UNIVERSITY OF CAPE COAST

ANALYSIS OF GLYCEMIC LOAD OF FOUR TYPES OF RICE POPULARLY CONSUMED IN GHANA: A CASE STUDY IN CAPE COAST METROPOLIS

ELIZABETH OFORI

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BY

ELIZABETH OFORI

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

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DECLARATION

Candidate's Declaration

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

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

Name: Elizabeth Ofori

Supervisors' Declaration

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

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

Name: Prof. (Mrs.) Sarah Darkwa

Co-supervisor's Signature: ………………………… Date:……………

Name: Dr. (Mrs.) Augusta Adjei Frempong

ABSTRACT

The purpose of the study was to investigate the Glycemic Load (GL) of four types of rice (local brown rice, local polished white rice, perfumed rice and polished perfumed white rice) popularly consumed in Ghana in order to examine its implications on health nutrition. The study sampled 12 healthy individuals into the trial. They consisted of six males and six females. Also, they were made up of six young people and six old people. After a fasting blood sample test, participants were each given a glucose solution prepared from 50g anhydrous glucose and 200ml of bottled water. The Glycemic Index (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 two hours at intervals 30, 60, 90, and 120th min. GL values were calculated based on the GI value for the test food. Both descriptive and inferential statistical tools were used to analyse the data. The study revealed that averagely, polished local rice (5.62 ± 0.28 mmol/L) recorded the highest blood glucose response, followed by that of polished perfumed rice (5.60 ± 0.56 mmol/L) and perfumed rice (5.55 ± 0.44 mmol/L). However, brown rice (5.21 ± 0.44 mmol/L) had the least blood glucose level. Also, all the GL values of the various types of rice tested were high. Also, people associated with cardiovascular diseases, obesity and type two diabetes should not consumed polished rice. However, they can consider taking-in brown rice since it recorded relatively lower GI and GL. The findings should assist health nutrition professionals, diabetics and consumers in their selection of rice.

KEY WORDS

Blood glucose

Glycemic index

Glycemic load

Rice

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DEDICATION

To my husband, Alfred Kweku Attom Prah, and children.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ACRONYMS

ALP	Atherogenic Lipoprotein Phenotype
ANOVA	Analysis of Variance
ATBC	Alpha-Tocopherol, Beta-Carotene Cancer Prevention
BMI	Body Mass Index
BP	Blood Pressure
Cis	Confidence Intervals
CVDs	Cardiovascular Diseases
FFQ	Food Frequency Questionnaires
FAO	Food and Agriculture Organisation
GI	Glycemic Index
GL	Glycemic Load
HDL	High-Density Lipoprotein
HR	Hassawi Rice
IAUC	Incremental Area Under the Curve
II	Insulinaemic Indices
IRB	Institutional Review Board
METS	Metabolic Equivalent Score
MOH	Ministry of Health
PAL	Physical Activity Level
PCA	Principal Component Analysis
PDS	Partially Defatted Soybean
RAG	Rapidly Available Glucose

RRs	Relative Risks
SAG	Slowly Available Glucose
SPSS	Statistical Package for Social Sciences
TM	Togo Marshall
UCC	University of Cape Coast
UN	United Nations
VLDL	Very Low-Density Lipoprotein
WC	Waist Circumference
WFR	Weighed Food Intake Records
WHO	World Health Organisation

CHAPTER ONE

INTRODUCTION

The glycemic load (GL) of foods has become an important tool used by healthy individuals including diabetics in the selection of their meals as a means to maintain good glycemic control. This is because food choices from intercontinental food list using GL with the help of glycemic index (GI) have become easier based on the premise that it has been determined and standardised. Alternatively, most staple food commodities in Ghana such as rice have limitations when it comes to issues on GI. It is, however, noteworthy that the consumption of rice tends to increase at a high rate in Ghana which makes it necessary to understand the rate at which this food commodity is converted to sugar in the body so as to assess its health implications. It could be argued that analysing the GL of four types of rice popularly consumed in Ghana could support an understanding of the issues related to implications on nutrition and health. Therefore, this study explores the GL of four types of rice popularly consumed in Ghana.

Background to the Study

Generally, food plays a pivotal role in human's healthy life. It provides nutritional support, energy, maintain life, stimulate growth and protects us from diseases. Essential to healthy living is the need for a balanced consumption of foods that serve the three main purposes of a diet. Food is essentially of plant or animal origin that contains nutrients such as carbohydrates, fats, proteins, vitamins and minerals. It is therefore, an important surviving factor for all nations. This is because most of the global human population lives on diets which are based on one or more of commodities such as rice, wheat, maize, millet, sorghum, roots and tubers as well as animal products. Rice, maize and wheat are among the 15 crops providing about 90 percent of per tropical human energy (Food and Agriculture Organisation [FAO], 2008). The Green Revolution initiative in the second half of the 20th century has led to a significant increase in the production of wheat and rice globally. This is a good initiative since it tends to increase the supply of food with high levels of carbohydrate as the main source of energy in the diet of most people. Carbohydrates play a very significant role in homeostasis and energy metabolism of man (Wormenor, 2015).

Tropical Africa contributes 30 percent to the world's cereal production while Tropical Asia produces twice the tonnage of cereal production by tropical Africa and America combined (FAO, 2008). Africa diets are usually based on a carbohydrate staple served with soups, relishes and sauces. Food crops such as grains, roots, tubers and plantains are the most consumed food of most people in Africa. According to FAO (2008), they have the highest yield of energy per unit of land. Although such foods as cereals, roots and tubers are the main sources of energy for most African countries, they also contain other nutrients, including a significant quantity of protein (FAO, 2012).

The situation is not different in Ghana, where major staples include maize, rice, yam, cocoyam, cassava, plantain, millet and sorghum. They are accompanied by thick, well-seasoned sauces, with okra, fish, beans, groundnuts and palava sauces being the most popular. Examples of favourite dishes include fufu, gari, agbelima yakeyake, ampesi, kenkey and porridge (Ministry of Health [MOH], 2012). Rice, however, is a staple with increased consumption throughout the country, especially in urban areas. This is due to its shelf life and the ease in its preparation. These traditional Ghanaian diets are of energy dense component with carbohydrate being the major nutritional component (Jones & Bartleft, 2013). Carbohydrates are one of the three basic macronutrients needed to sustain life (Brand, Nicholson, Thorburn & Truswell, 2016). Its role in metabolism makes it the body's main source of energy. It comes in simple and complex forms. The simple forms are the sugars of various types whereas the starches are the complex ones. This has resulted in differences in the energy contents and digestibility of carbohydrates. The simple ones elicit a quicker response from insulin than the complex ones. This is due to differences in the rate at which they are metabolised into glucose.

Carbohydrates can be polished or unpolished. Examples of polished carbohydrates are polished white rice, white flour, and white kenkey. Unpolished carbohydrates are whole meal cereals and their products, tubers and their products and starchy fruit such as plantain (MOH, 2012). According to Jenkins (2012), carbohydrates are metabolised in several stages by the digestive system and the liver and are converted into a simple sugar called glucose which is a preferred energy source for the brain and central nervous system as well as the placenta and foetus during pregnancy. Recently, too many carbohydrates have been labelled as the driving force behind the development of diseases in humans, fearlessly taking the reign from saturated fat (Gross, Ford & Liu, 2004; Jenkins et al., 2015). Over consumption of carbohydrates could incur unwanted weight gain, blood sugar issues, and a long list of chronic diseases. Likewise, too little consumption of carbohydrates could lead to hormonal imbalance, weight loss and major drops in athletic performance (Aston, Gambell, Lee, Bryant & Jebb, 2012).

While both sides of the argument project carbohydrates in an unpleasant light, this shows that man must consume the right and appropriate quantity of carbohydrate at a time. This is so because eating the appropriate amount of carbohydrates can help one achieve healthy life. The question therefore is, are people aware of the right types and amount of carbohydrates? Do people know the right levels to consume? The researcher is of the view that lack of knowledge in GL could be the major cause of the increasing rate of cardiovascular diseases (CVDs) in Ghana. A study conducted in the Britain concluded that a very good glucose control is paramount in the prevention of complications resulting from diabetes (Moses, Barker, Winter, Petocz & Brand-Miller, 2009). Wormenor (2015) also reported that diabetes is on the rise in Ghana, with the current estimate of the prevalence rate of about 450,000 cases occurring in 2014.

In 2014, a committee of experts were brought together by the Food and Agriculture Organisation (FAO) of United Nations (UN) and World Health Organisation (WHO) to review the available research evidence regarding the importance of carbohydrates in human nutrition and health. The committee endorsed the use of GL for classifying carbohydrates. The committee recommended that the GI values of foods be used in conjunction with information about food composition to guide food choices. To promote good health, the committee advocated the consumption of high carbohydrate diets ($\geq$ 55% of energy from carbohydrate) with the bulk of carbohydrates containing foods that rich in non-starch polysaccharides with a low GI. Rice is basically composed of carbohydrate in the form of starch which account for about 90 percent of the total dry weight and 81 percent of the total caloric content. The starch is made of long chains of glucose known as amylase and amylopection that contributes to the texture and digestibility of rice. Rice has given a wide range of results in GI and GL studies around the world. The GI of white rice ranged from 54–121 when bread (GI - 100) was used as the reference food. Although, related studies have provided evidence that high consumption of white rice is associated with undesirable metabolic outcomes, potential mechanisms have not been explained clearly, and more so in Ghana.

The concept of GI which classifies the blood-raising potential of carbohydrate foods relative to glucose or white bread has shown that foods similar in carbohydrate content do not usually have the same impact on blood glucose levels (Brand et al., 2016; Wormenor, 2015). The GI is a parameter used to classify foods according to their postprandial glycemic response. However, since the glycemic response is also affected by the amount of the consumed carbohydrate, glycemic load has been considered a better parameter to quantify the impact of carbohydrate in the glycemia. This calls for the need to find the GL of rice in Ghana so as to utilise a better parameter to assess the postprandial glucose response.

Statement of the Problem

Postprandial hyperglycemic is a risk factor for CVD, particularly in diabetic patients (Gross et al., 2004). Studies in the area of health nutrition have suggested a link between dietary carbohydrates and CVD risk (Jenkins, 2012; Moses et al., 2009). It is also clear that a control of postprandial provides cardiovascular benefits, thus contributing to the overall decrease of haemoglobin. In order for most people to regulate their intake of carbohydrates, there is the need for them to know their body mass indexes (BMI). GI is usually used to regulate ones intake of carbohydrate. According to Wormenor (2015), GI of foods have become an important tool used by healthy individuals and mostly diabetics in their food choices to maintain good glycemic control. Intercontinental food list is easier for glycemic control because their GI are determined and standardised. The same cannot be said about most of the rice consumed in Ghana. With the increased consumption of some of the polished rice comes a need to understand the rate of converting this food to sugar in the body which is a measure of their GI since inappropriate conception of such foods can trigger CVDs among consumers.

Globally, studies conducted on the causes of CVDs demonstrate a significant relationship between dietary carbohydrates and CVDs and diabetes with dietary carbohydrate being a major determinant of postprandial glucose levels (Jenkins et al., 2015; Wormenor, 2015). Nearly, 75 percent of diabetes patients have died of heart disease, which makes the control of diabetes dyslipidemia an important strategy in the primary prevention of CVD (Wormenor, 2015). The necessity of consumers of starchy foods such as rice knowing the GI of the rice they consume, therefore, cannot be under estimated. According to

Wormenor (2015), one of the appropriate ways that consumers can look for healthy foods is to know the GI of what they are consuming. However, most of the studies that assessed the GL of rice focused on developed countries such as China, USA, Australia, Japan, Britain and Netherlands (Lui et al., 2013).

In Ghana, though there have been studies on dietary carbohydrates and CVDs (Wormenor, 2015), only few works have been conducted experimentally to examine the GL of rice in Ghana and its consequences on CVDs. Based on the aforementioned, this study seeks to investigate the impact of blood glucose on four types of popularly consumed rice in Ghana and analyse the extent to which each of them affects the blood glucose level. Thus, when consumers are well informed on the rate at which the glucose is released into the blood stream, they will be cautious about their choice of rice and even the time they eat it. This could go a long way to minimize the prevalence of CVDs and diabetes in the country since rice is the most popular food consumed by people in the country.

Purpose of the Study

The purpose of the study was to assess the GL of four types of rice (brown rice, local white rice, perfumed rice, and polished perfumed rice) popularly consumed in Ghana in order to examine its implications on health nutrition of Ghanaians. Specifically, the study sought to:

1. determine the GI of brown rice, local white rice, perfumed rice, and polished perfumed rice;
2. determine the GL of brown rice, local white rice, perfumed rice, and polished perfumed rice;

3. determine the impact of brown rice, local white rice, perfumed rice and polished perfumed rice on consumers' blood glucose level;
4. determine the effects of gender and age on consumers' blood glucose level; and
5. examine the health implications of GI and GL of the four types of rice.

Research Questions

Based on the first, second, third, and fifth specific purposes of the study, the following researcher questions were formulated to guide the study. The questions formulated were as follows:

1. What is the GI of brown rice, local white rice, perfumed rice, and polished perfumed rice?
2. What is the GL of brown rice, local white rice, perfumed rice and polished perfumed rice?
3. What is the impact of brown rice, local white rice, perfumed rice and polished perfumed rice on consumers' blood glucose level?
4. What are the health implications of GI and GL of the four types of rice (brown rice, local white rice, perfumed rice and polished perfumed rice)?

Research Hypotheses

Based on the fourth specific purpose of the study, the following research hypotheses were formulated to be tested. The hypotheses are as follows:

H^1_0: There is no statistically significant difference between male and female participants with regard to their blood glucose level.

H^2_0: There is no statistically significant difference between young and old participants with regard to their blood glucose level.

Significance of the Study

The GI is a parameter used to classify foods according to their postprandial glycemic response. However, since the glycemic response is also affected by the amount of the consumed carbohydrate and quality, GL has been considered a better parameter to quantify the impact of carbohydrate on the glycemia. The research will provide data on the GL of brown rice, white rice and polished perfumed rice. The results will serve as a guide for both diabetics and pre-diabetic individuals in their choice of rice.

Furthermore, it will serve as a wakeup call to all Ghanaians to be cautious in their choices. It will also guide nutritionists, dieticians and diet therapist in their counselling and treating reactive hypoglycemia. Generally, when eating low GI foods, people tend to snack less, which may be helpful in weight control as well as blood sugar control. Also, the findings of the study will reach a wide spectrum of the reading public, teachers, students, health practitioners and other related researchers to have knowledge as well as add up to existing literature of the GL of local foods.

Delimitations

The study was to determine the GL of rice in Ghana using four brands of rice popularly consumed in Ghana. Analysis was made on only rice, therefore, generalisation of findings were made with regards to only rice and not any other local food. The study was delimited to non-diabetic individuals. The study focused on blood glucose levels after food had digested, therefore, people who were already diabetic and had elevated blood glucose level were not considered as appropriate participants for this study.

Limitations

Although every effort was made in the current study to decrease any extraneous variables, certain limitations to the current research exist. With these limitations in mind, explanations regarding the significance of the study may be inferred. In the first place, the study depended on laboratory samples to obtain the data; hence, there is the risk of being unstandardized since the instruments and the chemical used may have some defects without the knowledge of the researcher. The sample population and the number of participants used were limited, which can affect generalisation of the findings.

Furthermore, the study considered only four brands of rice; although, there are more than ten brands of rice in the Ghanaian market. An expansion on the present study to include other brands of rice and even other staple foods would allow greater knowledge into the implications of GI and GL on health nutrition. Furthermore, the study assumed that the selected participants will abide by the rules and requirements of the experiment since they were presumed to be honest people. However, this was not verified. Lastly, the findings and conclusions of the study may not be projected for the future since issues related to GL, GI and health nutrition keep changing with time.

Definition of Terms

Blood glucose is the main sugar that the body makes from the food in the diet.

Calories are units of energy in food

Diet is made up of what we eat and drink.

Glycemic index is a figure representing the relative ability of a carbohydrate food to increase the level of glucose in the blood. According to the GI Group of the University of Sydney, in Australia, a glycemic index value of 70 or higher is considered high, 56 – 69 is considered medium, and 55 or lower is considered low.

Glycemic load of food is a number that estimates how much the food will raise a person’s blood glucose level after eating it. It takes into consideration both the GI of a food and the amount of carbohydrate in the portion of food eaten. In general, a serving of food with a GL of 1 – 10 is considered to have a low GL, 11 – 19 is a medium GL, and 20 or higher is a high GL.

Nutrition is about eating a healthy and balanced diet

Rice is a swamp grass which is widely cultivated as a source of food, especially in Asia.

Organisation of the Study

The study is organised into five chapters. Chapter One is the introduction which covers the background to the study, statement of the problem, purpose of the study as well as research questions and hypotheses. It also presents the significance of the study, delimitation and limitations of the study. The second chapter looks into the review of the related literature. Chapter Three describes the methodology used for the study. Chapter Four presents the results and discussions of the study. Chapter Five summarizes the findings and draws conclusions for the study based on the findings. It also presents relevant recommendations and suggestions for further research.

CHAPTER TWO

LITERATURE REVIEW

Introduction

This chapter reviews literature that pertains to the research. Its aim is to enable the researcher have a better understanding of the problem, identify where gaps exist in the research literature and most importantly generate relevant methods such as the design of the research and questions to elicit responses from research respondents. The focus of the review is on the interaction of the concept and themes as they relate to other concepts and research works. That is, it is a review of a few very pertinent and appropriate concepts that serve as the framework of the study. Some related empirical studies were reviewed in order to understand the issues regarding GL of four types of rice popularly consumed in Ghana and its implications on health nutrition much better.

Dietary Carbohydrates

Generally, the fundamental process of digestion is the same, people however differ in tolerance and handling of carbohydrate (Atkinson, Foster-Powell & Brand-Miller, 2008). The type of carbohydrate plays an important role. According to Atkinson et al. (2008), the diet component has the greatest influence in the glycemia in carbohydrate. Although changes in the quantity and quality of fat have received considerable attention, the role of carbohydrates is less clear (Wolever, Vuksan & Jenkins, 2011). Increases in refined sugar intake have been accompanied by more subtle changes in starchy foods in most Ghanaian urban communities. Example, technologically processed rice has replaced more traditionally processed rice. Because carbohydrate is the main dietary component affecting insulin secretion and postprandial glycemia, it is implicated in the etiology of many chronic diseases (Wormenor, 2015). Both the amount and type of carbohydrate consumed have an effect on both insulin secretion and postprandial glycemia, with differences not explained by glucose chain length. The review first looked at the dietary carbohydrates in order to understand the facet of it.

Carbohydrates are organic compounds that contain carbon, hydrogen and oxygen in the ratio 1:2:1 (Widdowson & McCance, 2009). Carbohydrates were once considered carbon *hydrates* (carbon substances containing water), which is now known to be untrue, but the term has persisted. According to a modern definition, carbohydrates are polyhydroxic aldehydes or ketones, which are substances with hydroxy (OH) and aldehyde (CHO) or ketone (C=O) functional groups (Widdowson & McCance, 2009). Most carbohydrates consist of one or more sugar molecules, such as glucose or fructose. The fundamental role of carbohydrate in human diet makes it necessary an issue to consider in the concept of GI and GL. Modern humans require a reliable source of glycemic carbohydrate to support the normal functioning of our brain, kidney medulla, red blood cells and reproductive tissues. The brain alone accounts for 20 – 25 percent of adult basal metabolic expenditure (Aston et al., 2012).

