UNIVERSITY OF CAPE COAST

GLYCAEMIC INDEX AND GLYCAEMIC LOADS OF SIX SELECTED GHANAIAN FRUITS

SANDRA AMOAKOAA ANTWI

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BY

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DECLARATION

Candidate's Declaration

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

Candidate Signature……………………… Date ……………………

Name: Sandra Amoakoaa Antwi

Supervisors' Declaration

I 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

ABSTRACT

This study assessed the glycaemic index and glycaemic loads of six selected Ghanaian local fruits and their impact on blood glucose levels. The main goal of this research was to find out if the consumption of the selected fruits has any impact on blood glucose levels. The purpose of this investigation is to help consumers who are prediabetic, diabetic, and hypertensive in making right choices when selecting fruits and taking in right quantities to promote good health. The study sought: to find out the nutritive value of the selected fruits, find the glycaemic indices of the six fruits, the glycaemic load of the six fruits, and compared how these fruits affected blood glucose levels. The experimental research design was used. The study was conducted in the Cape Coast Metropolis in the central region. The six Ghanaian local fruits: African locust bean, African grapes, Shea fruit, Tropical almond, Baobab and Breadnut were used. A blood glucose test was conducted to determine the effects of the six fruits on blood glucose levels. Findings from the data collected by the researcher showed that the glycaemic indices ranging from 18.42 to 41.39 of all the fruits were low as well as glycaemic loads ranging from 0.61 to 6.09. Proximate analyses was used to assess the protein content, fat content, ash content, moisture content and available carbohydrates. The were found to have significant levels of minerals which is good for the body.

KEYWORDS

Blood glucose

Glycaemic index

Glycaemic loads

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DEDICATION

To my big sister, Abigail Adomaa Antwi, the Antwi family and the Kumi-Kyereme family.

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CHAPTER ONE

INTRODUCTION

Background to the Study

Foster-Powell, Holt, and Brand-Miller (2002) state that in 1997, the Food and Agriculture Organization (FAO) of the United Nations and the World Health Organization (WHO) put together a committee of specialists to research the data on the significance of carbohydrates for human health and nutrition. Its members advised the use of food glycaemic index ratings in conjunction with understanding on composition of food to help people make informed food decisions and supported the use of the glycaemic index technique for classifying meals high in carbohydrates. The chemical classification of carbohydrates (as simple or complex, as sugars or starches, or as available or unavailable) has proven to be a less useful nutritional concept than the glycaemic index, allowing for new insights into the relationship between the physiologic effects of carbohydrate-rich foods and health (Ludwig, 2002). Numerous prospective observational studies have found an elevated risk of type 2 diabetes, cardiovascular disease, and other malignancies in those who frequently consume foods with a high glycaemic load (GI dietary carbohydrate content). According to Slavin and Lloyd (2012), fruits are the only food category that may be consumed fresh, in its natural taste, and also are an excellent source of antioxidants, vitamins, minerals, and fibre. Fruits ought to be consumed occasionally but moderately each day.

The glycaemic index (GI), which measures how meals affect blood sugar levels, has received attention as a result of the surge in diabetes incidence in Ghana. Fruits are commonly consumed based on their nutritive value with less attention to how it affects our blood glucose level. Fruits commonly found in Ghana are banana, mangoes, oranges, cashew amongst others but for the sake of this research, the focus will be on the following indigenous fruits; Breadnut, African grape fruits, African locus bean fruit, Shea fruit, Tropical almond, Baobab. These fruits are found in different parts of Ghana and enjoyed by both the young and the old.

Breadnut, scientifically known as *Artocarpus camansi* which is locally known as “Dee ball”. Even though, its name portrays it as a nut it is not a nut but instead it is a roughly spherical shaped fruit. It is green and has a rough skin that covers the edible skin. A single fruit contains a lot of seeds, when ripe, the fruit splits open revealing its seeds. These are mostly found in the Southern zone of Ghana. This fruit is appreciated for its edible seeds.

African grape fruit, scientifically name known as *Lannea microcarpa* locally known as “sisibi” by the Frafras. In Ghana, the sisibi tree produces a sweet grape-like fruit called “Sisibi” during the rainy season's sowing period. Sisibi grapes' hard seeds, which sort of looks like peanut, are what set them apart from other grapes. The sisibi fruit is purple in colour and grows similarly to grapes, making it easy to confuse the two fruits, but it has a unique flavour that is adored by all throughout the northern part of Ghana.

Shea fruit, scientifically known as *Vitellaria paradoxa* is locally known as “Taani” (plural tama). Shea fruit is available during the rainy season in Ghana. Shea fruits have spherical, elongated, or torpedo-like forms and resemble green plums. Their green skin is smooth and may have very minor vertical ribbing. A thin layer of greenish-yellow pulp lies behind the skin of the fruit, which softens over time. A huge, smooth brown nut with a thumbprint-sized rough patch is located in the centre. The pulp has the texture of a ripe pear and is only slightly sweet.

African locust bean fruit, scientifically known as *Parkia biglobosa* is locally known as “dorawa” in Hausa. In Ghana, the African locust bean tree is a perennial tree that reaches heights of 7 to 30 metres. The tree's locust beans, which can contain up to 30 seeds, are typically 30 to 40 cm long. The seedpods are collected by using a crook to remove them from the trees. The seeds separate from the covering when the pulp and seeds are pounded together in a wooden pestle after the husks have been removed. The pulp is then either consumed as it is or ground into flour to make porridge. The seeds are then left to dry in the sun for a day; once dry, they can either be used right away or saved for later.

Baobab, scientifically known as *Adansonia digitata* the fruit is locally known as “Toro” in the Gurini languge in the Upper West Region. The Guinea and Sudan Savannah zones of Northern Ghana are home to the enormous, slowly growing baobab tree. The tree's huge fruit pods, also referred to as "monkey bread" or "cream of tartar fruit," have a dry, nutrient-rich fruit pulp with a tangy citrus flavour that is sweet and sour. They can be found in powdered form and are commonly used in desserts, stews, soups, and smoothies.

Tropical Almond, scientifically known as *Terminalia catappa* is locally known as “Abrofo Nkate3”. The tropical almond is a huge tropical tree that has become a native of Ghana and West Africa. It is a neglected edible nut species that thrives in the tropical coastal regions of West Africa and other parts without the need of irrigation water. The fruit of the tropical almond tree ranges in size from 3 to 5.5 centimetres in width to 4 to 7 centimetres in length. Fruits are greenish when unripe, then turn yellow and eventually scarlet as they ripen. The fruit is known for its delicious nut which has an almond-like flavour.

The purpose of this study was to identify six fruits that are popular in Ghana, ascertain their glycaemic loads and indices.

Statement of the Problem

The prevalence of type 2 diabetes mellitus, a diet-related non-communicable disease, poses a public health challenge globally and in Ghana, where it affects approximately 2% of adults, with projections indicating a rise by 2045 (IDF, 2021). Central to this issue is the glycaemic response to foods, quantified by the glycaemic index (GI) and the glycaemic load (GL). While extensive research has clarified the glycaemic properties of staple foods like yams, cassava, and cereals (Eli-Cophie et al., 2017), indigenous Ghanaian fruits such as Breadnut (*Treculia africana*), African grapefruit, Shea fruit (*Vitellaria paradoxa*), African locust bean fruit (*Parkia biglobosa*), and Tropical Almond (*Terminalia catappa*) remain understudied despite their dietary and cultural significance. This gap limits evidence-based dietary recommendations for T2DM prevention and management, particularly in a context where local foods are preferred and accessible.

Prior studies highlight this research difference. Oboh and Ademosun (2021) assessed nutritional profiles of indigenous fruits without glycaemic data, and Akinyemi et al. (2020) explored hypoglycaemic potential without quantifying GI or GL. This study addresses these deficiencies by evaluating the nutritive composition, GI, and GL of the six selected fruits, chosen for their prevalence and lack of prior glycaemic analysis. The methodological complexity of GI or GL measurement, requiring controlled human trials, has deterred such investigations, yet the urgency is evident given Ghana's rising T2DM burden, driven by urbanization and dietary shifts. Without this data, healthcare practitioners, nutritionists, and policymakers lack the tools to integrate these fruits into T2DM management strategies effectively.

The relevance of this research extends beyond individual health, offering potential economic and policy impacts by identifying diabetes-friendly fruits that could boost local agriculture and inform public health guidelines. Comparative analysis of past studies shows the novelty of this work, as no prior research addresses these fruits' glycaemic properties. This study aims to empower diabetic individuals with informed food choices, equip professionals with clinical evidence, and contribute to a broader regional understanding of indigenous diets' role in combating non-communicable diseases.

Purpose of the Study

The purpose of this study was to find out the glycaemic loads and glycaemic indices of six indigenous fruits in Ghana.

Objectives of the Study

The following objectives were sought.

1. Assess the nutritive composition of the six selected fruits
2. Determine the glycaemic indices (GI) of the six selected fruits
3. Determine the glycaemic loads (GL) of the six selected fruits
4. Compare how these fruits affected blood glucose levels

Hypothesis

H_0: There is no statistically significant difference in the glycaemic indices and loads of the six selected fruits on blood fasting glucose.

Significances of the Study

Glycaemic load seems to play a significant role in diet plans intended to treat metabolic syndrome, insulin resistance, and weight loss. It is hoped that findings from this study will provide the ideal portion sizes for these fruits. The nutritional value of these fruits could help promote their consumption. For public health & nutritional guidelines, GI results thus findings from this work can be utilised by the governments and health organisations and policy makers to create dietary recommendations (e.g., advocating the consumption of our local fruits).

Fruit glycaemic index (GI) influences dietary recommendations, and healthcare regulations, encouraging low-GI fruits to improve blood sugar regulation and discouraging excessive intake of processed fruits. Dietitians, medical professionals, and public health should take initiatives to inform consumers about the advantages of whole, fibre-rich fruits over high-GI substitutes like processed drinks, it has an impact on nutrition practices. GI research is used by the food and agricultural industries to create healthier fruit-based products and promote the sustainable production of low-GI fruit varieties.

Findings from this research can contributes to educational initiatives that promote healthier eating habits. Finally, findings from the results of this study will contribute to the literature on these fruits especially their nutritional content, glycaemic load, and glycaemic index.

Delimitation

This study was delimited to determining the glycaemic load and glycaemic index of the six selected local fruits in Ghana. There are varieties and different types of fruits found in Ghana but this study focused on only six types of indigenous fruits found in Ghana. The blood samples from the ten respondents were only used to determine glycaemic loads and their blood fasting sugar.

Limitations

A minor constraint was it took a day for the supplies to reach Cape Coast for the study. They weren't freshly picked because the majority of these fruits are cultivated in Ghana's northern rather than central region. As a result of the fruits not being freshly picked, their chemical qualities may be somewhat limited. The glycaemic index result, however, could not have been impacted by the likely constraint.

It was difficult to reach out to participants since many of them were uncomfortable having their fingers pricked to check their blood sugar levels.

Definition of Terms

FAO - Food and Agriculture Organization

WHO - World Health Organization

GL - Glycaemic Load

GI - Glycaemic Index

iAuc - Incremental area under the curve

FBS - Fasting Blood Glucose

OGTT - Oral Glucose Tolerance Test

Organization of the Study

There are five chapters in the study. The study's background, problem statement, purpose, research hypothesis, significance, delimitation, limitations, definition of words, and organizational structure are all introduced in the first chapter. Chapter 2 contains a review of the literature. The third chapter discusses the research methodology. This comprises the data collection process, the source of the data collection, the instrument used in collecting the data, the methods used in gathering the data, and the method of data analysis. It also includes the research design, the sample, and the sampling strategy. In chapter four, the findings are presented and discussed. Chapter five, presents the conclusion, summary, recommendations and suggestions for further study.

CHAPTER TWO

REVIEW OF RELATED LITERATURE

Introduction

This chapter reviews literature relevant to the study. It consists of empirical evidence on determining the glycaemic load of foods. The review covers the concept of glycaemic index, the concept of glycaemic loads, shea fruit, breadnut, tropical almond, baobab, African grapefruits, African locust bean fruit, and carbohydrates. The effect of carbohydrates on the blood glucose level and glycaemic load of those who consume these fruits.

Theoretical Review

The Glycaemic Index (GI) framework, originally proposed by Jenkins et al. in 1981, continues to serve as the preeminent theoretical model for evaluating the effects of carbohydrate-rich foods on postprandial glycaemia. This paradigm categorizes foodstuffs according to their capacity to increase blood glucose concentrations relative to a reference standard, typically glucose or white bread, thereby providing a physiologically grounded metric that transcends the rudimentary binary classification of carbohydrates as simple or complex. The application of this theory to the analysis of six indigenous Ghanaian fruits, namely Breadnut (Artocarpus camansi), African grapefruit (Citrus paradisi), Shea fruit (Vitellaria paradoxa), African locust bean fruit (Parkia biglobosa), Baobab (Adansonia digitata), and Tropical Almond (Terminalia catappa), is particularly pertinent given the escalating incidence of type 2 diabetes mellitus in Ghana and the underexplored nutritional potential of these fruits. By determining the glycaemic index and glycaemic load of these species, such research yields essential data regarding their appropriateness for inclusion in diabetic dietary regimens, potentially contributing to the formulation of evidence-based public health policies and localized nutritional guidance.

The versatility of the GI framework is well-documented in prior research works. For instance, Philippou (2016), in The Glycaemic Index: Applications in Practice, provides comprehensive evidence supporting the utility of GI in the management of diabetes, cardiovascular disease, and obesity across heterogeneous populations. Similarly, Arvidsson-Lenner et al. (2024) substantiated the framework's relevance to health policy by demonstrating that low-GI diets correlate with enhanced glycaemic regulation and diminished cardiovascular risk. Furthermore, Brouns et al. (2015) emphasized used Glycaemic Index theory to ascertain the necessity of methodological precision in GI research, thereby reinforcing the scientific integrity underpinning such studies. Taken together, these investigations affirm that the GI theory constitutes a durable and adaptable analytical tool, rendering it an optimal framework for elucidating the metabolic implications of Ghanaian fruits within the context of nutritional science and public health.

Conceptual Review

The Concept of Glycaemic Index and Glycaemic Load

The idea behind the glycaemic index (GI) is to provide a numerical rating of foods high in carbohydrates based on the theory that this information would be helpful when a person's ability to tolerate glucose is impaired. According to Jenkins et al. (2002), the concept of glycaemic index was essentially a continuation of Burkitt and Trowell's dietary fibre theory, which postulated that meals with slower absorption could improve diabetic metabolism and lower the risk of coronary heart disease (CHD). The concept of Glycaemic Index (GI) provides a standardized method for evaluating the impact of carbohydrate-containing foods on blood sugar levels. It measures how quickly the carbohydrates from a particular food are broken down and absorbed into the bloodstream, leading to changes in blood glucose levels. Foods with a high GI are digested and absorbed rapidly, leading to a quick increase in blood sugar levels, while foods with a low GI are digested and absorbed more slowly, resulting in a gradual rise in blood sugar levels (Foster-Powell et al., 2002).

The GI of a food is determined by various factors including its carbohydrate composition, fibre content, fat content, and the presence of other nutrients or substances that affect digestion and absorption (Jenkins et al., 1981). Foods with a higher fibre content or those containing fats and proteins tend to have a lower GI because they slow down the rate of digestion and absorption of carbohydrates (Foster-Powell et al., 2002). The concept of GI is particularly relevant for individuals with diabetes as it helps them to manage their blood sugar levels more effectively. Choosing foods with a lower GI can help prevent rapid spikes in blood sugar levels, which is crucial for diabetes management (Ludwig et al., 1999). Additionally, low-GI foods are often associated with other health benefits such as improved satiety and weight management due to their slower digestion and absorption (Foster-Powell et al., 2002). However, it's important to note that GI is just one factor to consider when planning a healthy diet. Other factors such as portion size, overall nutrient content, and individual health goals should also be taken into account (Atkinson et al., 2008).

The GI of a food is influenced by various factors related to its composition and structure. Carbohydrates with a simpler molecular structure, such as those found in refined grains and sugars, are typically digested and absorbed more quickly, leading to higher GI values. In contrast, complex carbohydrates, such as those found in whole grains, legumes, and fibrous fruits and vegetables, are digested and absorbed more slowly, resulting in lower GI values (Jenkins et al., 1981). Although the glycaemic index of a particular food can help understand the relative ranking of different foods, the glycaemic index does not precisely represent how a serving of a particular food would affect blood sugar levels. As a result, Foster-Powell et al. (2002) argue that the GI concept has been extended to also take into account the effect of the total amount of carbohydrate consumed. While GI and Glycaemic Load (GL) are closely related concepts, GL offers a more thorough explanation of how various foods impact blood sugar levels. GL considers both the quality and amount of carbohydrates taken in a single serving of a certain item, whereas GI evaluates the quality of carbohydrates in a diet based on how quickly they elevate blood glucose levels. According to Foster-Powell et al. (2002), glycaemic load (GL) was subsequently introduced as an additional instrument to help determine the effect of eating carbohydrates on blood sugar more precisely. They argue that GL reflects the quantity of carbohydrates in a meal, whereas GI simply shows how quickly a specific carbohydrate becomes sugar. As a result, GL provides a more comprehensive picture than GI.

Determination of Glycaemic Index

The definition of GI is the area under the glucose response curve, following the ingestion of 50g of a test food divided by the area under the curve following the ingestion of 50g of a control food (either glucose or white bread). It is a description of the ability of foods high in carbohydrates to raise blood sugar levels in comparison to glucose or white bread.

The process of determining a food's Glycaemic Index (GI) involves carrying out controlled experiments to measure how the blood glucose responds to a given quantity of carbohydrates from that food when compared to a reference food, which has a GI value of 100 (Atkinson et al., 2008). The GI is calculated by carefully choosing test and reference foods for the experiment by the researchers. Generally, foods of interest containing carbohydrates that are being studied for their effects on blood glucose levels are included in the test food category. These foods, which include grains, fruits, vegetables, processed foods, and other food groups, are selected for their applicability to consumer consumption patterns and dietary patterns. Conversely, reference foods are chosen according to their established GI values, which are frequently obtained from standardized databases or earlier studies.

The International Organization for Standardization (ISO) and the World Health Organization (WHO), two respectable organizations, have produced standardized standards that this methodological technique complies with (Atkinson et al., 2008). By ensuring consistency and repeatability in GI assessments across trials, these techniques enable insightful comparisons across different diets. Through systematic control of experimental parameters like the quantity of carbohydrates given, when blood glucose readings are taken, and whether or not participants are fasting, researchers can precisely determine how various foods affect post-glycaemic reactions. The stringent scientific methodology for calculating GI values, as well as the useful insights it offers into the relative effects of various foods on blood sugar levels and the dietary recommendations it informs for people who want to effectively manage their glycaemic control, are highlighted by the ISO and WHO guidelines (Atkinson et al., 2008).

In the process of determining GI, researchers usually recruit healthy individuals (Chlup et al., 2004) or individuals with specific conditions, such as diabetes, to take part in the study (GI). These individuals are essential in providing information on how different foods affect blood glucose regulation by providing data on blood glucose response to a variety of foods. Participants may be asked to fast for the entire night before the experiment to maintain consistency and accuracy in the results. This is because fasting helps establish a baseline for blood glucose levels and reduces the possibility of confounding factors influencing glycaemic reactions. This standardized method highlights the significance of controlling variables to obtain reliable GI values and is in line with established protocols advised by respectable organizations like the World Health Organization (WHO) and the International Organization for Standardization (ISO) (Atkinson et al., 2008). Through the recruitment of participants with varying health backgrounds and adherence to standardised fasting protocols, researchers can produce comprehensive data on the glycaemic impact of various foods. This information may then be used to inform dietary recommendations for those who want to properly manage their glycaemic control.

Subsequently, the researcher carefully determined standardised portion sizes that accounted for the quantity of accessible carbohydrates in each serving. This procedure is essential for maintaining consistency between subjects and experiments because it reduces participant variability in carbohydrate consumption and makes it easier to compare blood glucose responses accurately. To guarantee that participants ingest a constant quantity of carbohydrates throughout the trial, standardized portion sizes are usually established based on the amount of carbohydrates in each food item (Chlup et al., 2004). Researchers can improve the repeatability and reliability of GI measures by reducing any confounding factors associated with variations in food intake by using uniform portion sizes. Participants either eat the test food or the reference food after fasting for the entire night.

Blood is then drawn at predefined intervals such as 15, 30, 60, 90, and 120 minutes to assess blood glucose levels with a glucometer or other blood glucose monitoring device (Chlup et al., 2004; Shobha et al., 2020). By ensuring uniformity in the time and frequency of blood glucose tests, this standardised methodology enables researchers to precisely evaluate the postprandial glycaemic response to various diets. By choosing particular time points, the temporal profile of blood glucose levels after eating can be characterised, offering important information about the speed and extent of glycaemic changes. Statistical analysis is conducted to validate and ensure the reliability of the results. To get accurate results, the study takes into consideration variables like participant variability and experimental settings.

