted particles. According to O'Dea *et al.*, (1980), and Collier and O'Dea k (1982), changing the particle form of some foods affects their glycemic index. A research conducted by ASPNG (1987), showed that the way a particular food is processed has a large impact on its glycemic index. Starches which are normally found in most carbohydrates exist in large forms of granules. During processing, these granular structures are destroyed so that the amylose and amylopectin macromolecules become more available for hydrolysis. Grinding of corn to produce flour destroys its outer layer, granules and increases digestion. Shifting of flour to remove unwanted particles eliminated the dietary fibre content in flour therefore making it easy to digest.

Glycemic index of foods are usually influenced by the content or composition of sugar present in the food. For instant, sucrose which is composed of glucose and fructose has a lower glycemic index than glucose. The chemical makeup of fructose in sucrose is the reason why it elicits a low blood glucose response. In addition, sucrose has a medium glycemic index figure of 68 whiles glucose has a high glycemic index figure of 100 (Pi SFX, 2002). Table sugar or granulated sugar (simple carbohydrate) was used in the preparation of *abolo*. It is normally referred to as sucrose, a disaccharide, which is composed of both fructose and glucose. Sucrose is an easily absorbed carbohydrate (macronutrient) that yields a quick source of energy by resulting in a rapid raise in blood glucose levels upon consumption.

Even though sucrose has lower glycemic index, it has been discovered that it speeds up the rate of digestion when it is added to food. This makes food easily digested and absorbed rapidly in to the blood stream. This could have resulted in the medium glycemic index figure of *abolo*.

Slow cooking methods such as baking and steaming normally yields a lower glycemic index figures than compared with some quick methods of cooking such as boiling, pressure cooking and microwave cooking. Steaming is a slow method of cooking which works by boiling water continuously and allowing it to vaporize into steam. Steam then transport heat to near food, thus cooking the food. The food is kept separate from the boiling water but has a direct contact with the steam resulting in a soft texture to the food. Most food nutrients are retained in steaming since it is a slow method of cooking food. In the preparation of *abolo*, the steam from the boiling water was used to cook the food. This could have resulted in a lower gelatinization of starch since boiling water did not come into contact with the food directly but rather the steam from the boiling water cooked the food. This resulted in lesser disruptions of the amylose and amylopectin ratios making it difficult to be broken down by digestive enzymes. This slow method of cooking could account for the reason why *abolo* had a medium glycemic index figure.

Cassava is presumed to induce an increased glucose response on ingestion since it consists of a large size of amylopectin which is more branched and more available to digestives enzyme amylases. However, the nutrient content of cassava differs depending on the type of cooking method. *Locally made kokonte* as well as *processed kokonte* were prepared using cassava through the process of boiling. Even though both cassava staples *locally made* and *processed kokonte* had lower glycemic index values, 7 and 18 respectively, their total dietary fibre content per 100g as well as their specific quantities that contained 50 g of available carbohydrate differed. *Locally made kokonte* had a total dietary fibre content of 1.1g per 100

g and 0.66 g per its specific quantity that contained 50 g of available carbohydrate (60 g). *Processed kokonte* had no amount of dietary fibre both per 100 g as well as its specific quantity that contained 50 g of available carbohydrate (60 g). The same quantity of 60 g was measured for both *locally made* and *processed kokonte* so that their variations and glycemic index could be measured and compared weight for weight. This can account for the reason why *processed kokonte* had a high glycemic index figure of 18 whiles *locally made kokonte* had a glycemic index of 7 even though both staples were in the low glycemic index values. This explains the function of dietary fibre in controlling the way food is digested and absorbed into the bloodstream and also in delaying gastric emptying. Since *processed kokonte* had no dietary fibre, it was rapidly digested and absorbed in to the blood stream causing a rapid increase in the blood glucose level than *locally made kokonte*.

Just like the other corn staples, cassava went through some series of processing methods and then finally boiled before consumption. These processing methods include peeling, washing, cutting into specific sizes, sun drying/fermentation, pounding, milling and sieving/shifting. During the process of sun drying, fermentation occurred and this introduced some amount of acetic acid into the cassava. Acetic acid is a type of organic which is normally formed during process of fermentation and the presence of these organic acids in foods tend to reduce the glycemic index of such foods. During the cassava fermentation process, microorganisms that make fermentation occur are not intentionally or artificially introduced but rather, they occur naturally (Ascheri and Vilela 1995, Cereda and Bonassi, 1995). According to Demiate *et al*., (1999) and Pereira *et al*., (1999), some organic acids such as acetic acids are formed during cassava fermentation. This can be a contributing factor to the reason why both *processed* and *locally made kokonte* had lower glycemic index value.

Also, according to Brand *et al*., (1985), certain factors such as sun drying and cooling affects starch breakdown and in turn affects glycemic response and glycemic index figures. The hot

temperature treatment and cooling cycles which occurred during the cassava flour production could have caused some amounts of retrograded starches. The presence of these starches in flour makes it less susceptible to be digested. These however, reduce glycemic response and in turn reduce the glycemic index figure. This could also account for the reason why both *locally made* and *processed kokonte* had low glycemic index figures.

During the preparation of both *processed* and *locally made kokonte*, the cassava flour was added to boiling water and kneaded. More flour was added to the mixture and kneaded to prevent the formation of lumps and achieve the desired thickness. The fire was reduced then to prevent food from burning. This in turn reduced the amount of heat which was applied to the food. The final product was taken from fire and allowed to cool for some few minutes. The reduction of heat during the process of preparation and cooling occurred at the end of cooking could have resulted in retrogradation and this could have introduced some amounts of resistant starches which are not normally susceptible to digestion by the digestive enzymes. This factor could also account for the reason why both processed and locally made kokonte had low glycemic index values.

4.7 CERTAIN INDICIES THAT INFLUENCED THE GLUCOSE RESPONSE.

The differences in the test foods as well as reference food could be attributed to certain indices which are explained below.

4.7.1 Effect of Fibre

The amount and availability of dietary fibre present in a food has an impact on the glycemic response of a food. Dietary fibre has been noted to extend and lengthen gastric emptying and absorption of carbohydrate and also raising or improving satiety play an essential role in reducing the glycemic index of a food. The fibre content of test foods varied significantly in their raw and processes states. This is due to the fact that processing has an effect on the total

dietary fibre content. Test foods were both corn and cassava staples. The fibre content of both cassava and maize in their raw states per 100 g are 1.8 g and 7.3 g respectively but in their processed forms per 100 g of each test food, *abolo* had a fibre content of 0.6 g, *kafa* 0.3 g, *akple* 0.3 g, *locally made kokonte* 1.1g and *processed kokonte* 0.0 g. In their specific quantities or sizes that contain the 50 g of available carbohydrates, abolo had a fibre content of 1.04 g, *kafa* 1.07 g, *akple* 0.71 g, *locally made kokonte* 0.66 g and *processed kokonte* 0.0 g. *Kafa* had the highest dietary fibre content among the test foods and had a lower glycemic index figure as well. Even though *processed kokonte* has the lowest dietary fibre content, it still had a low glycemic index value. This goes a long way to explain that glycemic index of foods are affected by other indices that will include but not limited to the total quantity of fibre in the food item (Eli-cophie *et al.,* 2016).