In addition to the demands of the brain, red blood cells require approximately 20g glucose per day directly from the bloodstream. Under normal circumstances, a glucose requirement of approximately 170 g/day is met by a mixture of dietary carbohydrate and gluconeogenesis from noncarbohydrate sources, such as the glycerol moiety of fats, some amino acids (e.g., alanine), or absorbed propionate from gut fermentations of dietary carbohydrates (Aderson & Woodend, 2013). The main dietary source of the monosaccharide glucose is from the digestion of glycemic carbohydrates (also referred to as available carbohydrates). Available carbohydrates comprise 40 – 75 percent of modern dietary energy intake (Jenkins et al., 2015), of which starch is the most abundant. Starch is digested slowly and incompletely in raw crystalline form, but more rapidly after cooking. Plants also contain many other carbohydrates, including cellulose and other structural polysaccharides in cell walls, and various types of mono-, di-, and oligosaccharides.

However, many polysaccharides and oligosaccharides are considered unavailable because they are not hydrolysed by human upper gut enzymes, and pass into the large intestine, where some are fermented by gut microbiota. Among the products of these fermentations are the short-chain fatty acids, butyrate, propionate and acetate, which can be absorbed from the gut and provide 5 – 10 percent of the energy requirement of adults (Wormenor, 2015). The FAO/WHO report provides a classification for the main categories of food carbohydrates based on their degree of polymerisation (see Table 1). Such an approach is a compromise between a chemical classification and a physiological classification.

Table 1: Major Dietary Carbohydrates

Class (DP*)	Sub-Group	Components
Sugars (1-2)	Monosaccharides	Glucose, galactose, fructose
	Disaccharides	Sucrose, lactose, trehalose
	Polyols	Sorbitol, mannitol
Oligosaccharides (3-9)	Malto-oligosaccharides	Maltodextrins
	Other oligosaccharides	Raffinose, stachyose, fructo-oligosaccharides
Polysaccharides (>9)	Starch	Amylose, amylopectin, modified starches
	Non-starch polysaccharides	Cellulose, hemicellulose, pectins, hydrocolloids

Source: FAO/WHO, 2014 DP * = Degree of polymerisation

Although humans consume a variety of carbohydrates, digestion breaks down complex carbohydrates into a few simple monomers for metabolism: glucose, fructose and galactose (Wormenor, 2015). Glucose constitutes about 80 percent of the products, and is the primary structure that is distributed to cells in the tissues. Most of the fructose and galactose travel to the liver, where it can be converted to glucose. Ultimately, glucose is distributed to cells to be broken down or stored as glycogen (Brand et al., 2016). The section looks at carbohydrate digestion briefly.

Carbohydrate Digestion

The extensive amount of studies conducted on GI is due to the influence of carbohydrates on our hormonal response, and human diseases through their effect on metabolic and physiologic processes (FAO/WHO, 2014). To define the functionality of carbohydrates in metabolism, there is the need to understand the site, extent and rate of digestion in, and absorption from the gastrointestinal tract

(Aderson & Woodend, 2013). Digestibility and absorption are important components that are also useful in the characterisation and functional classification of carbohydrates. The GI of a carbohydrate food is directly influenced by its rate of digestion and absorption. Carbohydrate digestion begins in the mouth. A research by Aston et al. (as cited in Wormenor, 2015) showed how the GI of stone ground wholemeal bread differed from more finely ground wholemeal bread.

Accordingly, how well a food is chewed in the mouth before swallowing could affect the rate of digestion in the stomach and small intestines. Chewing would increase the surface area for enzyme activity and thus increase the rate of digestion and absorption. According to Jenkins et al. (2015), digestion and absorption take place in the gastrointestinal tract with the aid of certain fluids and enzymes. From the mouth to the small intestines numerous enzymes work on ingested food. Some carbohydrates and other food substances like fibre may escape digestion into the large intestines where they could undergo fermentation into gases and some other useful by products of metabolism like butyrates and propionates (Brand et al., 2016).

The Glycemic Index (GI) Concept

Glycemic index (GI) is defined as classification of foods according to their glucose raising potential (Jenkins, 2012) and measured by determining the incremental area under the blood glucose response curve after the ingestion of a test meal containing 50g available carbohydrate as a percentage of that elicited by a reference food (mainly glucose or white bread) taken by the same individual (FAO/WHO, 2014). Glycemic index measurement is thus equicarbohydrate, because equal quantities of available carbohydrate are involved, as compared to glycemic impact which is a measure of the weight of glucose that would induce a glycemic response equivalent to that induced by a given amount of food (Miller-Jones 2007). Glycemic index is a more established concept though it appears to be a simple index (FAO/WHO, 2014).

A number of factors influence the postprandial glycemic response of a food when ingested. These factors range from extrinsic components such as composition of the whole meal and variations in the overall diet, to intrinsic properties such as the amylose to amylopectin ratio, presence or absence of viscous fibre and the length of the monosaccharide units. Such factors as particle size, processing methods, nature of starch and antinutrients present are not commonly available in food tables, yet they have very significant effects on physiological properties of food highlight the importance of GI determination and use.

According to the GI Group of the University of Sydney, in Australia, a glycemic index value of 70 or higher is considered high, 56–69 is considered medium, and 55 or lower is considered low (FAO/WHO, 2014). To determine a food's GI value, researchers gave 10 or more volunteers a portion of the food being tested that contains 50 grams of carbohydrate. The volunteers' blood glucose levels have checked before they eat the food and periodically during the two hours after they eat it. On another occasion, those same volunteers consume a portion of glucose (or sometimes white bread is used) that contains 50 grams of carbohydrate, and the same blood glucose measurements are taken. The two sets of measurements are then compared. Ten or more volunteers are used in these tests, and their results are averaged, because each person responds to food slightly differently.

Not only does the GI of a food vary slightly from person to person, but it also depends on whether the food is eaten in isolation or with other foods. Consuming a food along with protein, fat, or other carbohydrates that have a lower GI effectively lowers its GI value. Other things that can affect a food's GI value include the ripeness of fruits (under ripe fruits have a lower GI than ripe fruit) and how foods are cooked or otherwise processed. In people with diabetes, the GI value of a food is additionally affected by a person's premeal blood glucose level. If a person's blood glucose level is elevated, the GI of a food is lower than normal, and if a person's blood glucose is low, the GI of the food goes up.

Research has demonstrated that when the botanical structure of rice is disrupted, the amount of available carbohydrates in it increases (O'Dea, Nestel & Antonoff, 2010). The disruptions of botanical structures of foods are also an underlining cause to the unexpected differences in the GI values of different foods. The defining standard of GI determination, glucose has a value of 100. Glycemic index is expressed in percentages and commonly represented on an absolute scale where foods with values of 55 or less, 56 to 69, and 70 or more are classified as low GI, medium GI and high GI foods respectively. GI measures postprandial glucose which can be manipulated by varying the amount and type of dietary carbohydrates consumed. Meals which have a low GI tend to slow insulin response and decrease postprandial glucose concentration (Jenkins et al., 2015). Basically, the GI concept provides us with a numerical representation of the combined effect of digestion and absorption on the rate at which blood sugar rises upon ingestion of a particular carbohydrate containing food or meal.

Determination of Glycemic Index

After the introduction of the GI concept in the 20th century, a number of research works have been done to determine the GI of various foods. Although the usefulness of GI has been endorsed by FAO/WHO expert consultation committee, its application has been difficult because there is still a large number of common foods in developing countries whose GI is not known (Jahan, 2013). Furthermore, the GI values of some particular food items in these countries provided by different laboratories showed some variations, which may be cause by the way they were cooked or prepared (Rogers, 2013). In the case of Ghana, the typical examples of such food items are maize, rice and millet (Wormenor, 2015).

In order to allow for harmony and reduced variation of GI values obtained for the same food in different places, a standardised method of determination such as GI and GL are used. According to FAO/WHO recommendation (as cited in Wolever et al., 2011), the approved standard method of determination of the GI of a food is *in vivo*, where a test food containing 50g available carbohydrate is ingested and the rate at which the food is digested and absorbed into the blood stream measured. The glycaemic response measured by the rate of digestion and absorption is illustrated with *in vitro* digestion models that mimic what happens in human digestive tract.

According to International Carbohydrate Quality Consortium [ICQC] (2014), there is a strong correlation between the rates at which sugar is released from starchy foods using digestive enzymes *in vitro* to increase in blood glucose levels in humans. Carbohydrate foods that are digested and absorbed slowly and thus elicit a slow rise in blood sugar levels give a low GI value and are thus classified as low GI foods whilst those that are digested and absorbed more rapidly are classified as high GI foods.

The measurement of glycemic response is done by taking blood samples for glucose test at timed intervals which start at the first bite of the test food (Wolever et al., 2011). In determining GI of a number of carbohydrate foods, the incremental area under the curve for the reference food is used as a denominator to each test food. According to the standard methodology, the reference food is repeatedly measured to allow for precision. Any variations in the glycemic response from the reference food will have a more profound effect on the GI than variations in the test foods (Similä, 2012). To this effect, Similä (2012) recommends the repetition in measurements of the reference food at least once in each participant of a GI determination research.

In the case of this study, the GI is the ratio between the incremental area under curve (IAUC) of 50g available carbohydrate of the test rice and the mean IAUC of 50g available carbohydrate of the reference food obtained from the same subjects multiplied by 100. Subjects who had GI exceeding 2s.d were also excluded from the group (known as outliers) and a final GI was recalculated to give each test of rice a GI. The formula of GI calculation is as follows:

GI = [IAUC of test rice ÷ Mean IAUC of reference food] x 100

Reference Food

The determination of GI requires the use of a standardised reference food item against which the test food will be measured. Over the years, a number of foods have been used as reference foods in the determination of GI. An updated database of GI of some 1300 food measurements involved about 10 different reference foods including: glucose, rice, bread, white bread, whole barley bread and wheat. Glucose and white bread were however the major reference foods used (Lin, Wu, Lu & Lin, 2010; Passos et al., 2014).

According to Brown, Mssallem, Frost and Hampton (2015), not much study has been done on the glucose raising effect of commonly used white bread. Nonetheless, its use has shown an appreciable level of consistency in the determination of GI of various test meals. Using white bread as a reference food produces a comparatively higher GI value than using glucose as a reference food. The GI of white bread as determined in some nine studies has yielded a value of 73 consistently (Delport, 2016). White bread composition and preparation may however differ from one experimental setting to another as was supposed in a study where white French bread produced a GI value of 97 (Brouns et al., 2016). There are concerns about the extreme sweetness of glucose and some persons also complain of a nauseating effect when they take in glucose solution in the morning after a 10 – 14 hours fast (Brouns et al., 2016). Pure glucose is, however, more likely to be the same in most experimental settings. This makes it easier to compare results from other laboratories.

Basically, variations in glycemic response to glucose or white bread usually yield significant variation in the GI of the test foods (Jenkins et al., 2015). To reduce these variations, Brouns et al. (2016) revealed that the mean of three trials of the reference food used in the determination reduce variations, although there were no substantial data to affirm this position. Subsequently, various theoretical assessment and simulation studies have indicated that either three or two trials of the reference food are acceptable (Brouns et al., 2016). However, in the case of this study, glucose was used as the reference food.

Blood Sampling

Glucose concentrations can be measured from whole blood or plasma from various parts of the body. Blood samples could be taken from the veins, arteries or capillaries. Arteries are blood vessels that deliver blood from the heart to the tissues and will obviously be richer in nutritional composition. An assessment of the arterial blood could have yielded the truest reflection of the glucose concentration being delivered to the various body tissues. However, the arteries are found deeper within the body than the capillaries and veins, and such drawing arterial blood could come with associated risks. This notwithstanding, capillary blood approximates the composition of arterial blood and therefore, a better alternative to the more invasive arterial blood (Oboh et al., 2015).

There is a marked effect of ambient temperature on the flow rate of venous blood. Thus, venous blood which can be taken from the forearm among other visible parts of the body has been found to be more variable in its glucose concentration than capillary blood (Wolever et al., 2011). Measured glucose concentration in the capillaries is comparatively higher than in venous blood and thus makes it easier to detect very small changes in blood sugar concentrations over time. In the determination of GI, blood from the capillary taken from the fingertip or earlobe is thus more convenient and better for the assessment of glycemic response (Lin et al., 2010). The current study adopted this approach, by taking blood from the capillary specifically from the fingertip and earlobe of participants since that method is perceived to be more convenient and better for the assessment of glycemic response.

Many food factors including fat, protein and carbohydrate are important determinants for the GI. The proportion of fat, protein and carbohydrate may influence the glycemic responses of foods or meals. Fat reduces the blood glucose responses by slowing the gastric emptying, and a large amount of protein, e.g. milk protein, stimulates the insulin secretion and consequently can reduce the blood glucose responses (Fan, Song, Wang, Hui & Zhang, 2012). Also, particle sizes as well as the amount of starch play an important role in the size of the glycemic response and GI.

The higher proportion of amylose versus amylopectin in starch, the lower blood glucose response occurs (Wang et al., 2013). Furthermore, the authors added that the processing and storage of foods have an essential influence on their GI. Again, ripening of fruits such as bananas decreases the amount of resistant starch and increases the blood glucose response (Alkaabi, 2015). Also, the eating time, composition and GI of a previous meal as well as the size and meal frequency influences the glycemic response to the same meal or food, since the glucose responses depend both on the quantity and the quality of carbohydrates (Augustin, Francesch, Jenkins, Kendall & La Vecchia, 2016).

Pathophysiology of Study Subjects

Glycemic index determination is a measure of postprandial glucose response and this is influenced by an individual's insulin response and glucose tolerance. There were concerns on the physiological state of persons participating in GI studies. Numerous studies have however tried to address the issue to give an accurate perspective on the right subject characteristics for GI determination study. The work of Foster-Powell, Holt and Brand-Miller (2012) on GI and GL values indicates that subject characteristics have no significant effect on the mean GI of a food.

A study by McNeil (2016) on "prediction of the relative blood glucose response of mixed meals using the white bread glycemic index" confirmed an intra-individual variation in glycemic response to white bread. McNeil (2016) observed that normal apparently healthy subjects showed intermediate intra-individual variation in glycemic response, whilst subjects with type II diabetes showed a less significant intra-individual variation as compared to subjects with type I diabetes. McNeil (2016) thus recommended the use of apparently healthy individuals in the determination of GI to increase precision. The current study in line with previous studies, selected 12 healthy individuals for the study.

The Concept of Glycemic Load

Glycemic load of food is a number that estimates how much the food will raise a person's blood glucose level after eating (Yeboah, 2017). It measures the amount of carbohydrate in a food and how a gram of the carbohydrate in the food raises blood glucose level. GL is used to quantify the overall glycemic effect of a serving of food. GL is based on the GI, and it is calculated by multiplying the grams of available carbohydrate in the food by the foods GI and dividing by 100.

That is, the GL takes into consideration both the GI of a food and the amount of carbohydrate in the portion of food eaten. For one serving of a food, a GL greater than 20 is considered high, a GL of 11–19 is considered medium, and a GL of 10 or less is considered low. Foods that have a low GL in a typical serving size almost always have a low GI. Foods with an intermediate or high GL in a typical serving size range from a very low to very high GI (Yeboah, 2017).

GL = [GI x Carb.] ÷ 100

Where Carb. = The amount of available carbohydrate contained in a specified serving size of the food.

A high GI food does not always have a high GL value. For instance, although carrot has a high GI value (GI = 131), a 3oz serving of carrot is small (GL = 11.8). This is because carrot is not a high carbohydrate food. There is only 9g of carbohydrate present in 3oz of carrot. As a result, patients with diabetes should not solely refer to GI values of food to make their food choices. In the revised international table of GI, the GL of food per serving is listed (Foster-Powell et al., 2012), as shown in Table 2 of selected foods.

Table 2: Glycemic Load of Some Selected Foods

Food	GI Glucose = 100	Available CHO (g/serving)	GL
Cranberry juice drink	56	29	17
Rice (white)	69	43	30
Milk (skim)	32	13	4
Apple	40	16	6
Beans, dried	36	30	11

Source: Adapted from Foster-Powell et al. (2012)

Some researchers have questioned the value of using GL as a basis for weight-loss programmes (Villegas et al., 2014). Das (2015) conducted a study with 36 healthy, overweight adults, using a randomised test to measure the efficacy of two diets: a high GL and a low GL. The study concluded that there is no statistically significant difference between the outcomes of the two diets. GL appears to be a significant factor in dietary programmes targeting metabolic syndrome, insulin resistance, and weight loss. Studies have shown that sustained spikes in blood sugar and insulin levels may lead to increased diabetes risk (Brand et al., 2016).

A study published in 2011 found that the GL of a portion of a single food or of a meal (with a mix of foods) was a better predictor of after-meal blood glucose level than the carbohydrate content of the food portion or meal. However, the study subjects did not have diabetes, so it is not yet known whether the same would hold true for people with diabetes (Brand et al., 2016). Therefore, it is appropriate for future researchers to experiment on participants in order to see whether calculating the GL of their meals and snacks help them to anticipate their after-meal blood glucose levels better than carbohydrate counting alone.

GI on the other hand, as indicated earlier, as a number associated with the carbohydrate in a particular type of food is a medium for determining how fast or slow a carbohydrate food is converted to glucose after consumption (Wolever et al., 2011). GI shows the effect of the carbohydrate on a person's blood sugar or glucose level two hours after consumption. This suggests that low GI foods result in slow, prolonged glucose disposal after consuming a meal.

Most researchers have indicated that many low-GI foods are relatively less refined than are their high-GI counterparts and are more difficult to consume. The lower energy density and palatability of these foods are important determinants of their greater satiating capacity. In obese children, the ad libitum consumption of a low-GI diet has been associated with greater reductions in body mass indexes (Mirrahimi et al., 2012). However, some experts have raised concerns about the difficulties of putting advice about GI values into practice and of the potentially adverse effects on food choice and fat intake. For this reason, the American Diabetes Association does not recommend the use of GI values for dietary counselling. However, the European Association for the Study of Diabetes, the Canadian Diabetes Association, and the Dieticians Association of Australia all recommend high-fibre, low-GI foods for individuals with diabetes as a means of improving postprandial glycemia and weight control (Wormenor, 2015).

The discussion so far shows that high GI foods are rapidly digested and absorbed, whereas low GI foods are digested and absorbed slowly. Also, high GI foods produce a higher rise in postprandial blood glucose levels and a greater overall blood glucose response during the first two hours after consumption compared with low GI foods (Foster-Powell et al., 2012). Generally, low GI foods consist of non-starchy vegetables, fruits, dairy products, lentils and sugars such as fructose and lactose. Medium GI foods include unprocessed grains and mixed dishes. High GI foods are refined grains, potatoes, rice and some types of bread.

Factors that Can Affect Glycemic Load

After two decades of Jenkins et al. (as cited in Jenkins, 2012) first index published journal on the relative glycemic effect of carbohydrate exchange from 51 foods, there has been several reviews from 1995 on the first edition of international table of GI with 565 entries (FAO/WHO, 2014). Many researchers have raised concerns about the variations in published GI and GL values for apparently similar foods (Aderson & Woodend, 2013; Ramdath, 2014). These variations may reflect methodological factors and true differences in the physical and chemical characteristics of the foods (Foster-Powell et al., 2012). There could, therefore, be a possibility where two similar foods which may have different ingredients or may have been processed with different methods, have significant differences in GI and GL. Also, different testing methods used in different parts of the world contribute to the variations. This may include the use of different types of blood samples, different experimental periods and different portions of food (Yeboah, 2017).

GI values were determined in studies where volunteers ate portions containing 50 grams of carbohydrate of each test food (Lui et al., 2013). However, 50 grams of carbohydrate is not necessarily a usual portion size. For example, 50 grams of carbohydrate from popcorn is ten cups popped, while 50 grams of carbohydrate from white rice is about one cup cooked. Lui et al. (2013) indicated a wide variation in values assigned to the same food. One source may say a russet potato has a GI of 56 and another source may say the GI is 111. Also, GI values can vary depending on the ripeness of the food, the degree of processing, and the cooking method.