Scholars can effectively estimate the glycaemic impact of various diets by correcting for possible errors and taking into account a variety of variables, Chlup et al. (2004).

Table 1: Classification of glycaemic index and glycaemic loads

Glycaemic Index	Glycaemic Load
The incremental area under the glucose curve (iAUC) following the consumption of the test food is divided by the matching iAUC following the consumption of the control food (pure glucose) to determine the GI. GI = $(iAUC_{test\ food}/iAUC_{glucose}) \times 100$ 55 or less = low 56–69 = moderate 70 or higher = high	A food's GL is determined by multiplying its GI by the grams (g) of carbohydrates it contains per serving, then dividing the result by 100 (4). $GL_{Food} = (GI_{Food}$ x amount (g) of available $carbohydrate_{Food}$ per serving)/100 10 or less = low 11–19 = moderate 20 or more = high

Note. Adapted from "Glycaemic Index and Glycaemic Load," by Linus Pauling Institute, n.d., Oregon State University. Retrieved January 11, 2024, from https://lpi.oregonstate.edu/mic/food-beverages/glycaemic-index-glycaemic-load.

Portion Size and Glycaemic Control

Portion size is very important for glycaemic management, especially for people who are trying to control their blood sugar levels or have diabetes. The amount of food an individual consumes at a time can have a big impact on the body's glycaemic response, which affects blood sugar levels within a particular period. Larger portion sizes are frequently linked to higher consumption of carbohydrates, which in turn causes a higher glycaemic response and a more significant spike in blood sugar levels after a meal (Breen et al., 2009). Studies like Breen et al. (2009) have documented this phenomenon, which highlights how important portion control is for regulating glycaemic levels and blood sugar management in general. Larger serving sizes have the potential to worsen glycaemic fluctuations and lead to unfavourable health consequences, especially for people who are trying to control their blood sugar levels or have medical illnesses like diabetes. To optimize metabolic health and avoid related issues, portion sizes and macronutrient composition must be closely monitored in dietary management (Breen et al., 2009).

Large quantities of high-GI foods can cause blood sugar levels to surge quickly and then crash, which can have long-term implications on glycaemic control in addition to causing fluctuations in energy levels (Breen et al., 2009). This phenomenon emphasizes how crucial it is to take into account food glycaemic index and portion sizes when designing a diet for an individual, especially if that person has a medical condition like diabetes or wants to keep their blood glucose levels steady for general health. Large quantities of high-GI foods can cause fast changes in blood sugar levels, which can upset the balance of the metabolism and increase the risk of developing insulin resistance and other metabolic diseases in the long run (Breen et al., 2009). Thus, adhering to portion control guidelines and opting for low-GI alternatives are essential strategies for mitigating glycaemic fluctuations and promoting long-term metabolic health (Breen et al., 2009).

It is worth noting that portion size is a critical factor in calculating a meal's GL, which is a concept that includes the amount of carbohydrates taken in a dish of a particular item as well as its quality as determined by the GI (Foster-Powell et al., 2002). The delicate relationship between carbohydrate intake and its impact on blood sugar levels is highlighted by the fundamental relationship between portion size and GL, which has been extensively studied in studies like the one conducted by Foster-Powell et al. Taking into account not just the GI but also the quantity of carbohydrates ingested, the GL offers a more thorough comprehension of how various foods impact glycaemic reactions. Greater portion sizes usually result in higher GL because they involve consuming more carbohydrates, which have a more significant impact on blood glucose levels (Foster-Powell et al., 2002). For people who want to effectively regulate their glycaemic responses and make informed dietary choices to support general health and well-being, they must comprehend the notion of GL and its relationship to portion size (Foster-Powell et al., 2002).

Also, Delahanty et al. (2014), indicate that restricting the amount of food consumed, particularly when it comes to foods high in carbohydrates, becomes an essential strategy to help people maintain optimal glycaemic control and control their blood sugar levels (Delahanty et al., 2014). This crucial component of diet management has been thoroughly investigated by Delahanty et al., who emphasize the importance of portion control in reducing postprandial glycaemic reactions. Through careful control of the quantity of carbohydrates taken in each meal, people can better control their blood glucose levels and lessen the chance of suffering severe swings that could jeopardize their overall metabolic health. Following portion control recommendations support long-term glycaemic management goals by promoting improved adherence to dietary recommendations which will result in stable blood sugar levels (Delahanty et al., 2014). Additionally, incorporating portion management strategies into regular eating routines can encourage healthier eating habits and a greater awareness of what is consumed, which can improve overall health outcomes and lessen the risk of developing chronic illnesses like type 2 diabetes and cardiovascular disease (Delahanty et al., 2014).

According Delahanty et al. (2014), quantifying portion sizes with common instruments like measuring cups, scales, or visual aids is a useful strategy that can enable people to precisely estimate and control their carbohydrate consumption. Through the use of these measurement techniques, people can better understand how much carbohydrate they eat, which will allow for more accurate control over their blood sugar levels and glycaemic management in general. Measuring portion sizes makes it possible for people to consistently consume carbohydrates, which improves adherence to dietary guidelines and maintains stable blood glucose levels. Furthermore, these instruments offer concrete, numerical information that encourages responsibility and understanding about dietary decisions, ultimately supporting long-term glycaemic management goals (Delahanty et al., 2014). A systematic approach to portion control is fostered by incorporating such measurement techniques into regular dietary routines, which can improve overall health outcomes and reduce the chance of acquiring chronic illnesses linked to dysregulated blood sugar levels.

Franz et al. (2014), recommend that portion sizes and carbohydrate intake should be adapted to each person's health needs, taking into account variables like age, weight, degree of physical activity, medication schedule, and glycaemic objectives. This personalised approach to diet management acknowledges that each person has a different ideal intake of carbohydrates and portion sizes depending on their specific metabolic profiles and health objectives. Age and weight are two factors that affect metabolic rate and energy requirements, which in turn affect the amount of carbohydrates needed. Furthermore, the degree of physical activity has a big impact on how well carbohydrates are used and how the body responds to glucose. Glycaemic control is maintained by adjusting carbohydrate consumption in response to medication regimens that include insulin or oral hypoglycaemic medications. Franz et al. (2013), add that personalised glycaemic targets direct the choice of suitable carbohydrate sources and portion sizes to support general health and well-being while achieving targeted blood sugar levels. People can create dietary programs that are specifically designed to reduce blood sugar levels and promote long-term glycaemic control by taking these individual aspects into account.

Franz et al. (2013) underline that seeking advice from a registered dietitian or healthcare practitioner is crucial for those who want to create personalised meal plans that meet their specific dietary needs and preferences while promoting optimal glycaemic control. These medical specialists are skilled in evaluating personal characteristics including age, weight, degree of physical activity, prescription schedule, and glycaemic targets, which allows them to customize nutritional advice appropriately. People can get individualized advice on choosing carbohydrate intake levels and portion sizes that fit their unique lifestyle and health goals by working with a qualified dietitian or healthcare professional. Furthermore, consultation with these experts provides a chance to discuss dietary issues or problems, obtain useful meal-planning techniques, and acquire important knowledge about nutrition concepts supporting glycaemic control (Franz et al., 2013). This cooperative approach creates a safe space where people may comfortably navigate food choices, enabling them to make well-informed decisions that optimize blood sugar levels and advance general health. Glycaemic regulation is greatly influenced by portion size, with larger servings of high-GI meals possibly causing more changes in blood sugar levels. Through adequate portion control and selection of carbohydrate-containing meal serving sizes, people can enhance overall glycaemic control and better control their blood sugar.

Classification of Dietary Carbohydrates

Dietary carbohydrates are one of the three important macronutrients, alongside proteins and fats that the body needs to function properly. They are the body's main source of energy. These organic substances are found in a wide range of foods, such as cereals, fruits, vegetables, legumes, dairy products, and sweets. They are composed of atoms of carbon, hydrogen, and oxygen. Carbohydrates are essential for maintaining physical activity and metabolic activities, as well as for powering internal body operations and cellular energy production. Furthermore, carbohydrates improve the entire sensory experience of meals by adding to the flavour, texture, and palatability of different foods. Due to its importance to the proper functioning of the body, every human needs the required amount of carbohydrates in the body. This basic knowledge of the importance of carbohydrates in the diet emphasizes the vital function they play in providing energy needs and promoting general health and well-being (Slavin, 2013; Wylie-Rosett & Segal-Isaacson, 2016).

Total carbohydrates represent the sum of all types of carbohydrates present in a food or beverage, including simple sugars, complex carbohydrates, and dietary fibre. For people managing their carbohydrate consumption, especially those with diabetes or other diseases requiring blood sugar management, this assessment is essential. Nutrition labels reflect the total amount of carbohydrates, which are important factors in figuring out a food product's overall nutritional makeup. Making educated dietary decisions and keeping a balanced diet requires an understanding of total carbohydrates. For instance, while arranging meals, people may need to take the total amount of carbohydrates into account to make sure they get the energy they need while controlling their intake of sugars and starches. Furthermore, total carbohydrates give helpful information for determining net carbohydrates, which is particularly important for people on diets with low carbohydrates or managing their carbohydrate intake to control their weight (Evert et al., 2019). Additionally, paying attention to total carbohydrates makes it possible for people to calculate net carbohydrates or the quantity of carbohydrates that have a major effect on blood sugar levels. This helps with counting carbohydrates to manage diabetes or low-carbohydrate diets. All things considered, total carbohydrates are an important part of nutrition labels and meal plans, assisting people in making decisions that will support their overall well-being and health.

Carbohydrates can be classified into three main types based on their chemical structure: sugars, starches, and fibre. Simple carbohydrates are easily absorbed and broken down by the body to provide rapid energy. They are made up of one or two sugar molecules. Glucose, fructose, lactose (milk sugar), sucrose (table sugar), and maltose (found in grains) are a few examples of simple carbohydrates. These sugars are added to processed meals and beverages for sweetness, and they can also be found naturally in a variety of foods such as fruits, vegetables, and dairy products. Simple carbohydrates are a quick source of energy, but they can also cause blood sugar levels to rise quickly, especially if they are ingested in excess or without additional macronutrients like fibre or protein. As a result, Slavin, (2013) and Wylie-Rosett and Segal-Isaacson (2016) caution that simple carbohydrates should be consumed in moderation as part of a balanced diet to promote general health and lower blood sugar levels.

On the other hand, complex carbohydrates, comprising long chains of sugar molecules, are integral components of various foods and contribute to sustained energy release and dietary fibre intake. Grains, legumes, and starchy vegetables are among the staple foods that are high in starches, a type of complex carbohydrate. These foods offer vital elements that are important for maintaining general health and well-being, such as vitamins, minerals, and dietary fibre (Slavin, 2013). Complex carbohydrates release glucose into the bloodstream more gradually than simple carbohydrates because of their complex structure, which also helps to maintain stable blood sugar levels and promote satiety (Slavin, 2013). To maintain optimal health, it is advised to include a range of complex carbohydrate-rich foods in the diet as part of a nutritious and balanced eating pattern.

Furthermore, fibre is another type of dietary carbohydrate that supports digestive health and general well-being. Unlike other carbohydrates, fibre is not digested by the body; instead, it passes through the digestive tract mostly undigested, supporting regularity in bowel movement and the removal of waste. Fibre's unique health benefits such as boosting satiety, controlling blood sugar levels, and decreasing cholesterol are made possible by its indigestible nature. According to Slavin (2013), a diet rich in plant-based foods such as fruits, vegetables, whole grains, nuts, and seeds is necessary to guarantee that the body gets enough dietary fibre. People can promote digestive health, maintain a healthy weight, and lessen the risk of digestive disorders by including foods high in fibre in their meals and snacks (Slavin, 2013).

Table 2: The Major Dietary Carbohydrate Classifications

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

Source: (FAO/WHO, 1998)

Available and Unavailable Carbohydrates

Available carbohydrates refer to the percentage of total carbohydrates that the body can digest and absorb to produce glucose, which gives energy to the body. This group comprises some kinds of starches and simple sugars, which during digestion are converted into glucose. Dietary fibre and certain sugar alcohols are not considered available carbohydrates since they are either fully or partially indigestible and do not raise blood sugar levels (Franz et al., 2002). Those who follow certain dietary patterns or have diabetes should pay special attention to the amount of carbohydrates that are accessible since this has a direct effect on blood sugar levels. Franz et al. (2002) indicate that knowing how much carbohydrates are available in various foods and drinks helps people make well-informed dietary decisions to properly control their blood sugar levels. For example, they can give preference to foods that are higher in dietary fibre or have a lower glycaemic index, as these options can help control blood sugar levels and improve general health. In addition, the computation of accessible carbohydrates enables people to precisely modify their carbohydrate consumption to preserve glycaemic control. In general, those who want to maximize their carbohydrate consumption and support their health and wellness goals must have a thorough awareness of the available carbohydrates.

Digestion of Carbohydrates in the Body

The process by which carbohydrates are broken down in the human body is complex and involves a variety of biochemical pathways. It begins in the mouth and moves down the gastrointestinal system. Carbohydrates represent one of the fundamental macronutrients in the human diet, encompassing a variety of compounds such as sugars, starches, and dietary fibres. Within the oral cavity of the mouth, complex carbohydrates are hydrolysed into simpler sugars like maltose and dextrin by the salivary enzyme amylase, which is released by the salivary glands (Gropper, Smith, & Groff, 2021). After eating, the partially digested carbohydrates pass down the oesophagus and into the stomach, where the acidic environment promotes more enzyme activity. However, the stomach's acidic pH, which suppresses salivary amylase activity, momentarily stops the breakdown of carbohydrates. The primary stage of the breakdown of carbohydrates takes place in the small intestine, where the chime – a semi-liquid mixture of partially digested food and stomach juices –enters.

Within the small intestine, the pancreas secretes pancreatic amylase, which complements the enzymatic action initiated by salivary amylase, breaking down remaining starches into disaccharides like maltose and isomaltose (Whitney & Rolfes, 2019). This enzyme action is in addition to that of salivary amylase. Furthermore, further enzymes like lactase, maltase, and sucrase that are found on the brush border of intestinal cells catalyse the hydrolysis of disaccharides into monosaccharides like glucose, fructose, and galactose (Gropper et al., 2021). The resulting monosaccharides, predominantly glucose, are then absorbed across the intestinal epithelium and transported into the bloodstream via specialized transporters, facilitated by concentration gradients (Whitney & Rolfes, 2019). Upon entering the bloodstream, glucose plays a vital role as an energy source for many body tissues and cells, supporting metabolic functions and meeting cellular energy demands (Gropper et al., 2021).

Blood Glucose Control

Blood glucose control, also known as glycaemic control, is essential for preserving the best possible physiological function because it keeps blood glucose levels within a specific range (Shahbazian et al., 2014). The pancreas secretes the endocrine hormone insulin, which is principally responsible for orchestrating this process (American Diabetes Association, 2019). After a meal, insulin is released into the bloodstream as blood glucose levels rise, which makes it easier for glucose to enter cells for cellular energy production or storage (American Diabetes Association, 2019). On the other hand, when blood glucose levels fall, the liver releases stored glucose into the bloodstream in response to the production of another hormone called glucagon, guaranteeing sufficient quantities to fulfil cellular energy requirements (Shahbazian et al., 2014). Sustaining appropriate blood glucose regulation is essential for general well-being and plays a pivotal role in averting complications linked to ailments like diabetes mellitus.

Many factors, including food consumption, exercise, insulin sensitivity, and pancreatic function, affect blood glucose regulation (Boulé et al., 2001; Franz et al., 2002). By offering a steady supply of energy and averting sharp spikes in blood sugar, a diet rich in complex carbohydrates, fibre, lean proteins, and healthy fats helps to maintain blood glucose levels (American Diabetes Association, 2019; Franz et al., 2002). Moreover, frequent exercise is essential for blood glucose regulation because it increases insulin sensitivity and makes it easier for muscles to absorb glucose for energy production (Colberg et al., 2010; Franz et al., 2002). These dietary changes and increased physical activity are examples of lifestyle alterations that are essential for improving blood glucose management and lowering the risk of complications associated with conditions like *Diabetes mellitus.*

Diabetes patients experience chronically high blood sugar levels as a result of inadequate insulin production or resistance to insulin action, which compromises blood glucose control (American Diabetes Association, 2019). The goal of managing diabetes effectively is to achieve and maintain optimal blood glucose control using a multimodal approach that includes pharmacological interventions (such as insulin therapy or oral antidiabetic medications), lifestyle modifications, and regular blood glucose monitoring (American Diabetes Association, 2019). The core elements of diabetes management that enhance blood glucose control and general health include dietary changes to control carbohydrate intake, frequent physical activity, and maintaining a healthy body weight (American Diabetes Association, 2019; American Association of Diabetes Educators, 2017). In order to achieve target blood glucose levels and lower the risk of complications related to diabetes, medications prescribed for diabetes management, such as insulin or oral antidiabetic agents, are specifically designed to address specific metabolic defects contributing to impaired blood glucose regulation (American Diabetes Association, 2019).

An essential component of reducing the risk of diabetic complications is maintaining appropriate blood glucose control. These problems include retinopathy, neuropathy, cardiovascular disease, and renal disease (American diabetic Association, 2019). People with diabetes can greatly lower their risk of these crippling complications by carefully controlling their blood glucose levels within a specified range. This will improve their overall quality of life and long-term health outcomes (American Diabetes Association, 2019). Additionally, stable blood glucose levels support long-term energy and wellness, enabling better day-to-day functioning and promoting a sense of vigour in those with diabetes (American Diabetes Association, 2019). Maintaining optimal blood glucose control through medication adherence, lifestyle adjustments, and routine monitoring is essential for preventing problems connected to diabetes and promoting improved overall well-being.

Clinical Significance of GI and GL

Glycaemic Index measures how quickly blood sugar levels are raised after eating foods high in carbohydrates (Atkinson et al., 2008). Due to their rapid digestion and absorption, foods with a high GI cause immediate increases in blood sugar levels, while those with a low GI cause more gradual and prolonged rises in blood sugar levels (Atkinson et al., 2008). Since diet-related carbohydrates affect blood glucose regulation, GI monitoring is especially important for those with diabetes (Kaur & Kaur, 2014). People with diabetes can reduce their risk of hyperglycaemia episodes and better control their blood glucose levels by choosing foods with a lower GI (Kaur & Kaur, 2014). Since diet-related carbohydrates affect blood glucose regulation, GI monitoring is especially important for those with diabetes (Kaur & Kaur, 2014). People with diabetes can reduce their risk of hyperglycaemia episodes and better control their blood glucose levels by choosing foods with a lower GI (Kaur & Kaur, 2014). By including low-GI foods in meal planning, people with diabetes can achieve better glycaemic control and more consistent blood glucose levels, both of which enhance overall health outcomes.

Glycaemic load provides a more sophisticated assessment of a food's impact on blood sugar levels by taking into account both the kind and amount of carbohydrates in a meal (Sacks et al., 2004). Glycaemic load (GL) is a more complete measure of the glycaemic impact of food than the glycaemic index (GI), which only accounts for the quality of the carbohydrates. It also takes into account the amount of food that is ingested. (Sacks et al., 2004). For those with diabetes, this comprehensive method of measuring glycaemic response is especially helpful since it makes meal planning and carbohydrate management techniques more accurate, leading to the best possible blood glucose control (Sacks et al., 2004). Through taking into consideration the kind and quantity of carbohydrates ingested, GL helps people with diabetes to make educated dietary decisions that support stable blood glucose levels.

According to Atkinson et al. (2008), incorporating foods with a lower glycaemic index (GI) into the diet might help stabilize blood sugar levels and reduce swings that can cause energy crashes, hunger pains, and cravings. According to Atkinson et al. (2008), people who are controlling their diabetes as well as those who are at risk of insulin resistance or metabolic syndrome will benefit most from this effect. People can better control their blood sugar levels by choosing foods with a lower GI, which encourages sustained energy levels and lowers the chance of experiencing abrupt reductions or spikes in blood sugar (Atkinson et al., 2008). By managing food proactively, blood sugar dysregulation's negative consequences can be lessened and metabolic health is generally supported. Compared to glycaemic index (GI), glycaemic load (GL) provides a more thorough evaluation of the glycaemic impact of foods since it takes into account both the kind and quantity of carbohydrates ingested (Sacks et al., 2004). Choosing foods lower in GL can help people better control their blood sugar levels, which lowers their risk of insulin resistance, type 2 diabetes, and cardiovascular disease (Sacks et al., 2004). Because it provides a more nuanced knowledge of how different foods affect blood glucose levels depending on both their carbohydrate content and portion size, this technique is especially helpful for people who are worried about glycaemic management (Sacks et al., 2004). Individuals can make educated dietary decisions that enhance general metabolic health and well-being by giving priority to foods with lower GL.

