UNIVERSITY OF CAPE COAST

HEALTH AND AESTHETIC BENEFITS OF ALCHORNEA CORDIFOLIA IN CASSAVA FUFU

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2021

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HEALTH AND AESTHETIC BENEFITS OF ALCHORNEA CORDIFOLIA IN CASSAVA FUFU

BY

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

DECEMBER 2021

DECLARATION

Candidate's Declaration

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

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

Name: ……………………………………………………………………………..

Supervisor's Declaration

I hereby declare that the preparation and presentation of the thesis were supervised following the guidelines on supervision of thesis laid down by the University of Cape Coast.

Supervisor's Signature: .... Date: ....

Name: ……………………………………………………………………………

ABSTRACT

The existence of bioactive chemicals in plants is essential for the development of their therapeutic qualities. In order to establish the scientific foundation for their use, it is necessary to test medicinal plants on a regular basis going forward.

The study was experimental research that explored the health and aesthetic benefits of *Alchornea cordifolia* (ogyama) in preparing cassava fufu. Specifically, the study proximately analyzed the cassava plantain fufu, cassava fufu, and cassava ogyama fufu determined the glycaemic index and glycaemic load of the three fufu varieties and conducted a sensory evaluation of the acceptance of the foods. Questionnaires were used to gather data for the sensory evaluation. One-way analysis of variance and independent-sample t-test were employed in the analysis of the data with a statistical significance set at 95%. The study showed that all three varieties of fufu have high glycaemic indices and are high glycaemic load foods. Cassava fufu has the highest glycaemic index of 78.3, cassava plantain fufu also has a glycaemic index of 73.9, while cassava ogyama fufu has the least glycaemic index of 54.3. Cassava plantain fufu was the most preferred in terms of colour, taste, aroma, mouth feel, after taste, and overall acceptability whereas cassava fufu was the least acceptable. The study recommends that the consumption of cassava ogyama fufu can be recommended more often to diabetics who wish to continue enjoying fufu while they manage their health.

KEYWORDS

Alchornea cordifolia

Euphorbiaceae

Trypanosomiasis

Galega officinalis L

Papaver somniferum L

Manihot esculenta Crantz

ACKNOWLEDGMENTS

I acknowledge the enormous guidance, support, and contribution given to me by my supervisor, Prof. Sarah Darkwa. I am grateful.

I am again grateful to my father Mr. Justice Mark Dadzie and Phyllis Amoah for their unflinching support throughout my course of study. Finally, I wish to thank my family and friends for their support.

DEDICATION

To my lovely family and friends.

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LIST OF ABBREVIATIONS

AGPD	-	Agricultural Gross Domestic Product
ANOVA	-	Analysis of Variance
BMI	-	Body Mass Index
FBS	-	Fasting Blood Sugar
GI	-	Glycaemic Index
GL	-	Glycaemic Load
OGTT	-	Oral Glucose Tolerance Test
WHO	-	World Health Organization

CHAPTER ONE

INTRODUCTION

Background to the Study

Plants have been a source of medicine for humanity for centuries, particularly in the poor countries. The use of plants for medical reasons is the world's most extensive use of biodiversity (Qaddoori, 2016). Apart from providing food, plants have historically been an effective weapon against illness. Both traditional healers and pharmaceutical researchers have turned to plants for treatments for infectious and non-infectious illnesses for centuries. For centuries, medicinal plants have been utilized to cure human illness because they contain chemicals with therapeutic properties. Some parts of plants contain substances that kill or inhibit the growth of some bacteria and so are said to have antibacterial activity. The antibacterial activities of most medicinal plants depend on certain active ingredients such as alkaloids, saponnins, tannins, flavonoids, and various oils (Arekemase, Kayode, & Ajiboye, 2011). For a plant to be described as a medicinal plant, the species of the plant from which the drugs are obtained, the chemical nature of the extracts from the plants, and the purpose for which the plant species is used must be known (Sofowora, 1992). Since ancient times, plants as sources of therapeutic chemicals have played a significant role in the maintenance of human health. According to the World Health Organization (WHO), about 80% of people in poor countries depend on traditional medicine for basic health care, and approximately 85% of traditional medicine utilizes plant extracts.

As far back as the beginning of time, people have used plants to treat illnesses. Herbal medicine utilizes herbs/plants in their purest form to cure illness. Almost all civilizations have utilized a range of plants or compounds derived from plants to prevent and cure illness (Adedapo, Shabi, & Adedokun, 2005). Additionally, plants have been utilized as a source of food and medicine for ages, and this expertise has been handed down from generation to generation (Adedapo, Shabi, & Adedokum, 2005).

Medicinal plants are also a valuable source of antibacterial compounds, which may be acquired from a variety of sources (Kubmarawa, Ajoku, Enwerem, & Okorie, 2007). As a natural remedy, many of the medicines now accessible to doctors have a lengthy history (Elumalai & Eswariah, 2012). Plant-based medications are used by about 70 percent of the world's population, according to Pravin (2006), and the WHO estimates that 80 percent of the population in certain Asian and African nations rely on herbal medicine for some element of primary health care (WHO, 2008). Majority of Africans still rely on herbal medicine (Eliakim-Ikechukwu & Riman, 2009). It is widely believed that there are some cheap, effective herbal treatments and conventional therapeutic regimens (Ekor, 2014). The expanded material worth of clinical treatment and their solid physiological or compound impacts, high cost of pharmaceutical and nutritional products contribute to reasons why people utilize natural treatment (Ebenyi & Uraku, 2017). Ghana is one of the Countries in Africa endowed with a vast array of plants that have been locally used for medicinal or nutritional purposes. One of such plants is *Alchornea cordifolia* which belongs to the family Euphorbiaceae.