Furthermore, Lui et al., (2013) indicated that GI values measured the effect of a test food when that food was eaten alone. Most meals contain a variety of foods in combination. The glycemic effect of a food changes when it is combined with other foods. For example, fat delays digestion. Also, the effect of food on blood sugar can vary from person to person. Blood sugar levels are also affected by activity, exercise, hormones, and medications. In addition, a lower GI value does not necessarily mean the food is a better choice. For example, a chocolate candy bar and one cup of brown rice may both have a GI of 55, but the overall nutritional value is very different.

Although it is clear that, GI values are generally reproducible from place to place, there are some instances of wide variations for the same food. Rice for example, shows wide variation values but the variation is due to inherent botanical differences from country to country rather than methodological differences. Differences in the amylose content could explain the variation. The GI values of rice cannot reliably be predicted on the basis of the size of the grain or the type of cooking method, therefore rice is a type of food that needs to be tested by brand by brand locally (Passos et al., 2014). As a result, the current study calculated the GI of four types of rice popular consumed in Ghana.

Rice Classification

Rice is the seed of the grass species oryza sativa (Asian rice) or oryza glaberrima (African rice). As a cereal grain, it is the most widely consumed staple food for a large part of the world's human population, especially in Asia. It is the agricultural commodity with the third-highest worldwide production (rice, 741.5 million tonnes in 2014), after sugarcane (1.9 billion tonnes) and maize (1.0 billion tonnes) (FAO/WHO, 2014). The rice plant can grow to 1-1.8 m (3.3-5.9 ft.) tall, occasionally more depending on the variety and soil fertility. It has long, slender leaves 50-100cm (20-39 inch) long and 2-2.5cm (0.79-0.98 inch) broad. The small wind pollinated flowers are produced in a branched arching to pendulous inflorescence (12-20 inch) long. The edible seed is a grain (caryopsis) 5-12mm (0.20-0.47 in) long and 2-3 mm (0.079-0.118 inch) thick.

Rice, a monocot, is normally grown as an annual plant, although in tropical areas it can survive as a perennial and can produce a Raton crop for up to 30 years. Rice cultivation is well-suited to countries and regions with low labour costs and high rainfall, as it is labour-intensive to cultivate and requires ample water. However, rice can be grown practically anywhere, even on a steep hill or mountain area with the use of water-controlling terrace systems. Although its parent species are native to Asia and certain parts of Africa, centuries of trade and exportation have made it common food in many cultures worldwide.

The varieties of rice are typically classified as long-, medium-, and short-grained. The grains of long-grain rice (high in amylose) tend to remain intact after cooking; medium-grain rice (high in amylopectin) becomes stickier. Medium-grain rice is used for sweet dishes, for “risotto” in Italy, and many rice dishes, such as “arose negre” in Spain. Some varieties of long-grain rice that are high in amylopectin, known as Thai Sticky rice, are usually steamed (Ramdath, 2014). Stickier medium-grain rice is used for sushi: stickiness allows rice to hold its shape when moulded. Medium-grain rice is used extensively in Japan, including accompanying savoury dishes, where it is usually served plain in a separate dish. Short-grain rice is often used for rice pudding, and other dishes which require very soft texture.

Instant rice differs from parboiled rice in that it is fully cooked and then dried, though there is a significant degradation in taste and texture. Rice flour and starch often are used in batters and breading to increase crispiness. Wild rice, from which the crop was developed, may have its native range in Australia (Mohan et al., 2016). Chinese legends attribute the domestication of rice to Shennong, the legendary emperor of China and inventor of Chinese agriculture. Genetic evidence has shown that rice originates from a single domestication 8,200-13,500 years ago in the Pearl River valley region of Ancient China (Mohan et al., 2016). Previously, archaeological evidence had suggested that rice was domesticated in the Yangtze River valley region in China (Passos et al., 2014).

From East Asia, rice was spread to Southeast and South Asia (Jahan, (2013). Rice was introduced to Europe through Western Asia, and to the Americas and Africans through European colonisation. Rice plants produce their own chemical defences to protect themselves from pest attacks. Some synthetic chemicals cause the plant to increase the production of certain defensive chemicals and thereby increase the plant's resistance to some types of pests (Xin et al., 2014). Conversely, other chemicals, such as the insecticide imidacloprid, can induce changes in the gene expression of the rice that cause the plant to become more susceptible to attacks by certain types of pests.

While most rice is cultivated for crop quality and productivity, there are varieties selected for characteristics such as texture, smell, and firmness. There are four major categories of rice worldwide: indica, japonica, aromatic and glutinous. The different varieties of rice are not considered interchangeable, either in food preparation or agriculture, so as a result, each major variety is a completely separate market from other varieties. It is common for one variety of rice to rise in price while another one drops in price (Choi, 2016). Rice can be classified based on length, texture, colour and aroma. Figure 1 shows the different types of rice popular consumed with regard to length. As indicated in Figure 1, the picture labelled 'A' represents long grain rice while the pictures labelled 'B' and 'C' represent medium and short grain rice respectively.

A = Long grain rice B = Medium grain rice C = Short grain rice

Figure 1: Classification of Rice by Length

The next to consider is classification of rice by texture. When cooking rice dishes, you will want to think about the desired texture of the rice. The starch content varies from rice type to rice type. It indicates whether rice is sticky or light and fluffy. Figure 2 depicts the pictures for sticky and parboiled rice.

A = Sticky rice B = Parboiled rice

Figure 2: Classification of Rice by Texture

Sticky rice, also known as sweet rice, is grown mainly in Southeast and East Asia and is used in many traditional Asian dishes, desserts, and sweets. When cooked, sticky rice is especially sticky and is often ground into rice flour (Xin et al., 2014). Parboiled rice on the other hand is a type of “rough” rice which has gone through a steam-pressure process before milling that gelatinizes the starch in the grain. This process produces a more separate grain that is light and fluffy when cooked. Converted rice is also a type of parboiled rice that has been further pre-cooked, which ultimately allows you to whip up dishes of rice even faster.

In relation to colour, rice is naturally brown after harvesting, but once the nutrient-rich outer layer of bran is removed, it is white in colour. Red rice, black rice, and purple rice all feature unique pigmentation in the bran. For these colourful rice varieties, the bran layer usually remains for added visual appeal and added nutritional value. Figure 3 shows examples of rice with different colours.

A = Polished rice B = Brown rice

C = Forbidden rice D = Wild rice

Figure 3: Classification of Rice by Colour

Polished rice (Picture A), refers to white rice that has had its outer brown layer of bran and germ removed. Rice that has shed its bran layers can also be referred to as “milled rice.” Brown rice on the other hand is healthful rice that sheds its outer husk and retains its bran and germ layers that give it a characteristic tan colour. Though brown rice takes a little longer to cook than white rice, the nutrient-dense layers are rich in vitamins and minerals (Xin et al., 2014). Brown rice grains have a chewy texture when cooked. They impart a pleasant, slightly nutty flavour in any dish. The nutritious bran layers are left on brown rice so it can retain its natural goodness and tan colour. Rich in vitamins and minerals, brown rice is a 100 percent whole grain food. It is one of the versatile rices that becomes light and fluffy when cooked. This ensures that the grains are not stuck together.

Forbidden rice is high in nutritional value. This rice is also known as black rice and has a mild nutty flavour. Slightly sticky when cooked, it is used in a variety of Chinese or Thai dishes, including Chinese black rice cake and mango sticky rice (Xin et al., 2014). Mix it with white rice, and it also adds colour to any rice pilaf or rice bowl. In relation to wild rice grains, they are harvested from the genus Zizania of grasses. High in protein, wild rice adds a colourful, exotic flair to any rice dish. Serve it with stir frys, mushroom soups, or casseroles for something new.

Lastly, rice can be classified based on the aroma. Aroma is a factor to consider when cooking with rice, because certain rice varieties give off pleasing fragrances while being cooked. Figure 4 shows two of such rice that are classified based on aroma.

A = Basmati rice B = Jasmine rice

Figure 4: Classification of Rice by Aroma

The first to consider is Basmati rice, which is a type of long-grain rice that is popular among Indian cuisine and other ethnic dishes. Cooked basmati rice imparts a subtle nutty or popcorn-like flavour and aroma. Jasmine rice, sometimes known as Thai fragrant rice, is also a type of long grain rice with a long kernel and slightly sticky texture when cooked. One can use it to infuse a subtle jasmine flavour and aroma into his/her dishes. Cultivated in Thailand, jasmine rice will bring an exotic flair and flavourful accent to any dish. It develops a pleasant jasmine aroma while it is cooking. It is used for making a variety of traditional Asian dishes, including curries and stir-frys, since the moist, soft texture is ideal for soaking up spices and flavours.

Rice Popularly Consumed in Ghana

Rice (Oryza sativa) is a dietary staple foods and one of the most important cereal crops, especially for people in Asia, but the consumption outside Asia has increased, recently (Brown et al., 2015). According to Akoto (2015), the main rice types produced in Ghana are Oryza Sativa and Oryza Glaberima. Rice production in Ghana increased from 0.09 and 0.16 million hectares while yields fluctuated between 1.7 and 2.7 tonnes per hectare. It however, appears that from 2007, rice production has been on the increase with 2010 production levels being more than double 2007 levels, from 185 300 tonnes in 2007 to 491 600 tonnes in 2010, with average annual growth of more than 15 percent over the period, despite the production drop experienced in 2007 (Wormenor, 2015). Reasons for this increase could be attributed to the favourable rain patterns as well as the 2008 Fertilizer subsidy programme, and the Block Farm programme of 2009 which were also contemplated in the production of Ghana Rice strategy.

Most of the rice cultivated in Ghana is from low-quality seed with mixed varieties, which brings about uneven maturity at harvest and wide variations in the size and shape of rice grains (Wormenor, 2015). Generally, this results in a gap between the quality of local and imported rice. In Ghana, rice is considered to be among the main staples with rice consumption in 2013/14 estimated to reach 64,000 MT (Wormenor, 2015). Most researchers are of the view that polished rice, perfumed rice, and brown rice are the most consumed rice in Ghana (Akoto, 2015; Wormenor, 2015).

Per capita consumption of rice in 2015/2016 is pegged at about 32.8 kg with urban areas accounting for about 79.2 percent of total rice consumption (Rahaman, 2017). In urban areas, rice is preferred over other staples as it is easy and convenient to prepare and it allows for a wide variety of dishes. Additionally, the rising number of fast food restaurants and vendors in the major cities has increased the demand for rice. Rice consumption, especially polished and perfumed rice, in rural areas is much lower than in urban areas and thus less vulnerable to price fluctuations (Rahaman, 2017). The increase in demand for rice can be attributed in a large part to rapid urbanisation and ease of cooking and storage. Imported rice is also perceived to be of better quality than local rice and thereby reported to command higher prices.

Furthermore, in Ghana, local rice production hardly meets the annual rice demand of the people. That is, domestic production of rice in Ghana has been less than consumption needs, for a long period of time. Demand for rice began to outstrip supply due to population increase and improved standard of living. Other problems include low yields and low profitability, reduction of the productive capacity of the soil, coupled with over liberalisation of rice trade in Ghana, locally cultivated rice is often unattractive to prospective buyers or consumers, and sometimes not available to them at all.

Unreliable production and marketing arrangements have also contributed to the poor production of local rice in Ghana. As a result, rice imports have been increasing steadily since 1980s and now accounts for more than 50 percent of all rice consumed in the country (Rahaman, 2017). The author contrived that rice is central to Ghana's economy and agriculture, accounting for nearly 15 percent of Gross Domestic Product (GDP). This may mean that the perception that Ghana has low average annual rice consumption per capita, compared with most West African countries, is a notion of the past. This could be said to have been the case when Ghana had consumption per capita of about 9kg, while the average for other countries in the same sub-region was 25kg (Akanko as cited in Rahaman, 2017).

Notwithstanding the seemingly high production, the government of Ghana imports up to 200 percent of rice from other countries to compensate for short falls in supply (Dogbe as cited in Wormenor, 2015). The imported rice largely comprise of polished, perfumed and brown rice which are considered to be the most popularly consumed types of rice in Ghana (Akoto, 2015). Rice is by every account an important crop in the Ghanaian.

Rice and Nutrition

Rice is central to the lives of billions of people around the world. It provides 21 percent of global human per capital energy in 15 percent of per capital protein (Bjorck, Granfledt, Liljeberg, Tovar & Asp, 2013). Rice is basically composed of carbohydrate in the form of starch which account for about 90 percent of the total dry weight and 81 percent of the total caloric content. The starch is made of long chains of glucose known as amylose and amylopectin that contributes to the texture and digestibility of rice. Rice has given a wide range of results in GI and GL when studies around the world were compared (Akoto, 2015; Brown et al., 2015; Jahan, 2013; Lu, 2016; Passos et al., 2014; Rahaman, 2017).

The GI of white rice has ranged from as low as 54 to as high as 121 when bread was used as the reference food (Jenkins et al. as cited in Jenkins, 2012). This makes it difficult to classify rice as a high or low GL food. Recent findings however, revealed that rice-eating pattern including consumption of white rice per se or combined with beans or grain could have different effect on the risk of the metabolic syndrome (Passos et al., 2014). Consumption of rice with bean and multi- grains compared to white rice was significantly related to lower risk or central obesity and impaired fasting glucose (Akoto, 2015).

Rice provides the bulk of daily calories for many companion animals and humans (Cheng et al., 2012). In fact, rice has greater variability of the GI depending on type, and cooking method. The unique taste of rice makes it easy to combine rice with other foods to achieve better taste and nutritional balance. Some studies revealed some health effects of rice and its products (Brown et al., 2015; Lu, 2016; Rahaman, 2017). The pigment of certain rice can inhibit the formation of atherosclerotic plaque, because it has anti-oxidative or anti-inflammatory effects. Rice is also considered to be a potential food vehicle for the fortification of micronutrients because of its regularly consumption (Rahaman, 2017).

According to Rahaman (2017), other studies have also emphasized that combinations of white rice with whole grain including barley or brown rice was accompanied by better postprandial outcomes including reduced postprandial levels of glucose, insulin and ghrelin, as well as better control and improvement of lipid profiles and antioxidant enzymes activity. Although most related studies provide evidence that high consumption of white rice is associated with undesirable metabolic outcomes, potential mechanisms have not explained clearly (Rahaman, 2017).

The concept of GI has shown that foods similar in carbohydrate content do not usually have the same impact on blood glucose levels (Rahaman, 2017). According to Rahaman (2017), since glycemic response is affected by amount of consumed carbohydrate, GL has been considered a better parameter to quantify the impact of carbohydrate in the glycemia. This has motivated the researcher to determine the GL of various types of rice popularly consumed in Ghana so as to serve as a better parameter to know their postprandial glucose response.

Implications of Glycemic Index and Glycemic Load on Health Nutrition

The rate of glucose being released into the bloodstream and the duration of the rise in postprandial blood glucose levels is known to cause many hormonal and metabolic changes that could affect health and disease parameters (Gannon, Nutall, Neil & Westphal, 2012). A recent systematic review and meta-analysis by George (2015) showed reduced risk markers related to persons who are overweight, obese, and diabetic or at risk of coronary heart disease when low GI/GL diets were used in the intervention. This meta-analysis was done by collecting data from 45 controlled dietary intervention trials. The findings show that diets with high GI/GL are independently associated with increased risks of developing obesity, type two diabetes, and cardiovascular disease.

The GL has been used to study whether or not high GL diets are associated with increased risks for type two diabetes and cardiac events. In a large meta-analysis of 24 prospective cohort studies, researchers concluded that people who consumed lower GL diets were at a lower risk of developing type two diabetes than those who ate a diet of higher GL foods (Livesey, Taylor, Livesey & Liu, 2013) Similar type of meta-analysis concluded that higher GL diets were also associated with an increased risk for coronary heart disease events (Mirrahimi et al., 2012).

Based on the glucostatic theory of food intake regulation introduced by Meyer (as cited in Arvidsson-Lenner et al., 2014), low blood glucose is one of the metabolic signals for hunger. However, later studies showed that the transient decline in blood glucose rather than the absolute blood glucose concentration, gives a signal to glucostatic receptors in the central nervous system that fuel is low and the body needs to be replenished (Livesey et al., 2013; Walker, 2014). Livesey et al. (2013) added that the more rapid the decline in blood glucose following a meal-induced peak, the higher the hunger ratings. Therefore, insulin-induced hypoglycemia caused by high-GI food consumption can encourage over-eating and hence promote weight gain as the body homeostatic system attempts to restore energy. On the other hand, low-GI foods minimize postprandial insulin secretion, promote satiety and therefore, lower subsequent voluntary food intake (Ludwig, 2012; Brand et al., 2016).

Glycemic Index, Glycemic Load and Diabetes

The original purpose of GI was to supplement the existing carbohydrate exchange list used by people with diabetes in meal planning, so that the patients could have an appropriate intake of glucose according to their physiological requirement (Jenkins et al., 2002). However, Gilbertson's group suggested that low-GI dietary approach could provide a better quality of life for patients with type 1 diabetes compared with carbohydrate exchange dietary approach (Similä, 2012). According to Similä (2012), low GI diets can help by improving the glycemic control and reducing demand on the pancreatic beta cell in the post-prandial period. Low-GI diets elicited lower concentrations of glucose and insulin. Jenkins (2012) added that patients with type 2 diabetes who consumed low-GI diets have lower plasma glucose and insulin compared with a high-GI diet.

This shows that the consumption of high-GI and -GL diets for several years might result in higher postprandial blood glucose concentration and excessive insulin secretion. This might contribute to the loss of insulin-secreting function pancreatic β-cells and lead to irreversible type 2 diabetes mellitus (Willett, Manson & Liu, 2012). High-GI and -GL diets have been associated with an increased risk of type 2 diabetes in several large prospective cohort studies. A recent updated analysis of three large US cohorts indicated consumption of foods with the highest versus lowest GI was associated with a risk of developing type 2 diabetes that was increased by 44 percent in the Nurses' Health Study (NHS) I, 20 percent in the NHS II, and 30 percent in the Health Professionals Follow-up Study (HPFS) (Bhupathiraju, Tobias & Malik, 2014). Bhupathiraju et al. (2014) further found out that high-GL diets were associated with an increased risk of type 2 diabetes (+18%) only in the NHS I and in the pooled analysis of the three studies (+10%).

Additionally, the consumption of high-GI foods that are low in cereal fibre was associated with a 59 percent increase in diabetes risk compared to low-GI and high-cereal-fibre foods. High-GL and low-cereal-fibre diets were associated with a 47% increase in risk compared to low-GL and high-cereal-fibre diets. Moreover, obese participants who consumed foods with high-GI or -GL values had a risk of developing type two diabetes that was more than 10-fold greater than lean subjects consuming low-GI or -GL diets (Bhupathiraju et al., 2014).

Glycemic Index, Glycemic Load and Obesity

Low-fat, high-carbohydrate diets are recommended for the prevention and management of overweight. Obesity and overweight have increased during the last decade despite declines in fat intake. It is possible that some high-carbohydrate diets are counterproductive to weight control because of their high-glycemic nature. Consumption of high-GI foods is associated with lower satiety and reduced access to fat as a source of fuel (Bahado-Singh et al., 2013). By contrast, low-GI foods could enhance weight control because they promote satiety, minimize postprandial insulin secretion, and increase fat oxidation. Sixteen studies have shown that low-GI foods are more satiating, delay the return of hunger, or decrease subsequent food intake (Ludwig, 2012).