4.7.2 Effects of Previous Meal

The glycemic index value and glycemic response can differ based on the meal eaten previously. For example, it has been noted that eating a diet that has a low glycemic index rather than a diet that has a high glycemic index has an important impact by reducing the post prandial level after the next meal and vice versa (Frost, 2005). The content or nutrient make up of a diet eaten in the evening the day before the test is conducted may influence or have an impact on the test results or outcome. Meals that contain high amounts of carbohydrate or fat when eaten in the evening before the test have a high impact on the test results or outcome. Fat tolerance is poorer following a carbohydrate-rich meal whiles glucose tolerance is poorer following a fat-rich evening meal (Robertson *et al.,* 2002). Robertson further explained that the impact of an evening meal on fat tolerance is higher than the impact of glucose tolerance. However, the glycemic index of evening meals may sometimes have an impact on test results or outcome which is not based on the macronutrient content of a meal. According to Wolever *et al.,* (1988b) and Thorburn *et al.,* (1993), evening foods that have a low glycemic index

yield an enhanced and better glucose tolerance than evening meals that have a high glycemic index in the morning of testing. Prior to the days of testing, subjects were oriented as to the time they have to take their last meal so as to undergo the 10-14 h fast but they were restricted in terms of the meals they should eat. It was discovered that two of the study subjects or participants consumed high fibre diets in the evening prior to the day of fasting. Subject SA80 consumed *kenkey* and *okro stew* in the evening prior to the testing of *abolo*. Though the study subject did not have the lowest glucose response for all the test foods, the IAUC of *abolo* for subject SA80 was the lowest (51.32). The same was noticed for study subject BE90 who consumed brown rice and vegetable stew in the evening prior to the testing of *kafa*. This study subject had the lowest IAUC figure of 65.38 for *kafa*. For study subject JE40 who consumed *kelewele* a diet low in fibre and high in fat in the evening prior to the testing of *processed kokonte,* had the highest IAUC value of 182.3 for *processed kokonte*.

4.7.3 The Time and Length of Fasting

The specified extent of the fasting thorough out the night is an essential factor that can affect the glycemic response. According to a study conducted by Klein *et al*., (1993) and Samra *et al* ., (1996), the steady state which occurs after the whole night fast is duration of essential variation or changes in the view of reducing plasma insulin concentration and raising lipolysis. In this study, study subject SA08 who over fasted in the evening prior to the morning of testing processed kokonte had the lowest fasting blood sugar level of 3.5mmol/L.

4.7.4 Effect of Portion Size

It has been noted that a food item that has a larger portion size has a higher glycemic index value while a food item that has a small portion has a low glycemic index value. The portions of tests foods were 359 g, 238 g, 173 g and 60 g for *kafa, akple, abolo* and both *processed and locally made* respectively. Both *locally made* and *processed kokonte* had the smallest

portion sizes and had low glycemic index figures as well. In contrast, even though *kafa* had the largest portion size, it had a low glycemic index figure. *Abolo* had the second lowest portion size of 173 g but had a medium glycemic index figure. *Apkle* had the second highest portion size but had the highest glycemic index figure. Eventhough large portion sizes can yield a higher glycemic response and vice versa, when juxtaposing the glucose response of the same amount of available carbohydrate portions, the quality and processing indices play important roles (Eli-cophie *et al.*, 2016).

4.7.5 Effects of Soup, Meat and Fish Eaten Together With Test Food

Due to the nature of the test foods they could not be eaten alone and therefore were served with other accompaniments. *Abolo* was served with 30 g of anchovies which are popularly known as one man thousand which comprise of 5.52 g of protein, 0.45 g of fat and no amount of carbohydrate and dietary fibre. Whereas *akple, kafa, locally made kokonte* and *processed kokonte* were eaten or consumed with 140g of groundnut soup and 30g of beef (cow meat). The groundnut soup comprised of 7.98 g of protein, 21.14 g of fat, 0.28 g of total carbohydrate and 0.14 g of dietary fibre. The beef (cow meat) also comprised of 5.64 g of protein and 3.09 g of fat. The glycemic index of a particular meal is usually based and influenced by the content of that particular food. It is mostly believed and has been found that various factors which includes the existence of fat (Collier and O'Dea, 1983), the existence of protein (Granfeldt *et al.*, 1991), the existence of some anti-nutrients (Throne *et al.*, 1983) and the presence of some acidic compounds (Liljeberg *et al.*, 1995; Liljeberg and Bjorck 1996, 1998) in one way or the other influence or affects the glycemic index of a meal. When a particular food is consumed with other accompaniments, the glucose response to this meal is normally different than consuming that particular food alone without any accompaniment. Fat, carbohydrate, protein and other nutrients when consumed together with other test food have an effect on both glucose and insulin responses. However, according to a study

conducted by Wolever and Bologensi (1996b), the amount and quantity of carbohydrate is what has an impact on the glucose response to a meal.

Insulin and glucose response to a carbohydrate food varies with the amount of fat, protein or both with which it is ingested. Fat and protein may influence gastric emptying and insulin secretion, but the effects of glycemic index are not seen unless there are relatively large amount of fat and protein per 50 g of available carbohydrate. For fat and protein to affect the glycemic index of a meal it must have total quantities of about 30 g of protein and about 50 g of fat (Wolever *et al.,* 1994). Further studies was done with the groundnut soup with beef (cow meat) and anchovies to find out if it had an impact on the glycemic index of test foods it was eaten with. At the end of the study, it was discovered that groundnut soup had a low glycemic index value of 4 whereas anchovies also had a low glycemic index of 0.9. To get the actual glycemic index figures for the test foods, the glycemic index of the accompaniments were subtracted from the test foods. The glycemic index figure of groundnut soup with beef was subtracted from the glycemic index figures of akple, kafa, locally made and processed kokonte whereas the glycemic index figure of anchovies was subtracted from the glycemic index figure of abolo.

CHAPTER FIVE

5.1 CONCLUSION

This study has made available the glycemic index (GI) of Akple, Abolo, Kafa, Locally made kokonte and Processed kokonte. Kafa, Locally made kokonte and processed kokonte had low glycemic index. Abolo had a medium glycemic index figure whiles Akple had the highest GI. Essential and needful data on various indices that hamper and affect the glycemic figures of foods have been assessed.

There was no significant difference between locally made kokonte and processed kokonte indicating that the form of processing had no significant effect on the GI of kokonte. Further comparison revealed a significant difference between Abolo, Apkle and Kafa which are all corn based staples but comprise of varied amounts of fibre and different cooking and processing methods. Kafa was boiled and allowed to cool whereas abolo was fermented and steamed. Apkle was boiled continuously and kneaded. The data from the study also suggests that the glycemic index of specific foods should be assessed and tested differently and not based on foods that are similar in nature. The glycemic index figures from the study can serve as a tool for health professionals who have the power to assist, guide and advice individuals especially diabetics on their diet and provide Medical Nutrition Therapy.

5.2 RECOMMENDATION

Kafa, locally made kokonte and *processed kokonte* have low glycemic index and be can be recommended for diabetics.

Futher research must be conducted on other Ghanaian foods to make available a more comprehensive database of the glycemic index of Ghanaian foods.

A nutrient current analysis of all our local staples should be done since calculation of available carbohydrates is centered on the nutrient analysis done on the food.

5.3 LIMITATION OF STUDY

- Most of the study subjects complained about the nauseating effect of glucose which was taken on a two trial after the 10-14 hr fast.
- Willingness of other subjects to be included in the study due to the number of times they were going to pricked in a day.
- Subjects included in the study also complained about the number times they were pricked in a day.
- Some of the subjects were absent during the study period therefore it was rescheduled for them to take their tests on different days.