Eating meals low on the glycaemic index (GI) has been linked to feelings of fullness and decreased hunger, which may help regulate caloric intake and promote weight loss (Slabber et al., 1994). When compared to high-GI foods, these foods have a slower and more persistent effect on blood sugar levels, which results in a gradual release of energy and a longer-lasting feeling of fullness (Slabber et al., 1994). Low-GI foods may help people stick to their calorie-controlled diets more successfully by encouraging satiety and decreasing appetite, which may promote weight maintenance or facilitate weight loss (Slabber et al., 1994). Including a range of low-GI items in the diet can be a helpful tactic for people who want to control their weight and improve their general health. By directing dietary choices toward options that have a lower influence on blood sugar levels, glycaemic load (GL), which considers both the quality and quantity of carbohydrates consumed, offers a useful strategy for managing weight (Slabber et al., 1994). People can choose more nutrient-dense foods that enhance satiety, curb hunger, and aid in weight reduction and weight maintenance by giving priority to foods with lower GL (Slabber et al., 1994). This is because, in comparison to high-GL foods, foods with a lower GL typically promote a slower and more gradual rise in blood sugar levels, which enhances feelings of fullness and pleasure (Slabber et al., 1994). Thus, incorporating a range of low-GL foods into the diet can be a useful tactic for people seeking to manage their weight while also optimizing their overall health and well-being.

Meals high in foods low in both GI and GL, mostly made up of fruits, vegetables, whole grains, and legumes, has been associated with a lower risk of developing chronic illnesses such type 2 diabetes, cardiovascular disease, and several types of cancer (Barclay et al., 2008). Individuals may see benefits in their lipid profiles, inflammatory markers, and insulin sensitivity by choosing these nutrient-dense, low-GI, and low-GL meals. These factors are important in reducing the risk of chronic diseases and enhancing general health (Barclay et al., 2008). This diet plan has a strong emphasis on eating whole, unprocessed foods that minimize blood sugar spikes and offer sustained energy and vital nutrients, promoting metabolic health and the avoidance of disease.

Fruits in Ghana

It is essential for people who are controlling their blood sugar levels to take into account the GI and GL of the fruits they consume. Many fruits, including those that are native to Ghana, are typically regarded as healthy options because of their high fibre content, vitamins, and antioxidants, even though they include natural sugars. Fruits' ability to raise blood sugar levels can also be addressed by eating them with foods high in protein or healthy fats. Fruits play a significant role in the diet and culture of Ghana, offering a wide variety of flavours, nutrients, and culinary uses. Many fruits, including both native and exotic species, are grown in Ghana due to its tropical climate. Not only are these fruits eaten raw, but they are also blended into classic meals, drinks, and sweets.

Among many fruits that are grown in Ghana include mango, pawpaw, plantain pineapple, banana, orange, water melon and avocado (Okyere & Nyarko, 2020). Ghanaian fruits offer a plethora of nutritional benefits, making them valuable components of a healthy diet. Vitamin C is abundant in pawpaw, mango, and pineapple and is necessary for wound healing, collagen formation, and immune system activity. These fruits also have beta-carotene and vitamin A, which promote healthy skin, eyes, and an immune system. Complex carbohydrates, which give long-lasting energy and encourage satiety, are abundant in plantains and bananas. Additionally, they provide potassium, which supports heart health and blood pressure regulation. Watermelons and oranges are hydrating fruits that are rich in flavonoids and lycopene, antioxidants that boost the immune system and may prevent chronic illnesses. Avocado is unique in that it has a lot of fibre, which helps with weight control and promotes digestive health, and a high concentration of heart-healthy fats, especially monounsaturated fats. Fruits from Ghana have a rich nutritional profile that makes them vital for preserving general health and wellbeing.

In addition, the consumption of Ghanaian fruits aligns with dietary recommendations that aim to increase fruit intake in order to promote good health and prevent chronic diseases (Achaglinkame et al., 2019). Fruits such as plantains, bananas, and avocados contain fibre, which helps to maintain digestive health by facilitating regular bowel movements and preventing constipation. The vitamins, minerals, and antioxidants present in these fruits also lower the risk of a number of health conditions, such as cardiovascular diseases, some cancers, and inflammatory disorders. A variety of Ghanaian fruits can be included in a diet to provide vital nutrients that support immune system function, skin health, and vitality. As a result, Achaglinkame et al. (2019) indicate that encouraging the consumption of these fruits can have substantial public health implications, especially in the fight against malnutrition and promoting overall well-being in Ghanaian communities.

Characteristics of Shea Fruit

The shea fruit, scientifically named *Vitellaria paradoxa*, is a priceless native indigenous fruit that grows best in the savannah regions of West Africa, particularly Ghana (Kar, 2019). Shea fruit, which has a broad range of uses and a high nutritional content, has a spherical form and a green, pulpy outer layer that surrounds a large, woody nut that contains the shea butter. This fruit ripens primarily in the dry season, and depending on the region, harvesting takes place primarily in June and September (Wiesman et al., 2004). Beyond its financial worth, shea fruit is significant because it provides local populations with essential nutrition and sustenance, exhibiting amazing culinary diversity and being used in traditional medicinal practices (Kar, 2019; Maranz, Wiesman, Bisgaard, & Bianchi, 2004). Shea fruit has a unique flavour that is defined by a soft blend of moderate sweetness and nuttiness that becomes richer as the fruit ripens. Its flesh has an avocado-like soft, oily consistency that provides a distinct sensory experience. Shea fruit is traditionally consumed both raw and as a major component of a wide range of processed foods and other products. One of these products is shea butter which is a well-known product that is derived from the nut and is highly valued for its extensive application in skincare products, makeup, and culinary products (Kar, 2019). Moreover, the pulp of shea fruit is an important ingredient in the making of shea wine, a traditional alcoholic beverage made by fermenting and distilling the fruit to represent the cultural significance and culinary heritage of select West African communities (Maranz et al., 2004).

Figure 1: Freshly plucked shea fruits

The shea fruit is a source of vital nutrients and bioactive compounds that underscore its significance as a dietary staple. Shea fruit is a notable source of vitamins A and E, and is highly valued for its powerful antioxidant qualities that are essential for promoting healthy skin, a strong immune system, and clear vision (Kar, 2019). In addition, the fruit's high dietary fibre content promotes sensations of fullness and offers significant digestive benefits all of which support overall digestive wellbeing (Maranz et al., 2004). In addition, shea fruit is unique in that it contains important fatty acids, such as oleic and stearic acid, which are critical for heart health and general wellbeing (Kar, 2019). Owing to these exceptional nutritional qualities, shea fruit becomes an important element of a diet, especially in areas where it is grown and used in traditional recipes.

Characteristics of Baobab

The baobab fruit, which is harvested from the well-known Adansonia baobab tree, is highly valued as a special and incredibly nutritious fruit that is native to the savannah regions of Africa, which include Ghana, Senegal, and

Madagascar. This unique fruit comes from the baobab tree, which is known for its recognizable swelling trunks and outstanding longevity—some specimens are said to have survived for millennia (Wickens & Lowe, 2008). The baobab fruit, which is distinguished by its hard outer shell that encloses a pulpy pulp and seeds, is a prominent dietary resource and cultural symbol in its native regions. It combines cultural symbolism and nutritional richness that is deeply embedded in the customs and practices of the area (Chadare et al., 2009).

Figure 2: Baobab fruit and fruit powder

The baobab fruit, which is well-known for its unique features, has a big, pod-like form with a solid, woody shell. It can reach up to 20 centimetres in length and weighs between 400 and 800 grams on average (Chadare et al., 2009). There is an inner pulp with a dry, powdery texture that contains many seeds inside its fibrous matrix, and this pulp is enclosed by its rough, woody outer shell (Chadare et al., 2009). The baobab fruit's importance as a valuable dietary resource is highlighted by the fibrous pulp, which acts as the fruit's main nutritional reservoir and contains a wealth of important vitamins, minerals, and bioactive compounds that are crucial for human health and well-being (Chadare et al., 2009).

The baobab fruit is renowned for its exceptional nutritional qualities, since it contains an abundance of vital vitamins, minerals, antioxidants, and dietary fibre, all of which add to its highly regarded status as a superfood. Interestingly, the fruit is a unique source of vitamin C, with amounts higher than those in regularly consumed fruits like kiwis and oranges (Chadare et al., 2009). Baobab fruit is also notable for having a high concentration of other important vitamins, such as vitamin B6, thiamine, and riboflavin, as well as a variety of important minerals, such as potassium, calcium, and magnesium (Chadare et al., 2009). The pulp of the fruit is particularly highly valued for its abundant supply of dietary fibre, which helps maintain a healthy gut flora and regularity in the digestive system, as well as enhancing satiety (Chadare et al., 2009).

The distinctively tangy and slightly sour flavour of baobab fruit pulp, reminiscent of citrus fruits with a subtle sweetness, renders it a versatile ingredient appreciated in culinary and medicinal practices across Africa. Baobab fruit pulp is a natural flavouring agent that may be eaten raw or dried and powdered into a fine powder to improve the flavour of a variety of food and drink products (Chadare et al., 2009). Frequently incorporated into customary African meals, baobab fruit powder is used to enhance a wide range of foods, including as drinks, porridges, sauces, and desserts, by adding a distinct taste and nutritional value (Chadare et al., 2009). Baobab fruit pulp is not only useful for cooking; it is also an important part of traditional African medicine. It is considered to have medicinal qualities and is used to treat a variety of illnesses, including fever, diarrhoea, and respiratory infections (Chadare et al., 2009).

Characteristics of African Locust Bean

According to N'Diaye et al. (2011), the African locust bean, or *Parkia biglobosa* as it is scientifically called, is a highly valued leguminous tree that is indigenous to West Africa. It is particularly common in Senegal, Mali, Ghana, and Nigeria. The important tree is valued for its unique fruit, also known as dawadawa or African locust bean, which has contributed significantly to the culinary, nutritional, and medicinal fields (Ouoba et al., 2004). However, it is valued for its many uses. A key component of West African cuisine, the fruit of the African locust bean tree adds a distinctive and delicious flavour to a variety of traditional meals when it is used as a flavouring agent (N'Diaye et al., 2011). Additionally, the African locust bean has noteworthy nutritional qualities. It is an excellent source of protein, vitamins, minerals, and vital amino acids, which improves the nutritional content of meals in the areas where it is consumed (Ouoba et al., 2004). The fruit is also important in traditional medicine, where it is used for its supposed therapeutic qualities to treat a variety of illnesses and enhance overall health (N'Diaye et al., 2011).

The African locust bean has long, elongated pods that are 30 to 60 centimetres long. When the pods ripen, they turn from green to a dark brown or black colour (Ouoba et al., 2004). Each pod has a number of seeds embedded in a sticky, fragrant pulp that adds to the distinctive flavour and scent of African locust beans (N'Diaye et al., 2011). The fibrous, brownish pulp that surrounds the seeds is what gives the fruit its unique flavour and perfume, making it a highly sought-after ingredient in West African cooking (Ouoba et al., 2004). This fibrous pulp, which is essential to the area's culinary and cultural traditions, captures the African locust bean's rich culinary legacy and nutritional significance. African locust beans are well known for their delicious flavour and strong aroma. The fermented seeds and pulp have a characteristic umami taste, with a combination of sweet, sour, and slightly bitter notes. African locust beans have a nutty, earthy, deep scent with notes of fermented cheese and caramel. The distinctive flavour and fragrance of African locust beans make them a highly valued component in customary West African culinary traditions.

Figure 3: African locust bean

The African locust bean is high in nutrients, including a variety of vital nutrients and bioactive substances (Ouoba et al., 2004). This adaptable fruit has a notable high protein content in both its pulp and seeds, making it a valuable plant-based protein source that is especially helpful in areas where availability to animal protein may be limited (N'Diaye et al., 2011). African locust beans also include high levels of dietary fibre, minerals including calcium, iron, and phosphorus, and vitamins like vitamin C and several B vitamins (Ouoba et al., 2004). A variety of antioxidants included in the fruit also boost immune system function, digestive health, and nutritional metabolism, all of which are linked to general health and wellbeing (N'Diaye et al., 2011). The nutritional makeup of African locust beans emphasizes its importance as a mainstay in West African cooking as well as their potential as a beneficial dietary supplement for fostering optimum health.

African locust beans have been an integral component in both traditional West African meals and herbal healthcare practices in regions where it is grown (Akinola et al., 2021). African locust bean pulp and fermented seeds are used in cooking as a condiment and flavouring, adding a unique flavour and aroma to a variety of foods, including stews, soups, and sauces (Ouoba et al., 2004). These classic recipes gain depth and complexity from the distinct flavour profile of African locust beans, which also improves the dishes' entire sensory experience (N'Diaye et al., 2011). Additionally, African locust bean is valued for its alleged therapeutic qualities and is used in herbal treatments to treat a variety of illnesses, including as skin diseases, respiratory infections, and digestive issues (Ouoba et al., 2004).

Characteristics of African Grape Fruit

African grapes, often called wild or forest grapes, are the fruits of the Vitaceae family plant, the African grapevine (Awika et al., 2017). Native to several parts of Africa, including Ghana, Nigeria, Cameroon, and South Africa, these fruits constitute an essential component of the regional ecosystems and customary diets (Chivandi et al., 2017). African grapes are prized for their rich nutritional profile and bioactive chemicals, which may have health advantages beyond only their sweet and tart taste (Chivandi et al., 2017). They support African communities' local economies and culinary traditions by being consumed either fresh or processed into a variety of goods such jams, jellies, juices, and wines (Awika et al., 2017). African grapes are small, round to oval-shaped fruits that are endemic to many parts of Africa. They are distinguished by their development in clusters on woody vines (Awika et al., 2017). When fully ripe, these fruits have a range of colours, from green to purple-black, and their skin can be smooth or somewhat rough, with a powdery bloom possible (Chivandi et al., 2017). One to four large seeds, proportional to the size of the fruit, are usually seen in African grapes (Awika et al., 2017). Due to their rich nutritional profile and bioactive components, African grapes are coveted for their potential health advantages despite their tiny size (Chivandi et al., 2017). They can be eaten raw or processed to make a variety of goods, like jams, jellies, juices, and wines, contributing to both culinary traditions and local economies in African communities.

Figure 4: African grapes

African grapes are known for their sweet and tangy flavour. They provide a distinct tropical spin on classic grapes, with the variety and ripeness of the fruit influencing the taste (Akubugwo et al., 2007). These fruits are known for their unique eating experience because of their normally luscious and succulent flesh, which has a texture akin to grapes but slightly stiffer (Akubugwo et al., 2007). African grapes are a flexible ingredient in many culinary applications, from fresh consumption to processing into juices, jams, and sweets. This is due to their balance of sweetness and acidity (Akubugwo et al., 2007). Their robust flavour profile enhances food and drink, enhancing African traditional and modern cuisines alike. Moyo et al. (2011) assert that African grapes, which are highly valued for their abundant nutritional content, provide a plethora of vital nutrients that are necessary to sustain good health. What makes these fruits special is how much dietary fibre, vitamins, minerals, and antioxidants they contain (Kolawole & Maduagwu, 2015). These nutrients all work together to promote health. According to Kolawele and Maduagwu (2015), vitamin K, which is necessary for blood clotting and bone health, and vitamin C, a strong antioxidant that boosts immune system and skin health, are both abundant in African grapes. These fruits also possess abundance of minerals, such as manganese, which is essential for metabolism and bone building, and potassium, which helps to regulate blood pressure and muscular function (Moyo et al., 2011). Furthermore, African grapes are an excellent source of dietary fibre that supports healthy digestion and helps to regulate blood sugar levels (Kolawole & Maduagwu, 2015).

Due to their adaptability, African grapes are valued in many different ways by different culinary traditions (Kolawole & Maduagwu, 2015). These fruits are used in a variety of sweets, jams, jellies, and drinks to impart their distinct sweet and tart profile, or eaten fresh as a revitalizing snack or added to fruit salads to improve their flavour and texture (Chivandi et al., 2017). Additionally, certain African societies add to the cultural value of African grapes by fermenting them to make traditional alcoholic beverages (Chivandi et al., 2017). In addition to being used in food, African grapes are valued for their alleged therapeutic qualities and are used in traditional herbal treatments for a range of illnesses, including fever, respiratory conditions, and digestive issues (Akubugwo et al., 2007).

Characteristics of Breadnut

Breadnut, scientifically known as *Artocarpus camansi*, is a tropical fruit tree belonging to the Moraceae family, alongside other popular fruits like jackfruit and breadfruit (Mohamad et al., 2018). Although breadnut is indigenous to the Pacific Islands and other parts of Southeast Asia, it has been cultivated for millennia in many tropical nations across the world, such as those in Africa, the Caribbean, and Central America (Food and Agriculture Organization of the United Nations, 1998). Its nutrient-dense edible seeds, which may be eaten raw or cooked in a range of culinary preparations, are the reason this adaptable fruit tree is highly valued (Zhang et al., 2018). Breadnut shows promise as a useful crop for tackling issues with food security due to its resilience to a variety of climates and potential as a sustainable food source breadnut holds promise as a valuable crop for addressing food security challenges in tropical regions.

Figure 5: Breadnut fruits

Breadnut fruits, characterized by their large, round to oval shape, are covered with a spiky, green to brownish rind that undergoes a softening process, turning more yellowish as the fruit ripens (Paull & Duarte, 2012). The fruit's aesthetic attractiveness and tactile sensation are enhanced by the potential for a rough or knobby texture on the rind's exterior (Paull & Duarte, 2012). Breadnut fruits are known for having many seeds buried within a fibrous pulp and can range in weight from several kilos to several pounds (Mohamad et al., 2018). The fruit of the breadnut is an important food source in tropical countries because of its nutritious seeds, which are the main edible part of the plant. The seeds can be eaten raw or cooked in a variety of gourmet ways.

Breadnut fruits, renowned for their starchy, nutty flavour profile, offer a culinary experience akin to boiled potatoes or chestnuts when cooked (Zhang et al., 2018). The main edible part of breadnuts are the seeds, which can be cooked by roasting, boiling, or steaming them. The seeds have a mild, somewhat sweet flavour that improves the flavour profile of food as a whole

(Mohamad et al., 2018). When cooked, breadnut flesh takes on a smooth, creamy texture that adds to its versatility as a component in a variety of gourmet recipes (Zhang et al., 2018). Breadnuts are treasured for their unique flavour and texture, which lend depth and richness to traditional cuisines in tropical countries. They are used in both savoury and sweet dishes. Breadnut stands as a valuable and nutritious food source, boasting a rich array of essential nutrients crucial for overall health and well-being (Paull & Duarte, 2012). Paull and Duarte (2012) highlight the remarkable presence of these seeds due to their elevated level of complex carbohydrates, which offer prolonged energy and function as a mainstay in numerous tropical diets. Additionally, the high dietary fibre content of breadnut seeds supports digestive health and satiety, both of which are advantageous in areas where food access may be restricted (Mohamad et al., 2018). In addition, breadnut seeds are a notable source of protein, which makes them an important dietary addition, especially in areas where animal protein might be harder to get by (Mohamad et al., 2018). Furthermore, these seeds are abundant in crucial minerals like potassium, calcium, and magnesium as well as vital vitamins like vitamin C, vitamin A, and several B vitamins, all of which are critical for maintaining general health and vigour (Mohamad et al., 2018; Paull & Duarte, 2012).

Famous for their adaptability and nutritional value, breadnut seeds are used extensively in tropical cooking traditions as a main ingredient in a wide range of recipes (Paull & Duarte, 2012). To maximize their flavour and contribute to the diversity of tropical cuisines, these seeds are cooked using a variety of techniques such as roasting, grilling, mashing, and boiling (Paull &

Duarte, 2012). Breadnut seeds are processed into flour in some cultures, providing a healthy substitute for bread, porridge, and other baked items (Paull & Duarte, 2012). Furthermore, breadnut seeds can be pureed or made into a paste to use as a natural thickening agent in sauces, stews, and soups, giving these meals more texture and nutrition (Mohamad et al., 2018). Breadnut seeds are popular in tropical locations due to their mild flavour and creamy texture, which make them a versatile and sought-after component in savoury and sweet culinary creations.

Characteristics of Tropical Almond

Terminalia catappa, also known by its scientific name, is a tropical tree that belongs to the Combretaceae family and is valued for its ornamental and culinary uses (Ibrahim et al., 2017). Once native to parts of Southeast Asia such as India, Malaysia, and Indonesia, tropical almond has become widely cultivated in tropical and subtropical locations worldwide due to its many uses and attractive appearance (Pasa et al., 2015). The tree is valued for both its ornamental value, which adds to the attractiveness of the landscape in tropical and subtropical areas, and its edible nuts, which are used in a variety of culinary applications (Pasa et al., 2015). Because of its versatility and capacity to adapt to a wide range of temperatures, the tropical almond is significant in both agricultural and cultural contexts, representing a cherished component of tropical biodiversity.