Dietary high-GI index foods promote carbohydrate oxidation at the expense of fat oxidation in the postprandial period. As a consequence, they alter fuel partitioning in a way that may be conducive to body fat gain. Respiratory quotient values and glycogen stores are higher after consumption of high-GI carbohydrates (Febbraio, 2014). This suggests that there is greater reliance on carbohydrate as a source of fuel. A connection between high-GI diets and obesity is also supported by a small number of intervention studies in humans showing that energy-restricted diets based on low-GI foods produce greater weight or body fat loss than equivalent diets based on high-GI food (Spieth, Harnish & Lenders, 2014).

Glycemic Index, Glycemic Load and Cardiovascular Disease

High level of postprandial blood glucose after the consumption of high-GI diet may affect risk for cardiovascular disease. According to DeVegt (as cited in Dodd, 2016), there is a significant relationship between cardiovascular death and post-load blood glucose concentrations in subjects with normal fasting glucose concentration after adjustment for known risk factors. A higher GL, but not protein or fat intake, has a strong association with an increased risk of cardiovascular disease (relative risk of 1.9 comparing highest and lowest quintiles of GI) after multivariate adjustment (Dodd, 2016). Hyperinsulinemia, which is caused by hyperglycemia with the presence of insulin resistance, is associated with dyslipidemia high very low-density lipoprotein (VLDL) cholesterol, high triglycerides, and low high-density lipoprotein (HDL). This is because numerous studies have shown a high-GI diet is negatively associated with HDL-cholesterol and positively associated with triglyceride levels.

Based on the above submissions, one may argue that Ghanaians who consumed high-GI/GL diets had a lower high-density lipoprotein cholesterol level. Fajkusova et al. (2017) study showed that when saturated fat was replaced by carbohydrates, with no change in caloric intake, subjects had a significant decrease in HDL-cholesterol and an increase in triglyceride concentration. In contrast, low-GI diets have beneficial effect on lipid metabolism (Jenkins et al., 2015). This result is echoed in a study by Gross, Li, Ford and Liu (2014) which indicated that low-GI diets may outweigh the conventional low fat diet recommended by the American Heart Association in prevention and treatment of CVD.

Empirical Review

To understand the current concepts and issues under study much better, the issues were reviewed empirically. This helped in gaining better knowledge on the issues by means of direct and indirect observation or experience of previous researchers or studies. The record of other researchers' observation or experience were critiqued and analysed quantitatively and qualitatively to gain more information about the issues under investigation. The review of empirical studies concentrated on the implications of GI and GL on health nutrition of consumers. Effects of some background characteristics such as gender and age were also considered.

Similä (2012) examined the GI in epidemiologic study of type 2 diabetes. Type 2 diabetes prevalence and costs related to this are on the rise. The carbohydrates inducing a rapid postprandial elevation in blood glucose have been suggested to increase diabetes risk. GI classifies foods based on their postprandial blood glucose response compared with the response of reference food (glucose solution or white bread). GL on the other hand is a measure of both quantity and quality of carbohydrates. The aim of Similä's (2012) study was to investigate the associations between dietary GI, GL, and intake of high-, medium-, and low-GI carbohydrates and the risk of type 2 diabetes. The study also evaluated the applicability of GI to epidemiologic studies.

In a postprandial study (n=11), variations in glycemic responses and GI values of foods were examined and the effects of methodologic choices on variation compared (capillary and venous sampling, white wheat bread and glucose solution as reference foods, and repeating the reference measurement). Both within-subject and between subject variation was considerable. The variation was smaller when capillary samples were used and when the reference food was tested at least twice. Similä (2012) compiled the GI database for dietary GI and GL calculation for the Alpha-Tocopherol, Beta-Carotene Cancer Prevention (ATBC) study participants. The GI values were obtained from the GI measurement laboratory of the National Institute for Health and Welfare and from publications meeting the methodologic criteria. The ATBC Study cohort comprised 25,943 male smokers, aged 50-69 years, among whom 1,098 diabetes cases were identified from the national drug reimbursement register during a 12-year follow-up. Diet was assessed by a validated food frequency questionnaire.

The relative risks (RRs) and confidence intervals (CIs) for diabetes were analysed using Cox proportional hazard modelling, and multivariate nutrient density models were applied to examine the substitutions of macronutrients. Similä (2012) found out that dietary GI and GL were not associated with diabetes risk: RR (and 95% CI) for the highest versus the lowest quintile in the multivariate model was 0.87 (0.71, 1.07) for GI and 0.88 (0.65, 1.17) for GL. Substitution of low-GI (GI<55) carbohydrates for an isoenergetic amount of high-GI (GI"70) carbohydrates or low-GI carbohydrates for medium-GI (55<GI<70) carbohydrates was not associated with diabetes risk. Substitution of medium-GI carbohydrates for high-GI carbohydrates was inversely associated with diabetes risk (RR 0.75 (0.59, 0.96).

Furthermore, Similä (2012) found out that the total carbohydrate intake (as percentage of total energy intake, E%) was inversely associated with the incidence of diabetes, RR 0.78 (0.64, 0.94). Moreover, a higher intake of medium-GI carbohydrates was associated with lower diabetes risk, RR 0.69 (0.57, 0.84). Intake of neither high- nor low-GI carbohydrates was associated with diabetes risk. Also, total carbohydrate substitutions for total fat and protein were inversely associated with diabetes risk, the multivariate RRs for 2 E% substitution were 0.96 (0.94, 0.99) and 0.85 (0.80, 0.90), respectively. Carbohydrate substitution for saturated plus trans fatty acids, but not unsaturated fatty acids, was inversely associated with diabetes risk. Carbohydrate substitution for total, meat, or milk protein was associated inversely with diabetes risk, independently from GI (Similä, 2012).

Similä (2012) further realised that within-subject and between-subject variations in measured food GI were considerable. In addition, the same total dietary GI and GL results from several different food combinations, thus reflecting different properties of the diet, not only the carbohydrate quality. These factors limit the possibilities of epidemiologic studies to observe reliable associations between glycemic effects of diet and disease risk. In this study population, GI was not associated with diabetes risk. A higher percentage of carbohydrate intake was associated with decreased diabetes risk; the risk was lowered when fat or protein was replaced with carbohydrates (Similä, 2012).

Diabetes is a metabolic disorder with many potential complications over the long term. Therefore, any measure either to prevent precipitation of the disease or to alleviate the ailment is always a great help to diabetics. Since it is not possible to prevent or cure diabetes completely, it can be kept under control through appropriate diet therapy. It is always preferable to modify the diet based on individual life style considering the traditional eating pattern and food habits. Hence, Jahan (2013) selected commonly consumed south Indian breakfast product idli made with rice rawa and jowar rawa for his study. The raw materials were procured from a local market in Hyderabad. Initially 15 members were selected from Vasantha Nilayam Ladies hostel at Angrau campus within the age group of 22-23 years. Subjects were excluded if they reported a history of gastrointestinal disorders, suffered from diabetes, were taking medication for any chronic disease conditions, or intolerant or allergic to any of the foods. Finally, ten healthy subjects were identified for the study from the initial 15 members.

The GI of the breakfast product-idli made with rice rawa and jowar rawa was assessed in non-diabetic young subjects using blood sampling schedule and method of incremental area under the curve (IAUC) using glucose as reference food. The IAUC of rice rawa idli was 592.5 mg/dl against the glucose value of 1110 mg/dl. The GI of the rice rawa idli was 56.3, which is considered as medium GI food. The 50g of carbohydrate can be taken in one serving i.e. five medium sized rice rawa idlis. The GL of the experimental rice rawa idli was calculated as 26.65, which is considered as high GL (Jahan, 2013).

Jahan (2013) further found out that the IAUC of rice jowar idli was 562.5 mg/dl against the glucose value of 1110 mg/dl. The GI of the jowar rawa idli was 51.2, which is considered as low GI food. The 50g of carbohydrate can be taken in one serving, that is six medium sized jowar rawa idlis. The GL of the experimental jowar rawa idli was calculated as 25.3, which is consider as high GL. Also, the In Vitro Starch Digestibility (IVSD) value of rice rawa idli 18.9 and IVSD value of jowar rawa idli 20.92. Vitro Starch Digestibility value of rice rawa idli is lower than IVSD value of jowar rawa idli. The correlation value of the GI and IVSD of the idli made with rice rawa is 0.899 which is found significant at 5 percent level and similarly the jowar rawa idli is calculated and the value is 0.849 which is found significant at five percent level.

In addition, results that emerged from Jahan's (2013) study indicated that the least glycemic response was observed with jowar rawa idli. Thus, the inclusion of jowar based breakfast product-idli may be recommended to the habitual diet for achieving a good glycemic control in diabetics. These findings should assist in development of high fibre and GI sorghum products with good amount of IVSD, which will help in development of functional foods.

Rohman, Helmiyati, Hapsari and Setyaningrum (2014) also investigated rice in health and nutrition. Rice is a dietary staple food and one of the most important cereal crops, especially for people in Asia. On one hand, the consumption of rice is associated with diabetes mellitus due to its high GI. On the other hand, some of rice's components namely rice bran and rice bran oil contained some minor components which are reported to have some biological effects.

Rice can be contaminated by toxic elements such as arsenic and mercury coming from water and land in which it grows. Besides, some mycotoxins and mould can be present in rice. Therefore, some governments control rice available in their market. Rice bran will produce rice bran oil and defatted rice bran. Defatted rice bran component consists of a number of polysaccharide and dietary fiber that support in cancer and cardiovascular diet therapy. The review of Rohman et al. (2014) covered some new research information on rice, rice bran and rice bran oil, especially in the biological activities and nutritional aspects to human. Such biological activities which are related to rice and its products are decreasing low density lipoprotein level, lowering cholesterol, reducing blood pressure (BP) and preventing colorectal cancer. The current study also focused on four types of rice popularly consumed in Ghana with regard to their GI and GL, and the implications of these on health and nutrition of consumers. Therefore, it is appropriate to consider most popular food consumed in a particular geographical area.

Furthermore, Passos et al. (2014) considered rice and beans which is one of the most popularly consumed foods in Brazil. The "baião de dois" is a typical Brazilian dish and a rich combination of rice and beans. This preparation has a high nutritional value but its effect on glycemic response is not yet studied. Determining the GI and GL of foods can help prescribe diets and as a result, improve the treatment and prevention of chronic diseases. Passos et al. (2014) study aimed to assess the GI and GL of "baião de dois". Following the protocol recommended by the Food and Agriculture Organisation (FAO), six (6) volunteers were recruited to perform blood glucose tests. Each volunteer performed three glucose tolerance tests and a test with “baião de dois”. All tests were undertaken in separate weeks.

Through the calculation of the areas under each of the curves, it was possible to assess the GI of “baião de dois” by the average values of six GIs found for each volunteer. It was calculated based on the GL of each portion tested and recommended savings per capita. Passos et al. (2014) found that “baião de dois” had low GI (44) and GL (6) at the recommended per capita, but high GL (22) at the portion tested (bigger than the recommended). The “baião de dois” do not present a potential risk for developing chronic diseases, but its recommended consumption is to be monitored.

In relation to Ghana, one may argue that the eating patterns of Ghanaians are changing due to urbanisation, globalisation, economic trends, as well as changes in social structure as a result of the increasing number of women working outside the home (Akoto, 2015). These changes in eating patterns include higher consumption of snack foods by all age groups. A snack food is often smaller than a regular meal and normally consumed between meal times. Among cereal-based snacks, wheat and corn are the most popularly used cereals as compared to rice. Locally grown and milled rice tends to be poorly patronised by consumers in Ghana due to quality defects, so incorporating this low grade rice into a ready to eat snack would provide an avenue for using the commodity which may otherwise be underutilised. Akoto’s (2015) study sought to develop a rice-soybean snack from low grade rice (parboiled or raw form) using extrusion-cooking technology.

Rice and partially defatted soy flour blends of composition (75:25-90:10) were obtained based on ratios that were determined using constrained mixture designs for two components. In all twenty formulations were obtained and extruded using an intermeshing co-rotating twin screw extruder at constant screw speed of 1000rpm, barrel temperature of 200^{o}C and a circular die diameter of 4mm. Evaluation of consumer sensory preference was carried out using a nine (9) point hedonic scale to obtain five most preferred extrudates with high percentage of rice (TMF3 (90% raw Togo Marshall (TM), 10% partially defatted soybean (PDS); TMF4 (75% raw TM, 25% PDS); TMF5 (82.5% raw TM, 17.5% PDS); PTMF3 (90% parboiled TM, 10% PDS); PTMF4 (75% parboiled TM, 25% PDS) for further analysis (Akoto, 2015). Physicochemical analysis on the five extrudates showed that increasing amount of PDS and rice parboiling treatment generally decreased expansion ratio, lightness and increased hardness.

For characterisation of proteins, amount of PDS and rice parboiling treatment had a substantial effect on accessible thiols, protein solubility and electrophoretic patterns. Extrudate made using 75% raw rice and 25% PDS (TMF4) showed the least protein digestibility suggesting the presence of antinutritional factors such as trypsin inhibitors. Akoto (2015) used Principal Component Analysis (PCA) to discriminate extruded snacks based on odour and taste from data obtained from electronic nose and tongue analysis. Taste characteristics were discriminated based on umami, saltiness, bitterness, sourness and astringency. It was concluded that amount of PDS and rice treatment has a significant effect on the physicochemical properties of the extrudates.

The discussion so far shows that high habitual dietary GI and GL may relate to elevated insulin resistance and therefore may be more important and relevant in populations known for high prevalence of insulin resistance. George (2015) investigated the dietary GI, GL and insulin resistance of a sample of healthy South Asians in Glasgow, UK. A total of 111 healthy individuals: 60 males, 30 South Asians and 30 Europeans; 51 females, 22 South Asians and 29 Europeans were sampled. Estimation of dietary GI and GL from weighed food intake records considered the GI values of single foods and mixed-meals from relevant publications and from laboratory food/mixed-meal GI measurements. The GI of key staple South Asian foods alone (chapatti, rice, pilau rice) and as mixed meals with curried chicken was measured using standard methods on 13 healthy subjects. The key staples had medium GI (chapatti, 68; rice, 66 and pilau rice, 60) and glycaemic responses to the mixed-meal of staples with curried chicken were found to be lower than the staples eaten alone. GI of the mixed-meals fell in the low GI category (chapatti with curried chicken, 45 and pilau rice with curried chicken, 41).

Weighed food intake records (WFR) (recorded for 3-7 days) and self-administered previously validated food frequency questionnaires (FFQ) (applied to habitual food intakes in the past 6 months) was assessed for agreement through correlation analyses, cross-classification analysis, weighted Kappa statistics and Bland and Altman statistics. The two methods mostly agreed in carbohydrate (CHO) food intakes implying that the WFR reflected habitual intakes (George, 2015). In consideration of potential confounding effect of physical activity on the relationship between dietary variables and HOMAIR, physical activity level (PAL) and Metabolic equivalent score (METS) of main daily activities of study subjects were derived from self-reported physical activity records (George, 2015). Mean PAL were similar between South Asian and European males (median PAL of 1.61 and 1.60, respectively) but South Asian females tended to be less physically active than European females (mean PAL of 1.57 and 1.66, respectively). South Asians were less physically active in structured exercise and sports activities, particularly South Asian females and South Asians (males and females combined) with reported family history of diabetes showing inverse relationships between daily energy expenditure and HOMAIR.

The findings that emerged from George's (2015) study revealed that South Asians were more insulin resistant than Europeans (HOMAIR median (IQR) of 1.06 (0.58) and 0.91 (0.47), p-value = 0.024 respectively in males; mean (SD) of 1.57 (0.80) and 1.16 (0.58), p-value = 0.037, respectively in females) despite similarities in habitual diet including dietary GI and GL. The mean habitual dietary GI of South Asians was within the medium GI category and did not differ significantly from Europeans. South Asian and European males' dietary GI (mean, SD) was: 56.20, 2.78 and 54.77, 3.53 respectively; p-value=0.086. South Asian and European females also did not differ in their dietary GI (median, IQR) was: 54, 4.25 and 54, 5.00; p-value = 0.071). Top three staples ranked from highest to lowest intakes in the South Asian diet were: unleavened breads (chapatti, Naan/Pitta, Paratha), rice, bread (white, wholemeal, brown), and potatoes. After statistically controlling for energy intake, body mass index, age, physical activity level and socio-demographic status, an inverse relationship (Spearman partial correlation analyses) between dietary GI and HOMAIR was observed (r, -0.435; *p*-value, 0.030) in South Asian males.

This may be explained by the observation that the lower the dietary GI, the lower, the total carbohydrates and fibre intakes and the higher the fat intake. In South Asian females, dietary GI and GL respectively, did not relate to HOMAIR but sugars intake related positively with HOMAIR (r, 0.486; *p*-value, 0.048). South Asian females, compared to European females, reported higher intakes of dietary fat (38.5% and 34.2% energy from fat, respectively; *p*-value=0.035). Saturated fatty acid (SFA) intakes did not differ between ethnic groups but SFA intakes were above the recommended level of 10% of total dietary energy for the UK in all groups, the highest being in South Asian females (George, 2015).

Based on the key findings that emerged from the study, George (2015) concluded that ethnicity (South Asian), having family history of diabetes, the wider diet profile rather than habitual dietary GI and GL alone (low GI, low fibre and high fat diets in males for instance; and high fat, high sugar diets in females) as well as low physical activity particularly in structured exercise and sports may contribute to insulin resistance in South Asians. These observations should be confirmed in larger future studies.

Furthermore, looking at the implications of GI and GL on health nutrition, one may argue that a high prevalence of Type 2 diabetes exists in most modern societies. According to Brown et al. (2015), this situation is now prevalent in Saudi Arabia. Epidemiological evidence suggests that low GI diets reduce diabetes risk. Yet, little is known about the GI of traditional Saudi Arabian staples such as Hassawi rice (HR). HR was evaluated in terms of its GI and insulinaemic indices (II). Comparisons were made *in vitro* assessing glucose released enzymatically. A long grain rice variety available in both the UK and Saudi was studied as a comparison.

For GI and II measurements, HR, Uncle Ben's rice (UBR) and a standard glucose solution were consumed by healthy subjects (n=13) on seven (7) randomised occasions. Capillary bloods were collected at specific times over two hours after food intake. FAO/WHO protocols were employed to determine GI and II. For the *in vitro* studies, cooked rice was incubated with hydrolytic enzymes under standardised conditions. Samples were taken at t=20 and t=120 min and rapidly available glucose (RAG) and slowly available glucose (SAG) were computed. Brown et al. (2015) found out that values of RAG and SAG were lower for HR compared to their respective values for UBR (p<0.001 & p=0.011, respectively). However, no significant difference was observed for GI (p>0.05) despite a lower insulin response noted for HR (p=0.007).

Brown et al. (2015) concluded that HR had a similar GI to UBR although a lower insulin response was evident. RAG and SAG values were different for the two rice varieties despite similar GI values. These differences may be important in terms of their metabolic impact and outcome on diabetes. However, the study failed to examine the impact of gender and age on the GI and GL of the participants. The current study examines the impact of these two background characteristics on the GI and GL of participants with regard to the four types of rice that will be examined.

Studies have supported the protective effect of high fruit consumption in the management of chronic diseases such as diabetes. Oboh et al. (2015) sourced for 13 fresh tropical fruits and the fruits juices were extracted, freeze dried, and then reconstituted for analysis. The sugar, starch, amylose, and amylopectin contents as well as glycemic indices, antioxidant properties, and the ability of the fruits to inhibit starch-hydrolyzing enzymes were determined. Also, the phenolic constituents of the fruits were characterised using high performance liquid chromatography coupled with diode array detector.