Alchornea cordifolia (Schumach. and Thonn.) Müll. Arg (Euphorbiaceae) is a plant that may be found across Central, Western, Eastern, and Southern Africa. It is a member of the genus Alchornea (Euphorbiaceae). As a climber or upright plant, this multi-stemmed shrub or small tree may grow up to 5 meters in height and extend its branches out over a wide area. Flowers are produced by the plant in both unisexual and sessile forms. The male flower contains two cup-shaped sepals and eight stamens, while the female bloom has a calyx that is divided into 2–4 lobed. The fruit is composed of a 3-lobed capsule that is typically green or red in colour and contains ovoide seeds (Noundou, 2012). In the case of Sarfo (2012), he found that this plant often grows to a considerable height extremely near to water banks, wet or marshy areas, while maintaining a shrubby or scrambling character. It has also been reported by Timibitei Alikwe, Wekhe, and Ohimain (2013) that *Alchornea cordifolia* is a lasting evergreen bush or little tree growing up to 4 – 8 m tall, with raised youthful shoots that later become level, empty, and glabrous. *Alchornea cordifolia* is a lasting evergreen bush or little tree growing up to 4 – 8 m tall, with raised youthful shoots that When youthful, the plant has a woody stem with various branches bearing leaves and is shaggy for all intents and purposes. Leaf blades are pleasant to the touch, simple, alternating roughly oval, 10–28cm long and 6.5–16.5cm wide, and usually covered with few glands at the base (Timibitei et al., 2013).

Its therapeutic properties are well-known across the region of distribution of *Alchornea cordifolia* (also known as Christmas bush, or *ogyama* in Akan). It is most often employed in local medicine preparations for its leaves, but it is also utilized for its bark and pith as well as its leafy stems, root bark and roots as well as its fruits. As an implantation or chewed fresh, the leaves or leafy stems are used to treat an assortment of respiratory issues like sore throat, cough, and bronchitis, genital-urinary issues like venereal illnesses and female sterility, and digestive issues like gastric ulcers, the runs, amoebic looseness of the bowels, and worms, among other things (Noumi & Yomi, 2001). They are utilized as a laxative and as a douche; high measurements taken orally are emetic when taken in large quantities (Mavar-Manga, Haddad, Pieters, Baccelli, Penge, & Quetin-Leclercq, 2008; Noumi & Yomi, 2001; Sandberg, Perera-Ivarsson, & El-Seedi, 2005).

Alchornea cordifolia leaves are also used as a blood cleanser, tonic, and treatment for anaemia and epilepsy, they have a long history. To cure ulcers of the mouth, toothache, and cavities, decoctions of the leaves and roots are extensively used as mouth washes. Twigs are also used for the same reasons, according to Kumar (2014). Applied remotely as a cicatrisant to wounds, to reduce torment like spinal pain and migraine, to breaks to speed recuperating, to treat eye contaminations, and an assortment of skin illnesses like venereal sicknesses, bruises, abscesses, yaws, and filariasis are all treated with crushed fresh leaves or powdered dry leaves. An application of a decoction or paste of leafy twigs is used as a wash to cure fever, malaria, rheumatic pains, and enlarged spleen, as well as a lotion or poultice to treat painful feet; vapour baths may also be used to treat these conditions (Osadebe & Okoye, 2003).

In some parts of Africa (Côte d'Ivoire and Ghana, specifically) Mavar-Manga, Marie, & Quetin-Leclercq, (2008) reported that the leaves of *Alchornea cordifolia* are applied as a haemostatic to stop delayed monthly cycle and a decoction of roots or leaves is applied in the vagina to stop post pregnancy discharge and to treat vaginitis. Also, the leaves and root bark are externally applied as an antidote to snake venom while the sap of the natural product is applied to fix eye issues and skin sicknesses (Agyare, Ansah, Ossei, Apenteng, & Boakye, 2014). In veterinary medication, a leaf or root imbuement is given to animals to treat trypanosomiasis (Boniface, Ferreira & Kaiser, 2016). These beneficial uses of *Alchornea cordifolia* cannot be overlooked in this age of Covid -19. Several individuals worldwide have resorted to concoctions prepared from different plant materials to fight and protect themselves from Covid -19. The prevalence of diabetes in Ghana is estimated to be 2.0% with a mortality rate as high as 13% (Ameyaw, Asafo-Agyei, Thavapalan, Middlehurst & Ogle, 2017) coupled with the fact that individuals with underlying chronic health conditions are affected most by Covid -19, it is important to study such health beneficial plants like *Alchornea cordifolia* in product development and nutritional use.

With success stories from individuals who patronise such concoctions and for the fact that Covid -19 has come to stay, it is important to look at other ways of including useful plant materials in our daily food. The leaves are likewise utilized as scrounge for little ruminants and poultry. Chicken produce egg yolks with a more profound yellow shading when taken care of consistently with the leaves, Mavar-Manga (2008) and colleagues reported.

According to Sarfo (2012), the leaves of *ogyama* plants are widely used for food colourisation and general dyeing purposes. The utilization of restorative plants in enhancing food is a practice that has existed for several decades (Baa-Poku & Enu-Kwesi, 2016). Sometimes, the plants are used to enhance the flavour or taste of the food. For example, *waakye*, a popular Ghanaian food, is cooked with dried sorghum leaves to enhance its flavour. It is significant, however, to take note of that the health/medicinal benefit of plants is a key reason for their usage in preparing food. Foods usually prepared with plants or herbs to enhance flavour or taste are those widely consumed. In Ghana and portions of West Africa, one of the widely consumed foods is fufu.

Fufu is usually made from cassava and/or plantain, cocoyam or yam, and, in Ghana, it is commonly eaten by all ethnic groups. Even though most people prefer the cassava and plantain combination, the cassava and yam or the cassava and cocoyam combination become an option for people especially during seasons when plantain becomes scarce and expensive in the country (Adu-Gyamfi, 2018). It is worth noting that some people prefer the other combinations to the cassava and plantain combination. In Ghana, fufu is traditionally made by boiling raw cassava, plantain, yam, or cocoyam and then pounding it in a mortar with a pestle to a smooth consistency. In the middle of blows from the pestle, the combination is turned a person, and water is added to it bit by bit till it becomes slurry and sticky. The combination is then shaped into a ball and presented with soup. Today, fufu is processed in other ways with the introduction of instant fufu flour and fufu pounding machines.