REFERENCES

- Adam C. K., Kouakou N. K., Yao D.N., & N'guessan G. A. (2015). Glycemic Index and Load Value Tested in Normoglycemic Adults for Five Food Stuffs: pounded yam, powdered cassava-plantain, placali, attieke and maize meal stiff porridge nutrients. 7.1267-1281; doi: 10.3390/nu7021267.
- Alkaabi, J. M, A.-D. B. (2011). Glycemic indices of five varieties of dates in healthy and diabetic subjects. *Nutr J., 10* (59), 10-59.
- American Cancer Society. (2007). Global Cancer Facts and Figures. *Journal of Clinical Nutrition*, 47,942-944.
- American Diabetes Association. (2008). *Diabetes Care*. 31(Suppl.1) S61.
- Annison, G., & Topping, D.L. (1994). Nutritional role of resistant starch: chemical Structure vs physiological function. *Annu Rev Nutr* ; 14:297–320.
- Arvidsson-Lenner, R., Asp, N. G., Axelsen, M., Bryngelsson, S., Haapa, E., & Jarvi, A. (2004). Glycemic Index. *Scandinavian Journal of Nutrition, 48*, 84-89.
- Ascheri, D.P.R., & Vilela, E.R. (1995). Alteration of Cassava Starch by fermentation in the manufacture of biscuits. *Agropec. Bras*. 30, 269–279.
- Asp N-G. (1987).Definition and analysis of dietary fibre. *Scand J Gastroenterol Suppl*; 129:16–20.
- Aston, L. M., Gambell, J. M., Lee, D. M., Bryant, S. P., & Jebb, S. A. (2008). Determination of the glycaemic index of various staple carbohydrate-rich foods in the UK diet. *European Journal of Clinical Nutrition, 62*, 279–285.
- Augustin, L.S., Dal Maso L., La Vecchia C., Parpinel M., Negri E., Vaccarella S., Kendall C.W., Jenkins D.J., & Franceschi S. (2001b). Dietary glycemic index and glycemic load, and breast cancer risk. A case-control study. *Ann Oncol*; 12:1533-8.

- Augustin L.S., Franceschi S., Jenkins D.J., Kendall C.W., & La Vecchia C. (2002). Glycemic index in chronic disease. A review. *Eur J Clin Nutr*; 56:1049-71.
- Bahado-Singh, P. S., Riley, C. K., Wheatly, A. O., & Lowe, H. I. (2011). Relationship between Processing Method and the Glycemic Indices of Ten Sweet Potato (Ipomoea batatas) Cultivars Commonly Consumed in Jamaica. *J Nutr Metab* , 2-6.
- Bender, D.A. (1997). Introduction to Nutrition and Metabolism. *Taylor & Francis LTD, London.*
- Bornet, F. R., Costagliola, D., & Blayo, A. (1987). Insulinogenic and glycemic indexes of six starch-rich foods taken alone and in a mixed meal by type 2 diabetics. *American Journal clinical Nutrtion , 45*, 588 - 95.
- Brand, J. C., Nicholson, P. L., Thorburn, A. W., & Truswell, A. S. (1985). Food Processing and Glycemic index. *American Journal of Clinical Nutrtion , 42*, 1192-1196.
- Brand-Miller, J., Hayne, S., Petocz, P., & Colaguiri, S. (2003). Low–Glycemic Index Diets in the Management of Diabetes. *Diabetes Care, 28* (8), 2261-2267.
- Brouns, F., Bjorck, I., Frayn K.N., Gibbs, A.L., Lang, V., Slama, G. & Wolever, T.M.S. (2005). "Glycaemic Index Methodology. *"Nutrition Research Reviews*, Vol.18, No.1, pp.145-171
- Bruns, W., Wagner, D., & Taubert, F.P. (1989). Studies on the Behaviour of Glycemia Insulinemic and lipids in non-diabetics and type 2 diabetics under 3 and 6 meals, respectively. Abstract Acr endocrine *10*, 85.
- Camille A. K., Nestor K. K., Aissatou C., Dennis Y. N., Georges Gnomblesson T., Lokrou A., & Georges N. A. (2014). Glycemic Index and Glycemic Load of Selected Staples Based on Rice, Yam and Cassava Commonly Consumed in Cote d'Ivoire. Food and Nutrition Sciences, 5 308-315.

- Canadian Diabetes Association. (2008). *Can J Diab*, 32 (Suppl.1)3.
- Cassano P. A., Rosner B., & Vokonas P.S. (1992). Obesity and body fat distribution in relation to the incidence of non-insulin-dependent diabetes mellitus. A prospective cohort study of men in the normative aging study. *American Journal of Epidemiology, 136(12):1474-1486.*
- Cereda, M.P., & Bonassi, I.A. (1985). Evaluation of the quality of commercial fermented starch on manioc (sour sprinkles).*organic acids and water absorptions* Rev. Bras. Manioc 3, 21–30.
- Chlup R, S. P. (2008). Automated computation of glycemic index for foodstuffs using continuous glucose monitoring. *J Diabetes Sci Technol, 2* (1), 67-75.
- Chlup, R., Bartek J., Řezníčková, M., Zapletalová, J., Doubravová, B., Chlupová, L., Sečkař, P., Dvořáčková, S., & Šimánek, V. (2004). Determination of the Glycaemic Index of Selected Foods (White bread & Cereal bars) in Healthy Persons. Pp 17-25.
- Chung, H.-J., Shin, D.-H., & Lim, S.-T. (2008). In vitro starch digestibility and estimated glycemic index of chemically modified corn starches. *Food Res Int, 41*, 579–585.
- Colditz G.A., Willett W.C., & Stampfer M.J.(1990). Weight as risk factornfor clinical diabetes in women. *American Journal of Epidemiology, 132(3):501-513.*
- Collier G., & O'Dea K. (1982). Effect of physical form of carbohydrate on the postprandial glucose, insulin, and gastric inhibitory polypeptide responses in type 2 diabetes. *Am J Clin Nutr*;36:10–4.
- Collier G., & O'Dea K. (1983) .The effect of coingestion of fat on the glucose, insulin, and gastric inhibitory polypeptide responses to carbohydrate and protein. *American Journal of Clinical Nutrition* 37, 941–944.

- Collier G., McLean A., & O'Dea K. (1984). Effect of co-ingestion of fat on the metabolic responses to slowly and rapidly absorbed carbohydrates. *Diabetologia*; 26:50–4.
- Collings P, Williams C, & MacDonald I. (1981). Effect of cooking on serum glucose and insulin responses to starch. *Br Med J*; 282:1032–3.
- Conn, J. W., & Newburgh, L. N. (1939). The glycemic response to isoglucogenic quantities of protein and carbohydrates. *Journal of clinical Investigation, 15*, 665 - 671.
- Coulston, A. M., & Reaven, G. M. (1997). Much ado about (almost) nothing. *Diabetes Care* (20), 241-3.
- Cummings, J. H., & Stephen, A. M. (2007). Carbohydrate terminology and classification. *European Journal of Clinical Nutrition*, S5 - S18.
- Diabetes Australia. (2006). Practice Guidelines For The Nutritional Management Of Type 2 Diabetes Mellitus For Adults.
- Diabetes and Nutrition Study Group (DNSG) of the European Association for the Study of Diabetes (EASD). (2000). *Eur J Clin Nutr*, 54 353.
- Demiate, I.M., Dupuy, N., Huvenne, J.P., Cereda, M.P., & Wosiaki, G. (1999). Relationship between banking behavior of modified cassava starches and starch chemical structure determined by FTIR spectroscopy. *Carbohydr. Polym*. 42, 149–158.
- Deville-Almond, J., Tahrani, A.A, Grant, J., Gray, M., Thomas, G.N, & Taheri, S. (2011).Am J Mens Health, 5, 30.
- Doku, E.V. (1965). Breeding for Yield in Cassava I, Indices of Yield. *Ghana Journal of Science*. *Ed 6th. Vol. 8.*