The findings that emerged from Oboh et al. (2015) study showed that the starch, sugar, amylase, and amylopectin contents were 3.01e3.89 g/100 g, 35.34e60.91 g/100 g, 0.84e1.46 g/100 g, and 1.68e2.86 g/100 g, respectively, while the glycemic indices were 28.01 e68.34, with African star apple (28.01) having the lowest and watermelon (68.34) the highest. Furthermore, the fruits exhibited high antioxidant properties as exemplified by their DPPH, ABTSþ, _OH, and NO radical scavenging abilities. Likewise, the fruits also demonstrated a-amylase and a-glucosidase inhibitory property with Soursop (IC50 ¼ 18.52 mg/mL), guava (IC50 ¼ 19.77 mg/mL), and African star apple (IC50 ¼ 20.86 mg/mL) showing the highest inhibitory potential among the 13 fruits. Similarly, the same trend was followed for a-glucosidase inhibitory activity. This shows that the fruits' low glycemic indices, strong antioxidant properties, and inhibition of a-amylase and a-glucosidase activities could be possible mechanisms for their use in the management and prevention of type-2 diabetes.

Choi (2016) also examined GL and risk of Alzheimer's disease, focusing on the cache county study on memory, health, and aging. According to Choi (2016), carbohydrates are a major energy source for the human body and particularly glucose is the only energy source for the brain. Thus glucose metabolism is important to maintain normal brain function. Evidence showed insulin resistance and diabetes are associated with cognitive decline and a large amount of highly processed carbohydrate intake; in other words, a high GL diet, which increases blood glucose faster and insulin demand, is associated with increased risk of insulin resistance and diabetes (Choi, 2016).

Based on this premise, the hypothesis that a high GL diet increases the risk of incident Alzheimer's disease (AD) was examined among Cache County elderly people in Northern Utah by Choi (2016). At the baseline survey, 3,831 participants 65 years of age or older completed a food frequency questionnaire (FFQ) and cognitive screening. Observation time to collect the data for incident AD was approximately 10 years. Incident AD was determined by final consensus conference after multi-steps of screening. GL was calculated as the product of carbohydrate intake and GI and adjusted for energy intake. FFQs from diabetics were considered to be invalid to assess dietary carbohydrates intake and excluded. The analysis of Choi's (2016) study was examined separately by gender.

The Cox proportional hazard regression model in survival analysis was used to relate GL to incident AD using a time variable with age of AD onset.

There was no association in men but a negative association in women in the unadjusted model (Choi, 2016). Evidence of confounding by total kcal was apparent in women, particularly in the lowest GL group, which had the highest total kcal mean intake. Finally no association between GL and AD was found after adjustment for education, myocardial infarction (MI), stroke, Body Mass Index (BMI), physical activity, smoking, alcohol use, APOE ε -4 alleles, multi-vitamins use, total kcal, and controlling interaction between GL and total kcal. The low GL group had unique characteristics in lifestyle factors, macro-nutrients intake, and pattern of food use. The inverse relationship between GL and total kcal may partly be explained by lifestyle factors, particularly alcohol intake. The characteristics of low GL group, current smokers, alcohol users, and their relationship and interaction between total kcal and risk of AD should be explored further (Choi, 2016).

Delport (2016) also conducted a comparative study in two parts. The objective of the first part was to compare the mean GI-values of two foods, i.e. Muesli (M) and Apple juice (A) from a mixed group of subjects (healthy, type 1 and type 2 diabetic), using the Medisense Precision QID Glucometre (MPQIDG) extra-laboratory (EL) to the mean GI-values of the same two foods from a group of healthy subjects intra-laboratory (IL), using laboratory equipment (YSI Analyser or YSI) and the MPQIDG, and determine whether the former method is an acceptable alternative for the latter. The study also compared the area under the curve (AUC), their means and GI values of each healthy subject, using the YSI and MPQIDG (IL).

In relation to subjects and methodology, Delport (2016) made use of a group of 12 trained subjects, aged 29-54 years (41+7), BMI 18-30 kg/m2 (24+4), which were tested IL (Group 1) under well-controlled conditions, as recommended by the FAO/WHO. (3) M and A were each tested once and the reference food (glucose) was tested on 3 occasions, using the MPQIDG and the YSI. Capillary blood glucose of participants was measured when they fasted for every 15min for 2h, after the glucose/test food was consumed (diabetic subjects measured blood glucose concentrations over 3h). Mean GI-values of M and A, obtained IL by Group 1 were compared to the mean GI-values of M, obtained EL by a mixed group of subjects (Group 3), and of A, obtained EL by another mixed group of subjects (Group 4), and the mean GI-values of M and A, obtained EL by the group of 12 healthy subjects (Group 2), using ANOVA. The AUC and GI values of each healthy subject of Group 1 were compared using Pearson's correlation coefficient (r). Lin's concordance correlation coefficient (rc) was used for testing agreement (4). Statistical significance was set at p=0.05.

The findings that emerged from Delport's (2016) study show that the mean GI-values of M and A, as determined by Groups 1, 2, 3 and 4 (using ANOVA) did not differ significantly for M (p = 0.2897) and A (p = 0.8454). Pearson's correlation coefficient (r) was acceptable and significant for the AUC-values of Glucose 1 (r = 0.7; p = 0.0081), good and significant for the GI-value of A (r = 0.8; p = 0.0043) and very good and highly significant for the AUC-values of Glucose 2 (r = 0.9; p<0.0001), Glucose 3 (r = 0.9; p<0.0001), M (r = 0.9; p<0.0001) and A (r = 0.9; p<0.0001) and the GI-value of M (r = 0.9;p = 0.0003), respectively, after removal of outliers. The mean AUCMPQIDG of all the foods tended to be higher than the mean AUCYSI, after removal of outliers, but this was not significant (p = 0.69301; p = 0.20838; p = 0.43311; p = 0.32926; p = 0.49199 for Glucose 1, 2, 3 M and A, respectively). Lin's concordance correlation coefficient, which tests reproducibility/agreement (*rc*), was acceptable for the AUC-value of Glucose 1 (*rc* = 0.7) and the GI-value of A (*rc* = 0.7), good for the AUC-value of Glucose 2 (*rc* = 0.8) and very good for the AUC-value of Glucose 3 (*rc* = 0.9), M (*rc* = 0.9) and A (*rc* = 0.9) and the GI-value of M (*rc* = 0.9), respectively, after removal of outliers.

The objective of the second part was to compare the GI-values from a mixed group of subjects using the MPQIDG, EL with GI-values from a group of healthy subjects IL, using laboratory equipment laboratories A-E who took part in an inter laboratory study (39) and determine whether the former method is an acceptable alternative for the latter. A mixed group of 10 trained subjects (5 males: 2 diabetic and 3 healthy; 5 females: 3 diabetic and 2 healthy) were tested EL under well-controlled conditions, as recommended by the FAO/WHO. The test foods were White bread, Barley, Rice, Instant potato and Spaghetti (reference food: glucose). Capillary blood glucose concentrations were measured fasting and every 15min after the glucose/test food was consumed for 2h (healthy subjects) and 3h (diabetics), using the MPQIDG. Mean GI-values were compared to the weighted mean GI-values of the 5 laboratories (laboratories A–E), using the analysis of variance (paired t-test). The standard error (SE), confidence interval (CI) width and mean GI-values of each of the laboratories for each of the five foods were compared to the weighted means of the rest of the laboratories, for these parameters. The mean GI-values were also compared using ANOVA.

The findings that emerged from Delport's (2016) study were that the GI-values of all five foods for each laboratory were compared to the weighted means of the rest of the laboratories (including EL). There was no significant difference for laboratories A and B. There were significant differences ($p<0.05$) for one of the foods for laboratories D, E and EL and three of the foods for laboratory C, respectively. The results of the ANOVA test for variance confirmed these findings. Delport (2016) concluded that using a mixed group of subjects and the MPQIDG to conduct GI-tests EL seems to be an acceptable alternative to using a conventional group of subjects and laboratory equipment, IL.

The GI provides a measure of the rise in blood glucose following consumption of a test food relative to a reference food. Various associations have been found between certain dietary GIs and a number of diseases. GI has also been used to assist people with diabetes to choose foods that help to stabilise their blood glucose levels. The overall GI of a whole meal or diet has been estimated using a summation model of the individual components. The GI of each component is weighted according to its available carbohydrate contribution (Dodd, 2016). The validity of this model has not been thoroughly tested. Two simple meals of bread and beans have been used to test the model, with one study finding good agreement, and the other finding little agreement between predicted and observed GI. Therefore, the aim of Dodd's (2016) study was to robustly assess how well the summation model predicted the GI of typical mixed meals. A secondary aim was to compare the GI of three meals containing meat, vegetables and sauce that differed in their major carbohydrate source.

Thirty healthy participants aged between 21-49 years old were recruited from the public via posters and e-mails throughout the University of Otago. Fifteen people from each sex including ten from three age brackets (18-30yr, 30-40yr, 40-50yr) were recruited. Four reference glucose beverages (two 50g and two 25g), seven test foods (potato, rice, pasta, kumara, peas, carrots, sauce) and three meals containing potato, rice or pasta plus the other vegetables, sauce and 50g pan-fried chicken were tested by all participants. Dodd (2016) performed nutrient analysis to determine carbohydrate content of the seven test foods. Capillary blood glucose was measured before eating and over two hours post-prandially. Incremental areas under the blood glucose curve were calculated, and a mean GI was obtained for all foods and meals. Meal GI was predicted by inserting the observed GI for each food into the summation model and this was compared to the observed GI for each meal.

Mean (95% CI) GI values for the foods were: potato 72 (62, 85), rice 48 (41, 62), spaghetti 56 (48, 66), kumara 84 (72, 98), peas 29 (25, 34), carrots 31 (27, 36), and sauce 35 (30, 41). Dodd (2016) found out that the observed and predicted mean (95% CI) GI values for the potato, pasta and rice based meals were: 53 (46, 62) *cf* 63 (56, 70), 38 (33, 45) *cf* 51 (45, 56) and 38 (33, 44) *cf* 55 (49, 61) respectively. The predicted meal GIs were greater than the observed meal GIs in all three cases ($p<0.001$). The summation model overestimated GI by 19-45% when applied to mixed meals. Dodd's (2016) study provided reliable information regarding the ability of the summation model to predict a composite GI. Using measured and published GI values for foods resulted in significant and variable overestimation of measured meal GIs. Researchers using this model to predict meal or dietary GI should be aware of the limitations associated with the model.

Al-Jazzaf (2017) investigated the effects of different lifestyle strategies for reversing some of the lipid and lipoprotein abnormalities commonly known as an atherogenic lipoprotein phenotype (ALP) in groups at increased risk for cardiovascular disease (CVD), such as type 2 diabetes mellitus (T2 DM), the overweight and obese. These strategies included a low glycaemic index (GI) diet, energy restriction, a low carbohydrate Atkins diet, and increased exercise level. The diets were tested either alone or in combination to examine the potential for additive effects on outcome measures. The effects of a low GI diet, alone and in combination with energy restriction, were investigated in overweight/obese T2 DM patients in Kuwait. For this purpose, the glycaemic and insulinaemic indices of some staple foods in the Kuwaiti diets were determined to provide data from which low GI foods could be selected.

A standard WHO procedure was used for determining the GI and insulinaemic index (II) of seven types of bread and a type of white rice that are consumed extensively by the Kuwaiti population. Six of the breads in the Kuwaiti diet were shown to have GI values that fell within an intermediate GI range, which was comparable to the GI values of similar foods reported in the literature. The exception to this was brown pita bread which gave a high GI value and a relatively higher II value compared with glucose. Iranian bread also had a high II value compared to that of the glucose standard.

The effects of two low GI diets, with and without energy restriction, were examined on markers of CVD risk in overweight/obese T2 DM patients and compared with a control diet, in a six (6) weeks, randomised controlled trial. The average GI of the diet was reduced by 12 units in the intervention groups. An additive effect of weight loss in the energy-restricted low GI diet group was not shown because of the limited amount of weight loss in this group (3% reduction from baseline weight); a direct result of poor compliance. Both intervention groups produced similar effects that included a decrease in the concentration of plasma triacylglycerol (TAG) and increase in high density lipoprotein cholesterol (HDL-C). Glycaemic control, as measured by fructosamine levels, improved significantly in the low GI group compared to the control. Lowering the GI of the diet also resulted in a significant decrease in the proportion of small, dense LDL (sdLDL) and an increase in HDL2 (Al-Jazzaf, 2017).

Al-Jazzaf (2017) compared in his study the effects of a low-carbohydrate, 'Atkins' diet either alone, or in combination with an exercise programme, to provide evidence for the potential of exercise to modify the effects of this type of diet over 6-months in a randomised trial. Participants all together in this study had a 6.4% reduction in body weight. The low carbohydrate diet had some significant beneficial effects on the components of an ALP, in particular, decreasing plasma TAG, increasing both HDL-C and HDL size, and decreasing the proportion of sdLDL. Hyperinsulinaemia was unaffected by the consumption of a low carbohydrate diet. The favourable changes in lipids with the low carbohydrate diet were associated with weight loss as a result of decreased energy intake.

Al-Jazzaf's (2017) study was however unable to differentiate between the effect of exercise and the low carbohydrate diet on an ALP, probably because of poor compliance to the exercise programme. Taken together, both of the intervention studies resulted in reductions in metabolic risk factors for CVD, including a decrease in plasma TAG and increase in HDL-C across the two studies. Poor compliance to the energy-restricted diet in the low GI study in Kuwait, and to exercise regimens in the Atkins study did not allow any further interpretation of these experimental approaches. The promotion of the dietary approaches used in this thesis should be considered for the management of obesity and/or T2 DM and their associated CVD risk factors.

Yeboah (2017) also determined and assessed 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 two hours at intervals of 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.

Yeboah (2017) found out that among the test foods that had their glycemic index 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 (WC) were 23.1±2.60years, 24.39±3.1kg/m2, 64.1±7.9kg, 161.40±6.04cm and 74.6±6.9cm, respectively. There was no statistically 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.

Summary of Literature Reviewed

There are gaps in the current literature on GI and GL, particularly where the summation model and predictability of the GI in staple meals is concerned. Many of the downfalls of GI concept with regard to staple meals have arisen from small sample sizes, limited use of standardised GI testing protocols, large intra-individual variation and not testing the carbohydrate content or GIs of the individual foods. The summation model has been utilised by numerous studies to link GI with disease, but only two early studies have specifically tested the model, albeit somewhat inadequately and with varying results. Furthermore, if the GI is to have clinical utility, composite GIs obtained from published and measured values should be similar when inserted into the model. Robust testing of the model is essential if it is to be used in the clinical setting to guide food choice, in dietary GI prediction in epidemiological research and to help improve the methods of dietary GI assessment.

The literature study revealed that the GI reduced the risk of diabetes, CVDs and cancer. The review shows that GI improved glycemic control in diabetic subjects and caused a significant reduction in total cholesterol. Also, the results of an inter-laboratory study showed that the observed between-laboratory variation in GI could mainly be attributed to random, day-to-day variation of blood glucose responses within subjects. Finding ways to reduce within-subject variation of glycemic responses would, therefore, probably be the most effective strategy to improve the precision of measurement of GI values.

CHAPTER THREE

RESEARCH METHODS

Introduction

This chapter describes the overall approach that was used to achieve the study's objective which was to analyse the GL of four types of rice popularly consumed in Ghana, and examine their nutrition and health implications. The research methods guided the researcher in data collection and method of analysing data collected from the field. It also discussed the various methods that were employed in generating research data to answer the research questions and to test the research hypotheses.

Research Design

A quantitative approach was used to answer the research questions and also to test the research hypotheses with regard to the GL of four types of rice popularly consumed in Ghana, taking into consideration its related health nutrition implications. To accomplish this, an experimental research design which is the crossover design type was used with rice consumers randomly selected from Cape Coast Metropolis. The determination of GI was carried out experimentally. It was necessary to use a crossover trial since the subjects who were given the test foods were the same subjects who were given the reference food. The homogenised method used demanded that the test be carried out in human beings due to some conditions that influence the metabolism of food in the human body.

A crossover design is a repeated measurement design such that each experimental unit (patient) receives different treatments during the different time periods, i.e., the patients cross over from one treatment to another during the course of the trial (Piantadosi, 2015). This is in contrast to a parallel design in which patients are randomized to a treatment and remain on that treatment throughout the duration of the trial. The reason why this design was considered was that it could yield a more efficient comparison of treatments than a parallel design, i.e., fewer patients might be required in the crossover design in order to attain the same level of statistical power or precision as a parallel design. Intuitively, this seems reasonable because each element or participant was served as his/her own matched control. Every participant received the four treatments that were made, that is, eating the four types of rice at different time periods.

The study was *in vivo* since the experiment was done within the living. In order words, the participants were those in which the effects of various biological entities with regard to GI and GL were tested. According to Piantadosi (2015), an *in vivo* experiment is done in the body of a living organism as opposed to a laboratory method that does not use the living organism as the host of the test. As a result, the standard protocol required the test being carried out *in- vivo* because a number of factors affect the metabolism of food in the human body. The *in-vivo* approach was deemed the best means of determination if the outcome could be used as reference data. Extrapolation from tables has been found not to be exactly accurate. Every food item is somehow different from the other even when they are of the same species.

The experimental design adopted served two functions: (1) it established the conditions for the comparisons required with regard to the specific purposes of the study, and (2) it enabled the experimenter, through statistical analysis of the data, to make a meaningful interpretation of the results of the study. According to Kumar (2016), the most important requirement in an experimental study is that the design must be appropriate for examining the specific purposes of the study. The mark of a sophisticated experiment is neither complexity nor simplicity but, rather, appropriateness. A design that will do the job it is supposed to do is the correct design. The experimenter’s task is to select the design that best arranges the experimental conditions to answer the research questions and also to test the stated hypotheses of the study.

Babbie (2013) added that the design must provide adequate control so that the effects of the independent variable can be evaluated as unambiguously as possible. Unless the design controls extraneous variables, you can never be confident of the apparent relationship between the variables of the study. Randomisation is the single best way to achieve the necessary control. Experimental studies utilising randomisation provide the best evidence for determining the effectiveness of practices and programmes, and they are considered the gold standard for determining “what works” in educational research (Best & Kahn, 2014). Therefore, the best advice is to select a design that uses randomisation in as many aspects as possible.

Some of the drawbacks of experimental designs are that it is time consuming, difficult to administer and expensive, particularly if the researcher is interested in measuring the long-term effects (Best & Kahn, 2014). Also, it may be impossible to control for the effects of the extraneous variables, particularly in a field environment that uses the crossover design and the *in vivo* approach.

Mindful of the above challenges, the researcher took care to plan, organise and develop the experiment, and was objective and independent as possible. The researcher further ensured that there was no threat to validity. The researcher ensured that the manipulation of the independent variables or treatments actually caused the observed effects of the dependent variable since control of extraneous variables is a necessary condition for establishing internal validity. That is, the amount of water, salt, heat and other ingredients of cooking rice were measured equally.

Sample Collection

In this study, four types of rice were used: local brown rice, local polished white rice, perfumed rice and polished perfumed white rice. Since there was lots of perfumed rice on the market, a pilot study was conducted to select two of the most preferred ones, (Fortune and Cindy) The four samples were purchased at Kotokoraba market, in the Cape Coast Metropolis.

Sample Preparation

All unwanted material and visibly spoilt rice were removed and washed to remove dirt. The various types of rice were boiled with enough and appropriate water to make it soft (plain boiled rice). A regulated heat source was used to cook all the rice. The cooked rice was served to the 12 selected participants. This was one of the steps in dietary glucose response analysis. Rice for the proximate analysis, were boiled very soft and blended to increase the surface area for easy analysis.