Fufu is a carbohydrate-rich food. It is worth mentioning that starches fluctuate as far as their actual design, substance structures, molecule size, and fiber content which affect diverse plasma glucose and insulin reaction (Jenkins, Wolever, & Taylor, 1981). According to Kouassi, Tiahou, Abodo, Camara-Cisse, and Amani (2009), dietary management is necessary for getting an improved glycaemic control to diminish the chance of diabetic difficulties and to protract life range. An improvement of glycaemic control by evening out dietary admission with insulin levels is a fundamental point of convergence in the nourishing administration of diabetes (Kalergris, De Gandpre, & Anderson, 2005). The way forward to maintain a balance between blood glucose and insulin levels is the glycaemic index and glycaemic load. The categorizing of how rapid or slow a carbohydrate food is transformed into glucose after eating is an estimation of its glycaemic index (Eli-Cophie, Agbenorhevi, & Annan, 2016). Carbohydrate food varieties that are rapidly corrupted into glucose subsequent to eating are delegated a high glycaemic record while those that consume a large chunk of the day to change over into glucose are likewise named a low glycaemic index (Eli-Cophie et al., 2016). The glycaemic indexes of foods are categorized on a scale of 0-100 with 100 assigned to foods with a high glycaemic index and 0 assigned to foods with a low glycaemic index. Factors that can influence the glycaemic index of food include processing, variety, methods of cooking, ripeness, and storage time (Aston, Gambell, Lee, Bryant & Jebb, 2008).

According to Thomford, et al. (2015), *Alchornea cordifolia* leaves extract has anti-diabetic properties. In fact, for this and other medicinal benefits indicated earlier, the plant is widely used in different ways and occasionally added to food. Against this backdrop, the study explored the health and aesthetic benefits of *Alchornea cordifolia* in cassava fufu (a staple widely consumed in Ghana).

Statement of the Problem

Over the years, people have been using “Ogyama” leaves to cook cassava in fufu preparation with the sole aim of improv1ing on the aesthetic properties of the fufu without knowing the nutritional composition or the health benefits the “Ogyama” leaves added to the food.

The use of plants as a source of therapeutic substances has continued to play a significant part in the preservation of human health from the beginning of humanity. In traditional treatments utilized by the majority of the world's population, plant extracts or their active components are employed as folk medicine, according to the World Health Organization (WHO). According to the World Health Organization, 80 percent of people in poor nations depend on traditional medicine for their primary health care, with plant extracts accounting for about 85 percent of all traditional medication. This implies that about 3.5 to 4 billion people across the globe depend on plants as a source of pharmaceuticals (Chandrawat, Mathur, & Sharma, 2014). Natural products (including their derivatives and analogs) continue to account for more than half of all medicines now in clinical use, with higher plant-derived natural products accounting for 25 percent of the total in clinical use today. A few notable examples include galegine, derived from *Galega officinalis L.*, which served as a model for the synthesis of metformin and other antidiabetic drugs; and papaverine, derived from *Papaver somniferum L.*, which served as a model for the synthesis of verapamil, which is used in the treatment of high blood pressure. Opium is best recognized as the source of medicines such as morphine and codeine. Opium is also used to make heroin (Cragg & Newman, 2014).

Plants generate bio-active chemicals that have pharmacological or toxicological effects on other organisms, and these substances are known as bioactive compounds. Despite the fact that nutrients (such as vitamins and minerals) may have pharmacological or toxicological effects when eaten in large quantities (e.g., when consumed in large quantities), nutrients in plants are usually not included in the phrase "bio-active plant components." Secondary metabolites are liable for the creation of most of bioactive chemicals in plants. In this case, bioactive molecules in plants may be characterized as optional plant metabolites with pharmacological or toxicological effects in both humans and animals, respectively (Aksel, 2010 cited in Qaddoori, 2016). They include alkaloids, phenols, tannins, glycosides, and essential oils.

The existence of bioactive chemicals in plants is essential for the development of their therapeutic qualities. The screening of medicinal plants must continue in order to not only establish the scientific foundation for their use, but also to uncover potential new active chemicals that may be found in them. (Canini, Karou, & Savadogo, 2006). The main advantages of utilizing plant-derived medications are that they are much less expensive than synthetic equivalents while also providing substantial therapeutic effects and being more inexpensive than synthetic alternatives. A considerable lot of the plant materials utilized in customary medication are easily accessible in rural regions, which has resulted in the old system of medicine being much less expensive than modern treatment as a result.

Plants with traditional uses have been studied widely in the pharmaceutical industry. There have been an enormous number of studies conducted to identify the various antimicrobial and phytochemical constituents of medicinal plants and to utilize them in the treatment of microbial diseases as possible options in contrast to antibiotics and other chemotherapeutic agents, to which numerous infectious microorganisms have developed resistance. These plants are often tested by mimicking their uses and when found active, the essential ingredients are extracted for use often in the pharmaceutical industry. *Alchornea cordifolia* is one of such plants which have been extracted and used widely in pharmaceuticals with its vast health benefits. Previous studies of the plant found that the leaf extracts induced a dose-dependent with a significant decrease in the blood glucose level (Mohammed, Ibrahim, Atawodi, Eze, Suleiman, & Malgwi, 2013). Also, ethanolic extract of *Alchornea cordifolia* leaves significantly decreases the fasting blood sugar level (Thomford, et al. 2015).