Figure 6: Tropical almond

Tropical almond trees are notable evergreen fixtures that range in height from 15 to 25 meters, and are distinguished by their medium to large stature (Basha et al., 2012). These trees have a unique architectural character with a spreading canopy that is symmetrical and ornamented with large, elliptical-shaped leaves that are known for having a pale green look on the lower surface and a glossy green tint on the top surface (Basha et al., 2012). The distinctive feature of the tropical almond tree is that it produces small, spherical fruits that contain a single seed or nut, which further enhances the tree's aesthetic value and ecological appeal (Pasa et al., 2015). The tropical almond is a prized element of tropical landscapes and ecosystems because of its unusual size, foliage, and fruit combination.

Tropical almond fruits, or *Terminalia catappa* as it is formally called, are small and green in colour when they are first picked and turn brown when they are ready to eat or be processed (Jiang et al., 2019). Every fruit contains a single seed or nut that is shielded from the kernel inside by a hard, woody shell (Ibrahim et al., 2017). The freshness and quality of the nuts are indicated by their smooth and glossy surface, which measures around 2 to 3 centimetres in diameter (Ibrahim et al., 2017). The nut contains a pale kernel inside its protective shell that is highly valued for its high oil content and unique almond-like flavour character (Jiang et al., 2019). This nut is a highly valued oil source and culinary item that contributes to the diverse applications of tropical almond in culinary and industrial sectors. The fruit is sometimes referred to as "tropical almond" because to the delicious flavour profile of its kernel, which is evocative to actual almonds (Ibrahim et al., 2017). Because of their sweet and nutty taste, nuts are very adaptable in the kitchen. They may be eaten raw or roasted, making them a great snack or a tasty addition to a variety of recipes (Pasa et al., 2015). Moreover, the nuts are ground into flour, which enhances baking recipes and helps to create confections and palate-pleasing desserts (Pasa et al., 2015).

In addition, the nuts are pressed in order to extract almond oil, which is highly valued for its nourishing qualities and pleasant aroma and is used in cosmetics, haircare, and cookery goods (Ibrahim et al., 2017; Pasa et al., 2015). This versatile use emphasizes the importance of tropical almond nuts for both cosmetic and culinary purposes, enhancing their standing as a prized element of tropical biodiversity. The nuts are frequently used as a snack or an ingredient in a variety of culinary recipes. They can be consumed raw or roasted. Additionally, they are milled into flour and used in confections, baking, and dessert preparation. Almond oil is also extracted from the almonds through pressing, and this oil finds applications in haircare, skincare, and cookery items. In addition to its culinary value, the tropical almond tree is widely valued for its aesthetic qualities, which is why it is so commonly grown in gardens, parks, and urban are (Forestry.com, n.d.). The tree is a popular choice for landscaping because of its impressive foliage and large canopy. It also provides great shade (Forestry.com, n.d.). The tree is visually appealing all year round because of its large, elliptical leaves, which have a glossy texture and vibrant green coloration. In some climates, the leaves change dramatically, turning bright shades of red or yellow before falling gracefully (Pasa et al., 2015).

In areas where tropical almond trees are abundant, traditional medicine uses various elements of the tree, including as the nuts, leaves, and bark, for their alleged medicinal benefits (Wahida et al., 2019). Bark and leaf extracts are prized for their possible anti-inflammatory, antibacterial, and antioxidant properties, making them important ingredients in herbal medicines used to treat a range of illnesses (Wahida et al., 2019). The long-standing history of using tropical almond tree products as part of traditional healing traditions is reflected in the frequent use of these natural remedies in the treatment of illnesses like diarrhoea, skin infections, and inflammatory diseases (Wahida et al., 2019). In conclusion, the tropical almond tree is a multipurpose plant valued for its nut-eating potential, aesthetic appeal, and historical medical applications. The tree's lovely foliage and spreading canopy make it a popular choice for landscaping in tropical areas, and the nuts, which have a sweet, nutty flavour akin to real almonds, are utilized in culinary applications.

Empirical Review

Empirical Review on the Nutritive Composition of Fruits

Monteiro et al. (2022) conducted a study in Angola's Namibe province to evaluate the nutritional properties of baobab pulp from different regions.

The research aimed to assess the nutritional composition and bioactive properties of baobab fruit pulp collected from multiple municipalities. A quantitative research design was employed, incorporating laboratory-based analytical techniques, including high-performance liquid chromatography (HPLC) and principal component analysis (PCA), to determine the nutrient composition. The study sampled baobab pulp from four municipalities, collecting multiple samples per location for a comprehensive analysis. Key findings revealed significant variations in moisture, ash, protein, and antioxidant content among samples from different municipalities, with some regions exhibiting higher levels of calcium, phosphorus, and vitamin C, while others showed poorer bioactive content. The study acknowledged limitations, such as the influence of soil conditions on nutrient composition and the need for further exploration of post-harvest handling effects. The conclusion emphasized that baobab pulp has strong nutritional potential and could be promoted for local and international markets. Future research should explore the long-term storage effects and extend the study to other regions in Angola.

Alcon et al. (2021) conducted their study in the Philippines to evaluate the proximate composition, antioxidant capacity, and functional properties of breadnut seed flour (*Artocarpus camansi*). The primary objective of the research was to determine the chemical composition and functional properties of breadnut seed flour, particularly its potential as an alternative or complementary flour to wheat flour. The study employed an experimental research design, involving laboratory analysis of nutrient composition, antioxidant capacity measurement via DPPH scavenging activity, and functional property assessment. The sample population consisted of breadnut fruits collected from Roxas, Isabela, Philippines, which were processed into flour and tested at different ratios with wheat flour. Key findings indicated that breadnut seed flour is rich in carbohydrates (75.39%), contains 6.16% protein, and has a high antioxidant capacity (97.53% DPPH scavenging activity). Functional testing showed that a 50:50 breadnut-wheat flour blend had favourable water absorption, fat absorption, and emulsification properties. However, the study highlighted limitations, such as the short shelf-life of raw breadnut seeds and the need for further exploration of its functional applications in various food products. The conclusion emphasized that breadnut seed flour is nutritionally comparable to wheat flour and could serve as a functional ingredient with health benefits. Future studies should explore its potential in different food matrices and investigate its health effects more comprehensively.

Jeridi et al. (2023) conducted a study in Tunisia to analyse the nutritional composition of fresh banana fruits (*Musa spp.*) grown in the coastal oasis of South Tunisia. The study aimed to determine the chemical content, minerals, and vitamin levels in six triploid banana accessions. A quantitative laboratory-based research design was used, involving chemical and mineral composition analysis using high-performance liquid chromatography (HPLC) and spectrophotometry. The study analysed 120 banana samples collected during peak production from two selected regions. Key findings showed that bananas contained high levels of potassium (1211.68 mg/100 g DM), significant iron content (up to 1945 mg/100 g DM), and varying levels of glucose, fructose, sucrose, and vitamin C. However, disparities in mineral content among accessions were noted. Limitations include the lack of data on the effects of soil quality on banana nutrition. The study concluded that banana fruits are a rich source of essential minerals and recommended further investigation into their role in dietary health and food security.

Aguzue et al. (2013) conducted a study in Nigeria to evaluate the nutritional and elemental composition of shea (*Vitellaria paradoxa*) fruit pulp. The research aimed to analyse its proximate composition and mineral content. A laboratory-based experimental design was used, employing standard methods for proximate and elemental analysis, including atomic absorption spectrophotometry. The study examined oven-dried fruit pulp samples collected from Sheda Science and Technology Complex, Abuja. Key findings revealed that shea pulp contained high carbohydrates (72.02%), crude fibre (9.6%), and calcium as the most abundant mineral. However, iron and cadmium were found in minimal amounts. A major limitation was the lack of data on how processing affects the nutritional value. The study concluded that shea fruit pulp is a valuable nutritional resource, recommending further research on its industrial applications.

Aluko et al. (2016) carried out a study in Tanzania to evaluate the nutritional quality and functional properties of baobab (*Adansonia digitata*) pulp. The objective was to determine the chemical composition and functional characteristics of baobab pulp from different locations. A laboratory-based experimental design was used, including proximate analysis, HPLC, and spectrophotometry. Baobab samples were collected from three locations in Tanzania. Results showed high carbohydrate content (80.49%-85.19%), vitamin C (169.74-231.57 mg/100 g), and significant emulsification and foaming properties. However, variations in nutrient content among locations were observed. The study was limited by its focus on a few geographical locations, potentially overlooking broader variations. It concluded that baobab pulp is a nutrient-rich food with functional properties beneficial to the food industry, recommending further research on its applications in processed foods.

Dauda et al. (2014) conducted a study in Nigeria on the nutritive and anti-nutritive composition of the locust bean tree emperor moth larvae (*Bunaea alcinoe*). The study aimed to analyse the proximate, mineral, fatty acid, and anti-nutritional composition of these larvae. A laboratory-based experimental design was used, employing proximate analysis and atomic absorption spectrophotometry. Samples were collected from locust bean trees in Niger State, Nigeria. Key findings showed that the larvae were rich in protein (44.23%), lipids (10.85%), and essential minerals such as calcium and phosphorus. However, the presence of anti-nutritional factors like oxalates (15.47 mg/100 g) and phytates (18.21 mg/100 g) was noted. A limitation was the study's lack of data on how processing methods could reduce these anti-nutrients. The study concluded that these larvae could serve as a potential protein source, recommending further research on their safety and processing methods.

Bindu et al. (2019) conducted a study in India to assess the phytochemical, nutritional potential, and antifungal activity of tropical almond (*Terminalia catappa*) seeds. The study aimed to determine the seed's nutrient content and bioactive properties. A laboratory-based experimental design was used, involving standard proximate analysis and antifungal testing against Candida albicans. The study examined almond seeds collected from the coastal region of Alappuzha, Kerala. Key findings showed that the seeds contained significant amounts of protein (20.86%), carbohydrates (16.2%), and fat (14.5%). The methanol extract exhibited strong antifungal activity, inhibiting Candida albicans growth. However, the study lacked data on potential toxicity and long-term health effects. The conclusion emphasized the nutritional and medicinal potential of tropical almond seeds, recommending further research into their pharmaceutical applications.

Empirical Review on the glycaemic indices and glycaemic loads of Fruits

Gomina et al. (2021) conducted a study in Benin to determine the glycaemic index (GI) and glycaemic load (GL) of four local fruits among young adults. The study aimed to assess the impact of these fruits on blood glucose levels. A quasi-experimental, interventional study was conducted, where 33 young adults consumed reference foods (glucose or white bread) and fruit servings, followed by glucose level monitoring. Key findings revealed that mango had the highest GI (117.09), while watermelon, papaya, and pineapple had significantly lower GI values. Mango also had the highest glycaemic load. Limitations included a small sample size and the need for further studies on diverse populations. The study concluded that watermelon, papaya, and pineapple can be recommended for safe consumption, suggesting further research on other local fruits.

Keyla et al. (2022) conducted a randomized controlled trial in Portugal to evaluate the effect of baobab fruit (*Adansonia digitata L.*) on postprandial glycaemia. The objective was to analyse the impact of baobab on blood sugar levels, bioactive compounds, and antioxidant activity. The study involved 31 healthy adults, divided into control and intervention groups, where the latter consumed baobab aqueous extract after an oral glucose tolerance test. Results indicated that baobab significantly reduced postprandial glycaemia and had high antioxidant activity due to polyphenols and tannins. However, the study was limited by its small sample size and short duration. The conclusion emphasized baobab's potential as a natural hypoglycaemic and antioxidant agent, recommending further clinical trials.

Gomina et al. (2021) carried out another study in Benin to assess the glycaemic index and glycaemic load of local fruits among young adults. The study aimed to determine the glycaemic response of papaya, mango, pineapple, and watermelon. A quasi-experimental interventional study was conducted with 33 participants, measuring blood glucose levels over time. Findings showed that mango had the highest GI (117.09), whereas papaya, watermelon, and pineapple had significantly lower values. The study's limitation was the small sample size and the exclusion of participants with pre-existing conditions. The conclusion recommended watermelon, papaya, and pineapple for safe consumption, with further research suggested on other regional fruits.

Kamchansuppasin et al. (2021) conducted a study in Thailand to determine the glycaemic index and glycaemic load of commonly consumed Thai fruits. The research aimed to classify low, medium, and high GI fruits. A randomized study was conducted with 120 healthy participants, who consumed 25 g available carbohydrates from different fruits, followed by blood glucose monitoring. Key findings showed that most Thai fruits had low GI values, while pineapple had the highest GI (72.1%). Limitations included variations in ripeness and carbohydrate composition across different fruit samples. The study concluded that low GI fruits can be included in diabetic diets, recommending further studies on fruit processing effects on GI.

Gaps and Lessons learnt from the Review

Firstly, while studies such as those by Monteiro et al. (2022) and Aluko et al. (2016) analysed the nutritive composition of baobab pulp, they focused on regional variations in nutrients without correlating them directly with glycaemic response. Similarly, Aguzue et al. (2013) examined the nutritional and mineral composition of shea fruit pulp but did not explore its impact on blood glucose levels. This study addresses this gap by not only analysing the composition of these fruits but also linking them to their glycaemic effects.

Secondly, research on the glycaemic indices of fruits has primarily been conducted on common tropical fruits such as mango, pineapple, and papaya, as seen in Gomina et al. (2021) and Kamchansuppasin et al. (2021). However, there is little to no data on indigenous Ghanaian fruits such as African grapes, breadnut, and African locust bean, which may have unique carbohydrate compositions affecting their GI and GL. This study bridges this gap by determining the GI and GL of these lesser-studied fruits, thereby expanding knowledge on regional dietary impacts on glycaemia.

Additionally, while Rita et al. (2022) showed that baobab significantly reduces postprandial glycaemia, they focused on baobab fruit extract rather than whole fruit consumption, which may have different effects on glycaemic response due to fibre content. This research fills the gap by analysing the GI and GL of whole baobab fruit and powder in its natural state.

Lastly, studies like Dauda et al. (2014) on locust bean larvae focused more on protein content and anti-nutritional factors rather than its glycaemic effects. Similarly, Bindu et al. (2019) examined tropical almond's nutritional value and antifungal properties but did not explore its impact on blood sugar levels. This study therefore fills the gap by comparing how these indigenous fruits influence blood glucose levels, which is crucial for dietary planning and diabetes management.

There is limited data on the GI and GL of indigenous Ghanaian fruits, making this study a valuable addition to nutritional research. The nutritional composition of fruits alone does not determine their glycaemic response, as seen with baobab's high vitamin C content yet low GI impact. Previous research has not directly compared the glycaemic responses of these six fruits, which this study will do to provide comprehensive dietary recommendations.

Conceptual Framework

The schematic representation in Figure 7 delineates the interrelationship between the six selected indigenous Ghanaian fruits, designated as the independent variable, and four dependent variables: glycaemic index (GI), glycaemic load (GL), nutritive composition, and postprandial blood glucose levels.

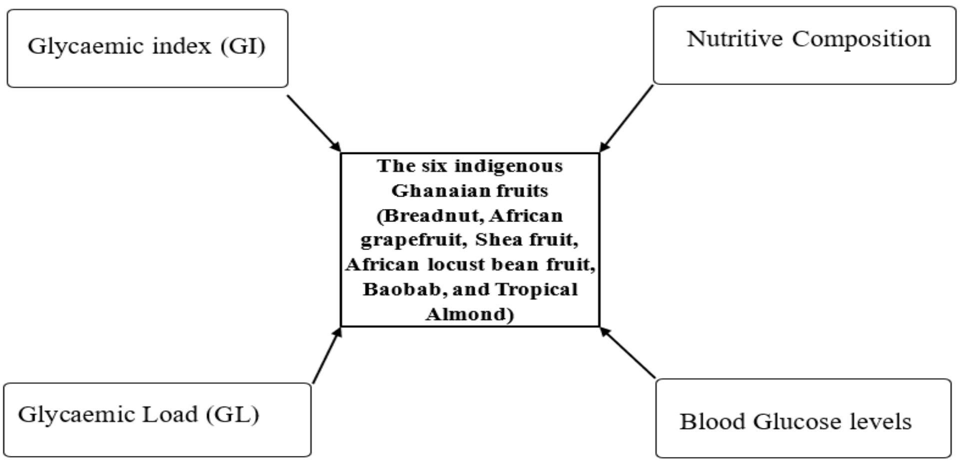

Figure 7: Conceptual Framework Linking Indigenous Ghanaian Fruits to GI, GL, Nutrient Content, and Blood Glucose Levels

These fruits constitute the primary focus of the investigation, exerting an influence on the quantifiable outcomes associated with each dependent variable. The GI and GL serve as metrics to evaluate the fruits' effects on postprandial glycaemia, with the GI encapsulating the rate of blood glucose elevation relative to a reference standard, and the GL integrating both this rate and the quantity of available carbohydrates. The nutritive composition encompasses the macro- and micronutrient profiles of the fruits, which may modulate glycaemic responses through their biochemical properties. Collectively, these variables coalesce to determine the resultant blood glucose concentrations following consumption, thereby elucidating a direct linkage between the fruits and their prospective utility in the management or exacerbation of glycaemic disorders, such as type 2 diabetes mellitus.

CHAPTER THREE

RESEARCH METHODS

This chapter presents the materials, methodology and procedures that were used when conducting this study. The methodology includes the research design, study area, study subjects, study participants, data collection procedure, how data was analysed and interpreted and ethical considerations.

Research Design

The study employed an experimental design, specifically, the crossover experimental design. An experimental study is one in which the investigator controls at least one independent variable while keeping other important variables under control and then observes or predicts what is going to happen to the participants as a result as stated by (Amedahe ,2009).

A crossover design is repeated measurements design such that each experimental unit (participants) receives different treatments during the different time periods, i.e., the participants cross over from one treatment to another during the course of the whole trial. Sambandan and Turcu-Stiolica (2019) states that in crossover studies, the study participants will be switched throughout all the treatment groups (both test and reference formulations) after a washout period. Being the same set of the population, the advantage of crossover studies is that participants act as their own control.

Study Area

This study was conducted in Ghana because the selected local fruits are eaten and enjoyed by different ethnic groups in the country. The study was specifically carried out in the University of Cape Coast- Cape Coast, in the Central Region of Ghana. To conduct the clinical test, permission was sought from the Department of Physician Assistant Studies, University of Cape Coast in Cape Coast Municipality to use their skills laboratory and expertise. The University community which is an academic community consists of individuals from all over Ghana, so selection of participants for the clinical trial was easier.

This site was chosen because it is well resourced and has professionals who can easily assist in the collection of data (blood glucose test). Being a health facility that trains health professionals that attend to diabetic's patients and patients with non-communicable diseases, collection of data was made easy and identification of any medical condition which could impact on the results was carried out.

Population of the Study

According to William (2011), population is the larger group of people or objects that the researcher intends to generalize the study's findings to. The population in this study consisted of both individuals and the food sample. All healthy people without any underlying health condition from the University of Cape Coast in the Central Region without any health condition met the inclusion criteria and were, therefore, eligible. The target population for this study was adults from 18 years to below 60 years. Persons below 18 years and 60 years and above have been reported not to be ideal for such exercise (WHO/FAO, 1998). The accessible population was all healthy individuals in the University of Cape Coast campus who met the inclusion criteria and was willing to participate in the study. The results from this study were generalized to people with or without chronic diseases (diabetes, obesity, hypertension etc.). For the food samples baobab, shea fruit, African grapes fruit, tropical almond, African locust bean and breadnut were used.

Sampling Procedure

Purposive sampling was used to select the individuals for the blood glucose test. Purposive sampling is a nonprobability sampling strategy that uses a researcher's own judgement when selecting participants out of number of people to take part in a study, according to Lewis-Beck, Bryman, and Liao (as referenced by Adu- Gyamfi, 2018). They contend that it involves specifically looking for participants who possess particular qualities in order to meet the demands of the evolving analysis and emerging theory.

Study Food Samples

The consumables for the study were Baobab, Shea fruit, African grapes, Breadnut, African locust fruit, and Tropical Almond. The fruits for the research were purchased from fruit sellers in local markets across the country. Samples of the Baobab, Shea fruit, African grapes and African locust fruit, were bought in the Northern Region of Ghana and the tropical almond and breadnut bought from Accra and Kumasi respectively. The cost in purchasing these fruits was One Thousand Ghana Cedis (GHC 1000.00). To obtain the right quantity of each fruit to give to the participants to eat, the quantity of each fruit that would provide the 50g of glucose was determined through proximate analysis to obtain the amount of soluble carbohydrates or sugar.

Study Subjects

For the blood glucose test, ten healthy participants were purposefully selected from the University community. Based on the World Health Organization and the Food and Agriculture Organization (1998) recommendation for the determination of glycaemic index (GI), ten subjects were chosen. This kind of test may be done in six additional participants, according to FAO/WHO for more precise results. According to Bronus et al. (2005) and Vuksan, Wolever, and Jenkins (2011), ten individuals should be used to determine the glycaemic index. Since individuals often complete inclusion requirements before taking part in the study and are purposively sampled.