- Eli-Cophie, D., Jacob k., A. & Reginald A., A. (2016). Glycemic Index of Some Local Staples. *Food Science & Nutrition*. Doi: 10.1002/fsn3.372
- Englyst, K. N., Liu, S., & Englyst, H. N. (2007). Nutritional characterization and measurement of dietary carbohydrates. *European Journal of Cliical Nutrition, 61*, S19 - S39.
- Englyst H, Wiggins H.S., & Cummings J.H. (1982), "Determination of the non-starch polysaccharides in plant foods by gas–liquid chromatography of constituent sugars as alditol acetates," *The Analyst, vol. 107*, no. 1272, pp. 307–318.
- Eyeson, K. K., Ankrah, E. K., Sundararajan, A. R., Karinpaa, A., & Rudzka, M. J. (1975). *Composition of Foods Commonly Used in Ghana.* Accra: Secretariat of the council for Scientific and Industrial Research.
- Fajkusova, Z., Jadviscokova, T., Pallayova, M., Matuskova, V., Luza, J., & Kuzmina, G. (2007). glycaemic index of selected foodstuffs in healthy persons. *Biomed Pap Med Fac Univ Palacky Olomouc Czech Repub , 151* (2), 257-261.
- Fan, J., Song, Y., Wang, Y., Hui, R., & Zhang, W. (2012). Dietary Glycemic index, Glycemic Load, Risk of Coronary Heart Disease, Stroke and Stroke Mortality: A Systematic Review and Meta Analysis. *PLoS One , 7* (12), 521 - 82.
- FAO/WHO. (1998). *Carbohydrates in human nutrition.* Report of a Joint FAO/WHO Expert Consultation, (FAO Food and Nutrition Paper - 66). Food and Agriculture Organisation of United Nations, Rome.
- Farrell, J.J, Feldman,M, Friedman, L.S, & Brandt, L,J.(2010). Digestion and Absorption of Nutrients and Vitamins. Sleinsenger & Frordtran's. Gastrointestinal and Liver Disease. *(9th ed.) Philadelphia*, pa: Saunders Elsevier: chap 100.
- Food and Agriculture Organization of the United Nations. (2014). *Cassava.* Retrieved July 15, 2014, from FAO/UN: http://www.fao.org/ag/agp/agpc/gcds/

- Foster-Powell, K., & Brand - Miller, J. (1995). International tables of glycemic index.. 62,. *Am. J. Clin. Nutr , 62*, 871S – 893S.
- Foster-Powell, K., Holt, S. H., & Brand-Miller, J. C. (2002). International table of glycaemic index and glycaemic load values. *American Journal of Clinical Nutrition, 76*, 5 – 56.
- Frayn, K. N., Whyte, P. L., Benson, H. A., Earl, D. J., & Smith, H. A. (1989). Changes in forearm blood flow at elevated ambient temperature and their role in the apparent impairment of glucose tolerance. *Clinical Science, 76*, 323-328.
- Franceschi, S., Dal Maso, L., Augustin, L.S, Negri, E., Parpinel, M., Boyle, P., Jenkins D.J.A, & La Vecchia, C. (2001). Dietary glycemic load and colorectal cancer risk. *Ann Oncol* ; 12:173-8.
- Frost, G.S., & Dornhurst, A. (2005). Glycemic index. In: *Encyclopedia of human nutrition*, vol. 2, edn 2. Allan, L., Prentice, A. and Caballero B. Eds, Academic Press. pp 413–418.
- Frost, G., Leeds, A., Trew, G., Margara, R., & Dornhorst, A. (1998). Insulin insensitivity in women at risk of coronary heart disease and the effect of a low glycemic diet. *Metabolism, 47*, 1245-51.
- Gannon, M.C., Nuttall, F.Q., Krezowski, P.A., Billington, C.J., & Parker, S. (1986). The serum insulin and plasma glucose responses to milk and fruit products in type-2 (non-insulin-dependent) diabetic patients. *Diabetologia. 29*, 784–791.
- Gannon, M., Ercan, N., & Westphal, S. (1993). Nuttall FQ. Effect of added fat on plasma glucose and insulin response to ingested potato in individuals with NIDDM. *Diabetes Care*; 16:874–80.
- Giovannucci, E. (1995). Insulin and colon cancer. *Cancer Causes Control*; 6:164-79.

- Giovannucci. E. (1999b). Insulin-like growth factor-I and binding protein-3 and risk of Cancer. Horm Res; 51:34-41.
- Gning, S.B., Thiam, M., Fall F., Ba-Fall, K., Mbaye, P.S., & Foucarde, L., (2007). Diabetes Sugar in Sub-Saharan Africa: *Epidemiological aspects, exchange difficulties Medicine Tropicale*. Vol. 67, No.6, pp-607-611.
- Golay, A., Coulston, A. M., & Hollenbeck, C. B. (1986). Comparison of metabolic effects of white beans processed into two different physical forms. *Diabetes care, 9,* 260-6.
- Granfeldt, Y., Bjorck, I., & Hagander, B. (1991). On the importance of processing conditions, product thickness and egg addition for the glycaemic and hormonal responses to pasta: a comparison with bread made from 'pasta ingredients.' *Eur J Clin Nutr* ; 45:489–99.
- Haber, G. B., Heaton, K. W., Murphy, D., & Burroughs, L. F. (1977). Depletion and Disruption of dietary fibre, Effects on satiety, plasma-glucose and serum-insulin. *Lancet, 2,* 679-82.
- Hartz A.J., Rupley D., & Kalkhoff R.D. (1983). Relationship of obesity to diabetes: influence of obesity level and body fat distribution. *Preventive Medicine, 12(2):351-357.*
- Henry C. J., Lightowler H. J., Strik C. M., & Storey M. (2005). Glycemic Index Values of Commercially Available Potatoes in Britain. *Br J Nutr. 94 (6):917-21.*
- Hodgson, J.M., Hsu-Hage, B.H., & Wahlqvist, M.L. (1994). Food variety as a quantitative descriptor of food intake. *Ecology of Food and Nutrition*, 32:137-148.
- Holt, S.H.A., Brand Miller, J.C., & Petocz, P. (1996). Interrelationships among postprandial satiety, glucose and insulin responses and changes in subsequent food intake. *Euopean Journal of Clinical Nutrition*, 50:788-797.

- Holt, S.H., Miller, J.C., & Petocz, P. (1997). An insulin index of foods: the insulin demand generated by 1000-kJ portions of common foods. *Am J Clin Nutr* ; 66:1264–76.
- International Carbohydrate Quality Consortium (ICQC). (2014). Glycaemic index: did Health Canada get it wrong? Position from the International Carbohydrate Quality Consortium (ICQC). *British Journal of Nutrtion , 111*, 380-382.
- Itam, E.H., Itam, A.H., Odey, M.O., Ejennot-Nwadiaro, R., Asenye, M.E., & Ezike, N.N. (2012). Effects of Processing Methods on the Glycemic Index of Some Carbohydrate Staples (Manihot esculanta, Ipomoea batata, & Dioscorea rountundata) in both diabetics and non-diabetics. *Scholars Research Library. Anals of Biological Research*, 3(12): 5507-5510.
- Jakobsen, M. U., O'Reilly, E. J., Heitmann, B. L., Pereira, M. A., Balter, K. & Fraser, G. E. (2009). Major types of dietary fat and risk of coronary heart disease: a pooled analysis of 11 cohort studies. *Am J Clin Nutr , 89*, 1425-1432.
- Jenkins A. L, K. V. (2010). Effect of adding the novel fibre, PGX®, to commonly consumed foods on glycemic response, glycemic index and GRIP: a simple and effective strategy for reducing post prandial blood glucose levels - a randomised contolled trial. *Nutr J , 9* (58), 2891-9-58.
- Jenkins, A.L., Jenkins, D.J., Zdravkovitz, U., Wursch, P., & Vuksan, V.(2002). Depression of glycemic index by high levels of beta-glucan fiber in two functional foods tested in type 2 diabetes. *Eur J Clin Nutr, 56*, 622–628.
- Jenkins, D.J., Kendall, C.W., Augustin, L.S., Franceschi, S., Hamidi, M., Marchie, A., Jenkins, A.L., & Axelsen, M. (2002) Glycemic index: overwiew of implications in health and disease. *Am J Clin Nutr, 76*, 2665–2673.