Despite the wide usage of *Alchornea cordifolia*, there is a paucity of knowledge on the benefits of the plant in preparing food. Studies conducted on *Alchornea cordifolia* in the past had different foci, other than its benefits in preparing food. Some focused on the plant's antimicrobial activities (Agbor, Léopold, & Jeanne, 2004; Gatsing, Nkeugouapi, Nji-Nkah, Kuiate, & Tchouanguep, 2010; Mambe, Voukeng, Beng, & Kuete, 2016), antibacterial constituents (Lamikanra, Ogundaini, & Ogungbamila, 1990), medicinal application (Kigigha & Atuzie, 2012) and nutritional evaluation (Ebenyi, & Uraku, 2017). Others (Mohammed, et al., 2013; Thomford, et al., 2015) investigated the antidiabetic and haematological effects of the plant.

Presently, there is a gap in knowledge specifically concerning the benefits of *Alchornea cordifolia* in preparing food. The study, thus, aims at addressing this lacuna by exploring the health and aesthetic benefits of *Alchornea cordifolia (ogyama)* in preparing cassava fufu.

Purpose of the Study

The purpose of the study is to explore the health and aesthetic benefits of *Alchornea cordifolia* (ogyama) in preparing cassava fufu.

Objectives of the Study

The study seeks to:

1. Determine the composition of cassava-plantain fufu, cassava fufu, and cassava-ogyama fufu;
2. determine the glycaemic load of cassava-plantain fufu, cassava fufu, and cassava-ogyama fufu;
3. compare the effect of cassava-plantain fufu, cassava fufu, and cassava ogyama-fufu on blood sugar level;
4. evaluate the acceptance of cassava fufu and cassava-ogyama fufu.
5. find out if there is a statistically significant difference between cassava plantain fufu and cassava ogyama fufu based on specific sensory characteristics.

Hypothesis

H_0= There is no statistically significant difference in the glycaemic load of cassava-plantain fufu and cassava-ogyama fufu.

Significance of the Study

Essentially, *Alchornea cordifolia*, which is known to have numerous health benefits in pharmaceuticals might be more helpful in the creation of food varieties. This is because, in pharmaceutical industries, extractions of essential nutrients in medicinal plants like *Alchornea cordifolia* are often used. On the other hand, *Alchornea cordifolia* can be used as it is in food preparation. It is expected that findings from this study will provide adequate literature on the health and aesthetic benefits of using *Alchornea cordifolia* in preparing cassava fufu to serve as a basis for further research in food preparation.

This study may also improve on knowledge and inform people who have blood sugar issues to patronise the plant as well as foods that have been prepared with *Alchornea cordifolia*. It may also inform dieticians and nutritionists to recommend diabetic patients to include *Alchornea cordifolia* in their diets for good management and prevention of diabetes. This study is also hoped to inform and open more avenues for research into plants for nutrition since there is adequate knowledge of plants in terms of their medicinal uses across Ghana. They will as well obtain the associated health benefits like dealing with respiratory problems and pain in this Covid -age. It will open the avenue for more research into the use of *Alchornea cordifolia* in food production. It is anticipated that findings from this study will go a long way to enrich the scarce literature on *Alchornea cordifolia* with regards to its uses and benefits in food production like the preparation of cassava fufu.

Delimitation of the Study

This study was delimited to exploring the health and aesthetic benefits of *Alchornea cordifolia* in preparing cassava fufu. The use of dried *Alchornea cordifolia* leaves in the preparation of cassava fufu was analyzed as well as cassava fufu alone at the School of Agriculture Laboratory. Also, respondents used was certified by a medical officer to be healthy in terms of their body mass index (BMI). Healthy individuals were used for the study which was conducted at the University of Cape Coast hospital. Blood samples taken from the respondents were used to determine the glycaemic load of the test foods and the respondents' blood fasting glucose.

Organization of the Study

The study is organized into five chapters. Chapter one introduces the study by providing a background to the study. The chapter also includes the problem statement, objectives, and hypothesis of the study, as well as the significance of the study. In chapter two, an extensive review of the relevant empirical literature (related to the study) was conducted. The review was conducted under the following themes: the concept of glycaemic load, glycaemic index, the concept of proximate analysis, the origin of *Alchornea cordifolia*, classification of cassava, and plantain and, classification of carbohydrate. The third chapter details the methods and procedures used in the study. Specifically, the study design, study area, population, sample and sampling procedure, and methods of data collection and analysis are detailed. In chapter four, the results of the study are presented and discussed while chapter five provides the summary, conclusion, and recommendations of the study.

CHAPTER TWO

LITERATURE REVIEW

Introduction

This chapter presents a review of relevant literature, which provides critical knowledge on the research topic. This chapter also includes a conceptual framework and empirical evidence, relevant and appropriate to explain key issues in the study. The literature was reviewed under the following headings:

- Classification of cassava and plantain
- Classification of carbohydrate
- Concept of glycaemic load
- Concept of glycaemic index
- Concept of proximate analysis
- Origin of *Alchornea cordifolia*
- Studies on *Alchornea cordifolia*

Classification of Cassava and Plantain

Cassava

The main yields in the Tropic, cassava (*Manihot esculenta Crantz*) is a carbohydrate staple. Following cereal crops, cassava is the third most significant wellspring of calories in the tropics, as per the Food and Agriculture Organization of the United Nations (2008). Its yearly output of over 10 million tonnes in Ghana places it third in Africa behind Nigeria and the Democratic Republic of the Congo. Ghana's cassava production represents about 8% of all cassava production in Africa (FAO Food Outlook, 2009). The starch content in the root differs as per assortments and contains the most noteworthy measure of starch (Nanda, Sajeev, Sheriff, & Hermasankari, 2005). Cassava is the 6th most important supplier of energy in human nutrition on a global scale, and the 4th highest important source of power after rice, sugar, and corn (Heuberger, 2005).