Inclusion criteria:

1. Individuals ranged in age from 18years to 60 years.
2. Participants were healthy, without any sugar intolerance.
3. Participants were not on any medication, and would be available for the entire course of the study period.
4. Participants do not have allergies for any of the fruits presented.

Exclusion criteria

The following exclusion criteria were used:

1. Subjects aged below 18 years and above 60 years but have histories or complain of diabetes or any form of metabolic disorders.
2. Participants should be without glucose intolerance and any metabolic disorder.
3. Obese individuals with or without diabetes.
4. Subjects who miss any of the required session for the test fruits.

Three days prior to the test day, all of the participants were gathered for an orientation. They were informed of the procedures and preparations required before the test. Prospective participants were asked to abstain from alcohol and smoking during the study.

Methods and Materials

The fruits tested were bought from the Tamale market in the Northern region, Bantama market in the Ashanti region and Talmond shop in the Greater Accra region. The fruits were weighed, washed and packed in ziplock bags prior to the blood glucose test. The amount of fruit that would provide 50g of glucose to the participants calculated for each fruit based on the proximate analysis of the fruit. The total glucose content in each fruit was calculated in duplicate. The mean weight of the available glucose was calculated by adding the two grams and dividing by half. So for the mean glucose of all the fruits was calculated as follows:

- Baobab fruit $\frac{160.2333g+160.3265g}{2} = 160.2799g$
- African locust bean fruit $\frac{135.2584+135.1145}{2} = 135.18645$
- Tropical almond $\frac{200.0214+200.0063}{2} = 200.01385$
- African Grapes fruits $\frac{140.1524+140.2102}{2} = 140.1813$
- Shea fruit $\frac{102.2658 +102.5693}{2} = 102.41755$
- Breadnuts $\frac{170.3625+170.2547}{2} = 170.3086$

Proximate Analysis

A key technique for determining the primary constituents or proximal principles in a food sample is to perform a proximate analysis. The proximate analysis offers important details regarding the make-up and nutritional value of the sample. To reduce bias, it's crucial to take into account elements like homogeneity and random sampling.

Hundred (100) grams of each of the six fruit was weighed (baobab, shea fruit, African grapes, Breadnut, African locust fruit, and Tropical

Almond), was milled and analysed proximately. The listed nutrients were identified;

1. Moisture content
2. Ash content
3. Protein content
4. Soluble Carbohydrates
5. Fat content
6. Fibre content

Moisture Determination

Porcelain crucibles were washed dried and weighed. About 10-12g each of the samples was 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. These were then kept in a thermostatically controlled oven at 105^0C for 48 hours. At the end of the period the samples were removed, cooled in a desiccator and reweighed. Each sample was carried out three times. The moisture content was then calculated as the percentage water loss.

$$\text{Moisture Content} = \frac{wet\ weight - weight\ after\ drying}{weight} \times 100$$

Ash Determination

The dried samples were then heated gently in an oven at 105°c for about an hour and then transferred to a furnace at a temperature of 550°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

Procedure

About 10- 12g of the milled samples were weighed into a 50 ×10mm Soxhlet extraction thimble. This was transferred IN 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 6 hours using a heating mantle as a source of heat. After the 6 hours the flask was removed and placed in an oven at 60^{o}C for 2 hours. The round bottom flask was removed, cooled in a desiccator and weighed. The percentage fat/oil was calculated as followed.

Calculation

Crude Fat (%) = $\frac{\text{W (g)} \times 100}{\text{Sample (g)}}$,

where W is Weight of Oil

Protein Determination

The Kjeldahl method was used for the determination of protein. The method is divided into three steps: digestion, neutralization or distillation and titration.

Digestion

About 0.2g of the fruit sample was weighed into a 100 ml Kjeldahl flask. About 4.4mL of the digestion reagent was added and the samples digested at 360^{o}C for two hours. A blank was prepared. (Digestion of the digestion mixture without sample) were carried out in the same way. After the digestion, the digests were transferred quantitatively into 100 ml volumetric flasks and made up to the volume.

Distillation

The steam distillation apparatus was flushed with distilled water for about twenty (20) minutes. After flushing out the apparatus, five (5) millilitres of boric acid indicator solution was poured into a 100 ml conical flask and placed under the condenser of the distillation apparatus with the tip of the condenser completely immersed in the boric acid solution. An aliquot of the sample digest was transferred to the reaction chamber through the trap funnel. About 10mL of alkali mixture was added to commence distillation immediately and about 50mL of the distillate was collected.

Titration

The distillate was titrated with 0.1N HCl solution until the solution changed 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. The titre values obtained were used to calculate the nitrogen content and subsequently protein content. The conversion factor used was 6.25.

$$\%\text{Total Nitrogen } (\%N) = \frac{(\text{Sample titre value} - \text{Blank titre value}) \text{ X } 0.1 \text{ x} 0.01401 \text{ x } 100}{\textit{sample weight X } 10}$$

% Protein = %N x 6.25

Crude Fibre Determination

Sodium hydroxide, 1.25%

1.25%. Dissolve 12.5g NaOH in 700ml distilled water in a 1000ml volumetric flask and dilute to volume.

Sulphuric Acid, 1.25%

Add 12.5g conc. Sulphuric acid to a volumetric flask containing 400ml distilled water and dilute to volume.

Procedure

About 1g of the fruit sample was weighed with an analytical balance and placed in a boiling flask. A 100ml of 1.25% sulphuric acid solution was added and boiled at 30°C to 35°C for 30mins. After boiling, the solution was filtered 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. Subsequently, the solution was filtered and further boiled. The residue was washed with boiling water and methanol. The crucible was dried in an oven at 105 degrees Celsius overnight and weighed. The crucible was placed in a furnace at 500 degrees Celsius for about 4 hours. The crucible was slowly cooled to room temp in a desiccator and reweighed.

Calculation

$$\% \text{ Crude fibre} = \frac{\text{weight loss thro ashing}}{\text{Sample weight}} \times 100$$

AOAC (2008)

Total carbohydrate was determined by difference.

Preparation of Sample Solution for the Determination of N, K, Na, Ca, Mg, P, Zn, Cu & Fe

The preparation of sample solutions suitable for elemental analysis involves an oxidation process which is necessary for the destruction of the organic matter, through acid oxidation before a complete elemental analysis can be carried out

Sulphuric Acid-Hydrogen Peroxide Digestion

The digestion mixture comprised of 350mL of hydrogen peroxide, 0.42g of selenium powder, 14g Lithium Sulphate and 420mL sulphuric acid. The digestion procedure as outlined in Stewarte et al 1974 was used. Between

0.1000g to 0.2000g of the oven-dried ground sample was weighed into a 100mL Kjeldahl flask and 4.4mL of the mixed digestion reagent was added. The samples were digested at 360^{o}C for two hours. Blank digestions (digestion of the digestion mixture without any fruit sample) were carried out in the same way. After the digestion, the digests were transferred quantitatively into 100mL volumetric flasks and made up to volume.

Colorimetric Determination of P using the Ascorbic Acid Method

The procedure required the preparation of colour forming reagent and P standard solutions. The colour forming reagent was made up of reagents A and B. Reagent A was made up of 12g ammonium molybdate in 20ml distilled water and 0.2908g of potassium antimony tartrate was dissolved in 100mL distilled water and 1L of 2.5M H_2SO_4. The three solutions were mixed together in a 2L volumetric flask and made up to volume with distilled water.

Reagent B was prepared by dissolving 1.56g of ascorbic acid in 200mL of reagent A. A stock solution of 100μgP/mL was prepared from which 5μgP/mL of the solution was used to prepare a set of working standards of P with the following concentrations 0, 0.1, 0.2, 0.4, 0.6, 0.8 and 1.0μgP/mL in 25mL volumetric flasks. About 2mL aliquot of the digested samples were each pipetted into 25mL volumetric flasks. About 2mL aliquot of the blank digests were each pipetted into each of the working standards to give the samples and the standards the same background solution.

Ten millilitres (10ml) of distilled water was added to the standards as well as the samples after which 4 mL of reagent B was added and their volumes made up to 25mL with distilled water and mixed thoroughly. The flasks were allowed to stand for 15minutes for colour development after which the absorbances of the standards and samples were determined using a spectrophotometer at a wavelength of 882.nm. A calibration curve was plotted using their concentrations and absorbances. The concentrations of the sample solutions were extrapolated from the standard curve.

Calculation

If C = μgP/mL obtained from the graph,

then μgP/g (sample) = $\frac{\text{C x Dilution Factor}}{\text{weight of sample}}$

(IITA, 1985)

Determination of Potassium and Sodium

Potassium and sodium in the digested samples were determined using a flame photometer. In the determination the following working standards of both K and Na were prepared: 0, 2,4,6,8 and 10 μg/mL. The working standards as well as the sample solutions were aspirated individually into the flame photometer and their emissions (readings) recorded. A calibration curve was plotted using the concentrations and emissions of the working standards. The concentrations of the sample solutions were extrapolated from the standard curve using their emissions.

Calculation

μgNa/g = $\frac{\text{C x solution volume}}{\text{Sample weight}}$

Stewarte et. al (1974)

Determination of Calcium and Magnesium by Edta Titration

The method involved chelation of the cations with ethylene diaminetetra-acetic acid (EDTA). The procedure involved the determination of calcium and magnesium together and the determination of calcium alone and magnesium was found by difference.

Calcium and magnesium together were determined by placing an aliquot of 10mL of the sample solution in a 250mL conical flask and the solution was diluted to 150mL with distilled water 15mL of buffer solution and 1mL each of potassium cyanide, hydroxylamine hydrochloride, potassium ferro-cyanide and triethanolamine (TEA). Five drops of erichrome Black T (EBT) were added and the solution was titrated against 0.005M EDTA. Calcium was determined by pipetting 10mL of the sample solution into 250mL conical flask and diluted to 150mL with distilled water. About 1mL each of potassium cyanide, hydroxyl-amine-hydrocloride potassium ferro-cyanide and TEA five drops of calcon indicator were added and the solution was titrated with 0.005M EDTA.

Calculations

$$\% \text{ Ca} = \frac{0.005 \text{ x } 40.08 \text{ x T}}{\text{Sample wt}}$$

$$\% \text{ Mg} = \frac{0.005 \text{ x } 24.31 \text{ x T}}{\text{Sample wt}}$$

Where T = titre value

Page et al (1992)

Determination of Iron, Copper and Zinc using atomic Absorption Spectrophotometer

Standard solutions of 1, 2 and 5μg/mL solutions of Fe, Cu and Zn were prepared. The standard solutions were aspirated into the atomic absorption spectrophotometer (AAs) and the respective calibration curves were plotted on the AAS. As the sample solutions were aspirated, their respective concentrations were provided.

Calculations

$$\text{Fe} (\mu g/g) = \frac{\text{C x solution volume}}{\text{Sample weight}}$$

$$\text{Cu} (\mu g/g) = \frac{\text{C x solution volume}}{\text{Sample weight}}$$

$$\text{Zn} (\mu g/g) = \frac{\text{C x solution volume}}{\text{Sample weight}}$$

Source: FAO (2008)

Data Collection Procedure

The proximate analysis of each fruit was carried out in the School of Agriculture, UCC, laboratory. The blood glucose test was conducted with the help of a skilled medical personnel at the Department of Physician Assistant Studies, University of Cape Coast skills laboratory. The researcher obtained ethical clearance from the University of Cape Coast's IRB prior to starting the study. All the 10 participants fasted for 10 hours to 12 hours between the hours of their last meal the night before the test and the morning of the test. On the day of the test, participants were instructed to arrive between 8:00 and 9:00 am for the 2-hour test to take place. The age, gender, weight in kilogram, and height in metres of each participants was taken and recorded.

Fasting Blood Glucose Test (FBGT)

On each day of the test, prior to administering the test and reference foods, each subject had their Fasting blood glucose (FBG) measured. Alcohol was applied to the fourth left finger, counting from the thumb, of each subject to accomplish this. A lancet was used to pierce their fingers in order to extract a capillary blood drop. The blood drop was used to measure the Fasting blood glucose (FBG) that was collected and placed into the URIT-25 Glucometer strip and readings taken and recorded.

Oral Glucose Tolerant Test (OGTT)

Each subject was provided with a glucose solution (reference food) made from 50 grams of glucose and 500 millilitres of water within five minutes. To make sure subjects took the glucose solution within five minutes, a timer was used. All of the subjects had a drop of capillary blood taken from their fourth finger and the blood tested for glucose 30 minutes after drinking the glucose solution. Subsequently, samples were collected from the subjects at the 30^{th} minute, 60^{th} minute, 90^{th} minute, and 120^{th} minute. These results were used to analyse the blood glucose concentration. At the end of each day's session, subjects were given breakfast or an early lunch. The OGTT was done on the first day of the test period.

Test Foods

The first test food was given a day after the OGTT. All participants were given 160g of baobab fruit powder. The night before the day of test, the participants were asked to fast for 10- 12 hours prior to taking their FBG teach morning. The time participants started eating was recorded and they were asked to complete eating within a period of five minutes. After eating, drops of capillary blood were taken from participants at the 30th, 60th, 90th and 120th minutes to check for blood glucose. This was done by wiping subjects' finger tips with alcohol to sanitize these. They were pricked with a lancet and a glucometer with a strip inserted was used to collect the drop of blood. Results were recorded in mmol/l. On subsequent days, the test on the rest of the fruits was carried out, the same processes used for the first test food were followed. However, the quantity for each test food used was different. This is because the fruits contained different amounts of glucose. Subjects were monitored throughout the study so as to ensure that they did not take in any other food or were not involved in strenuous activities that may affect the results of the study. They were also always informed of the day for the next test and were reminded to fast for 10-12 hours each night prior to the day of test. Participants were also advised to stay away from alcohol and smoking during the period of data collection.

Data Processing and Analysis

For the controls, the mean values for the increases of glucose at each period was computed from the fasting glucose test. For each time and each fruit, the mean blood sugar increases were calculated. Data was managed with Microsoft Excel 2016 and analysed using IBM SPSS Statistics 27 and GraphPad Prism 9. The proximate and mineral analyses were performed in triplicates, and results were expressed as mean ± standard deviation. Descriptive statistics were performed on the anthropometric characteristics of the participants. The GraphPad Prism was used to plot the glucose response curves and calculated the iAUC for each test food. The two-way repeated measures analysis of variance (ANOVA) with Bonferroni's correction was used to verify the effect of time on the glucose response curve. The data obtained from the different analyses were analysed using one-way ANOVA while Tukey's test was used to compare the means among fruit samples at $\alpha = 0.05$. The glucose area under the curve and glycaemic index for each fruit was calculated. The mean increments of glucose amount projected for the quantity of carbohydrate in the fruit was plotted. Brand-Miller et al.'s (2003) classification which places low GI at 55, moderate GI at 56–69, and high GI at 70, the glycaemic index was used to determine and categorize the fruit as low, medium, or high. The glucose load was also calculated by multiplying the fruit's carbohydrate content (measured in grams) by the food's GI and divided the results by 100.

Ethical Considerations

Before gathering data for the study, approval from IRB (Institutional Review Board) of the University of Cape Coast (UCC) was obtained. Participants were asked for their informed consent before continuing with the study**.** Individuals who participated in the study did that voluntarily. Issues regarding confidentiality, anonymity and privacy were given a priority in this study. Once approval was obtained from the IRB of UCC, all potential study participants were individually approached and their consent sought to voluntarily participate in the study. The consenting process involved explaining the purpose of the study, assuring confidentiality procedures, minimising risks, promoting benefits and the freedom to opt out of the study at any time without any penalty. After the study was thoroughly explained, to the prospective participants, they were recruited to participate in the study after they gave their consent by signing an informed consent form. To ensure participant’s data confidentiality, they were identified with numbers. Most importantly on the ethical issues of the study, pieces of information that were cited from earlier studies to support the review of related literature was duly acknowledged through both citation and referencing in order to avoid plagiarism.

CHAPTER FOUR

RESULTS AND DISCUSSION

Introduction

This chapter presents and discusses findings from the present study comparing observed trends with relevant literature. The discussion of the analysed data began with the proximate and mineral composition of six selected Ghanaian fruits. The demographic and anthropometric characteristics of the participants used for the glycaemic index study follows. The final part of the discussion describes the glycaemic response graph and links it to the observed trend regarding the glycaemic index and load values for the six selected Ghanaian fruits. The implications of the reported glycaemic index and load values to health professionals' and consumers were also highlighted.

Proximate Composition of the Six Selected Ghanaian Fruits

The nutritional value of food was determined by the proximate analysis, mineral and vitamin compositions. Having knowledge of these elements particularly for underutilized fruit crops are useful in providing a well-rounded diet, supply vital nutrients and facilitate digestion (Raymond & Morrow, 2022). In fruit crops, the type of fruit, cultivar/variety, agronomic and cultivation methods, maturity, ripeness and storage conditions are factors that influence their nutritional composition (Rodriguez-Amaya et al., 2008). Table 3 shows the proximate composition of the six fruits assessed.

African grape fruit, shea fruit and breadnut recorded the high moisture contents of over 60% whereas tropical almond had the least moisture content (4.38%). The moisture content for baobab and African locust bean/ dawadawa (~18%) were significantly different from the other fruit samples ($p<0.05$).

These moisture contents were slightly lesser than those reported by Okullo et al. (2010) who worked on shea fruits, Muhammad et al. (2018) on African grape fruits, Abdurraman & Haliru (2019) on locust bean, and Sadiq et al. (2009) on baobab. These variations could be attributed to differences in geological or varietal influence. Knowledge of a fruit's moisture content is useful in effective postharvest management (Lufu, Ambaw & Opara, 2020). Fruits with high water content tend to spoil faster, necessitating meticulous postharvest care. Conversely, fruits with low moisture have a longer shelf life, but lose weight under high temperatures (Ahmad et al., 2015). Based on the reported moisture contents, tropical almond is expected to be the most shelf stable fruit while African grape fruit, shea fruit and breadnut constitute the highly perishable fruits.

Ash content, the residual inorganic minerals post-oxidation, serves as an index for mineral and heavy metal content in fruits (Ogoloma et al. 2013). It is critical for maintaining quality control as it influences the organoleptic properties (Alam & Saqib, 2015). Baobab fruit had the highest ash content (5.33%), followed by African locust bean/ dawadawa fruit (3.88%), tropical almond (3.50%), African grape fruit (1.70%), breadnut (1.03%) with shea fruit having the least ash content (0.79%). The ash content among the fruit samples were significantly different from each other except breadnut and shea fruit ($p<0.05$). The findings in the present study are comparable to that reported by Sadiq et al. (2009) for baobab however lesser than those of Abdurraman & Haliru (2019) reported for African locust bean/ dawadawa fruit.

Table 3: Proximate composition of six selected Ghanaian fruits

Sample/Parameter	Moisture (%)	Ash (%)	Protein (%)	Fat (%)	Fibre (%)	Available Carbohydrate (%)
Baobab Fruit	17.74±0.08a	5.33±0.34d	4.11±0.01a	0.73±0.03a	10.14±0.25a	61.96±0.29e
African Locust Bean/ Dawadawa Fruit	18.32±0.14a	3.88±0.15c	9.68±0.19b	2.16±0.05b	6.29±0.14b	59.67±0.32d
Tropical Almond	4.38±0.04b	3.50±0.03[c]	23.33±0.51c	40.38±0.10c	9.79±0.09a	18.63±0.67a
Breadnut	62.38±0.07c	1.03±0.09a	5.78±0.13d	2.81±0.07d	2.01±0.02c	25.99±0.07bc
African Grape Fruit	67.42±0.48d	1.70±0.05b	3.34±0.04e	1.10±0.13e	1.40±0.02d	25.04±0.43b
Shea Fruit	66.36±0.48e	0.79±0.03a	1.94±0.05f	0.43±0.01f	3.84±0.20e	26.65±0.34c

Source: Field data (2024)

Values are represented as mean of triplicate analysis ± standard deviation

Values in the same column with different letters are significantly different at $p<0.05$

Table 4: Mineral composition of six selected Ghanaian fruits

Sample/Parameter	Baobab Fruit	African Locust Bean Fruit	Tropical Almond	Breadnut	African Grape Fruit	Shea Fruit
Potassium (mg/100g)	1300.43±3.4.9a	97.70±1.11b	497.86±6.53c	518.14±1.20d	655.04±0.89e	470.30±6.94f
Sodium (mg/100g)	30.87±6.94c	16.28±0.02b	31.40±0.35c	10.48±0.08a	16.17±0.08b	16.06±0.13b
Zinc (mg/100g)	53.51±1.36a	53.65±0.41a	41.69±0.50b	17.29±0.26c	23.14±0.70d	20.65±0.51e
Copper (mg/100g)	6.83±0.04a	5.97±0.01b	6.50±0.17a	2.91±0.06c	3.54±0.25d	1.93±0.00e
Iron (mg/100g)	27.74±0.91a	27.59±0.03a	54.09±1.36b	30.29±0.30c	65.19±1.17d	24.61±0.03e
Calcium (mg/100g)	2.46±0.07b	2.22±0.06a	2.20±0.05a	1.68±0.04c	2.29±0.09a	1.87±0.03d
Magnesium (mg/100g)	0.22±0.01b	0.17±0.00a	0.14±0.00c	0.11±0.00d	0.16±0.00a	0.17±0.00a
Phosphorus (mg/100g)	123.70±1.92a	125.55±0.98a	200.92±0.93d	174.66±0.62c	147.96±3.90b	174.95±3.37c

Source: Field data (2024)
Values are represented as mean of triplicate analysis ± standard deviation
Values in the same row with different letters are significantly different at $p<0.05$

Tropical almond recorded the highest fat (~40%) and protein (~23%) contents whereas shea fruit had the least contents of fat (0.43%) and protein (~2%). There were significant differences in the protein and fat content among the fruit samples ($p<0.05$). The fat content of the tropical almond was below the average fat content (>50%) in most almond varieties (Roncero et al., 2021). The high fat content, and mono- and poly- unsaturated fat contained in almonds makes it a health valuable alternative when consumed as milk or oil (Roncero et al., 2021). Even though shea nuts are known to be rich in fat, the fruits pulp has negligible fat content. Likewise, the health benefits of proteins in bodily functions like tissue building and repair, and production of enzymes and hormones makes almond proteins significant (Hussain et al., 2021).