Study Participants

After the research was approved by the Institutional Review Board (IRB) of the University of Cape Coast (UCC), 12 healthy individuals were enrolled into the experiment or trial. They consisted of six males and six females. Also, they were made up of six young people (below 45 years) and six old people (above 45 years). All participants were above 24 years of age. The categorisation in this study with regard to age is in line with that of Bhupathiraju et al. (2014) and FAO/WHO (2014) who both used age 45 as midpoint to group the respondents into old and young age groups. These individuals agreed to take part in the research and were also enrolled in line with the FAO/WHO (as cited in Wormenor, 2015), recommended procedure for the determination of the GI. 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 communicated through an orientation that was done before data collection commenced.

Inclusion criteria

The following inclusion criteria were used:

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

- People who are capable or willing to take the test meal.

Exclusion criteria

The following exclusion criteria were used:

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

All participants were grouped together a week before the start date of the experiment for orientation. They were counselled to go by the rules of engagement in the research. Also, they were informed about the importance of the exercise. Participants were informed of a strict abstinence from smoking or drinking within the period of the study. Again, they were made to understand that they will be having 10 – 14 hours over-night fast, not to do unusual vigorous activities on the day before the test, and not to drink alcohol or smoke before the test. They were also asked to report to the testing centre early in the morning for the test. Some basic data such as sex, history of CVDs or diabetes, age, family health history and the last meal eaten were enquired from the participant.

Procedures and Determination of Nutrient Content of Test Meals

In relation to the four types of rice, the study made use of 100g of each type. They were tested at the laboratory to know the coefficients of the various components. The tests were done four times for each of the rice. The average percentage recorded with regard to glucose were 32.14 for perfumed rice, 87.33 for local polished rice, 27.82 for brown rice, and 25.66 for polished perfumed rice. Based on the average figures, the study calculated the corresponding grams of rice that will generate 50g of carbohydrate. Perfumed rice was 156g while local polished rice, brown rice, and polished perfumed rice were 134g, 180g, and 195g respectively.

Moisture determination: Porclain crucibles were washed dried and weighed. About 10-12g of the fresh samples were put into clean oven-dried crucibles and weighed. The crucibles containing the sample were spread over the base of the oven to ensure equal distribution of heat. They were then kept in a thermostatically controlled oven at 105^{o}c for 48 hours. At the end of the period the samples were removed, cooled in a desiccator and weighed. Each sample was done thrice. The moisture content was then calculated as the percentage water loss by the sample.

Ash determination: Dried samples were heated gently in oven at 105^{o}c for about an hour and then transferred to a furnace at a temperature of 550^{o}c overnight. The heating continued until all the carbon particles were burnt away. The ash in the dish was removed from the furnace cooled in a desiccator and weighed. The ash content was then calculated as a percentage of the original sample.

Oil/fat determination: The reagent used was petroleum spirit. The procedure was that about 10- 12g of the milled samples were weighed into a 50 ×10mm soxhlet extraction thimble. This was transferred to a 50ml capacity soxhlet extractor. A clean dry 250ml round bottom flask was weighed. About 150ml petroleum spirit was added and connected to the soxhlet extractor and extraction was done for six (6) hours using a heating mantle as a source of heating. After the six (6) hours the flask was removed and placed in an oven at 60^{o}c for two (2) hours. The round bottom flask was removed, cooled in a desiccator and weighed. The percentage fat/oil was calculated as followed. Crude fat (%) = [W (g) × 100] ÷ [Sample (g)], where W = Weight of Oil.

Carbohydrate determination: The reagent used was glucose solution. The first was stock solution: (1ml is equivalent to 0.25mg glucose), 0.250g D-glucose (dried in a vacuum oven at 70◦c oven P_2O_5) was dissolved in water and diluted to 1liter.Working standards: a range from 0 – 20ml stock solution was pipette into 50ml flasks such that 2ml of each standard gives a range from 0 - 0.20mg glucose and diluted to volume. The second reagent considered was anthrone reagent. The study added carefully 760ml conc H_2SO_4 was carefully added to 330ml water in a boiling flask and kept cool while mixing. Add 1g of anthrone, and 1g of thiourea were dissolved using a magnetic stirrer. It was transferred to a dark bottle and left for two hours before use. Store at + 1^{o}c.

The procedure regarding extraction had 50mg of the milled sample weighed into a 50ml conical flask, 30ml of distilled water was added and a glass bubble placed in check to simmer gently on a hot plate for two (2) hours. It was topped up to 30ml periodically and allowed to cool slightly. It was then filtered through a No.44 Whatman paper into a 50ml volumetric flask and diluted to volume when it was cool. The extract was prepared shortly before colour development. A blank was prepared by taking it through the same procedure.

Colour development: 2ml of each standard was pipette into a set of boiling tubes and 2ml of the extract and blank water was also pipetted into a boiling tube. Standards and samples were treated the same way. Furthermore, 10ml of anthrone solution was added rapidly to mix and the tubes immersed in running tap water or an ice bath. The tubes were placed in a beaker of boiling water in a dark fume cupboard and boiled for 10minutes. The tubes were then placed in cold water and allowed to cool, preferably in the dark. The optical density was measured at 625nm or with a red filter using water as a reference. A calibration graph was prepared from the standards and used to obtain mg glucose in the sample aliquot. The blank determination was treated the same way and subtraction were done where necessary.

Soluble carbohydrates (%) = [C(mg) × extract volume (ml)] ÷ [10 × aliquot (ml) × sample wt(g)]

Where C = carbohydrate concentration from the calibration graph

Protein determination: Determination of total nitrogen (micro-kjedahl method) distillation sulphuric acid-hydrogen peroxide digestion. The digestion mixture comprises 350mL of hydrogen peroxide, 0.42g of selenium powder, 14g Lithium Sulphate and 420mL sulphuric acid. The digestion procedure as outlined in FAO Lab. Manual 2008 states that between 0.10 to 0.2g of the oven-dried ground sample was weighed into a 100mL Kjeldahl flask and 4.4mL of the digestion reagent was added and the samples digested at 360°c for two hours. Blank digestions (digestion of the digestion mixture without sample) were carried out in the same way.

After the digestion, the digests were transferred into 50mL volumetric flasks and made up to the volume. A steam distillation apparatus was set up and steam passed through it for about 20 minutes. After flushing out the apparatus, a 100mL conical flask containing 5mL of boric acid indicator solution was placed under the condenser of the distillation apparatus. An aliquot of the sample digest was transferred to the reaction chamber through the trap funnel. Also, 10mL of alkali mixture was added to commence distillation immediately and about 50mL of the distillate was collected. The distillate was titrated against 1/140MLHCI from green to the initial colour of the indicator (wine red). Digestion blanks were treated the same way and subtracted from the sample titre value. N (%) = [(T-B) x M x 14.007 x 100] ÷ [sample weight (mg)]

Where M = Molality of Acid, S = Sample titre value, B = Blank titre value, Protein = %N *6.25

Crude fibre determination: The first reagent was sodium hydroxide, 1.25%. Dissolve 12.5g NaoH in 700ml distilled water in a 1000ml volumetric flask and dilute to volume. The second reagent was sulphuric acid, 1.25%. Add 12.5g conc. Sulphuric acid to a volumetric flask containing 400ml distilled water and dilute to volume. In relation to the procedure, about 1g of the sample was weighed and placed in a boiling flask, 100ml of the 1.25% sulphuric acid solution was added and boiled for 30mins. After the boiling, filtration was done in a numbered sintered glass crucible. The residue was transferred back into the boiling flask and 100ml of the 1.25% NaoH solution was added and boiled for 30mins. Filtration continued after the boiling and the residue washed with boiling water and methanol. The crucible was dried in an oven at 105 degrees overnight and weighed. The crucible was placed in a furnace at 500 degrees for about three (3) hours. The crucible was slowly cooled to room temp in a desiccator and weighed. % Crude fibre = [weight loss thro ashing x 100] ÷ [Sample weight].

Data Collection Procedures

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

The data collection procedures started in the first week of June, 2018. Five weeks were used to collect the data. One week for each of the test. The reference food (glucose) was done in the first week while brown rice, polished local rice, perfumed rice, and polished perfumed rice were done in the subsequent weeks respectively. All the 12 subjects/participants were made to undergo a 10 to 14 hour fast from the time of taking the last meal of the previous night to the morning of testing. All participants reported to the premises of the university hospital at 06:45 to 07:45 am. The reporting time and venue was the same for both reference and test foods. On reporting for the first time test appointment, height, weight and waist circumference of each participant was taken. Also, participants on reporting were weighed without shoes on using a bathroom scale. The heights of participants were measured in an upright position with a stadiometre. The weight and height measurements were taken repeatedly for each participant. The average heights and weights obtained were used for the analysis done.

After the measurements were taken, capillary blood was taken from each participant to examine for the fasting blood sugar using an Ultra 2 glucometer. The time of taking the fasting blood sugar was recorded to confirm that each participant had undergone the 10 -14 hours fast prior to testing.

After a fasting blood sample test, participants were each given a glucose solution prepared from 50g anhydrous glucose and 200ml of bottled water. The stop watches were started when subjects started to drink the glucose solution. The time each participant begins to drink the glucose solution was recorded. The exercise started at 08:00 am. Thirty minutes after the start of consumption of the glucose solution the reference sample, capillary blood was taken from all the participants and examined for glucose. Subsequently, samples were taken from all participants at specific time interval. That is, the blood sample test was taken at 30, 60, 90, and 120 minutes respectively, and evaluated for the glucose concentration in mmol/L.

Participants were asked to ensure very minimal activity. They were asked not to leave the lab premises as a measure to ensure that an extremely low level of physical activity took place within the testing period. Capillary blood was obtained by finger prick and whole blood glucose obtained. Capillary blood was preferred because it was easier to obtain. Also, the rise blood glucose is greater than venous plasma and the result of the capillary blood glucose are less variable than those for venous plasma glucose.

After the two hours period when all samples had been taken, participants were all informed of the next testing day and were appropriately reminded of the restrictions that accompanied their participation in the research work. After that was done, participants were each given lunch and were asked again 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 with regard to no smoking, alcohol and strenuous activities.

The first test food (brown rice) was administered a week after the glucose had been given. Participants, as with the reference food were required to undergo a 10-14 hours fast prior to the day of testing. Subjects were also required to abstain from smoking and drinking alcohol during the whole period. Just as with the reference food, participants reported at 6:45 – 7:45 am at the same venue. The last meal and time of meal of each participant was asked and recorded. The experiment started exactly 08:00am. 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 sugar in mmol/L.

Again, participants fasting blood sugar was measured and appropriately recorded. A measured amount (100g) of boiled brown rice 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 scheduled minutes and the glucose concentration recorded in mmol/l.

On the scheduled days, participants gathered at the same venue and times. Similarly, measured amounts of the other test foods, containing 50g available carbohydrate was given to each subject and eaten within a 10 minutes period. The timer was started when each participant commenced eating of the food. The first sample was taken 30 minutes after the start time. Samples were taken again at the 30, 60, 90, and 120, minutes respectively. Before any test food was given, capillary blood was taken and a fasting blood sugar ascertained for and appropriately recorded. Participants were given lunch after the whole exercise and then made to leave. Four types of rice: brown rice, polished local rice, perfumed rice, and polished perfumed rice were tested under the same pre conditions and procedure. Nutritional analysis was conducted on all the samples or the test food based on proximate analysis. This provided data on the available carbohydrate in each sample food which helped to calculate the GL.

Preparation of Test Meals

The processes that were involved in the individual preparation of the test foods with regard to the four types of rice were almost the same. First, a 100g of rice was purchased from the open market (Kotokoraba market). The rice was poured in boiling water and stirred on a gas stove. In relation to the stew, blended ingredients were put into the pot and fry for 45 minutes until the stew goes from watery to thick. The stew was stirred periodically during the preparation stage while in cooks and also on high heat. Seasoning salt and thyme plus green pepper were added to the stew. When the stew started boiling, the researcher stirred in the tomato sauce and tomato paste then turned the heat down to medium. This was done until the tomatoes were soft and deep red in colour. Same procedures and approaches were adopted with regard to the other types of rice cooked or prepared for the subjects.

Data Processing and Analysis

The incremental area under the glucose response curves were calculated using the trapezoid rule as recommended by FAO/WHO (as cited in Wormenor, 2015). The areas under the fasting baseline were ignored in the calculation. The GI 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). This helped in answering research questions one and two. The Microsoft Excel and Statistical Package for Social Sciences (SPSS) Version 21.0 software were used to analyse the data. The data were presented in tables and graph for interpretation and analysis based on the variables under study.

First, data on participants' characteristics were analysed frequency count, percentage, mean and standard deviation. Furthermore, means, standard deviation, frequency, percentage, and one-way analysis of variance (ANOVA) were used to analyse data regarding the four research questions. Data on the two research hypotheses were analysed using the independent samples t-test. This was done in order to examine the impact of sex and age on the GL of the different types of rice. Independent samples t-test is used to find out the difference between two independent groups where the distribution is normal and the variables are measured continuously such as GL of the four types of rice. It is also used to find out the impact of a categorical variable such as sex on a numerical variable. According to Best and Kahn (2014), it is appropriate to use the independent samples t-test when one wants to assess the impact of a categorical variable such as gender on a numerical variable such as GL of rice. This statistical tool was used again because it created room for the researcher to calculate the margin of the differences between the two independent groups, if any, using the Eta Square statistic.

Specifically, data on research question three were analysed using the one-way, between groups, analysis of variance (ANOVA). The one-way, between groups, ANOVA was used to analyse the data in order to examine the effect of type of rice (four categories) on their respective GL. This statistical tool was adopted because there were independent variables with more than two categories. This technique allowed the researcher to look at the individual and joint effect of the independent variables on the dependent variable (GL). According to Pallant (2010), to find out differences between independent groups that are more than two where the distribution is normal on numerically constructed variable such as GL which is measured continuously, it is appropriate to use the one-way ANOVA.

Ethical Issues Considered in the Study

The issue of ethics is an important consideration in research that involves human subjects (Best & Kahn, 2014). Research ethics is defined as the appropriate behaviour of a researcher relative to the norms of society (Creswell, 2014). The researcher, research subjects, and clients of the research were protected from any adverse consequences of the study by following laid down rules and procedures of ethics in research. The study considered ethical factors in a number of ways. Ethical issues that were catered for in this study included right to privacy, voluntary participation, no harm to participants, anonymity and confidentiality, deception and scientific misconduct. Creswell (2014) asserted that if researchers intend to probe into the private aspects of individuals' lives, their intentions should be made clear and informed consent should be sought from those who are involved.

For this study, official permission was obtained in writing from the Department of Vocational and Technical Education and the Institutional Review Board (IRB) of the University of Cape Coast (UCC) to conduct this research. First, in an *in vivo* experimental research, the clearest concern in ensuring the participants' interest and well-being is protecting their identity. In this regard, the researcher adopted anonymity and confidentiality techniques to ensure their protection. The participants were assured that the information they will provide would be kept as confidential as possible. On the issue of deception, the researcher did not consider it as a technique to collect from respondents as some investigators believe that it is appropriate sometimes to conceal a researcher's purpose in order to improve the quality of the study. Rather, the researcher introduced herself to the subjects/participants and made it clear to them that the study was meant for an academic purpose. The researcher did not hide her identity from the respondents with the view of tricking them for information. Also, all participants filled the consent form voluntarily.

Also, it must be stated that the research community opposes unethical behaviour such as research fraud and plagiarism. This behaviour is termed scientific misconduct which normally occurs when a researcher falsifies or distorts data or the method of data collection or plagiarizes the work of others. In this study, the researcher followed strictly the prescribed standard of scientific behaviour to avoid fraud and plagiary. To achieve this, the researcher collected information from the right participants experimentally and properly analysed them before writing the research report. Also, ideas, works and writings and references in this study were duly acknowledged in the in-text referencing and reference list.

To gather data from the sampled subjects, the researcher first submitted a copy of the proposed study to the review committee of the IRB, UCC to review. This was done to ensure that the research participants, the university community, and the country at large are protected. Based on the recommendations of the board, the researcher ensured that all ethical requirements such as academic honesty, plagiarism, acknowledgement of copyrighted materials used, and institutional ethical clearance were addressed. Furthermore, permissions were sought from management of the university hospital to carry out the indicated test. Approval was sought from managers of the health facility through the introductory letter. Also, the consents of the participants/subjects were sought using the consent form prepared by the IRB, UCC. Participants were informed about the purpose of the research and what objective it sought to achieve. The privacy and consent of participants were also negotiated and respected in the study. All these were done to ensure and secure the consent of the respondents.

Participants were encouraged to feel free and participate in the experiment objectively as possible and that they had the liberty to choose whether to participate or not. They also had the option to withdraw their consent at any time and without any form of adverse consequence. They were assured that the information they provided or samples collected from them will be used solely for research purpose and nothing else.

CHAPTER FOUR

RESULTS AND DISCUSSION

Introduction

This chapter presents the analyses of the data collected from the tests conducted. The discussion includes the interpretation of the data with reference to previous findings and concepts. The purpose of the study was to assess the GL of four types of rice popularly consumed in Ghana in order to examine its implications on health nutrition of Ghanaians. The first part of the chapter deals with the general characteristics of subjects or participants which serve as a preliminary analysis to the study. The second part is devoted to the specific research questions and hypotheses. Both descriptive and inferential statistics were employed in the data analysis. At the end of data collection, the study collected data from 12 participants, which represents 100 percent participation rate.

Analyses of Participants' General Characteristics

This part of the chapter deals with the general characteristics data distribution of the participant which is based on their sex, age, weight, height, blood pressure, waist circumference, and body mass index. Descriptive statistics were used to analyse the data. The cross tabulation of sex and age, and anthropometry characteristics of study subjects are presented as follows.

The first items considered are sex and age distribution of participants. As contained in Table 3, half (50.0%) of the participants were males while the other half were females. Also, half (50.0%) of the participants were within the youth age group, that is, they were less than 45 years. Similarly, half (50.0%) of the participants were also above 45 years. The results show that the study considered both male and female participants, and also both young and old participants.

Table 3: Age Distribution of Participants by Sex

	Sex of participants					
	Male		Female		Total	
Age of participants	No.	%	No.	%	No.	%
25 - 34 years	2	33.3	3	50.0	5	41.7
35 - 44 years	1	16.7	0	0.0	1	8.3
45 - 54 years	1	16.7	3	50.0	4	33.3
55 years and above	2	33.3	0	0.0	2	16.7
Total	6	100	6	100	12	100
% of participants	50.0%		50.0%		100%	

Source: Field survey, 2018

The study further examined the anthropometry characteristics of study subjects. The results are presented in Table 4. Table 4 shows mean age, weight, height, blood pressure, waist circumference and BMI of participants. As indicated in the table, the weight, height, blood pressure, waist circumference and body mass index were 69.84±14.58kg, 165.78±10.73cm, 1.55±0.11, 32.96±3.83inch, and 20.92±3.23kg/m2, respectively. The results show that participants have normal weight, height, blood pressure, waist circumference and BMI.

Table 4: Anthropometry Characteristics of Study Subjects

Participants	Weight	Height	BP	WC	BMI
Subject 1	56.7	159.2	1.7	33.0	17.88
Subject 2	54.6	155.0	1.7	29.0	17.62
Subject 3	49.0	150.4	1.6	26.0	16.5
Subject 4	71.6	161.2	1.5	37.0	22.13
Subject 5	74.5	159.6	1.5	37.0	23.34
Subject 6	54.6	155.0	1.7	29.0	17.62
Subject 7	91.2	181.5	1.5	37.0	25.34
Subject 8	73.7	168.5	1.5	31.5	21.67
Subject 9	60.7	166.5	1.5	30.0	17.94
Subject 10	77.0	173.6	1.4	35.0	22.18
Subject 11	83.3	177.3	1.4	34.0	23.5
Subject 12	91.2	181.5	1.5	37.0	25.34
Mean	69.84	165.78	1.55	32.96	20.92
Std. Dev.	14.58	10.73	0.11	3.83	3.23

Source: Field survey, 2018 (N = 12)

The study further presented data on cardiovascular or any metabolic disease of the participants. Table 5 presented study subjects' history of diabetes, cardiovascular or any metabolic disease. From the table, none of the study subjects has a history of diabetes, cardiovascular disease and any metabolic disorder.