Cassava is very low in fats and protein compared to cereals and pulses. Nevertheless, it contains more protein than that of other tropical food sources like yam, potato, and plantain. Cassava also contains antinutrients, for example, phytate, fibre, nitrate, polyphenols, oxalate, and saponins, which might lessen the bioavailability of nutrients in the body (Ebuehi, Babalola & Ahmed, 2005). A perishable food, cassava has a shelf life of just three days after harvest. Producing shelf-stable goods (thus decreasing losses) while increasing value at the local rural level and lowering the quantity to be sold are all possible via processing (Phillips, Taylor, Sanni & Akoroda, 2004). Cassava when processed, can be made into different kinds of food like *'gari', 'tapioca'* and *'akyeke'*. One common Ghanaian food, *'fufu'*, is prepared by boiling cassava and mixing with other boiled carbohydrate staples like plantain, yam, or cocoyam.

A 100g of raw cassava contains 38g carbohydrate, 1.8g fibre, and 1.7g sugar and could yield about 670 (kJ) of energy. Cassava has an amylose amylopectin ratio of 30:70, which makes it more accessible to digestive amylases hence the more likely to stimulate higher glucose response when it is consumed. Figure 1 is a picture of fresh and matured harvested cassava tubers.

Figure 1: Picture of freshly harvested cassava

Plantain

In Latin America, Africa, and South-east Asia, plantains (*Musa paradisiaca*) are a key supplier of carbohydrate (Marriott & Lancaster, 1983). Plantain is estimated to provide greater than 25% of the carbohydrate needs of 60 million people in West Africa (Ortiz & Vuylsteke, 1996). When it comes to agricultural gross domestic product (AGPD), plantains are much more important than cereals in Ghana (MOFA, 2006).Lescot (2000) reports that plantain’s per capita yearly utilization is higher than maize and yam. Plantains serve as significant origins of food especially in the Ashanti, Brong Ahafo, and Eastern regions of Ghana.

In West Africa, plantains come in a multitude of varieties. For example, French Horn Plantain can be classified as either the false or the true horn plantain (Ahiekpor, 1996; Hemeng & Bandful, 1996). It is known in Ghana as *'Apem', "Oniaba" or "Nyeritiana Apem". Asamienu and Aowin* are the sub-varieties of the False Horn variety. In Ghana, the variety that is mostly used in making 'fufu' is the *'Apantu pa'*. Raw unprocessed plantain contains 32g of carbohydrate, 15g sugar, and 2.3g fibre per 100g (United States Department of Agriculture, 2002).

Plantains, unlike bananas, are often processed before eating. They are cooked, fried, or roasted before eating. In Ghana, plantain can be boiled and pounded together with boiled cassava into *'fufu'*. The slightly ripe boiled plantain could also be mashed into *'eto'*, a food common to the Akans. Plantain has high fibre constituent's, and along these lines fit for bringing down cholesterol, and furthermore assists with alleviating constipation and consequently stopping of colon cancer. Other than this, its low glycaemic index makes it the desirable carbohydrate staple that is mostly recommended for diabetics (United States Department of Agriculture, 2002). According to Ng and Fong (2000), its potassium content is observed to be useful in the counteraction of raising circulatory strain and muscle cramp.

Plantain is recognized to be low in sodium (Chandler, 1995). It has almost no fat and no cholesterol; thus helpful in overseeing patients with hypertension and coronary illness. Plantain is, nonetheless, a seasonal and very perishable crop. More than 80% of the yield is reaped from September to February. Be that as it may, there is a lot of wastage during this time as a portion of the items do not store for an extensive time. The outcome of this is occasional inaccessibility and limits on the utilization by urban populaces. Below is a picture of fresh fingers of plantain.

Figure 2: Picture of a freshly harvested bunch of plantain

Classification of Carbohydrate

Carbohydrates are a gathering of natural mixtures including a proportion of one carbon atom to two hydrogen atoms to one oxygen atom. Carbohydrate compounds are made up of monosaccharide building units, and ranges from simple monosaccharides, disaccharides, and oligosaccharides to more complex forms such as starch and non-starch polysaccharides (Wormenor, 2015). The classification of carbohydrate foods has been based on the structural conformation or degree of polymerization of the major carbohydrate that is present in (FAO/WHO, 1998). Hence, it was classified as 'simple' and 'complex' carbohydrates. Simple carbohydrate contains either monosaccharides or disaccharides whiles the complex contains either the polysaccharides or the starch. These classifications are, however, based on the chemistry of the carbohydrates and do not necessarily reflect their specific physiological properties, nutritional or health effects (Cummings & Stephen, 2007). The chemical classification of carbohydrates into simple and complex started the mistaken assumptions that all simple carbohydrates would cause a fast glucose reaction in the body whereas the complex carbohydrate rather stimulates a slower glucose response. This idea influenced the preference of complex carbohydrates by people with various insulin disorders, as well as glucose intolerance.

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

Chewing would increase the surface area for enzyme activity and thus increases the rate of digestion and absorption (Wormenor, 2015). The food (chyme) then passes through the stomach into the small intestines. No absorption happens in the stomach. In the small intestines, the pancreas releases pancreatic amylase which breaks polysaccharides into disaccharides. Thereafter, the disaccharide is further broken down into monosaccharides with the help of the enzymes lactase, sucrase, and maltase. The end product of the digestion of carbohydrates is glucose, which is then absorbed. Absorption takes place in the gastrointestinal tract with the help of certain fluids and enzymes (Kaiser, 2016). Some carbohydrates and other food substances like fibre may escape digestion into the large intestines where they could undergo fermentation into gases.

Available and unavailable carbohydrates

To improve and help the comprehension of carbohydrates, McCane and Lawrence (2005), cited in Poutanen grouped them into available and unavailable carbohydrates. In the process of generating food tables for diabetic diets, it was discovered that some carbohydrates could not be broken down and absorbed. They further went on to discover that some carbohydrates escape digestion and assimilation in the small intestine but get to the large bowel where it is fermented. They defined available carbohydrates as starch and soluble sugars. FAO/WHO (1998), defines available carbohydrates as constituents of carbohydrates that are broken down to produce sugar which is further degraded to yield energy. According to Eli-Cophie, Agbenorhevi, and Annan (2017), paying more emphasis on available carbohydrates is very essential because it makes it clear which part of the carbohydrates are utilised to decide the glycaemic index of a particular food.