- Jenkins, D. J., Wolever, T. M., Kalmusky, J., Giudici, S., Giordano, C., & Wong, G. S. (1985). Low glycemic index carbohydrate foods in the management of hyperlipidemia. *The American Journal of Clinical Nutrition,, 42* (4), 604-617.
- Jenkins, D.J., Wolever, T.M., & Taylor, R.H. (1981) Glycemic index of foods: a physiological basis for carbohydrate exchange. *Am J Clin Nutr* ; 34:362–6.
- Kalergeris, M., De Gandpre E., & Anderson, C. (2005).”The Role of Glycemic Index in the Prevention and Management of Diabetes: A Review and Discussion”, *Canada Journal of Diabetes,* Vol.29, No.1,pp. 27-38.
- Klein, S., Sakurai, Y., Romijn, J.A., & Carroll, R.M. (1993). Progressive alterations in lipid and glucose metabolism during short-term fasting in young adult men. *American Journal of Physiology*. 265, E801–E806.
- Koussasi, K.N., Tiahou, G.G., Abodo, F.R.J., Camara-Cisse, M., & Amani, N.G. (2009). “Influence of the Variety and Cooking Method on Glycemic Index of Yam”, *Pakistan Journal of Nutrition*, Vol.8, No.7, pp. 993-999.
- Krezowski, P.A., Nuttall, F.Q., Gannon, M.C., & Bartosh, N.H. (1986). The effect of protein ingestion on the metabolic response to oral glucose in normal individuals. *Am J Clin Nutr*; 44:847–56.
- Leeds, A. R. (1987). Dieatary fibre. *Int. J Obes , 11* (1), 3-7.
- LeRoith, D., & Roberts, C.T. Jr. (2003). The insulin-like growth factor system and cancer. *Cancer Lett*; 195:127-37.
- Liljeberg, H.G., Lonner, C.H., & Bjorck, I.M. (1995). Sourdough fermentation or addition of organic acids or corresponding salts to bread improves nutritional properties of starch in healthy humans. *Journal of Nutrition.* 125, 1503–1511.
- Liljeberg, H.G., & Bjorck, I.M. (1996). Delayed gastric emptying rate as a potential mechanism for lowered glycaemia after eating sourdough bread: studies in humans

and rats using test products with added organic acids or an organic salt. *Am J Clin Nutr*; 64:886–93.

- Liljeberg, H., & Bjorck, I. (1998). Delayed gastric emptying rate may explain improved glycaemia. *European Journal of Clin. Nutr , 52*, 368-371.
- Lin, M.-H. A., Wu, M.-C., Lu, S., & Lin, J. (2010). Glycemic index, glycemic load and insulinemic index of Chinese starchy foods. *World J Gastroenterology, 16* (39), 4973-4979.
- Liu S., & Willett W.C. (2002) Dietary glycemic load and atherotrombotic risk. *Curr-Atheroscler.* Rep *4*, 454–61.
- Ludwig, D. S., Majzoub, J. A., Al-Zahrani, A., Dalla, G. E., Blanco, I., & Roberts, S. B. (1999). High Glycemic Index foods, overeating and obesity. *Pediatrics, 103*, E261 - 6.
- Ludwig, D. S. (2002). The glycemic index: physiological mechanisms relating to obesity, diabetes and cardiovascular disease. *JAMA, 287* (18), 2414-23.
- Macrae, R., Robinson, R.K., & Sadler, M.J. (1993). Encyclopaedia of Food Science, Food Technology and Nutrition. *Academic Press, London*.
- Mann, J., Cummings, J. H., Englyst, H. N., Key, T., Liu, S., & Riccardi, G. (2007). FAO/WHO Scientific Update on carbohydrates in Human nutrtion: conclusions. *European Journal of Clinical Nutrition, 61* (1), S132 - S137.
- Mash, K., & Brand-Miller., J. (2008) Glycemic Index Obesity, and Chronic Disease", *American of Lifestyle Medicine*, Vol.2, No.2, pp.142-150.
- Mendosa, D. (2009). *Mendosa.Com.* Retrieved May 5, 2014, from The Glycemic index of Some Foods. *European Journal of Clinical Nutrition,*64(1):2-5.
- Meyer, C., Woerle, J., Dostou, J.M., Welle, S.L., & Gerich, J.E. (2004) Am J Physiol Endocrinol Metab, 287 E1049. — 11

- McCane, R.A., & Lawrence, R.D. (1929). The carbohydrate content of foods. *Medical Research Council Special Report Series* 135 Her Majesty's Stationery Office, London.
- Mckevith Brigid (2004). Nutritional Aspect of Cereals. *British Nutrition Foundation, London UK.*
- McKeown-Eyssen, G. (1994). Epidemiology of colorectal cancer revisited: Are serum triglycerides and/or plasma glucose associated with risk? *Cancer Epidemiol Biomarkers Prev* ; 3:687-95.
- Michele, S. (2011). Food, Glycemic Response and Health. International Life Science Institute. *ISBN 9789078637318.*
- Miller-Jones, J. (2007). Glycemic response definitions. *Cereal Foods World*; **52:54**–5.
- Mirrahimi, A., J de Souza, R., Chiavaroli, L., Sievenpiper, J. L., Beyene, J. & Hanley, A. J. (2012). Associations of Glycemic Index and Load with Coronary Heart Disease Events: A Systematic Review and Meta-Analysis of Prospective Cohorts. *J Am Heart Assoc , 1* (5).
- Mitchell, H. L. (2008). The Glycemic index concept in action. *American journal of clinical Nutrtion , 87*, 244S-246S.
- Monro, J. A., & Shaw, M. (January 2008). Glycemic impact, glycemic glucose equivalents, glycemic index, and glycemic load: definitions, distinctions, and implications. *Am J Clin Nutr,* vol. 87 no. 1 237S-243S.
- Nils-George, L. A. (1995). Classification and methodology of food carbohydrates. *American Journal of Nutrition, 61*, 930S - 7S.
- Nuttall F.Q. (1993). Dietary fiber in the management of diabetes. Diabetes; 42:503–8.

- Nuttall, F.Q., Mooradian, A., Gannon, M., & Bartosh, N. (1984). Effect of protein Ingestion on the glucose and insulin response to a standardized oral glucose load. *Diabetes Care*; 7:465–70.
- Nuttall, F.Q., Gannon, M., Wald, J., & Ahmed, M. (1985).Plasma glucose and Insulin profiles in normal subjects ingesting diets of varying carbohydrate, Fat and Protein content. *J Am Coll Nutr* ; 4:437–50.
- O'Dea, K., Nestel, P.J., & Antonoff , L.(1980). Physical factors influencing postprandial

  Glucose and insulin response to starch. *Am J Clin Nutr*; 33:760–5.
- Ohlson L.O., Larsson B., & Svardussd K. (1985). The influence of body fat distribution on the incidence of diabetes mellitus. *Diabetes, 34(10):1055-1058*.
- Omoregie, E.S., & Osagie, A.U. (2008). Glycemic Indicies and Glycemic Load of Some Nigerian Foods. Department of Biochemistry, Faculty of Life Sciences, University of Benin, P.M.B 1154 Benin City, Nigeria.
- Otto, H., & Niklas, L. (1980). The different actions on glycemia of foods containing carbohydrates: consequences for the nutritional treatment of diabetes mellitus. *Med Hyg* ; 38:3424–9 (in French).
- Ostman, E., Granfeldt, Y., Persson, L., & Bjorck, I. (2005). Vinegar supplementation lowers glucose and insulin responses and increases satiety after a bread meal in healthy subjects. *European Journal of Clinical Nutrition, 59*, 983–988.
- Pi SFX. (2002). Glycemic Index and Disease. *Am J Clin Nutri*. 76:29085-2985.
- Raben, A. (2002). Should obese patients be counselled to follow a low-glycaemic index diet? *No. Obesity Reviews 3*, 245–256.
- Ramdath, DD., I. R. (2004). Glycaemic index of selected staples commonly eaten in the Caribbean and the effects of boiling v. crushing. *Br J Nutr. , 91* (6), 971-7.