Baobab and tropical almond fruits had the highest crude fibre content (~10%), followed by African locust bean/ dawadawa fruit (6.29%), shea fruit (3.84%), breadnut (2.01%) with African grape fruit having the least crude fibre content (1.40%). The fibre in baobab and tropical almond were significantly high compared to the other fruits. Dietary fibre is crucial for maintaining a healthy digestive system, preventing constipation, sustaining an optimal body mass, regulating blood sugar levels and keeping hunger in check (Jahan, Qadri & Younis, 2020). Fibre also feeds the good bacteria in our gut promoting a healthy gut microbiome and can lower cholesterol levels and reduce the risk of chronic diseases (Cronin et al., 2021). Thus, baobab, tropical almond and African locust bean/ dawadawa fruits can be promoted for their significantly high fibre contents.

Baobab fruit had the highest available carbohydrate content (~62%), followed by African locust bean/ dawadawa (~60%) whereas tropical almond had the least carbohydrate content (~19%). The carbohydrate content for breadnut was statistically similar to that of shea fruit and African grape fruit but different from baobab and locust bean. Foods high in available carbohydrates and low in dietary fibre typically have a higher GI, causing a rapid rise in blood sugar (Hodge et al., 2004; Liese at al., 2005). Based on the proximate findings highlighted in Table 3, determining the GI of the six selected Ghanaian fruits was important.

Mineral Composition of the Six Selected Ghanaian Fruits

Table 4 shows the mineral composition of the six fruits assessed. Essential minerals assayed in the present study included potassium, sodium, zinc, copper, iron, magnesium, calcium and phosphorus. These minerals fulfil a wide variety of functions, such as building materials for bones, influencing muscle and nerve function, and regulating the body's water balance (Gomes & Silva, 2021). They are also components of hormones, enzymes and other bioactive compound (Mitra et al., 2022).

Baobab fruit exhibited the highest levels of potassium (1300 mg/100g) compared to African locust bean/ dawadawa which recorded the least (97 mg/100g). The levels of potassium among the fruit samples were significantly different ($p<0.05$). This could be attributed to the natural variation in potassium levels among the different fruits. According to WHO (2012) the recommended daily intake of potassium for adults is at least 3,510 mg, implying that consuming 100g of baobab meets 37% of the daily intake. Adequate potassium intake supports heart health, maintains proper heart rhythm, promotes cardiovascular health and ensures proper muscle and nerve function (McLean & Wang, 2021). Thus, intake of baobab can help to reduce blood pressure and risk of cardiovascular disease, stroke, and coronary heart disease

Conversely, breadnut recorded the least sodium content (10 mg/100g) whereas tropical almond and baobab had the highest (31 mg/100g) which were significantly different from the other fruit samples ($p<0.05$). According to the WHO (2012), the recommended daily intake of sodium for adults is less than 2000 mg/day. Consuming these Ghanaian local fruits in moderation would be beneficial in managing the associated risk of excessive sodium intake like high blood pressures (Dong, 2018).

The relevance of zinc to human health include DNA creation, immune support, cell growth, tissue healing, and protein building. It also aids in taste, smell, and is crucial for healthy growth during childhood, adolescence, and pregnancy (Arfi, Khatoon & Alim, 2022). Although WHO lacks zinc intake recommendation, the U.S. Department of Health and Human Services (USDHHS) suggests 11 mg/day for men, 8 mg/day for women and 12.4 mg/day for pregnant women (National Institutes of Health, 2022). All six fruits had considerably higher levels of zinc compared to the USDHHS recommended daily intake. The levels of zinc for baobab and African locust/ dawadawa were significantly different from the other fruit samples.

The range of copper content among the fruit samples was from 1.93 mg/100g (shea fruit) to 6.83 mg/100g (baobab) which were higher than the USDHHS recommended intake of 0.9 mg/day (National Institutes of Health, 2022). The copper content of baobab and tropical almond were significantly higher than the other fruits ($p<0.05$). Copper is essential for red blood cell production, heart rate regulation, iron absorption, bone and connective tissue development, and immune system activation (Karim, 2018). Iron, in contrast, is vital for producing haemoglobin, transporting oxygen, supporting growth, and maintaining a healthy immune system. It helps prevent anaemia and protects against infections (Abbaspour, Hurrell & Kelishadi, 2014). Tropical almond and African grape fruit recorded iron contents of 54 mg/100g and 64 mg/100g, respectively. The iron contents of baobab and African locust bean/ dawadawa were significantly different from the other samples ($p<0.05$). The iron content of the fruits assessed were higher than the recommended daily intake of 8.7 mg for men and 14.8 mg for women by the USDHHS (National Institutes of Health, 2022). Thus, all fruits are a valuable source of dietary iron deficiency management.

Breadnut recorded the least calcium content of 1.68 mg/100g while baobab recorded the highest (2.46 mg/100g). With the exception of tropical almond, African locust bean/ dawadawa and African grape fruit, the calcium content of the fruits were significantly different ($p<0.05$). WHO (2012) commends a 500 mg daily intake of calcium for adults which is useful in promoting bone health and nerve function. The fruits are relatively inadequate in meeting the daily intake of calcium (Cashman, 2002). Thus, their consumption should be supplemented with calcium rich foods.

Magnesium is involved in numerous enzyme activities, regulates heart rhythm, and aids in energy creation (Al Alawi, Majoni & Falhammar, 2018) whereas phosphorus is essential for bone health, energy storage, muscle movement, and DNA synthesis (Serna & Bergwitz, 2020). The contents of magnesium and phosphorus among the fruits were within the range of 0.11-0.22 mg/100g and 124-201 mg/100g, respectively. Even though baobab had the highest magnesium content, it recorded the least phosphorus content. Breadnut recorded the least magnesium content whereas tropical almond has the highest phosphorus content. The USDHHS recommends a 310-420 mg of magnesium and 700 mg of phosphorus for adults (National Institutes of Health, 2022). Implying that these local Ghanaian fruits are capable of serving 18-29% of the RDI for phosphorus. However, they are inadequate in meeting the daily intake for magnesium.

Demographic and Anthropometric Characteristics of the Study Subjects

The summary statistics for the age, anthropometric data and blood pressure of the 10 participants selected for the glycaemic index study is illustrated in Table 5. Of the ten participants, 6 were males and the remaining 4 females. The average age, weight and height of the subject were 27.3 years, 75.3 kg and 7.1 m, respectively. The youngest person among the participants was 23 years while the oldest was 34 years. The height of the subjects ranged from 1.6 to 1.9 m whereas their weight ranged from 52 to 75 kg.

Waist circumference, BMI and blood pressure are measurements that can be used to index a person's nutritional or health status. The mean BMI of the subjects was 25.8 kg/m^2 signifying overweight classification (WHO, 2008) while that of the waist circumference was 33 in. The waist circumference of the females had higher (35 inches) than the males 32 inches. According to the WHO (2008) standard on waist circumference classifications, the males were in the range of normal risk (≤37 in) whereas the females were in the substantially increased risk (≥35 in). Last but not the least, the blood pressure of the participants were in the normal range averaging 111.4/74.9 mm Hg indicating that the subjects used for the study were not hypertensive.

Table 5: Age, anthropometric data and blood pressure of the study subject

Demographic (Unit)	Mean	Minimum	Maximum	Standard Error	Standard Deviation
Age (years)	27.30	23	34	1.11	3.50
height (m)	1.71	1.62	1.86	0.02	0.08
Weight (kg)	75.27	51.5	110	6.01	18.99
Waist circumference (in)	33.20	27	40	1.36	4.32
B.M.I (kg/m^2)	25.82	18	37.8	1.92	6.08
Systolic Blood pressure (mm Hg)	111.40	91	134	4.81	15.20
Diastolic Blood pressure (mm Hg)	74.90	61	99	3.54	11.20

Source: Field data 2024

Glycaemic Response and Index of Selected Underutilized Fruits in Ghana

Glycaemic Response of Test Fruit Samples

Figure 1 shows the glycaemic responses after consuming 50g available carbohydrate of the 6 selected underutilized fruits and D - glucose as reference food sample. The mean fasting blood glucose (FBS) of the 6 fruit sample and the reference sample ranged from 4.3 to 5.0 mmol/ L However, the differences in average (FBS) were not significant ($p<0.05$) the variation in mean fasting blood sugar could be linked to the individual metabolic rate of the participants and the influence of the last meal consumed (Östman, Elmståhl & Björck, 2001). Generally, the post prandial glycaemic response rose rapidly during the first 30 minute and observed to plateau at the 60th minute (D-glucose and breadnut) or decline. Among the samples, D-glucose was observed to show the highest glycaemic concentration of 6.97 mmol/L at the 60th minute.

Among the glucose response curves of the fruit samples, tropical almond and African grape fruit where observed as a bimodal distribution (showing two distinct peaks). Though the glycaemic concentration for breadnut and African grape fruits at the 30^{th} minute were almost the same, it increased slightly at the 60^{th} minute for breadnut whereas the African grape fruit decreased.

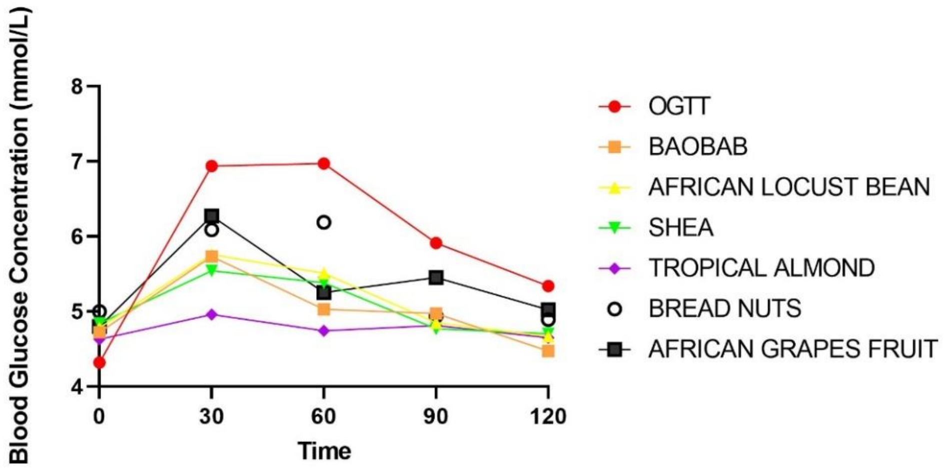

Figure 8: Blood glucose responses after consuming 50g available carbohydrate of test fruit samples and D- glucose as reference sample
Values are the mean ± SEM for 10 healthy subject

The summary statistics of the incremental area under the arc (iAUC) for the glucose response graph is shown in Table 6. The mean iAUC for D-glucose was significantly higher than the fruit samples ($p<0.05$). Among the selected Ghanaian fruits samples, breadnuts recorded the highest iAUC value (93.30 mmol*min/L) whereas tropical almond recorded the least (41.07 mmol*min/L).

Table 6: Incremental area under the arc values of the test samples

Factor	N	Mean	StDev	95% CI
D-Glucose	10	230.9	72.00	(204.1, 257.8)a
Baobab	10	71.54	21.95	(44.71, 98.37)b
African Locust Bean	10	69.84	21.49	(43.01, 96.68)b
Shea Fruit	10	49.50	31.60	(22.7, 76.3)b
Tropical Almond	10	41.07	14.55	(14.24, 67.91)b
Breadnuts	10	93.30	32.90	(66.4, 120.1)b
African Grape Fruit	10	82.30	64.80	(55.5, 109.1)b

Source: Field data (2024)

Glycaemic Index of Test Fruit Samples

Table 7 shows the summary statistics of the GI of the six underutilized fruits. From the study, breadnut had the highest mean GI of 41.39 while tropical almond had the least mean GI of 18.49 representing low glycaemic foods. Even though there were differences in the values of the mean GI of the fruits assessed, that of baobab, African grape fruit and African locust bean were statistically similar to the other samples. The GI of baobab (33.27) was slightly higher than the values (24.75-30.73) reported by Ibrahima et al. (2021) who determined the GI of unsweetened and sweetened baobab juice. Ibrahima et al. (2021) discovered that the addition of sugar to baobab turned the product from a low glycaemic food to a medium to high glycaemic food.

The GI of African locust bean (32.37) was also lesser than value (89.54) reported by Kouassi et al. (2017). The increased GI can be attributed to the addition of sucrose in the preparation of juice from the African locust bean/ dawadawa pulp. The low GI of shea fruit and particularly tropical almond can be attributed to the low available carbohydrate content and the high fibre content of the fruits.

Table 7: Glycaemic index (iAUC) of test food sample

Test Food Samples	Mean GI ± SEM	Min	Max
Baobab	33.27±3.97ab	14.15	51.65
African Locust Bean	32.37±4.21ab	15.13	61.00
Shea Fruit	21.49±3.76b	5.99	41.58
Tropical Almond	18.49±2.06b	10.97	30.85
Breadnut	41.39±3.98a	23.59	59.64
African Grape Fruit	32.73±5.87ab	7.08	64.73

Source: Field data (2024)
Values are represented as mean ± standard error of mean
Values in the same column with different letters are significantly different at $p<0.05$

Glycaemic load of Selected Local Fruits in Ghana

The serving size for snack portions of the various test fruits were deduced from the proximate analysis using a basis of 80 kilocalories. The results of snack portion of the six local Ghanaian fruits and their glycaemic load (GL) values are presented in Table 8. Tropical almond even though had the highest energy content (450.50 kcal/100g), had the least mean GI and GL values. This could be attributed to the high fat content which does not impact glycaemic response upon ingestion. Shea fruit with the least energy content (117.37 kcal/100g), conversely, had the second lowest GL and mean GI values. Although baobab ranked fourth in the weight of snack portion, it had the highest available carbohydrate content per snack portion results in the sample with the highest GL value. Breadnut which had the highest mean GI, was found to have the second highest GL value. The mean GI and GL values of the African locust bean and the African grape fruit were comparable to each other.

Table 8: Snack portion size and glycaemic load of the test fruits

Sample	% Protein	% Fat	% Carbohydrate (CHO)	Energy (kcal/100g)	Snack serving portion (g/80kcal)	Available CHO in snack portion	Mean GI	GL
Baobab Fruit	4.11	0.73	61.96	270.85	29.54	18.30	33.27	6.09
African Locust Bean	9.68	2.16	59.67	292.52	27.35	16.32	32.37	5.28
Tropical Almond	23.33	40.38	18.63	450.50	17.76	3.31	18.49	0.61
Breadnut	5.78	2.81	25.99	146.75	54.51	14.17	41.39	5.86
African Grape Fruit	3.34	1.10	25.04	121.22	66.00	16.53	32.73	5.41
Shea Fruit	1.94	0.43	26.65	117.37	68.16	18.16	21.49	3.90

Source: Field Data (2024)

CHAPTER FIVE

SUMMARY, CONCLUSION AND RECOMMENDATIONS

Overview

This chapter presents the summary of the key findings, conclusions, the recommendations made based on the findings and some of suggestions for further studies. The overview of this research work is also presented in this chapter.

Summary

The study determined the glycaemic index and glycaemic loads of six selected Ghanaian fruits namely; Shea fruit, Baobab, African locust bean/ Dawadawa fruit, African grapes fruit, Tropical almonds and the Breadnut. The study looked at four specific objectives and hypotheses. The required related empirical literature and relevant literature to the study was reviewed. The study adopted crossover experimental design because in scientific research, crossover experimental designs are a potent method that are commonly employed in domains such as psychology, medicine, and agriculture. When comparing the effects of various treatments or interventions on the same set of participants across time, it's extremely helpful for researchers.

. The test foods/ fruits were picked, weighed, washed/ cleaned and served to participants and their capillary blood samples and glucose were taken. The blood samples were taken by pricking their fingers at a 30 minutes' time interval for each fruit. The data from the test was managed with Microsoft Excel 2016 and analysed using IBM SPSS Statistics 27 and GraphPad Prism 9. The proximate and mineral analyses were performed in triplicates, and results were expressed as mean ± standard deviation.

Descriptive statistics were performed on the anthropometric characteristics of the participants. The GraphPad Prism was used to plot the glucose response curves and calculate the iAUC for each test food. The two-way repeated measures analysis of variance (ANOVA) with Bonferroni's correction was used to verify the effect of time on the glucose response curve. The data obtained from the different analyses were analysed using one-way ANOVA while Tukey's test was used for the comparison of means among fruit samples at $\alpha = 0.05$.

Key Findings

The major key findings have been summarized as follows:

1. The first research objective was to find out the nutritional composition of the selected fruits. To address the first objective, a proximate analysis was conducted. It was determined that the moisture content, ash content fat content, protein content and available carbohydrates were different. With certain fruits like Tropical almond, these have a high protein and fat contents whereas Shea fruit had the lowest fat and protein content. It was also found out that baobab had a high level of potassium. Lastly, it was determined that all the fruits had a considerable high level of zinc.
2. To answer the research objective two which was to determine the glycaemic indices of the six selected fruits. To determine the glycaemic index of the selected fruits namely African locust bean/ dawadawa fruit, Shea fruit, baobab fruit, African grapes fruit, Tropical almond and Breadnut, a blood glucose test was conducted where individuals were fed the fruits and capillary blood samples taken. It

was calculated using the iAuc and it was found out that all the fruits fell in the low category section of the glycaemic index groupings with Breadnut having the mean highest of 41.07.

3. The determination of the glycaemic load was the objective number three. It was subsequently calculated after the determination of the glycaemic index. It was found out that all the fruits had a low glycaemic load, with Baobab having the mean highest of 6.09 and Tropical almond with the least mean of 0.61.
4. The last research objective was to compare the effects of these fruits on blood glucose levels. It was established that all the six fruits had a low impact on blood glucose levels hence could be recommended for individuals living with diabetes and CVD's.

Conclusion

This study found the nutritional composition, glycaemic index and glycaemic loads of six selected Ghanaian local fruits. The study focused on Baobab, African locust bean, Shea fruit, Tropical almond African grapes fruit and Breadnut. The proximate analysis of the six was run and a blood glucose test done to determine the glycaemic index and glycaemic load of the six selected Ghanaian fruits, it was determined that all the six fruits had low glycaemic index ranging from 18.42 to 41.39 and glycaemic loads ranging from 0.61 to 6.09.

Therefore, it is important that low and intermediate glycaemic index fruits are identified and their consumption recommended. The results obtained from this study will serve as nutritional guidelines used by professionals for the prevention and management of some non-communicable diseases in

Ghana since these fruits are readily available in Ghana and less expensive as compared to the foreign or exotic fruits.

Recommendations

The following practical recommendations are made based on the key findings from the study;

1. The study showed that amongst the six types of fruits tested, all the fruits had low glycaemic index and glycaemic loads, hence these are recommended to persons living with diabetics and individuals suffering from the different kinds of CVD's.
2. Based on the findings that knowledge of GI and GL value of foods can help people improve their health, the study recommended to health experts, nutritionist and dieticians to ensure that they know GI and GL value of the various foods they recommend to their patients, especially those who live with diabetes and CVD's.
3. Sex and age had no effect on the GL and GL values. The study recommended to health practitioners to sensitize people not to think that their ages and sex are the cause of their health problems but rather their lifestyles.
4. The consumption of our local fruit should be encouraged amongst Ghanaians since it was found out from the study that these fruits are nutritious with low glycaemic index and glycaemic loads and hence their impact on blood glucose level was low and these fruits are relatively cheaper.