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

Dietary carbohydrate

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

Carbon molecules with ketone or aldehyde functional groups are classified as carbohydrates by the Joint FAO/WHO Expert Consultation Committee on Carbohydrates in Human Nutrition (FAO/WHO, 1998). According to the researchers, carbohydrates can be classified according to their molecular size or structural content. All starches contain amylose and amylopectin but in different ratios depending on the particular carbohydrate. For the same carbohydrate food item, the amylose/amylopectin ratios even differ with variety. Digestibility is greatly impacted by the proportion of amylose to amylopectin which is a great branched glucose chain (Wormenor, 2015).

Concept of Glycaemic Index (GI)

Researchers have discovered that the blood glucose response to the consumption of carbohydrate-containing meals may change altogether dependent on an assortment of variables, including the molecular structure of the carbohydrate, the amount of fiber in the food, and the degree of processing (Ludwig, 2002). More refined, highly processed carbohydrates are broken down and absorbed rapidly, causing a rapid rise in blood glucose levels; less refined carbohydrates, on the other hand, are absorbed more slowly, causing a slower, more persistent rise in blood glucose levels. On the premise that such data would be helpful in circumstances when glucose tolerance is compromised, Jenkins created the term "Glycaemic Index" to give a quantitative categorization of carbohydrate meals In other words, the glycaemic index is a proportion of the blood glucose reaction that carbohydrate-containing meals cause. If you want to know what the glycaemic index of a meal is, it's the contrast between the area under the glucose reaction bend generated by a standard control food (either glucose or white bread). According to the index, carbohydrate-containing foods have a higher glycaemic response than non-carbohydrate-containing meals. This index measures how quickly and by how much carbohydrate-containing food sources raises glucose levels. In contrast, meals with a high glycaemic index (HGI) cause a fast jump in blood glucose levels, whereas foods with a low glycaemic index (LGI) cause a gradual but longer lasting rise in blood glucose levels.

Glycaemic index is expressed in percentages and it is represented on an absolute scale where foods with values of 55 or less (≤ 55) have a low glycaemic index, foods with 56 to 69 have a medium glycaemic index and 70 or more (≥ 70) are classified as foods with higher glycaemic index (Brand-Miller, Hayne, Petocz, & Colagiuri, 2003). The glycaemic index of a food is mostly compared with a standard; pure glucose, which has a glycaemic index of 100. The glycaemic index measures postprandial glucose which can be influenced by varying the amount and type of dietary carbohydrates consumed. Meals containing low glycaemic index food varieties decrease both postprandial blood glucose and insulin responses (Food and Agriculture Organization, 1998).

Two examples of phrases commonly used in GI literature are "GI mechanism" and "GI utility". GI mechanism is typically used to describe the physiological and metabolic properties of a low or high GI food or dietary pattern. The relevance of these mechanisms is often described in terms of their role in the prevention or treatment of a given condition (e.g. Type 2 diabetes) (Grant & Wolever, 2011; Southgate & Wolever, 2012; Wolever, 2006a). This concept is deeply intertwined with another phrase; “GI utility”. GI utility is a general phrase used to describe the effectiveness of glycaemic index in a given setting and for a given outcome (Grant & Wolever, 2011; Kalergis, Pytka, Yale, Mayo, & Strychar, 2006; Southgate & Wolever, 2012). For instance, in a research setting, GI utility might be to foresee the relative glycaemic impact of two unique meals. On the other hand, GI clinical utility can be defined as the ability of low GI foods to lower postprandial glycaemic response, but also may be defined as a GI education materials' ability to increase client GI knowledge and/ or facilitate change in client diet GI. Depending on how one defines these terms, scientists may require the application of the different methodology and, in some cases, study design (Deuster, Christopher, Donovan, & Farrell, 2008; Tokuda, Okamoto, Yoshioka, et al., 2008).

Derivation of GI values

The GI value of a food is determined through human testing. Approximately 10 participants are given a quantity of the test meal that contains 50 grams of digestible carbohydrate in each serving. According to Henry, Lightowler, Strik, Renton, and Hails (2005), for low carbohydrate foods, 25 grams could be used. The evening before a test, volunteers should restrict from caffeine-containing drinks, avoid vigorous physical activity, and fast overnight (Henry, et al., 2005). The sample size for testing glycaemic index with sufficient statistical power should be at least 10 test subjects (FAO/WHO, 1998). Using ten subjects to test GI values has been shown to provide a healthy level of force and accuracy for epidemiological studies while remaining economical (Brouns, Bjorck, Frayn, et al., 2005).

Postprandial blood glucose concentrations are monitored by finger prick blood samples at 15 to 30 minutes intervals for two hours. The region under the two-hour blood glucose reaction curve is calculated for each person. On a separate occasion, the same individuals consume a 50gram portion of glucose which acts as the reference food. White bread is an accepted reference food for glycaemic index testing, as per the International Organization for Standardization scientific methodology for GI testing (Wolever, 2006b). Regardless of the reference food selected, all glycaemic index values must be reported on the glucose scale. In order to translate from the higher bread scale (GI of white bread = 100) to the lower glucose scale (GI of white bread = 71), a conversion factor of 0.71 is needed (Atkinson, Foster-Powell & Brand-Miller, 2008; Foster-Powell, Holt & Brand-Miller, 2002).

The GI value is determined by partitioning the region under the postprandial glucose curve (AUC) for the test food by the AUC for the glucose reference and duplicating by 100 to give a percentage. The mean of the individual subject percentages is the GI (%) of the tested food. As indicated by the FAO/WHO master report on the GI methodology, The GI is determined utilizing the accompanying condition:

$$\text{Glycaemic Index (GI)} = \frac{\text{IAUC for the test food containing (X)g of available CHO}}{\text{IAUC for the ref. food containing (X)g of available CHO}} \times 100$$

It is important to indicate that GI values are only allocated to carbohydrate foods and therefore foods with zero or negligible carbohydrate content such as meats, oils, and nuts are not allocated a value.