Table 5: Participants, Their History of Diabetes, Cardiovascular or Any Metabolic Disease

Participants	History of diabetes	History of CVD	Others
Subject 1	No	No	No
Subject 2	No	No	No
Subject 3	No	No	No
Subject 4	No	No	No
Subject 5	No	No	No
Subject 6	No	No	No
Subject 7	No	No	No
Subject 8	No	No	No
Subject 9	No	No	No
Subject 10	No	No	No
Subject 11	No	No	No
Subject 12	No	No	No

Source: Field survey, 2018 (N = 12)

In relation to the four types or varieties of rice (brown rice, polished local rice, perfumed rice, and polished perfumed rice), the results of their average chemical compounds and nutrients are shown in Table 6.

Table 6: Weight, Composition and Different Nutrition Contents of Four Types of Tested Rice with 50g of Carbohydrate

Sample	Wt (g)	% DM	% Moist	% Ash	% Protein	% Oil/Fat	% Fibre	% Glucose
Brown rice	180	24.56	75.44	1.12	15.48	1.40	0.66	32.11
Polished local rice	134	22.40	77.59	0.96	16.01	1.27	0.99	37.33
Perfumed rice	156	24.43	75.57	1.28	17.49	2.50	1.31	27.83
Polished perfumed rice	195	21.19	78.81	3.41	4.47	18.03	1.95	25.66

Source: Field survey, 2018 Where Wt = weight

As depicted in Table 6, in relation to weight, polished perfumed rice had the highest weight while polished local rice has the lowest weight. In relation to dry matter, brown rice had the highest percentage while polished perfumed rice had the lowest percentage. Furthermore, the laboratory test shows that polished perfumed rice had the highest moisture content while brown rice had the least. Polished perfumed rice had the lowest protein, however, in relation to oil/fat and fibre, it has the highest percentage of them. Lastly, results in Table 6 shows that polished local rice had the highest percentage of glucose. The blood sugar elevation for all four (4) types of rice after consumption of 50g carbohydrate is shown in Table 7.

Analysis Pertaining to the Specific Research Questions and Hypotheses

Based on the specific purposes of the study, four research questions and two hypotheses were formulated to guide the study. The first and second research questions focused on finding out the GI and GL of brown rice, local white rice, perfumed rice, and polished perfumed rice. The study first presented the mean blood glucose at different time points observed after consuming the various types of rice and reference food. The results are presented in Table 7. As indicated in Table 7, there were differences at time 0 (fasting) among the subjects for each of the test rice and the reference food. There were increase in fasting blood glucose after ingestion of each of the test rice and the reference food. Averagely, as indicated in Table 7, polished local rice (5.62 ± 0.28 mmol/L) recorded the highest blood glucose response, followed by that of polished perfumed rice (5.60 ± 0.56 mmol/L) and perfumed rice (5.55 ± 0.44 mmol/L).

Table 7: Mean Blood Glucose Responses of Subjects at Different Time Point After Consuming the Various Types of Rice and Reference Food

Test food	Time	Min	Max	Mean	Std. Dev.
Glucose	0 minute	4.20	6.10	4.9083	0.52129
	30 minutes	5.90	20.90	8.6250	3.97701
	60 minutes	5.10	11.80	8.2167	2.10576
	90 minutes	4.70	9.30	7.3167	1.34356
	120 minutes	4.30	8.00	5.9917	1.08582
Brown rice	0 minute	4.40	5.90	5.1750	0.58640
	30 minutes	4.80	7.40	5.8750	0.79558
	60 minutes	4.00	6.00	4.9917	0.67885
	90 minutes	4.20	5.90	5.0250	0.53619
	120 minutes	4.30	6.10	5.0000	0.47098
Polished local rice	0 minute	4.70	5.70	5.0750	0.33878
	30 minutes	5.90	7.20	6.4917	0.41001
	60 minutes	4.90	6.40	5.8333	0.45394
	90 minutes	4.30	6.40	5.3583	0.52477
	120 minutes	4.70	6.00	5.3417	0.44611
Perfumed rice	0 minute	4.70	5.70	5.1500	0.33166
	30 minutes	4.70	7.40	6.1250	0.83571
	60 minutes	4.20	7.10	5.7917	0.95390
	90 minutes	4.80	5.90	5.4667	0.34466
	120 minutes	4.40	5.90	5.2167	0.46090
Polished perfumed rice	0 minute	4.50	6.10	5.0583	0.49075
	30 minutes	5.50	9.30	6.8667	1.30477
	60 minutes	4.80	7.20	5.7333	0.68667
	90 minutes	4.50	6.20	5.3250	0.52936
	120 minutes	4.20	6.30	5.0333	0.53992

Source: Field survey, 2018 (N = 12)

Where Max = maximum, Min = minimum, and Std. Dev. = standard deviation

However, as indicated in Table 7, brown rice (5.21 ± 0.44 mmol/L) had the least blood glucose level. The study further calculated the GI and GL of the various tested food in order to answer the first and second research questions of the study.

Research Questions One and Two: What are the GI and GL of brown rice, local white rice, perfumed rice, and polished perfumed rice?

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). GI from 0-55 or below 55 are classified as low GI. Figures ranging from 56- 69 are also categorised as medium GI and finally, 70-100 are classified as high GI. Furthermore, the GI is the ratio between the iAUC of 50g available carbohydrate of the test rice and the mean iAUC of 50g available carbohydrate of the reference food obtained from the same subjects multiplied by 100. The formula of GI calculation follows that of Wolever et al. (2011): GI = [iAUC of test rice ÷ Mean iAUC of reference food] x 100. Results were expressed as mean ± standard deviation.

In relation to GL, a serving of food with a GL of 1 – 10 is considered to have a low GL, 11 – 19 is a medium GL, and 20 or higher is a high GL. The formula of GL calculation is = [GI x Carb.] ÷ 100, where Carb. = The amount of available carbohydrate contained in a specified serving size of the food. Table 8 shows the GI and GL figures of test food, their minimum and maximum values as well as their mean and standard deviations.

Table 8: Glycemic Index Figures and Glycemic Index Groups

Sample	GI Min (%)	GI Max (%)	GI (%)	SD	GI Class	GL (%)	GL Class
Glucose	100	100	100	0.0	High	70.12	High
Brown rice	56.44	87.50	74.35	0.13	High	38.76	High
Polished local rice	57.58	96.61	80.15	0.08	High	45.04	High
Perfumed rice	60.04	94.92	79.15	0.13	High	43.93	High
Polished perfumed rice	63.07	91.79	79.91	0.16	High	44.77	High

Source: Field survey, 2018 Where SD = standard deviation

Results in Table 8 shows that all the four types of rice tested, brown rice, polished local rice, perfumed rice, and polished perfumed rice, had a high GI of 74.35%, 80.15%, 79.15%, and 79.91% respectively. Among the various types of rice tested, polished local rice had the highest GI figure whereas brown rice had the lowest GI figure. However, the test foods were eaten with some accompaniments, the GI figures of these accompaniments were not tested separately in other to get the accurate GI figures of test foods. Therefore, the GI figures for the test foods include that of the accompaniments. General, individuals in modern and developed countries should plan and centre their meals that have a low GI to avoid chronic diseases which include coronary heart disease, obesity and diabetes.

Of all the types of rice tested, polished local rice had the highest GI value while brown rice had the lowest GI value. The lowest GI figure obtained by brown rice among the four types of rice was not 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 (Similä, 2012).

This therefore implies that; large amounts of dietary fibre may not reduce glycaemic response but also prevent colon cancer and other health nutrition problems. Hence it can be stated that foods that have a low GI with high amounts of fibre could be capable of improving the health of consumers. This presupposes that it is appropriate for consumers of rice to consume brown rice rather than polished local rice or polished perfumed rice since they have high GI values. Rice in general is considered as high GI food, and GI values of rice over 70 are typical (Brand et al., 2016). In this study, four types of rice tested were found as having high GI and GL values. Wide differences in digestibility and GI value of rice products have been ascribed to various factors. These include the fibre content, the botanical sources, food processing, physiochemical properties particularly gelatinisation characteristics, particle size, amylose to amylopectin ratio and the presence of lipid-amylose complexes (Choi, 2016). As indicated earlier, high fibre rice was believed to be able to reduce the blood glucose response and hence lower the GI of the rice.

A research conducted by Yeboah (2017) showed that the way a particular food is processed has a large impact on its GI. 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 and cassava 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. GI of foods are usually influenced by the content or composition of sugar present in the food. For instant, highly polished rice which is composed of glucose and fructose has a higher GI than glucose.

Polished local rice and polished perfumed rice are 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 the various types of rice differs depending on the type of cooking method. The various types of rice were prepared through the process of boiling. Even though both polished and non-polished rice had higher GI values, their total dietary fibre content per 100g as well as their specific quantities that contained 50g of available carbohydrate differed.

Table 8 further shows that all the GL values of the various types of rice tested were high. Brown rice (38.76%) had the least GL value while polished local rice (45.04%) and polished perfumed rice (44.77%) had the highest respective GL values. This shows that polished rice has the most potency in raising a person’s blood glucose level after eating. Therefore, polished rice may not be considered as healthy nutrient food for people, especially those suffering from diabetes and CVDs. The finding that all the types of rice tested had high GI and GL values are in line with the comments of most researchers who indicate that rice has a high level of carbohydrate, GI and GL (Jenkins et al., 2015; O'Dea et al., 2010).

Research Question Three: What is the impact of brown rice, local white rice, perfumed rice and polished perfumed rice on consumers' blood glucose level?

The study further determine the impact of brown rice, local white rice, perfumed rice and polished perfumed rice on consumers' blood glucose level in order to answer the third research question of the study. The one-way ANOVA was used to analyse the data in order to examine this specific objective. The study took blood from the capillary, specifically from the fingertip and earlobe of participants since that method is perceived to be more convenient and better for the assessment of glycemic response. In addition, a post-hoc test was conducted using Tukey HSD to find out where the actual differences lied. In order to quantify the differences and also to know the margin of the differences, the eta square value was calculated for the differences. The descriptive statistics regarding blo0d glucose levels of the test foods is depicted in Table 9.

Table 9: Descriptive Statistics on Mean Values of Blood Glucose Levels of Tested Foods

Test food	N	Mean	Std. Dev.
Glucose	12	7.01	1.48
Brown rice	12	5.21	0.44
Polished local rice	12	5.62	0.28
Perfumed rice	12	5.55	0.44
Polished perfumed rice	12	5.60	0.56
Total	60	5.79	0.97

Source: Field survey, 2018 (N = 12)

The one-way analysis of variance was used to analyse the data in order to test the blood glucose difference among the various test foods. The test foods were in five groups (Group 1: Glucose; Group 2: Brown rice; Group 3: Polished local rice; Group 4: Perfumed rice; Group 5: Polished perfumed rice). The various types of rice tested were treated as the independent variable while the dependent variable considered was the blood glucose level. As indicated in Table 9, there were differences in mean blood glucose levels of the participants. Polished local rice (5.62 ± 0.28 mmol/L) and polished perfumed rice (5.60 ± 0.56 mmol/L) demonstrated relatively high level of blood glucose while brown rice (5.21 ± 0.44 mmol/L) had the least blood glucose level. The differences that exist between the test foods as indicated were examined further using ANOVA table to find out whether the differences are statistically significant. Table 10 shows the results.

Table 10: ANOVA Table on the Differences among the Test Foods Regarding their Blood Glucose Levels

Blood glucose	Sum of Squares	df	Mean Square	F	Sig.	η^2
Between Groups	23.351	4	5.838	9.868	0.000	0.418
Within Groups	32.538	55	0.592			
Total	55.888	59				

Source: Field survey, 2018 Where η^2 = Eta Square

The results in Table 10 show that there was a statistically significant difference between the various test foods with regard to their blood glucose levels [F (4, 59) = 9.868, p < 0.01]. This illustrates that the type of rice consumed by participants has a statistically significant impact on their blood glucose level. The finding is consistent with the comments of ICQC (2014) which averred that the kind of rice consumed by participants has a significant impact on their blood glucose level. There is strong correlation between the rates at which sugar is released from starchy foods using digestive enzymes *in vitro* to increase in blood glucose levels in humans. A kind of rice that is digested and absorbed slowly and thus elicit a slow rise in blood sugar levels give a low GI value and thus classified as low GI foods whilst those that are digested and absorbed more rapidly are classified high GI foods. Therefore, all kinds of polished rice are likely to produce high blood glucose level as compare to brown rice. The blood glucose levels of the various sample foods tested is presented pictorially in figure 5.

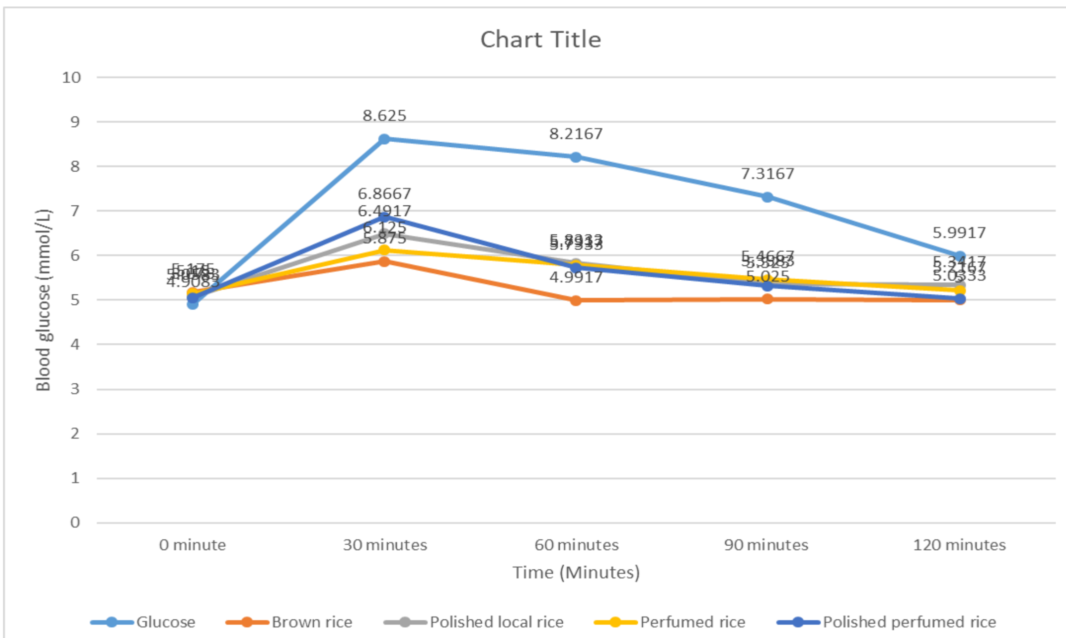

Figure 5: Blood Glucose Levels of the Various Rice Tested

Since there was a statistically significant difference among the test foods with regard to their blood glucose levels, the study went further to calculate the effect size, which shows that the margin of the difference is high ($\eta^2 = 0.418$). This shows that the kind of rice participants consumed had 41.8 percent impact on their blood glucose level. Also, the post-hoc comparison which makes use of the Turkey HSD test was conducted to know exactly where the difference is coming from with regard to type of rice and their blood glucose levels. The results are presented in Table 11.

Table 11: Post-Hoc Comparisons of Test Foods with regard to Blood Glucose

Blood glucose Tukey HSD (I) Type of rice	(J) Type of rice	Mean Difference (I-J)	Sig.
Glucose	Brown rice	1.798*	0.000
	Polished local rice	1.392*	0.000
	Perfumed rice	1.462*	0.000
	Polished perfumed rice	1.408*	0.000
Polished local rice	Brown rice	0.407	0.695
	Perfumed rice	0.070	0.999
	Polished perfumed rice	0.017	1.000
Perfumed rice	Brown rice	0.337	0.820
Polished perfumed rice	Brown rice	0.390	0.727
	Perfumed rice	0.053	1.000

Source: Field survey, 2018

As expected, there were statistically significant differences in mean blood glucose levels of the participants with regard to glucose and the four types of rice. However, in the case of the various four types of rice tested, there were no statistically significant differences among them. The findings that glucose produced high blood glucose level than any of the rice tested is in line with the findings of Yeboah (2017) who also glucose as a test food in finding out the GI of five corn and cassava staples in Ghana. Yeboah (2017) found out that glucose tested as standard food has significant difference with the test foods that had their glycemic assessed. The finding that there is no statistically significant difference among the various rice tested with regard to their blood glucose is also consistent with that of Yeboah (2017) who also found that 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*.

Testing the Two Research Hypotheses

The fourth specific purpose of the study determined the effects of gender and age on consumers' blood glucose level. The rationale of this purpose was to examine the impact of some background characteristics of respondents on their blood glucose level. Gender and age were measured categorically in two independent groups. As a result, the independent sample t-test was used to analyse the data. The results regarding the effect of gender and age on blood glucose level of participants are presented in Tables 12 and 13. The hypotheses formulated to be tested in order to tackle this purpose are as follows:

H^1_0: There is no statistically significant difference between male and female participants with regard to their blood glucose level.

H^2_0: There is no statistically significant difference between young and old participants with regard to their blood glucose level.

Table 12: Sex Difference in Blood Glucose Level of Participants

Variable	Gender	N	Mean	Std. Dev.	t-value	p-value
	Male	30	5.557	0.463	-1.600	0.141
Blood glucose	Female	30	6.029	0.526		

Source: Field survey, 2018

The results in Table 12 show that there was no statistically significant sex difference in male (5.557 ± 0.463 mmol/L) and female (6.029 ± 0.526 mmol/L) participants with regard to their blood glucose levels after consuming the test foods [$t = -1.600$, $p > 0.05$]. This shows that sex has no effect on the blood glucose level of participants after consuming the test foods. The study therefore failed to reject the hypothesis that there is no statistically significant difference between male and female participants with regard to their blood glucose level. Hence, the result is not statistically significant.

The finding corroborates with that of Choi (2016) who also found out that sex has no impact on the blood glucose level of participants. According to Choi (2016), the blood glucose levels, GI and GL of participants may be explained by lifestyle factors, particularly alcohol intake, rather than sex. The finding is further consistent with that of Dodd (2016) who performed nutrient analysis to determine carbohydrate content of the seven test foods. Capillary blood glucose was measured before eating and over two hours post-prandially. Incremental areas under the blood glucose curve were calculated, and a mean GI was obtained for all foods and meals. Dodd (2016) found out that the variance in the mean blood glucose levels and GI values are not as a result of sex of participants but may be linked to their lifestyle.

The study further examined the effect of age on participants' mean blood glucose levels. The results are presented in Table 13.

Table 13: Age Difference in Blood Glucose Level of Participants

Variable	Gender	N	Mean	Std. Dev.	t-value	p-value
Blood	Young (less than 45 years)	30	5.774	0.649	0.565	0.602
glucose	Old (45 years and above)	30	5.372	0.592		

Source: Field survey, 2018

As contained in Table 13, there was no statistically significant difference between young (5.557 ± 0.463 mmol/L) and old (5.557 ± 0.463 mmol/L) participants with regard to their blood glucose levels after consuming the test foods [$t = 0.565$, $p > 0.05$]. This shows that the blood glucose level of participants is not influenced by their age group. Therefore, age has no statistically significant effect on participants' blood glucose level. The study therefore, failed to reject the hypothesis that there is no statistically significant difference between young and old participants with regard to their blood glucose level. Hence, the result is not statistically significant.