- Rastogi, T., Devesa, S., Mangtani, P., Mathew, A., Cooper, N., Kao, R., & Sinha, R. (2008). Cancer Incidence rates among South Asians in four geographic regions: India,Singapore, UK and US. *Int J Epidemiol*.; 37:147-60.
- Rea, R.L., Thompson, L.U., & Jenkins, D.J.A. (1985). Lectins in foods and their relation to starch Digestibility. *Nutr Res*; 5:919-29.
- Robertson, M.D., Henderson, R.A., Vist, G.E., & Rumsey, R.D.E. (2002).Extended effect of evening meal carbohydrate/fat ratio on fasting and postprandial substrate metabolism. *American Journal of Clinical Nutrition.* 75, 505–510.
- Samra, J.S., Clark, M.L., Humphreys, S.M., Macdonald, I.A., & Frayn, K.N. (1996). Regulation of lipid metabolism in adipose tissue during early starvation. *American Journal of Physiology*. 271, E541–E546.
- Shaten B. J., Smith G. D., & Kuller L.N. (1993). Risk factors for the development of type two diabetes among men enrolled in the usual care group of the Multiple Risk Factor Intervention Trial. *Diabetes care, 16(10):1331-1339.*
- Sheard, N. F., Clark, N. G., Brand-Miller, J. C., Franz, M. J., Pi-Sunyer, F. X., & Mayer-Davis, E. (2004). Dietary Carbohydrate (Amount and Type) in the Prevention and Management of Diabetes. *Diabetes Care, 27* (9), 2266-2271.
- Sievert, D., Czuchajowska, A., & Pomeranz, Y. (1991). Enzyme resistant starch.III. X-ray diffraction of autoclaved amylomaize. *Cereal Chem*; 68:86–91.
- Silvester, K. R., Englyst, H. N., & Cummings, J. H. (1995). Ileal recovery of starch from whole diets containing resistant starch measured in vitro and fermentation of ileal effluent. *American Journal of Nutr , 62,* 403 - 11.
- Simpson, R.W., McDonald, J., Wahlqvist, M.L., Altey, L., & Outch, K. (1985). Macronutrients have different metabolic effects in nondiabetics and diabetics. *Am J Clin Nutr* ;42:449–53.

- Skarfors E. T.,Selinus K. L., & Lithell H. O. (1991). Risk factors for developing non-insulin dependent diabetes. *BMJ. 303(6805):755-760*.
- Spraul, M., Chantelau, E., Schonbach, A.M., & Berger, M. (1988) Glycemic effects of beer in IDDM patients. *Diabetes Care 11*,659–661.
- Stylianopoulos, C. L. (2005). Carbohydrates: Chemistry and Classification. In B. Caballero, *Encyclopedia of human nutrition* (second ed., pp. 304-309). Oxford, UK: Elsevier academic press.
- Su-Que, L. (2013). Effect of consumption of micronutrient enriched wheat steamed bread on postprandial plasma glucose in healthy and type 2 diabetic subjects. *Nutr J.* , 12.
- Tattersall, R., & Mansell, P. (1990). Fibre in the management of diabetes. 2. Benefits of fibre itself are uncertain. *BMJ* ; 300:1336–7.
- Thompson, L.U., Yoon, J.H., Jenkins, D.J.A., Wolever, T.M.S., & Jenkins, A.L. (1984). Relationship between polyphenol intake and blood glucose response of normal and diabetic individuals. *Am J Clin Nutr*. ;39:745-51.
- Thorburn, A., Muir, J., & Proitto, J. (1993). Carbohydrate fermentation lowers hepatic glucose output in healthy subjects. *Metabolism , 42*, 780-785.
- Thorne, M.J., Thompson, L.U., & Jenkins, D.J. (1983). Factors affecting starch digestibility and the glycaemic response with special reference to legumes. *American Journal of Clinical Nutrition*. 38,481–488.
- Trowel H. (1972). Dietary Fibre and Coronary Heart Disease. *Revue Europeeme D'Etudes Cliniques et Biologiques*. 17(4) 345-349.
- *United States Department of Agriculture.* (2002). Retrieved July 15, 2014, from Nutrient Database for Standard Reference: http://ndb.nal.usda.gov/ndb/nutrients/report/nutrients.

- Vaaler, S., Hanssen, K.E., & Aagenaes, O. (1984). The effect of cooking upon the Blood glucose response to ingested carrots and potatoes. *Diabetes Care*; 7:221–3.
- Van, Amelsvoort J.M, & Weststrate, J.A. (1992). Amylose-amylopectin ratio in a meal affects postprandial variables in male volunteers. *Am J Clin Nutr*; 55:712–8.
- Veen, B.J., & Green, T.J. (2007). Glycemic Index and Glycemic Load: Measurement Issues and Their On Diet-Disease Relationships. *European Journal of Clinical Nutrition*. 61 (suppl 1), S122-S131.
- Vinik, A. J., & Jenkins, D. J. (1988). Dietary Fibre in management of diabetes. *Diabetes Care, 11*, 160 - 73.
- Wang, L., Guo, L., Zhang, L., Zhou, Y., He, Q., & Zhang, Z., *et al*. (2013). Effects of glucose load and nateglinide intervention on Endothelial function and Oxidative stress. *J Diabetes Res,* 8492 - 95.
- WHO. (1995). Physical status: *the use and interpretation of anthropometry*. ISBN 978 92 4 150149 1.
- Willett, W.C. (1995). Diet, Nutrition, and Avoidable Cancer. *Environ Health Perspect*; 103:S165-70.
- Wolever, T. M., Katzaman-Relle, L., Jenkins, A. L., Vuksan, V., Josse, R., & Jenkins, D. J. (1994). Glycaemic index of 102 complex carbohydrates in Patients with diabetes. *Nutr. Res. , 4*, 651 - 669.
- Wolever, T. M. (2002, January 28). *The Glycemic Index: Flogging a Dead Horse?* Retrieved June 2, 2013, from Mendosa.Com.
- Wolever, T. M., Jenkins, D. J., Jenkins, A. L., & Josse, R. G. (1991). The glycemic index: methodology and clinical implications. *American Journal of Clinical Nutrition, 54*, 846 - 54.

- Wolever, T. M., Jenkins, D. J., Vuksan, V., Jenkins, A. L., Buckley, G. C., Wong, G. S., *et al*., (2009, July 30). Beneficial Effect of a Low Glycaemic Index Diet in Type 2 Diabetes. *Diabetic Medicine, 9* (5), pp. 451-458.
- Wolever, T., Katzman-Relle, L., Jenkins, A., Vuksan, V., Josse, R.G., & Jenkins, D.(2001). Glycaemic index of 102 complex carbohydrate foods in patients with diabetes. *Nutr Res*; 14:651–69.
- Wolever, T. M., Vorster, H. H., Bjorck, I., Brand - Miller, J., Brighenti, F., Mann, J. I., *et al*., (2003). Determination of Glycenic Index of Foods: Interlaboratory Study. *European Journal of Clinical Nutrtion , 57*, 475 - 482.
- Wolever, T. M. (2002, January 28). *The Glycemic Index: Flogging a Dead Horse?* Retrieved June 2, 2013, from Mendosa.Com.
- Wolever, T. M., Vuksan, V., & Jenkins, A. A. (2011). *Determination of Glycemic Index of: Hand-Stretched Cheese Pizza.* Toronto: Glycemic Index Laboratories Inc.
- Wolever, T.M.S., & Bolognesi, C. (1996b). Prediction of glucose and insulin responses of normal subjects after consuming mixed meals varying in energy, protein, fat carbohydrate and glycaemic index. *Journal of Nutrition*. 126, 2807–2812.
- Wolever, T.M.S., & Bolognesi, C. (1996c). Time of day influences relative glycaemic effect of foods. *Nutrition Research.* 16,381–384.
- Wolever, T.M., Jenkins, D.J., Ocana, A.M., Rao, V.A., & Collier, G.R. (1988b). Second-meal effect: low-glycaemic-index foods eaten at dinner improve subsequent breakfast glycaemic response. *American Journal of Clinical Nutrition*. 48, 1041–1047.
- Wolever, T.M.S. (2004b). Effect of blood sampling schedule and method calculating the area under the curve on validity and precision of glycaemic index values. *British Journal of Nutrition*. 91, 295–300.