In determining glycaemic index, consideration is given to three important variables: psychological characteristics of participants, blood sampling, and reference food (as indicated earlier).

Psychological characteristics of participants

Since GI determination measure the postprandial glucose response of a person, the physiological state of a person participating in GI studies must be considered because the individual's insulin response and glucose tolerance can influence the body's glycaemic response (Wormenor, 2015). On the other hand, type II diabetics show less intra-individual variance than type I diabetics. Therefore, to increase precision in GI determination, the use of healthy individuals is recommended (Brouns et al., 2005).

Blood sampling

Glucose concentrations can be estimated from entire blood or plasma from different parts of the body. Blood samples could be obtained from the veins, arteries, or capillaries. An assessment of the arterial blood could yield the truest reflection of the glucose concentration being delivered to the various body tissues because they are the veins that convey blood from the heart to the tissues and will be richer in nutritional composition. However, since the arteries are found deeper within the body than the capillaries and veins, drawing arterial blood could come with associated risks. This notwithstanding, capillary blood approximates the composition of arterial blood and therefore a better alternative to arterial blood (Brouns et al., 2005). Cavernous blood has a glucose content that is about three times higher than that in capillaries, making it simpler to detect very modest changes to blood sugar levels over time. In the determination of GI, blood from the capillary taken from the fingertip or earlobe is, therefore, more suitable and better for the assessment of glycaemic response (Wolever et al., 1994).

Reference food

The use of a standard food against which the test food will be measured is very necessary for the determination of the GI of a food. Over the years, several foods have been used as reference foods in the determination of GI (Foster-Powell, Holt & Brand-Miller, 2002). An updated database of GI of some 1300 foods measurements involved about 10 different reference foods including glucose, wheat chapatti, potato, rice, bread, white bread, whole barley bread, and wheat. Glucose and white bread, however, have been the main reference foods used (Foster-Powell et al., 2002).

The use of white bread as a reference food produces a relatively higher GI value than glucose. Wolever et al (1999) report that the GI of white bread as determined in some studies produces a value of 73 constantly. White bread composition and preparation may, however, differ from one experimental setting to another as was reported in a study where white French bread produced a GI value of 97 (Bornet et al., as cited in Brand-Miller et al., 2003).

The use of glucose as a reference food also raises some concerns such as its great sweetness. Some people also complain of a nauseating effect they feel when the glucose solution is taken toward the beginning of the day after a

10-14hour fast (Brouns et al., 2005). Pure glucose is, however, more likely to be the same in most experimental settings. This makes it easier to compare results from other laboratories (Wormenor, 2015). When computing the GI of the test foods, the IAUC of the reference food will be utilized as the denominator. As a result, many theoretical assessments and replication studies have revealed that either three or two trials of the reference diet are suitable to reduce these variances (Brouns, et al., 2005).

Factors influencing the GI of food

After consumption of carbohydrate food, the pace of glucose retention into the bloodstream is affected by the chemical and structural basis of the food like applied processing methods. A report by the joint Food and Agriculture Organization and World Health Organization (FAO/WHO) expert committee in 1998 indicated that several factors influence the postprandial glycaemic response of food when ingested. These factors were identified as the kind of starch in the food, monosaccharide components, quantities of protein or fat, types of dietary fibre, and degree of cooking or processing.

a. Starch structure

Starch in carbohydrate foods is a mixture of glucose polymers, amylose, and amylopectin. The more open, branched structure of amylopectin permits greater access to alpha-amylase compared to the linear structure of amylose resulting in more rapid digestion. Alpha-amylase inhibitors present in foods such as legumes inhibit enzyme action and therefore lower the GI (Behall, Scholfield, & Canary, 1988).

b. Monosaccharide components

As the monosaccharides fructose and galactose are extensively metabolised within the liver, a relatively small proportion is converted to glucose and released into the peripheral circulation, resulting in lower GI in comparison to glucose (Wolever, Nguyen, Chiasson, et al., 1994). Honey and fruit are commonly consumed sources of fructose, and dairy products that contain the disaccharide lactose provide the main sources of galactose.

c. Co-presence of fat or protein

Fat has been displayed to postpone gastric exhausting, and protein can stimulate insulin secretion independently of the carbohydrate consumed (Jenkins, Wolever, Taylor, et al., 1981). Pelletier, Donazzolo, Barbier-Latreille, Laure-Boussuge, Ruel, and Debry (1998) reported that the addition of 100 grams of cream cheese, which contains fat and protein, to a standard French breakfast pointedly decreased the glycaemic response. However, other studies suggest that the expansion of fat or protein makes little clinical difference to the glycaemic response. In a study of people with type 2 diabetes, the addition of 25 grams of protein to 25 grams of carbohydrate serves of potato and spaghetti slightly reduced the glycaemic response ($F=2.04$, $p<0.05$); the addition of 25 grams of fat-reduced the glycaemic response to potato ($F=14.63$, $p<0.001$) but not to spaghetti ($F=0.94$, $p>0.05$).

d. Dietary fibre

Soluble dietary fiber can postpone gastric purging and the rate of assimilation of glucose from the small digestive tract (Bjorck, Granfeldt, Liljeberg, Tovar, & Asp, 1994). Guar, a water-soluble gum used in foods as a thickener and stabiliser, and beta-glucan, a solvable dietary fibre found in grains and mushrooms, form viscous gels in the small intestine which decrease access of alpha-amylase to the starch portion. Insoluble fibre from the structure of plant cell walls can likewise bring down GI by giving actual boundaries which diminish access of alpha-amylase to starch grains, for example in multigrain bread and coarse-grained high fibre cereals. The effect is independent of particle size; finely milled grains provide fewer barriers to digestion and therefore products such as wholemeal and white pieces of bread have higher GI values than coarsely ground or whole-grain bread, irrespective of total fibre content.

e. Cooking and processing

The GI values of some foods can vary depending on the cooking and processing methods used in the preparation. Techniques such as extrusion, flaking, popping, and grinding can influence the molecule size and respectability of the starch molecules and plant cell walls. Heating and humid conditions allow gelatinization to occur in which starch granules grow and split open, giving the alpha-amylase more opportunity to do its work. to the starch (Augustin, Franceschi, Jenkins, Kendall, & La Vecchia, 2002). Processing techniques such as parboiling and cold extrusion decrease the glycaemic response by minimising gelatinisation. For example, the GI of potatoes is lower when cooled than when hot. When potatoes are cooked, starch granules gelatinise and separate, increasing access of alpha amylose to the granules. The gelatinisation reverses on cooling and some starch becomes resistant to hydrolysis, thereby decreasing the GI.