Suggestion for Further Research

This study recommends that,

1. To obtain the glycaemic index and glycaemic load of our local fruits, there should be more of our local fruits should be studied.
2. There is need to examine the relationship between fruit maturity and GI and GL. Thus fruits at different ripeness stages will be used to identify their impact on blood glucose level.
3. It will be interesting to determine how drying and other processing techniques may affect GI and GL. Thus compare the glycaemic response of fresh fruits against those in processed forms (such as juices, dried fruits, and canned fruits).

REFERENCES

Abbaspour, N., Hurrell, R., & Kelishadi, R. (2014). Review on iron and its importance for human health. *Journal of research in medical sciences: the official journal of Isfahan University of Medical Sciences*, *19*(2), 164.

Abdurraman, N., & Haliru, K. (2019). Comparative study on proximate and mineral composition on *Parkia biglobosa* (African locust bean) fruits and seeds. *FUDMA Journal of sciences*, *3*(3), 145-149.

Achaglinkame, M. A., Aderibigbe, R. O., Hensel, O., Sturm, B., & Korese, J. K. (2019). Nutritional characteristics of four underutilized edible wild fruits of dietary interest in Ghana. *Foods*, *8*(3), 104.

Adu- Gyamfi, C. A (2018). *Determining the glycaemic load of varieties of fufu in Ghana*. (University of Cape Coast, Ghana). Retrieved 3/092023, from https://ir.ucc.edu.gh/xmlui/handle/123456789/3855

Ahmad, M. S., Siddiqui, M. W., Ahmad, M. S., & Siddiqui, M. W. (2015). Factors affecting postharvest quality of fresh fruits. *Postharvest quality assurance of fruits: practical approaches for developing countries*, 7-32.

Akinola, M., Shorinwa, O., Akintola, T., & Popoola, J. (2021). Proximate composition of African locust bean (*Parkia biglobosa*). *Food science & nutrition*, 9(3), 1464-1468.

Akinyemi, A. J., Oboh, G., Olabiyi, A. A., & Ademiluyi, A. O. (2020). Inhibition of key enzymes linked to type 2 diabetes and sodium nitroprusside-induced lipid peroxidation in rat pancreas by water-extractable phytochemicals from unripe pawpaw fruit (carica papaya).

Journal of Basic and Clinical Physiology and Pharmacology, 25(1), 21–34. https://doi.org/10.1515/jbcpp-2013-0002

Akoma, O., Nma, N., Musa, S., & Salihu, A. (2018). Nutritional and Phytochemical Composition of Vitellaria paradoxa (Shea Fruit Pulp). *International Journal of Biochemistry Research & Review*, 22(1), 1–7. https://doi.org/10.9734/ijbcrr/2018/41714

Akubugwo, I. E., Obasi, N. A., Chinyere, G. C., Ugbogu, A. E., & Ude, V. C. (2007). Nutritional and chemical value of *Amaranthus hybridus L*. leaves from Afikpo, Nigeria. *African Journal of biotechnology*, 6(24), 2833-2839.

Alalawi, A. M., Majoni, S. W., & Falhammar, H. (2018). Magnesium and human health: perspectives and research directions. *International journal of endocrinology, 2018*.

Alam, F., & Saqib, Q. N. U. (2015). Pharmacognostic study and development of quality control parameters for fruit, bark and leaf of *Zanthoxylum armatum* (Rutaceae). *Ancient science of life*, *34*(3), 147-155.

Alcon, C. L. M., Barrion, A. S. A., & Nguyen-Orca, M. F. (2021). Proximate Composition, Antioxidant Capacity and Functional Properties of Breadnut Seed Flour (Artocarpus camansi). *Turkish Journal of Agriculture - Food Science and Technology*, 9(8), 1495–1499. https://doi.org/10.24925/turjaf.v9i8.1495-1499.4319

Allen, S. E., Grimshaw, H. M., Parkinson, J.A., Quarmby, C. and Roberts, J.D. (1974). *Chemical Analysis of Ecological Materials*. Blackwell Scientific Publications, Osney, Oxford and London.

Aluko, A. E., Kinyuru, J., Chove, L. M., Kahenya, P., & Owino, W. (2016). Nutritional Quality and Functional Properties of Baobab (Adansonia digitata) Pulp from Tanzania. *Journal of Food Research*, 5(5), 23. https://doi.org/10.5539/jfr.v5n5p23

Amedahe, F. K. (2009). *Fundamentals of Educational Research Methods*. Cape Coast, UCC Press.

American Association of Diabetes Educators. (2017). 4. Foundations of care and comprehensive medical evaluation. *Diabetes Care and Education in Older Adults*, 27-47.

American Diabetes Association. (2019). Introduction: Standards of medical care in diabetes—2019. *Diabetes Care*, 42(Supplement 1), S1-S2.

AOAC (2008). Official Method of Analysis. *Association of Official Analytical Chemists*, Maryland: AOAC International

Arfi, N., Khatoon, K., & Alim, F. (2022). Zinc Malnutrition in Children and Its Consequences on Health. *Microbial Biofertilizers and Micronutrient Availability: The Role of Zinc in Agriculture and Human Health*, 35-67.

Asbaghi, O., Moodi, V., Neisi, A., Shirinbakhshmasoleh, M., Abedi, S., Oskouie, F. H., & Miraghajani, M. (2022). The effect of almond intake on glycaemic control: A systematic review and dose–response meta-analysis of randomized controlled trials. *Phytotherapy Research*, *36*(1), 395-414.

Asibey-Berko, E., & Tayie, F. A. K. (1999). Proximate analysis of some under-utilized Ghanaian vegetables. *Ghana Journal of Science*, *39*, 91-96.

Atkinson, F. S., Foster-Powell, K., & Brand-Miller, J. C. (2008). International tables of glycaemic index and glycaemic load values: 2008. *Diabetes care*, 31(12), 2281-2283.

Atkinson, F. S., Foster-Powell, K., & Brand-Miller, J. C. (2008). International tables of glycaemic index and glycaemic load values: 2008. *Diabetes Care*, 31(12), 2281-2283.

Awika, J. M., & Yang, L. (2017). Grape. In: J. M. Awika, & L. Yang (Eds.), *Encyclopedia of Food Chemistry* (pp. 464-471). San Diego, CA: Academic Press.

Barclay, A. W., Petocz, P., McMillan-Price, J., Flood, V. M., Prvan, T., Mitchell, P., & Brand-Miller, J. C. (2008). Glycaemic index, glycaemic load, and chronic disease risk—a meta-analysis of observational studies. *The American Journal of Clinical Nutrition*, *87*(3), 627-637.

Basha, N. A. S., Anand, A. N., Vemmelil, M. M., & Pillai, V. N. (2012). Integrated approach for sustainable management of the cashew ecosystem in India. *Sustainable Agriculture Reviews*, 11, 33-68.

Bindu, P. K. (2019). Phytochemical and Nutritional Potential of Tropical Almond Seed and its Antifungal Activity against Candida Albicans. *International Journal for Research in Applied Science and Engineering Technology*, 7(6), 1749–1753. https://doi.org/10.22214/ijraset.2019.6293

Boulé, N. G., Haddad, E., Kenny, G. P., Wells, G. A., & Sigal, R. J. (2001). Effects of exercise on glycaemic control and body mass in type 2 diabetes mellitus: A meta-analysis of controlled clinical trials. *JAMA, 286(10)*, 1218-1227.

Brand-Miller, J. C., Atkinson, F. S., Gahler, R. J., Kacinik, V., Lyon, M. R., Wood, S., & Wong, H. (2009). Effects of dietary glycaemic index on adiposity, glucose homoeostasis, and plasma lipids in animals. *The Lancet, 373(9671)*, 126-132.

Brand-Miller, J., Hayne, S., Petocz, P., & Colagiuri, S. (2012). Low-glycaemic index diets in the management of diabetes: a meta-analysis of randomized controlled trials. *Diabetes care, 26(8*), 2261-2267.

Brand-Miller, J., Hayne, S., Petocz, P., & Colaguiri, S. (2003). Low–Glycaemic Index Diets in the Management of Diabetes. *Diabetes care,28 (8)*, 2261-2267.

Breen, C., Ryan, M., McNulty, B., Gibney, M. J., & Canavan, R. (2009). Portion size: a review and synthesis of existing research. *Appetite*, 52(1), 1-61.

Brouns, F., Brouns, F., Bjorck, I., Frayn, K. N., Gibbs, A. L., Lang, V., &Wolever, T. M. S. (2005). Glycaemic index methodology. *Nutrition research reviews*, *18(1)*, 145-171

Cashman, K. (2002). Calcium intake, calcium bioavailability and bone health. *British journal of Nutrition*, *87*(S2), S169-S177.

Chadare, F. J., Linnemann, A. R., Hounhouigan, J. D., Nout, M. J. R., & Van Boekel, M. A. J. S. (2008). Baobab food products: a review on their composition and nutritional value. *Critical reviews in food science and nutrition*, *49*(3), 254-274.

Chivandi, E., Davidson, B. C., Erlwanger, K. H., Jideani, V. A., & Makuza, S. M. (2017). The medicinal value of Vitis vinifera L. (common grape vine)–a review. *Food science and nutrition*, 5(5), 641-648.

Chlup, R., Bartek, J., Reznickova, M., Zapletalová, J., Doubravová, B., Chlupová, L., & Simánek, V. (2004). Determination of the glycaemic index of selected foods (white bread and cereal bars) in healthy persons. *Biomedical papers*, *148*(1), 17-25.

Colberg, S. R., Sigal, R. J., Yardley, J. E., Riddell, M. C., Dunstan, D. W., Dempsey, P. C., & Tate, D. F. (2010). Physical activity/exercise and diabetes: A position statement of the American Diabetes Association. *Diabetes care*, *33(12)*, e147-e167.

Cronin, P., Joyce, S. A., O'Toole, P. W., & O'Connor, E. M. (2021). Dietary fibre modulates the gut microbiota. *Nutrients*, *13*(5), 1655.

Dauda, B. (2014). Nutritive and Anti-nutritive Composition of Locust Bean Tree Emperor Moth Larvae Bunaea alcinoe (Lepidoptera-saturniidae Stoll 1780) from Gurara Local Government Area, Niger State, Nigeria. *Journal of Scientific Research and Reports*, 3(13), 1771–1779. https://doi.org/10.9734/jsrr/2014/7574

Delahanty, L. M., Sonnenberg, L. M., Hayden, D., & Nathan, D. M. (2014). Clinical and cost outcomes of medical nutrition therapy for hypercholesterolemia: a controlled trial. *The Journal of the American Medical Association*, 282(16), 1563-1570.

Dong, O. M. (2018). Excessive dietary sodium intake and elevated blood pressure: a review of current prevention and management strategies and the emerging role of pharmaconutrigenetics. *BMJ nutrition, prevention & health*, *1*(1), 7.

Eli-Cophie, D., Agbenorhevi, J. K., & Annan, R. A. (2017). Glycaemic index of some local staples in Ghana. *Food Science and Nutrition*, 5(1), 131–138. https://doi.org/10.1002/FSN3.372

F. A.O & World Health Organization. (1998). Carbohydrates in human nutrition: report of a joint FAO/WHO expert consultation. *FAO Food and nutrition Paper*, 66, 1–140.

Food and Agricultural Organization (2008). Guide for fertilizer and plant nutrient analysis. F.A.O. Communication Division, Rome.

Food and Agriculture Organization of the United Nations (1998). *Artocarpus camansi: breadnut.* Retrieved 11/06/2023, from: http://www.fao.org/ag /AGP/A GPC/doc/gbase/data/pf000016.htm.

Forestry.com. (n.d.). *Talisay tree*. Retrieved February 11, 2024, from https://forestry.com/trees/talisay-tree/

Foster-Powell, K., Holt, S. H., & Brand-Miller, J. C. (2002). International table of glycaemic index and glycaemic load values: 2002. *The American journal of clinical nutrition*, *76*(1), 5-56.

Franz, M. J., Bantle, J. P., Beebe, C. A., Brunzell, J. D., Chiasson, J. L., Garg, A., & Wheeler, M. (2002). Evidence-based nutrition principles and recommendations for the treatment and prevention of diabetes and related complications. *Diabetes care, 25(1)*, 148-198.

Franz, M. J., Boucher, J. L., Rutten-Ramos, S., & VanWormer, J. J. (2013). Lifestyle weight-loss intervention outcomes in overweight and obese adults with type 2 diabetes: a systematic review and meta-analysis of randomized clinical trials. *Journal of the Academy of Nutrition and Dietetics*, *113(10)*, 1373-1385.

Gnagnarella, P., Gandini, S., La Vecchia, C., & Maisonneuve, P. (2018). Glycaemic index, glycaemic load, and cancer risk: a meta-analysis. *The American Journal of Clinical nutrition, 87(6)*, 1793-1801.

Gomes, C. S., & Silva, E. A. (2021). Health Benefits and Risks of Minerals: Bioavailability, Bio-Essentiality, Toxicity, and Pathologies. In *Minerals Latu Sensu and Human Health: Benefits, Toxicity and Pathologies* (pp. 81-179). Cham: Springer International Publishing.

Gomina, M., Lawin, E., Salifou, T., Djidonou, G., & Zinsou, S. (2021). Glycaemic Index and Glycaemic Load of Four Local Fruits of Benin Among Apparently Healthy Young Adult Subjects. *Avicenna Journal of Medical Biochemistry*, 9(1), 1–7. https://doi.org/10.34172/ajmb.2021.01

Gropper, S. S., Smith, J. L., & Groff, J. L. (2021). *Advanced nutrition and human metabolism* (pp. 33-58). Bostom, MA: Cengage Learning.

Hodge, A. M., English, D. R., O'Dea, K., & Giles, G. G. (2004). Glycaemic index and dietary fibre and the risk of type 2 diabetes. *Diabetes care*, *27*(11), 2701-2706.

Hussain, S. Z., Naseer, B., Qadri, T., Fatima, T., & Bhat, T. A. (2021). Almond (Prunus dulcis)—morphology, taxonomy, composition and health benefits. In *Fruits Grown in Highland Regions of the*

Himalayas: Nutritional and Health Benefits (pp. 283-295). Cham: Springer International Publishing.

Ibrahim, M. H., Jaafar, H. Z. E., Karimi, E., Ghasemzadeh, A., & Yusop, M. R. (2017). *Impact of land uses on surface water quality in a tropical region: A multivariate analysis.* Ecological Engineering, 99, 113-122.

Ibrahima, C., Flore, A. E. E., Louise, A. A. A., & Ali, O. (2021). Influence of beverage consumption made from baobab pulp (Adansonia digitata L.) on postprandial glycemia in Côte d'Ivoire. *Food and Nutrition sciences*, *12*(7), 774-786.

IDF. (2021). Ghana - International Diabetes Federation. https://idf.org/our-network/regions-and-members/africa/members/ghana/

IITA (1985). *Laboratory Manual of selected Methods for soil and Plant Analysis* (pp. 15-18), IITA, Ibadan.

Jahan, K., Qadri, O. S., & Younis, K. (2020). Dietary fibre as a functional food. *Functional food products and sustainable health*, 155-167.

Jenkins, D. J. A., Wolever T. M., Taylor R. H., Barker H., Fielden H., Baldwin J.et al (1981), Glycaemic index of foods: A physiological basis for carbohydrate exchange. *The American journal of clinical nutrition*, 34:362-366.

Jenkins, D. J., Kendall, C. W., Augustin, L. S., Franceschi, S., Hamidi, M., Marchie, A., & Axelsen, M. (2002). Glycaemic index: overview of implications in health and disease. *The American journal of clinical nutrition*, *76*(1), 266S-273S.

Jenkins, D. J., Kendall, C. W., McKeown-Eyssen, G., Josse, R. G., Silverberg, J., Booth, G. L., & Banach, M. S. (2014). Effect of a low-glycaemic index or a high-cereal fibre diet on type 2 diabetes: a randomized trial. *JAMA, 312(23)*, 2531-2541.

Jenkins, D. J., Wolever, T. M., Taylor, R. H., Barker, H., Fielden, H., Baldwin, J. M., & Goff, D. V. (1981). Glycaemic index of foods: a physiological basis for carbohydrate exchange. *The American journal of clinical nutrition*, 34(3), 362-366.

Jeridi, M. (2023). Nutritional Analysis of Fresh Banana Fruits (Musa Spp.) Grown in South Tunisia M Ouna J Eridi *, S Azada S Iddiqui *, a Yesha S Iddiqua 1 ,. *Bangladesh J. Bot*., 52(2), 253–260.

Jiang, Y., Zhang, X., Wu, J., Zheng, S., Yang, X., Pan, J., & Lei, K. (2019). Physical and mechanical properties of different tropical hardwoods and their relationship with microstructure. *Construction and Building Materials*, 221, 182-192.

Kamchansuppasin, A., Sirichakwal, P. P., Bunprakong, L., Yamborisut, U., Kongkachuichai, R., Kriengsinyos, W., & Nounmusig, J. (2021). Glycaemic index and glycaemic load of commonly consumed Thai fruits. *International Food Research Journal*, 28(4), 788–794. https://doi.org/10.47836/ifrj.28.4.15

Kar, A. (2019). Shea Butter: A Multipurpose African Gift to the World. *In Natural Products and Drug Discovery: An Integrated Approach* (pp. 293-305). New York, NY: Springer.

Karim, N. (2018). Copper and human health-a review. *Journal of Bahria University Medical and Dental College*, *8*(2), 117-122.

Kaur, B., & Kaur, G. (2014). Glycaemic index and glycaemic load: important but underutilized predictors of chronic disease. *Journal of Food Science and Technology, 51(2)*, 342-353.

Keyla, R., Bernardo, M. A., Silva, M. L., Brito, J., Mesquita, M. F., Pintão, A. M., & Moncada, M. (2022). Adansonia digitata L. (Baobab Fruit) Effect on Postprandial Glycemia in Healthy Adults: A Randomized Controlled Trial. *Nutrients*, 14(2). https://doi.org/10.3390/nu14020398

Kolawole, F. L., & Maduagwu, E. N. (2015). Proximate analysis, phytochemical screening, antioxidant and antimicrobial activities of extracts of Vigna unguiculata (Linn) Walp (Fabaceae) and *Parkia biglobosa* (Jacq.) Benth (Mimosaceae). *Journal of Natural Sciences Research*, 5(10), 50-60.

Kouassi, A. K., Kouassi, N. K., Beugré, M. A. G., N'Dri, D. Y., Amani, G. N. G., & Gnakri, D. (2017). Glycaemic Index and Glycaemic Load of Juice from Edible Wild Fruits (Adansonia digitata, Tamarindus indica and Parkia biglobosa) Consumed in Côte d'Ivoire. *Journal of biosciences and medicines*, *6*(1), 63-74.

Li, S. C., Liu, Y. H., Liu, J. F., Chang, W. H., Chen, C. M., & Chen, C. Y. O. (2011). Almond consumption improved glycaemic control and lipid profiles in patients with type 2 diabetes mellitus. *Metabolism*, *60*(4), 474-479.

Liese, A. D., Schulz, M., Fang, F., Wolever, T. M., D'Agostino Jr, R. B., Sparks, K. C., & Mayer-Davis, E. J. (2005). Dietary glycaemic index and glycaemic load, carbohydrate and fibre intake, and measures of insulin sensitivity, secretion, and adiposity in the Insulin Resistance Atherosclerosis Study. *Diabetes care*, *28*(12), 2832-2838.

Linus Pauling Institute. (n.d.). *Glycaemic index and glycaemic load*. Oregon State University. Retrieved 17/ 01/ 2024, from https://lpi.oregonstate.edu/mic/food-beverages/glycaemic-index-glycaemic-load

Livesey, G., Taylor, R., Livesey, H. F., Buyken, A. E., Jenkins, D. J., Augustin, L. S., & Sievenpiper, J. L. (2019). Dietary glycaemic index and load and the risk of type 2 diabetes: a systematic review and updated meta-analyses of prospective cohort studies. *Nutrition, metabolism and cardiovascular diseases*, *18(6*), 363-375.

Ludwig, D. S. (2002). The glycaemic index: Physiological mechanisms relating to obesity, diabetes, and cardiovascular disease. *JAMA, 287(18)*, 2414-2423.

Ludwig, D. S., Majzoub, J. A., Al-Zahrani, A., Dallal, G. E., Blanco, I., & Roberts, S. B. (1999). High glycaemic index foods, overeating, and obesity. *Pediatrics*, 103(3), e26-e26.

Lufu, R., Ambaw, A., & Opara, U. L. (2020). Water loss of fresh fruit: Influencing pre-harvest, harvest and postharvest factors. *Scientia horticulturae*, *272*, 109519.