- Wolever, T., Jenkins, D.J., Kalmusky, J., *et al*., (1986). Glycemic response to pasta: effect of surface area, degree of cooking, and protein enrichment. *Diabetes Care*; 9:401–4.
- Wolever, T.M.S., Barbeau, M.C., Charron S., Harrington, K., Leung, S., Madrick. B., & CJDC. (2000).Glycemic Index and Glycemic load. 23-56.
- Yoon, J.H., Thompson, L.U., & Jenkins, D.J.A. (1983). The effect of phytic acid on in vitro rate of starch digestibility and blood glucose response. *Am J Clin Nutr*. ;38:835-42.

APPENDIX

FORMULA FOR CALCULATING GLYCEMIC INDEX

GLYCEMIC INDEX OF A TEST FOOD = AVERAGE IAUC OF TEST FOOD × 100
MEAN IAUC OF GLUCOSE

FOR EXAMPLE: HOW TO CALCULATE THE GLYCEMIC INDEX FOR ABOLO

SUBJECTS	**CC11**	**LA20**	**OF30**	**JE40**	**PK50**	**JA60**	**AB70**	**SA80**	**BE90**	**JN10**	**MEAN**
IAUC ABOLO	141.8	100.5	139.5	209.3	203.3	162	104.3	51.32	57.35	141.8	131.107
IAUC GLUCOSE MEAN	161.58	223.05	248.25	250.6	226.88	210.05	343.55	118.8	221.85	237.4	225.0975

GLYCEMIC INDEX OF ABOLO= 131.107/225.0975×100= 59.

GLYCEMIC OF ANCHOVIES= 0.9

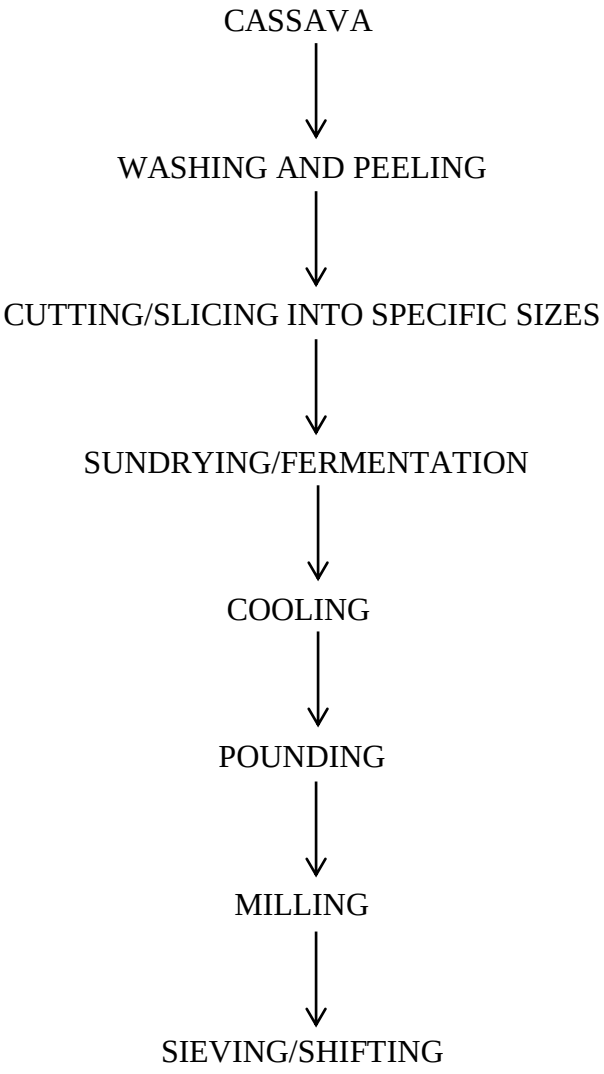
Since Abolo was eaten with Anchovies, glycemic index of abolo will be;

GI Abolo-GI Anchovies= 59-0.9= 58.1 approx. 58

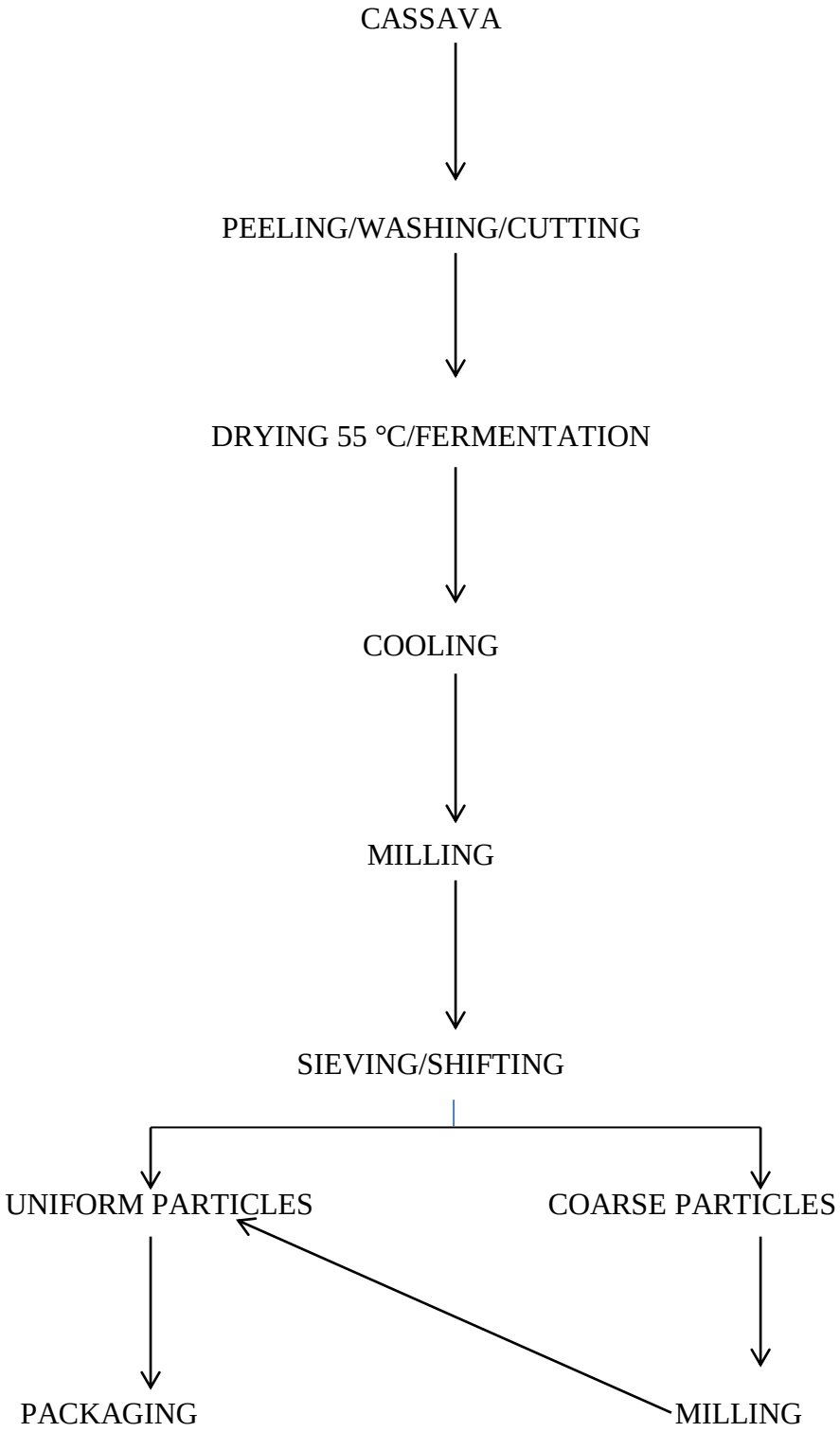
The Glycemic index of each test food was calculated as the mean GI as obtained by each subject in the study that consumed the test food. All GIs that were 2 SD above or below the mean GI value for a given g test were ignored as an outlier (Wolever *et al.,* 2011). The IAUC for each test food was expressed as a percentage of the mean IAUC of the glucose which was the reference food used.