The finding that the variances of participants' blood glucose level is not as a result of their age group is inconsistent with that of Jahan (2013) who selected commonly consumed south Indian breakfast product idli made with rice rawa and jowar rawa for his study. The GI of the breakfast product-idli made with rice rawa and jowar rawa was assessed in non-diabetic young subjects using blood sampling schedule and method of incremental area under the curve (IAUC) using glucose as reference food. The IAUC of rice rawa idli was 592.5 mg/dl against the glucose value of 1110. mg/dl. The GI of the rice rawa idli was 56.3, which is considered as medium GI food. Jahan (2013) found out that age group of participants (young and old) has a significant effect on their blood glucose level and GI value. However, Jahan (2013) further indicated that this effect is largely influenced by the lifestyle of the participant in question. Those who constantly do physical workout drink a lot of water, eat less salt, less sugar, and less fat foods.

However, the finding is inconsistent with that of Akoto (2015) who indicated that the mean blood glucose levels of participants are not influenced by their age, but rather their changing eating patterns. According to Akoto (2015), Ghanaians are changing their eating patterns as a result of urbanisation, globalisation, economic trends, as well as changes in social structure as a result of the increasing number of women working outside the home. These changes in eating patterns include higher consumption of snack foods by all age groups. A snack food is often smaller than a regular meal and normally consumed between meal times. Among cereal-based snacks, wheat and corn are the most popularly used cereals as compared to rice. Locally grown and milled rice tends to be poorly patronised by consumers in Ghana due to quality defects, so incorporating this low-grade rice into a ready to eat snack would provide an avenue for using the commodity which may otherwise be underutilised.

Research Question Four: What are the health implications of GI and GL of the four types of rice (brown rice, local white rice, perfumed rice and polished perfumed rice)?

The last research question of the study examined the health implications of GL with regard to the four types of rice sampled: brown rice, local white rice, perfumed rice and polished perfumed rice. Generally, the rate of glucose being released into the bloodstream and the duration of the rise in postprandial blood glucose levels is known to cause many hormonal and metabolic changes that could affect health and disease parameters. The calculations of the various test foods show that all the types of rice considered had high level of GL. This may mean that people associated with CVDs, obesity and type two diabetes are not supposed to consumed more of these types of rice. However, they can consider taking-in brown rice since it recorded relatively lower GI and GL. A recent systematic review and meta-analysis by George (2015) showed reduced risk markers related to persons who are overweight, obese, diabetic or at risk of coronary heart disease when low GI/GL diets were used in the intervention. The findings show that diets with high GI/GL are independently associated with increased risks of developing obesity, type two diabetes, and cardiovascular disease.

The GL has been used to study whether or not high GL diets are associated with increased risks for type two diabetes risk and cardiac events. As a result, one may refer from the earlier findings that polished local rice and polished perfumed rice are not good for people with type two diabetes or CVDs. This also means that people who consumed lower GL diets such as brown rice are at a lower risk of developing type two diabetes than those who consume diets of higher GL foods such as polished local rice or polished perfumed rice. Similarly, it could be said that frequent intake or consumption of polished local rice and polished perfumed may lead to an increase in risk for coronary heart disease events since they have high GL value.

The discussion so far shows that acquiring knowledge about the GI and GL of food help patients to have meaning and appropriate intake of glucose that is based on their physiological requirements. The original purpose of GI was to supplement the existing carbohydrate exchange list used by people with diabetes in meal planning. This means, low GI and GL dietary approach could provide a better quality of life for patients with diabetes compared with carbohydrate exchange dietary approach. According to Similä (2012), low GI diets can help by improving the glycemic control and reducing demand on the pancreatic beta cell in the post-prandial period. Low-GI diets elicited lower concentrations of glucose and insulin. Jenkins (2012) added that patients with type 2 diabetes who consumed low-GI diet have lower plasma glucose and insulin compared with a high-GI diet.

This shows that the consumption of high-GI and -GL diets for several years might result in higher postprandial blood glucose concentration and excessive insulin secretion. This might contribute to the loss of insulin-secreting function pancreatic β-cells and lead to irreversible type 2 diabetes mellitus. According to Willett et al. (2012), high-GI and -GL diets have been associated with an increased risk of type 2 diabetes in several large prospective cohort studies.

Furthermore, low-GI foods could enhance weight control because they promote satiety, minimize postprandial insulin secretion, and increase fat oxidation. Sixteen studies have shown that low-GI foods are more satiating, delay the return of hunger, or decrease subsequent food intake (Ludwig, 2012). Therefore, for participants to control their weight, they must reduce their intake of polished local or perfumed rice. Similarly, high level of postprandial blood glucose after the consumption of high-GI diet may affect risk for cardiovascular disease. This means, the higher one consumes more of polished local or perfumed rice, the higher his/her chances of having CVDs. According to Dodd (2016), there is a significant relationship between the eight-year risk cardiovascular death and two-hour post-load blood glucose concentrations in subjects with normal fasting glucose concentration after adjustment for known risk factors. A higher GL, but not protein or fat intake, has a strong associated with an increased risk of cardiovascular disease.

This may mean that, Ghanaians who consumed polished local rice, polished perfumed rice, or perfumed rice, which are all high-GI/GL diets, had a lower high-density lipoprotein cholesterol level. On the other hand, consumption of brown rice and other low-GI diets have beneficial effect on lipid metabolism. This is so because low-GI diets may outweigh the conventional low-fat diet recommended by the American Heart Association in prevention and treatment of CVDs.

Furthermore, looking at the implications of GI and GL on health nutrition, one may argue that a high prevalence of type 2 diabetes exists in Ghana largely because of modernisation and the adoption of western lifestyle. Epidemiological evidence suggests that low GI diets reduce diabetes risk (Brown et al., 2015). However, polished rice, which is high GI and GL diet, is now the most consumed diets in urban Ghana. Therefore, the country will continue to record high rates of CVDs and diabetes as long as its people continue to consume more polished rice. These challenges, however, can be reduced by the consumption of low GI and GL diets such as fruits that have strong antioxidant properties, and inhibition of a-amylase and a-glucosidase activities. Fruits can, therefore, be possible mechanisms or interventions in the management and prevention of type-2 diabetes. The discussion shows that low GI diet leads to energy restriction, low carbohydrate Atkins diet, and increased exercise level.

Chapter Summary

Rice is a dietary staple food and one of the most important cereal crops, especially for people in Asia and now in Africa. The analyses show that consumption of rice is associated with diabetes mellitus due to its high GI, especially that of polished perfumed and polished local rice. However, brown rice was found to have the least GI and GL when compare to other types of rice. Rice can be contaminated by some toxic elements such as arsenic and mercury coming from water and land in which it grows. Therefore, it is appropriate to prepare or cook rice using the require quantity of water, heat and other elements. Therefore, there is the need for some level of government control in rice available in the market. This will create room for the government to allow for more health nutrient rice to be available in the market. For example, the laboratory analysis of the four types of rice show that brown rice consist a number of polysaccharide and dietary fibre that support in type two diabetes and cardiovascular diet therapy. Rice with low level of GI and GL may lead to decreasing low density lipoprotein level, lowering cholesterol, reducing blood pressure and preventing CVDs.

CHAPTER FIVE

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

Introduction

This chapter presents the summary of the study and the conclusions drawn from the study. The first part focuses on the summary of the study and the key findings. The key findings are reported based on the research questions and hypotheses of the study. These are followed by the conclusions and recommendations of the study. The chapter also presents the suggestions for future research.

Summary

The summary of the study comprises of two parts: the overview of the study and the summary of key findings.

Overview of the Study

The study investigated the GL of four types of rice popularly consumed in Ghana in order to examine its implications on health nutrition of Ghanaians. Specifically, the study sought to determine the GI and GL of brown rice, local white rice, perfumed rice, and polished perfumed rice. Furthermore, the study determined the impact of brown rice, local white rice, perfumed rice and polished perfumed rice on consumers' blood glucose level, and the effects of gender and age on consumers' blood glucose level. Lastly, the study examined the health implications of GI and GL of the four types of rice.

A quantitative approach was adopted. A true experimental research design which is the crossover design type was used with rice consumers randomly selected from Cape Coast Metropolis. The determination of GI was carried out experimentally. The study was *in vivo* since the experiment was done within the living. In order words, the participants were those in which the effects of various biological entities with regard to GI and GL were tested. In this study, four types of rice were used. These are local brown rice, local polished white rice, perfumed rice and polished perfumed white rice. Since there were lots of perfumed rice on the market, a pilot study was conducted to select the two most preferred ones, Fortune and Cindy perfumed rice. All four samples were purchased at Kotokoraba market, in the Cape Coast Metropolis.

Prior to preparation, every unwanted material and visibly spoilt rice were removed and thoroughly washed to remove additional dirt. The various types of rice were plain boiled with enough and appropriate water to make it soft. A regulated heat source was used to cook the four types of rice. The cooked rice was served to the 12 selected participants. Rice for the proximate analysis, were boiled very soft and blended to increase the surface area for easy analysis.

The study sampled 12 healthy individuals into the experiment or trial. They consisted of six males and six females. Also, they were made up of six young people (below 45 years) and six old people (above 45 years). All participants were above 24 years of age. 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 communicated at an orientation that was done before data collection commenced.

Data such as age, sex, history of diabetes, metabolic disorder or any CVD, last meal eaten the previous night and time eaten were taken from the subjects. Weight and height were taken to calculate their BMI as well their waist circumference.

The data collection procedures started in the first week of June, 2018. Five weeks were used to collect the data. One week for each of the test. The reference food (glucose) was done in the first week while brown rice, polished local rice, perfumed rice, and polished perfumed rice were done in the subsequent weeks respectively. All the 12 subjects/participants were made to undergo a 10 to 14 hour fast from the time of taking the last meal of the previous night to the morning of testing. All participants reported to the premises of the university hospital at 06:45 to 07:45 am. The reporting time and venue was the same for both reference and test foods. On reporting for the first-time test appointment, height, weight and waist circumference of each participant was taken. Also, participants on reporting were weighed without shoes on using a bathroom scale. The heights of participants were measured in an upright position with a stadiometre. The weight and height measurements were taken repeatedly for each participant. The average heights and weights obtained were used for the analysis done.

After a fasting blood sample test, participants were each given a glucose solution prepared from 50g anhydrous glucose and 200ml of bottled water. The stop watches were started when subjects started to drink the glucose solution. The time each participant begins to drink the glucose solution was recorded. The exercise started at 08:00 am. Thirty minutes after the start of consumption of the glucose solution the reference sample, capillary blood was taken from all the participants and examined for glucose. Subsequently, samples were taken from all participants at specific time interval. That is, the blood sample test was taken at 30, 60, 90, and 120 minutes respectively, and evaluated for the glucose concentration in mmol/L.

Participants were asked to ensure very minimal activity. They were asked not to leave the lab premises as a measure to ensure that an extremely low level of physical activity took place within the testing period. Capillary blood was obtained by finger prick and whole blood glucose obtained. Capillary blood was preferred because it was easier to obtain. Also, the rise in blood glucose is greater than venous plasma and the result of the capillary blood glucose are less variable than those for venous plasma glucose. After the two hours period when all samples had been taken, participants were all informed of the next testing day and were appropriately reminded of the restrictions that accompanied their participation in the research work.

The Microsoft Excel and Statistical Package for Services and Solutions (SPSS) Version 21.0 software were used to analyse the data. The data were presented in tables and graphs for interpretation and analysis based on frequency distributions, percentages, descriptive and inferential analysis on the variables under study. Specifically, frequency count, percentage, means, standard deviation, one-way ANOVA, and independent sample t-test were used to analyse the data. The key findings that emerged from the study are as follows:

Summary of Key Findings

The first and second research questions of the study were to find out the GI and GL of brown rice, local white rice, perfumed rice, and polished perfumed rice. The key findings that emerged were:

i. There were differences at time 0 (fasting) among the subjects for each of the test rice and the reference food. There were increase in fasting blood glucose after ingestion of each of the test rice and the reference food.

ii. Averagely, polished local rice (5.62 ± 0.28 mmol/L) recorded the highest blood glucose response, followed by that of polished perfumed rice (5.60 ± 0.56 mmol/L) and perfumed rice (5.55 ± 0.44 mmol/L). However, brown rice (5.21 ± 0.44 mmol/L) had the least blood glucose level.

iii. All the four types of rice tested, brown rice, polished local rice, perfumed rice, and polished perfumed rice, had a high GI of 74.35%, 80.15%, 79.15%, and 79.91% respectively.

iv. Among the various types of rice tested, polished local rice had the highest GI figure whereas brown rice had the lowest GI figure.

v. Of all the types of rice tested, polished local rice had the highest GI value while brown rice had the lowest GI value. The lowest GI figure obtained by brown rice among the four types of rice was not surprising because it had the lowest available carbohydrate per 100g and had the highest amount of fibre, with regard to the specific quantity used, aside other underlying factors.

vi. The four types of rice tested were found as having high GI and GL values.

vii. All the GL values of the various types of rice tested were high. Brown rice (38.76%) had the least GL value while polished local rice (45.04%) and polished perfumed rice (44.77%) had the highest respective GL values.

The third research question of the study was to find out the impact of brown rice, local white rice, perfumed rice and polished perfumed rice on consumers' blood glucose level. The main findings that emerged were:

i. There were differences in mean blood glucose levels of the participants. Polished local rice (5.62 ± 0.28 mmol/L) and polished perfumed rice (5.60 ± 0.56 mmol/L) demonstrated relatively high level of blood glucose while brown rice (5.21 ± 0.44 mmol/L) had the least blood glucose level.

ii. There was a statistically significant difference between the various test foods with regard to their blood glucose levels [$F (4, 59) = 9.868$, $p < 0.01$].

iii. The margin of the difference between the reference and the test foods was 41.8 percent ($\eta^2 = 0.418$) which was seen as high.

iv. There were statistically significant differences in mean blood glucose levels of the participants with regard to glucose and the four types of rice. However, in the case of the various four types of rice tested, there were no statistically significant differences among them.

The first and second hypotheses of the study were to find out the effects of gender and age on consumers' blood glucose level. The key findings that emerged after analysing the data in order to test the hypotheses were:

i. There was no statistically significant difference in male (5.557 ± 0.463 mmol/L) and female (6.029 ± 0.526 mmol/L) participants with regard to their blood glucose levels after consuming the test foods [$t = -1.600$, $p > 0.05$].

ii. Therefore, sex has no effect on the blood glucose levels of participants after consuming the test foods.

iii. There was no statistically significant difference between young (5.557 ± 0.463 mmol/L) and old (5.557 ± 0.463 mmol/L) participants with regard to their blood glucose levels after consuming the test foods [$t = 0.565$, $p > 0.05$].

iv. Therefore, blood glucose level of participants is not influenced by their age group.

The last research question of the study was to find out the health implications of GI and GL of the four types of rice. The main findings that emerged were:

i. The calculations of the various test foods show that all the types of rice considered had high levels of GI and GL. Therefore, people associated with CVDs, obesity and type two diabetes should not consumed more of these types of rice. However, they can consider taking-in brown rice since it recorded relatively lower GI and GL.

ii. People who consumed lower GI and GL diets such as brown rice are at a lower risk of developing type two diabetes than those who consume diets of higher GI and GL foods such as polished local rice or polished perfumed rice. Similar, one can say that frequent intake or consumption of polished local rice and polished perfumed rice may lead to an increase in risk for coronary heart disease events since they have high GL values.

iii. GI and GL values of food help patients to have a standardised and meaningful intake of glucose that is based on their physiological requirements.

iv. Low GI and GL dietary approach could provide a better quality of life for patients with diabetes compared with carbohydrate exchange dietary approach.

v. People can control their weight by reducing their intake of polished local or perfumed rice. Similarly, high level of postprandial blood glucose after the consumption of high-GI diet may affect risk for cardiovascular disease.

Conclusions

In this study, four types of rice were tested (brown rice, polished local rice, perfumed rice, and polished perfumed rice), and the results show that they all have high levels of blood glucose. Polished local rice and polished perfumed were found to have high GI and GL values while brown rice was found to have relatively low GI and GL values. There was no statistically significant difference between brown rice, polished local rice, perfumed rice, and polished perfumed with regard to their GI and GL values. Further comparison revealed some level of difference between polished and non-polished rice. The data from the study also suggested that sex and age had no effects on GI and GL values of participants. The GI and GL figures from the study can serve as a tool for health professionals who have the power to assist, guide and advice individuals with diabetes and other CVDs on their diet, and provide medical nutrition therapy.

Recommendations

Based on the key findings and conclusions of the study, a number of practical recommendations for enhancing the nutrition and health of people were made.

1. First, the findings of the study show that among the four types of rice tested brown rice had the least GI and GL figures, it can therefore, be recommended for diabetics and individuals suffering from the different kinds of CVDs.
2. Furthermore, based on the findings that sex and age has no effects on GI and GL values of participants, the study recommends to health nutrition practitioners to sensitise people not to think their age and sex are the course of their health problems but rather their lifestyles.
3. Lastly, based on the finding that knowledge of GI and GL values of foods can help people improve their health, the study recommends to health nutritionists to ensure that they know the GI and GL values of the various foods they recommend to their patents, especially those with diabetes and CVDs.

Suggestions for Further Research

First, further research must be conducted on other Ghanaian foods to make available a more comprehensive database of the GI and GL of Ghanaian foods. A nutrient current analysis of all our local staples should be done since calculation of available carbohydrates is centred on the nutrient analysis done on the food. Also, future work should be carried out on the cooking and eating properties to see the relationship between the starch properties of the grain and cooking quality.

Data on physical characteristics and starch qualities could be used to select promising and adaptable varieties that are preferred by consumers in Ghana.

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APPENDIX A
UNIVERSITY OF CAPE COAST

COLLEGE OF EDUCATION STUDIES

FACULTY OF SCIENCE AND TECHNOLOGY EDUCATION

DEPARTMENT OF VOCATIONAL AND TECHNICAL EDUCATION

Test Guide for Participants

1. Sex of participant

   a. Male [ ]

   b. Female [ ]

2. Age range of participants

   1. 25 – 34 years [ ]
   2. 35 – 44 years [ ]
   3. 45 – 54 years [ ]
   4. 55 years and above [ ]

3. Weight of participants …………………………………………………………….
4. Height of participants …………………………………………………………..
5. Blood pressure of participant ……………………………………….………….
6. Waist circumference of participant …………………………………………….
7. Body mass index (BMI) ……………………………………………….………….

Test Record

Time	**Test 1 (Glucose)**	**Test 2 (B. rice)**	**Test 3 (P. L. rice)**	**Test 4 (P. rice)**	**Test 5 (P. P. rice)**
Fasting blood sugar (mmol/L)					
30 minutes (mmol/L)					
1 hour (mmol/L)					
1 hour 30 minutes (mmol/L)					
2 hours (mmol/L)					

Where B. rice = brown rice; P. L. rice = polished local rice; P. L. rice = perfumed rice; and P. P. rice = polished perfumed rice

APPENDIX B

INTRODUCTORY LETTER

VOTEC Department
University of Cape Coast
Cape Coast
13th June, 2018.

The Chairman
Institutional Review Board
University of Cape Coast
Cape Coast

Dear Sir,

ETHICAL CLEARANCE: MS. ELIZABETH OFORI

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

I am co-supervising the work with Dr. (Mrs.) Augusta Adjei Frimpong of the same department (VOTEC), University of Cape Coast. We have both read through her proposal and do approve it. Since it involves human subjects, efforts have been made to minimize negative effects on the respondents or participants as much as possible the inclusion of sensitive issues.

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

Thank you.

Yours faithfully,

Prof. (Mrs.) Sarah Darkwa

VOTEC Department
University of Cape Coast
Cape Coast
13th June, 2018.