Maranz, S., Wiesman, Z., Bisgaard, J., & Bianchi, G. (2004). Germplasm resources of Vitellaria paradoxa based on variations in fat composition across the species distribution range. *Agroforestry systems*, 60(1), 71-76.

McLean, R. M., & Wang, N. X. (2021). Potassium. In N. A. M. Eskin (Ed.), *The latest research and development of minerals in human nutrition: Advances in food and nutrition research (Vol. 96)*. (pp. 89-121). Cambridge, MA: Elsevier.

Mitra, S., Paul, S., Roy, S., Sutradhar, H., Bin Emran, T., Nainu, F., & Mubarak, M. S. (2022). Exploring the immune-boosting functions of vitamins and minerals as nutritional food bioactive compounds: A comprehensive review. *Molecules*, *27*(2), 555.

Mohamad, N. H., Omar, N., & Fathinul Fikri, A. S. (2018). Nutritional composition, phytochemical screening and total phenolic content of underutilized breadnut seeds (*Artocarpus camansi*). *Journal of tropical agriculture and food science, 46(2),* 117-126.

Monteiro, S., Reboredo, F. H., Lageiro, M. M., Lourenço, V. M., Dias, J., Lidon, F., Abreu, M., Martins, A. P. L., & Alvarenga, N. (2022). Nutritional Properties of Baobab Pulp from Different Angolan Origins. *Plants*, 11(17), 1–15. https://doi.org/10.3390/plants11172272

Morton, J. F. (1987). Tropical almonds. *In Fruits of warm climates* (pp. 398-402). Creative Resources Systems, Inc.

Muhammad, S., Hassan, L. G., Umar, K. J., & Sani, N. A. (2018). African grapes (Lannea microcarpa) fruits: the nutritional compositions. *International Journal of basic, applied and innovative research*, *7*(4), 121-128.

Mulholland, H. G., Murray, L. J., Cardwell, C. R., Cantwell, M. M., & Glynn, L. G. (2008). Glycaemic index, glycaemic load, and risk of digestive tract neoplasms: a systematic review and meta-analysis. *The American Journal of clinical nutrition, 89(2)*, 568-576.

National Institutes of Health. (2022). *Zinc - Health Professional Fact Sheet -* Office of Dietary Supplements (ODS). Retrieved 05/02/2024, from https://ods.od.n ih.gov/factsheets/zinc-healthprofessional/.

N'Diaye, C., Boakye-Yiadom, K., Samb, A., & Samb, M. (2011). Current situation, availability and utilization of locust beans in West Africa: A review. *African Journal of food, agriculture, nutrition and development*, 11(1).

Oboh, G., & Ademosun, A. O. (2021). Characterization of the antioxidant properties of phenolic extracts from some citrus peels. *Journal of Food Science and Technology*, 49(6), 729–736. https://doi.org/10.1007/S13197-010-0222-Y/METRICS

Ogoloma, M. U., Nkpaa, M. K., Akaninwor, J. O., & Uwakwe, A. A. (2013). Proximate, phytochemical and mineral elements compositions of some edible fruits grown in oil producing community of rivers state, Nigeria. *IOSR-JESTFT*, *5*, 38-46.

Okullo, J. B. L., Omujal, F., Agea, J. G., Vuzi, P. C., Namutebi, A., Okello, J. B. A., & Nyanzi, S. A. (2010). Proximate and mineral composition of shea (Vitellaria paradoxa CF Gaertn) fruit pulp in Uganda. *African Journal of food, agriculture, nutrition and development*, *10*(11).

Okyere, P. & Nyarko, (2020). *Fruit Processing in Ghana*. HortiFresh West Africa.

Östman, E. M., Elmståhl, H. G. L., & Björck, I. M. (2001). Inconsistency between glycaemic and insulinemic responses to regular and fermented milk products. *The American journal of clinical nutrition*, *74*(1), 96-100.

Ouoba, L. I. I., Parkouda, C., Diawara, B., Scotti, C., Varnam, A. H., & Amoa-Awua, W. K. (2004). The microbiology of Bandji, palm wine of Borassus akeassii from Burkina Faso: identification and genotypic diversity of yeasts, lactic acid and acetic acid bacteria. *Journal of applied microbiology*, 96(4), 1066-1074.

Pasa, A. A., Lima, L. K. F., Maia, G. A., Abreu, C. M. P., de Abreu, F. O. M. S., & Queiroga, R. (2015). A model to determine the carbon footprint of a tropical woody perennial crop based on an eco-physiological analysis: A case study on cacao. *Journal of cleaner production, 87*, 354-365.

Paull, R. E., & Duarte, O. (2012). *Tropical fruits*. CABI.

Pereira, D. M., Ferreres, F., Oliveira, J., Gaspar, L., & Valentão, P. (2007). A comparative study of the antioxidant properties of some commercially available tropical fruits processed juices. *Food chemistry, 103(3)*, 1003-1008.

Raymond, J. L., & Morrow, K. (2022). *Krause and Mahan's Food and the Nutrition Care Process*, 16e, E-Book: Elsevier Health Sciences.

Rodriguez-Amaya, D. B., Kimura, M., Godoy, H. T., & Amaya-Farfan, J. (2008). Updated Brazilian database on food carotenoids: Factors affecting carotenoid composition. Journal of *Food Composition and analysis*, 21(6), 445-463.

Roncero, J. M., Álvarez-Ortí, M., Pardo-Giménez, A., Rabadán, A., & Pardo, J. E. (2021). Influence of pressure extraction systems on the performance, quality and composition of virgin almond oil and defatted flours. *Foods*, *10*(5), 1049.

Sacks, F. M., Carey, V. J., Anderson, C. A., Miller, E. R., Copeland, T., Charleston, J., & Appel, L. J. (2004). Effects of high vs low glycaemic index of dietary carbohydrate on cardiovascular disease risk factors and insulin sensitivity: the OmniCarb randomized clinical trial. *JAMA, 312(23)*, 2531-2541.

Sadiq, I. S., Hassan, L. G., Dangoggo, S. M., Dogonyaro, A. I., & Itodo, A. U. (2009). Proximate analysis and mineral composition of the pulp and seeds of *Adansonia digitata* (baobab fruit). *International Journal of tropical agriculture and food systems*, *3*(2), 85-87.

Sambandan, G., & Turcu-Stiolica, A. (2019). *Clinical trials. clinical pharmacy education, practice and research, 323–344.*

Schwingshackl, L., & Hoffmann, G. (2013). Long-term effects of low glycaemic index/load vs. high glycaemic index/load diets on parameters of obesity and obesity-associated risks: a systematic review and meta-analysis. *Nutrition, Metabolism and Cardiovascular diseases, 23(8)*, 699-706.

Serna, J., & Bergwitz, C. (2020). Importance of dietary phosphorus for bone metabolism and healthy aging. *Nutrients, 12*(10), 3001.

Shahbazian, H., Rezaii, I., Vahdat, K., Pourbehi, M., & Shahbazian, H. (2014). Effects of aerobic exercise on indices of glycaemic control in patients with type 2 diabetes mellitus: A systematic review with meta-analysis of randomized controlled trials. *Brazilian Journal of physical therapy, 18(5),* 385-399.

Shobha, J., C., Reddy P., N. & Rao, P., V. (2020). Determination of Glycaemic Index and Glycaemic Load of Taste Good Biscuits in Healthy Human Adult Subjects, Under Fasting Conditions. *Indian Journal of nutrition, 7*(1) 1-4

Slabber, M., Barnard, H. C., Kuyl, J. M., Dannhauser, A., & Schall, R. (1994). Effects of a low-insulin-response, energy-restricted diet on weight loss and plasma insulin concentrations in hyperinsulinemic obese females. *The American Journal of Clinical Nutrition, 60(1)*, 48-53.

Slavin, J. L. (2013). Carbohydrates, dietary fibre, and resistant starch in white vegetables: Links to health outcomes. *Advances in Nutrition, 4*(3), 351-355. DOI: 10.3945/an.112.003699

Slavin, J. L., & Lloyd, B. (2012). Health benefits of fruits and vegetables. Advances in Nutrition, 3(4), 506-516

Sluijs, I., Beulens, J. W., van der, A., Grobbee, D. E., & van der Schouw, Y. T. (2010). Dietary glycaemic index, glycaemic load, and digestible carbohydrate intake are not associated with risk of type 2 diabetes in eight European countries. *The Journal of Nutrition, 140(12)*, 2311-2319.

Whitney, E. N., & Rolfes, S. R. (2019). *Understanding nutrition*. Cengage Learning.

WHO (2012) *Guideline: Potassium intake for adults and children*. Geneva: World Health Organization (WHO); 2012.

Wickens, G. E., & Lowe, P. (2008). *The Baobabs: Pachycauls of Africa, Madagascar, and Australia*. Springer Science & Business Media.

Wolever, T. M., Vuksan, V., & Jenkins, A. A. (2011). Determination of Glycaemic Index of: Hand-Stretched Cheese Pizza. *Glycaemic Index Laboratories Inc*, *Toronto.*

World Health Organization (2008). *Waist Circumference and Waist-Hip Ratio: Report of a WHO Expert Consultation*, Geneva, 8–11 December 2008; World Health Organization: Geneva, Switzerland, 2011.

Wylie-Rosett, J., & Segal-Isaacson, C. J. (2016). Low-carbohydrate diets: Finding a niche. *Current Diabetes Reports*, *16*(11), 1-8. DOI: 10.1007/s11892-016-0812-z

Zhang, J., Cao, S., & Li, C. (2018). Physicochemical properties and nutritional composition of breadnut (*Artocarpus camansi*) seeds. *Food science and human wellness*, 7(1), 25-32.

APPENDICES

APPENDIX A: INSTITUTIONAL REVIEW BOARD CLEARANCE LETTER

UNIVERSITY OF CAPE COAST

INSTITUTIONAL REVIEW BOARD SECRETARIAT

TEL: 0558093143 / 0508878309
E-MAIL: irb@ucc.edu.gh
OUR REF: IRB/C3/Vol.1/0463
YOUR REF:
OMB NO: 0990-0279
IORG #: IORG0011497

6TH NOVEMBER, 2023

Ms Sandra Amoakoaa Antwi
Department of Vocational and Technical Education
University of Cape Coast

Dear Ms Antwi,

ETHICAL CLEARANCE – ID (UCCIRB/CHAS/2023/99)

The University of Cape Coast Institutional Review Board (UCCIRB) has granted Provisional Approval for the implementation of your research **Glycemic Index and Glycemic Loads of Six Selected Ghanaian Fruits.** This approval is valid from **6th November, 2023** to **5th November, 2024**. You may apply for an extension of ethical approval if the study lasts for more than 12 months.

Please note that any modification to the project must first receive renewal clearance from the UCCIRB before its implementation. You are required to submit a periodic review of the protocol to the Board and a final full review to the UCCIRB on completion of the research. The UCCIRB may observe or cause to be observed procedures and records of the research during and after implementation.

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

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

Yours faithful

Kofi F. Amuquandoh
Ag. Administrator

ADMINISTRATOR
INSTITUTIONAL REVIEW BOARD
UNIVERSITY OF CAPE COAST

APPENDIX B: INTODUCTORY LETTER FROM DEPARTMENT

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

Direct: 03122-99210
Telegrams & Cables: University, Cape Coast

University of Cape Coast
Cape Coast

Our Ref: VTE/IAP/V.3/96

18th May, 2023.

The Head
Institutional Review Board
UCC

Dear Sir,

REQUEST FOR ETHICAL CLEARANCE

We have the pleasure of introducing to you Sandra Amoakoaa Antwi who is an MPhil student of this Department with registration number ET/HEP/21/0022 and working on the thesis topic, ***"Glycemic Index and Glycemic Load of Six Selected Ghanaian Fruits"***.

We would be most grateful if you could grant her Ethical Clearance to enable her proceed with the work.

Thank you.

Yours faithfully,

for:

Dr. (Mrs.) Patience Danquah Monnie
HEAD OF DEPARTMENT

APPENDICE C: SUPERVISORS INTRODUCTORY LETTER TO IRB

Department of VOTEC
University of Cape Coast
Cape Coast

18th May,2023

The Chairperson
Institutional Review Board
UCC
Cape Coast

Dear Sir,

INTRODUCTORY LETTER

I have the pleasure of introducing to you Sandra Amoakoaa Antwi, an M.Phil. Student at the Department of VOTEC, University of Cape Coast. She has successfully completed and passed all coursework and is working on the thesis topic **"Glycemic Index and Glycemic Loads of Six Selected Ghanaian Fruits".**

She is currently on the data collection stage and is applying for ethical clearance to enable her start the data collection for writing her thesis.

As her Principal supervisor I will be grateful if you could give her the necessary assistance.

Thank you.

Yours faithfully,

Prof. (Mrs.) Sarah Darkwa

APPENDIX D: INFORMED CONSENT FORM

INFORMATION SHEET

Title: Glycaemic Index and Glycaemic Loads of Six Selected Ghanaian fruits

Principal Investigator: Sandra Amoakoaa Antwi

Address: University of Cape Coast

General Information about Research

The goal of the study is to learn more about the glycaemic index, a measure of how quickly blood sugar levels rise after consuming specific Ghanaian fruits, specifically African grapes, Shea fruit baobab fruits, African locust bean, Breadnut, and Guava are among the food samples that will be used to analyse chemical composition, carbohydrate quality, glycaemic load, and potential health effects of the fruits on consumers. People with particular health issues like diabetes, obesity, hypertension, and stroke should greatly benefit from the research's findings while making meal selections. It will be useful for dieticians, nutritionists, and diet therapists to develop innovative menus for their patients as well as a tool for client counselling.

The study will be carried out at the UCC Hospital laboratory in the cape coast metropolitan assembly. It will be an 8 session event conducted with the space of 2 weeks. The first and second day will be used for administering the reference food glucose – which will be duplicated for the different days and the third to the 8th day will be used for administering the selected fruits. There will be inclusion and exclusion schedule for participants who will be willing to participants and only those who will be able to satisfy the inclusion criteria will be recruited for the study.

Procedures

To help with this investigation, I ask that you participate in this study project so that the researcher can help find answers to the research questions and hypotheses. If you decide to participate, you must do so with 10 other participants who also match the requirements for participation. Myself and two additional healthcare professionals will lead this exercise. The researcher will conduct a 2-day orientation for all participants a week before to the clinical trial to familiarize them with the study's protocols. As part of the study, the following protocols will be observed:

Undergo a 10 to 12 hour overnight fast during the period (before each session)

Not to engage in any rigorous or strenuous activity such as weeding skipping running weight lifting

No consumption of alcohol

No smoking and

No intake of breakfast before the exercise but you one can eat after the clinical trial each day. You are to arrive at the facility at 7:30 am each morning.

Anthropometric measures will be taken by trained health personnel and recorded by the researcher any time you visit the facility for the clinical trial. The last meal eaten a day before the session will also be recorded during the study. In addition, blood will be taken during each session to ascertain fasting blood glucose through finger pricking.

You will be expected to consume six fruits namely Baobab, Shea fruit, African grape fruit. African Locust Bean fruit, Breadnut and Guava containing 50g of available carbohydrate. Blood samples will be taken at a 30-minute interval for 5 times during each session. With the aid of a glucometer, the blood glucose level will be checked before and after consuming the fruit assigned to each day. Fingers will be pricked to draw blood for the test at each time.

If you have any allergy to the selected fruits, you are at liberty to fall out or withdraw. Photographs will be taken during the entire clinical trial and edited so that no one will be identified.

Possible Risks and Discomforts

The possible discomfort you may feel is a nausea and a bit of drowsiness when the glucose solution drank. You are also likely to feel a little pain when blood samples are taken through finger pricking and you would have to undergo 10 to 12 hours overnight fast before the clinical trials.

Possible Benefits

Participants will be taken through free anthropometric measures (weight, blood pressure, height, body mass index) and free glucose test each day of the session and possible weight loss may occur as result of the number of overnight fast you will undergo during the study. Socially, you will meet other people for social interaction. Results from the research will be of great benefit everybody and the nation as a whole.

Confidentiality

All data collected during the trial will be kept strictly confidential. The study will use codes / numbers as a form of identification, hence no names will be used when reporting the findings. Findings from clinical trial will be transmitted to the researcher in an anonymous form.

Data will be stored on a password protected media and saved online in computerized archives. The researcher’s personal custody of documents, hard copies, photos and all identifiable participant materials will be stored under a password protected file. The researcher would make every attempt protect your privacy.

Compensation

All participants will be given refreshments in a form of snacks and a meal at the end of the session. In addition, all transportation expenses would be covered by the researcher. Any form of injury sustained in the cause of the study will be medically attended to.

Voluntary Participation and Right to Leave the Research

The decision to take or not to engage in this research is voluntary. You will be asked to sign a consent form if you wish to engage in this investigation. You are also allowed to revoke your consent at any point after signing the consent document and discontinue participation without any cost or discrimination. Data from you will be destroyed if you withdraw from the research before data collection is complete.

Termination of Participation by the Researcher

A participant will be withdrawn from the study when he or she disregards any of the protocols set by the researcher.

Contacts for Additional Information

Please contact Sandra Amoakoaa Antwi, MPhil Home Economics, and a student in Department of Vocational and Technical Education, University of Cape Coast, directly by telephone at 0240092490 or email address Abenaamoakoaa2020@gmail.com or Professor Sarah Darkwa, sdarkwa@ucc .edu.gh at a time when you have questions about this research or if you suffer adverse effect arising from involvement in this research.

Contact of Ethical Review Board

This research has been reviewed and approved by the Institutional Review Board of the University of Cape Coast (UCCIRB). If you have any questions about your rights as a research participant you can contact the Administrator at the IRB Office between the hours of 8:00 am and 4:30 p.m. through the phone lines 0558093143/0508878309 or email address: irb@ucc.edu.gh.

APPENDIX E: VOLUNTEER'S AGREEMENT

I have read the above document describing the benefits, risks and procedures for the research title ***GLYCAEMIC INDEX AND GLYCAEMIC LOADS OF SIX SELECTED GHANAIAN FRUITS***. I have been given an opportunity to ask any question about the research and this has been answered to my satisfaction. I agree to participate as a volunteer.

Volunteer's Name: ……………………………………....
Volunteer's Signature……………..…………………..
Date: **…………………………………………………**

If volunteer cannot read the form themselves, a witness must sign here:
I was present while the benefits, risks and procedures were read to the volunteer. All questions were answered and the volunteer has agreed to take part in the research.

Witness's Name: …………………………………….
Witness's Signature…………………..………………
Date: ………………………………………………..

I certify that the nature and purpose, the potential benefits, and possible risks associated with participating in this research have been explained to the above individual.

Researcher's Name: ……………………………………...
Researcher's Signature……………..…………………….
Date: **……………………………………………………..**

APPENDIX F: INCLUSION CRIETERIA FORM

UNIVERSITY OF CAPE COAST

GLYCAEMIC INDEX AND LOADS RESEARCH

Researcher: Sandra Amoakoaa Antwi M.Phil. Home Economics

(Foods and Nutrition)

Inclusion Criteria Sheet

Participants code:

Sex:

Age:

Weight:

Height:

Waist Circumference:

Body Mass Index:

Blood Pressure:

Please tick if you have any history or family history of any of the underlined chronic non communicable disease.

Chronic Non Communicable Disease	YES	NO
Diabetes		
Stroke		
Hypertension		
Obesity		

APPENDIX G: QUESTIONNAIRE FOR PARTICIPANTS

Glycaemic Index and Loads Research

Sugar Profile Sheet

Researcher: Sandra Amoakoaa Antwi

M.Phil. Home Economics (Foods and Nutrition)

Participants code:

Sex:

Age:

Weight:

Height:

Waist Circumference:

Body Mass Index:

Blood Pressure:

Date: Time:

Session 1

Date:

Last meal:

Time of last meal:

OGTT 1

TIME (min)	FBS	60	90	120
Concentration (mmol/L)				

Session two

Date:

Last meal:

Time of last meal:

Baobab

TIME (min)	FBS	60	90	120
Concentration (mmol/L)				

Session three

Date:

Last meal:

Time of last meal:

African Grape Fruit

TIME (min)	FBS	60	90	120
Concentration (mmol/L)				

Session four:

Date:

Last meal:

Time of last meal:

Shea Fruit

TIME (min)	FBS	60	90	120
Concentration (mmol/L)				

Session five:

Date:

Last meal:

Time of last meal:

African Locust Bean Fruit

TIME (min)	FBS	60	90	120
Concentration (mmol/L)				

Session six:

Date:

Last meal:

Time of last meal:

Breadnut

TIME (min)	FBS	60	90	120
Concentration (mmol/L)				

Session seven:

Date:

Last meal:

Time of last meal:

Tropical Almond

TIME (min)	FBS	60	90	120
Concentration (mmol/L)				

APPENDIX H: PICTURES SHOWING GLUCOSE TEST

APPENDIX I: PROXIMATE ANALYSIS AT UCC LABORATORY