A SYSTEMIC PROCESS FLOW DIAGRAM FOR THE PRODUCTION OF CASSAVA FLOUR

LOCALLY MADE KOKONTE



PROCESSED OR INDUSTRY MADE KOKONTE



This was provided on the manufacturers guide.

BELOW IS A SAMPLE DATA COLLECTION SHEET FOR THE STUDY. EACH STUDY SUBJECT WAS GIVEN A CODE FOR EASY IDENTIFICATION.

GLYCEMIC INDEX RESEARCH

RESEARCHER: MISS EUNICE SERWAA YEBOAH MPHIL HUMUMAN NUTRITION DIETETICS

SUGAR PROFILE SHEET

Participant's Code:.....

AGE:..... WEIGHT:.....

HEIGHT:..... BMI:.....

WC……

DAY 1 Date:

Last meal……..

Time of last meal

OGTT1

Time (min)	FBS	15	30	45	60	90	120
Concentration (mmol/L)							

DAY 2 Date:

Last

Meal:.....

Time of Last Meal:

Abolo

Time (min)	FBS	15	30	45	60	90	120
Concentration (mmol/L)							

DAY 3 Date:

Last

Meal:.....

Time of Last Meal:

Kafa

Time (min)	FBS	15	30	45	60	90	120

Time (min)	FBS	15	30	45	60	90	120

Concentration (mmol/L)							

DAY 4 Date:

Last

Meal:.....

Time of Last Meal:

Akple

Time (min)	FBS	15	30	45	60	90	120
Concentration (mmol/L)							

DAY 5 Date:

Last

Meal:.....

Time of Last Meal:

OGTT 2

Time (min)	FBS	15	30	45	60	90	120
Concentration (mmol/L)							

DAY 6 Date:

Last

Meal:.....

Time of Last Meal:

Konkonte (processed i.e. neat kokonte)

Concentration (mmol/L)							

DAY 7 Date:

Last

Meal:.....

Time of Last Meal:

Kokonte (locally made)

Time (min)	FBS	15	30	45	60	90	120
Concentration (mmol/L)							

Oneway

```
ONEWAY iAUC BY Sample
 MISSING ANALYSIS
POSTHOC=TUKEY ALPHA(0.05).
```

ANOVA

iAUC

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	273146.494	5	54629.299	14.690	.000
Within Groups	200821.837	54	3718.923		
Total	473968.332	59			

Post Hoc Tests

Multiple Comparisons

Dependent Variable: iAUC

Tukey HSD

(I) Sample	(J) Sample	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
Abolo	Kafa	51.99660	27.27241	.409	-28.5792	132.5724
	Kokonte1	73.83950	27.27241	.090	-6.7363	154.4153
	Kokonte2	104.25673*	27.27241	.004	23.6809	184.8325
	Akple	-34.35700	27.27241	.805	-114.9328	46.2188
	Glucose	-93.99050*	27.27241	.013	-174.5663	-13.4147
Kafa	Abolo	-51.99660	27.27241	.409	-132.5724	28.5792
	Kokonte1	21.84290	27.27241	.966	-58.7329	102.4187
	Kokonte2	52.26013	27.27241	.404	-28.3157	132.8359
	Akple	-86.35360*	27.27241	.029	-166.9294	-5.7778
	Glucose	-145.98710*	27.27241	.000	-226.5629	-65.4113
Kokonte1	Abolo	-73.83950	27.27241	.090	-154.4153	6.7363
	Kafa	-21.84290	27.27241	.966	-102.4187	58.7329
	Kokonte2	30.41723	27.27241	.873	-50.1586	110.9930
	Akple	-108.19650*	27.27241	.003	-188.7723	-27.6207
	Glucose	-167.83000*	27.27241	.000	-248.4058	-87.2542
Kokonte2	Abolo	-104.25673*	27.27241	.004	-184.8325	-23.6809
	Kafa	-52.26013	27.27241	.404	-132.8359	28.3157
	Kokonte1	-30.41723	27.27241	.873	-110.9930	50.1586
	Akple	-138.61373*	27.27241	.000	-219.1895	-58.0379
	Glucose	-198.24723*	27.27241	.000	-278.8230	-117.6714
Akple	Abolo	34.35700	27.27241	.805	-46.2188	114.9328
	Kafa	86.35360*	27.27241	.029	5.7778	166.9294
	Kokonte1	108.19650*	27.27241	.003	27.6207	188.7723
	Kokonte2	138.61373*	27.27241	.000	58.0379	219.1895
	Glucose	-59.63350	27.27241	.261	-140.2093	20.9423
Glucose	Abolo	93.99050*	27.27241	.013	13.4147	174.5663
	Kafa	145.98710*	27.27241	.000	65.4113	226.5629
	Kokonte1	167.83000*	27.27241	.000	87.2542	248.4058
	Kokonte2	198.24723*	27.27241	.000	117.6714	278.8230
	Akple	59.63350	27.27241	.261	-20.9423	140.2093

*. The mean difference is significant at the 0.05 level.

Homogeneous Subsets

Iauc

Tukey HSD

Sample	N	Subset for alpha = 0.05			
		1	2	3	4
Kokonte 2	10	26.8503			
Kokonte 1	10	57.2675	57.2675		
Kafa	10	79.1104	79.1104		
Abolo	10		131.1070	131.1070	
Akple	10			165.4640	165.4640
Glucose	10				225.0975
Sig.		.404	.090	.805	.261

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 10.000.

Oneway

ANOVA

GI

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	26339.920	4	6584.980	11.464	.000
Within Groups	25848.293	45	574.407		
Total	52188.214	49			

Post Hoc Tests

Multiple Comparisons

Dependent Variable: GI

Tukey HSD

(I) Sample1	(J) Sample1	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
Abolo	Kafa	25.88521	10.71827	.130	-4.5702	56.3406
	Kokonte1	36.75494*	10.71827	.011	6.2995	67.2104
	Kokonte2	48.28355*	10.71827	.000	17.8281	78.7390
	Akple	-13.46582	10.71827	.719	-43.9212	16.9896
Kafa	Abolo	-25.88521	10.71827	.130	-56.3406	4.5702
	Kokonte1	10.86973	10.71827	.848	-19.5857	41.3252
	Kokonte2	22.39834	10.71827	.242	-8.0571	52.8538
	Akple	-39.35104*	10.71827	.005	-69.8065	-8.8956
Kokonte1	Abolo	-36.75494*	10.71827	.011	-67.2104	-6.2995
	Kafa	-10.86973	10.71827	.848	-41.3252	19.5857
	Kokonte2	11.52861	10.71827	.818	-18.9268	41.9840
	Akple	-50.22076*	10.71827	.000	-80.6762	-19.7653
Kokonte2	Abolo	-48.28355*	10.71827	.000	-78.7390	-17.8281
	Kafa	-22.39834	10.71827	.242	-52.8538	8.0571
	Kokonte1	-11.52861	10.71827	.818	-41.9840	18.9268
	Akple	-61.74938*	10.71827	.000	-92.2048	-31.2939
Akple	Abolo	13.46582	10.71827	.719	-16.9896	43.9212
	Kafa	39.35104*	10.71827	.005	8.8956	69.8065
	Kokonte1	50.22076*	10.71827	.000	19.7653	80.6762
	Kokonte2	61.74938*	10.71827	.000	31.2939	92.2048

*. The mean difference is significant at the 0.05 level.

Homogeneous Subsets

GI

Tukey HSD

Sample1	N	Subset for alpha = 0.05		
		1	2	3
Kokonte 2	10	11.3786		
Kokonte 1	10	22.9072		
Kafa	10	33.7769	33.7769	
Abolo	10		59.6621	59.6621
Akple	10			73.1279
Sig.		.242	.130	.719

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 10.000.