Concept of Glycaemic Load (GL)

In addition to the glycaemic index, portion size is also an important issue to consider when it comes to glucose management and weight management. When a person consumes food, their glucose response is influenced by both the quality and quantity of carbohydrate in the food (Sheard, et al., 2004). This led to the idea of glycaemic load, which is the total amount of carbohydrates consumed in addition to the glycaemic index (GL). The glycaemic load is therefore the better approach to assess the effect of carbohydrate utilization that takes into account the glycaemic index but provides a deeper picture than the glycaemic index does. To calculate glycaemic load, you multiply the glycaemic index of a food by the amount of total carbohydrate it contains (Salmeron, Manson, Stampfer, Colditz, Wing, & Willett, 1997). In other words, it is characterized as the weighted mean of the dietary glycaemic record increased by the level of all out energy from carbohydrates (Ludwig & Eckel, 2002). It is mathematically represented as;

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

Glycaemic load accounts for carbohydrates in food and how much each gram of it will raise an individual's blood sugar level. A "typical" portion of the item's glycaemic load, thus, would be considered a summary estimate for the relative glycaemic impact of a particular dish. Foods with a glycaemic load less than or equal to 10 ($\leq$ 10) are considered as low glycaemic load foods, those with a glycaemic load 11-19 are classified medium glycaemic load foods whereas foods with a glycaemic load greater than or equal to 20 ($\geq$ 20) considered high glycaemic load foods (Venn, et al, 2006).

To determine the glycaemic load of food, there is the need to first determine the glycaemic index of the food to use for the calculation of the glycaemic load. The FAO/WHO recommends that the standard on how to determine the glycaemic index of a food is in vivo, where a test food containing 50g available carbohydrate is ingested and the degree at which the food is processed and ingested into the bloodstream is measured (FAO/WHO, 1998). It is possible to raise or reduce the glycaemic load of a food by altering the glycaemic index of the food and the serving size; as such, increasing or decreasing the glycaemic load may be accomplished by changing any or both of these variables. As a result, achieving a low GL meal may be accomplished by either lowering the GI of the item or by removing the majority of the carbs from the diet (Jenkins, 2007).

The amount of glucose in the blood of healthy people is carefully controlled by the body's homeostatic regulating mechanisms. The physiological consequences of consuming high-glycaemic meals, on the other hand, call into question these processes. The fast rise in blood glucose levels after the eating of a high-glycaemic meal stimulates insulin release and suppresses glucagon release to a considerably larger degree than the ascent in blood glucose levels following the utilization of a low-glycaemic meal, according to the findings. In turn, this leads to an increase in glucose absorption by skeletal muscle, as well as fat accumulation and suppression of fat breakdown. There is a significant reduction in the production of the main metabolic fuels – glucose oxidation and free fatty acids – The degree of nutrient absorption from the gastrointestinal tract subsequently decreases as the physiologic effects of insulin release and glucagon suppression continue, resulting in a quick fall in blood glucose levels, frequently into the hypoglycaemic zone, and a rapid rise in blood glucose levels. Since there are insufficient amounts of metabolic fuels, a counter-regulatory hormone response occurs, which increases free fatty acids and induces an anaerobic physiological state. Current research indicates that repeated stimulation of these exaggerated physiological reactions may result in increased food consumption, beta-cell dysfunction, dyslipidemia, and endothelial dysfunction; as a result, there may be an increased risk for obesity, diabetes, and heart disease (Ludwig, 2002).

Proximate Analysis

It is essential for both theoretical and practical studies in food science and technology to be able to determine the composition of the food. This is often used to determine the nutritional content of a meal as well as the general acceptability of the item among customers (Wilson, 1979). (ie, a quantitative analysis of macromolecules in food). It also gives us an idea of its nutritional value. It involves a combination of different techniques, such as extraction, Kjeldahl, Near Infrared Reflectance (NIR) to partition food compounds into different categories. Using common chemical characteristics, the proximate analysis of food is a quantitative technique for determining the presence or absence of various macronutrients in foodstuff. Moisture (crude water), ash, protein, ether extracts (crude fat), and crude fibre are the categories to consider. It is computed by difference rather than by analysis to get nitrogen-free extract (NFE), which represents sugars and starches to a greater or lesser extent.

Moisture content

Moisture is a key component in maintaining the quality of foodstuffs and protecting them from deterioration (Aurand, Wood, & Wells, 1987). For a variety of scientific, technological, and commercial reasons, the moisture content of foods is very important to determine. When evaluating the nutritional worth of food, communicating discoveries of logical tests on a consistent origin, and complying with compositional ethics or regulations, it is necessary to know the moisture content of the food. Also, samples are best weighed for analytical findings while keeping in mind how much moisture they have, even if that amount is known beforehand. If the observed analytical limit does not change linearly or simply with an increase in dry matter content, this is particularly essential to consider (Pomeranz & Meloan, 1987). Dampness content affects the physical and synthetic qualities of food, which are identified with the freshness and stability of food when it is stored for an extended length of time. As a rule, items with a low dampness content ought to have fantastic capacity attributes (Akpapunam and Sefa-Dedeh, 1995). Following from this, it could be reasoned that the lower the dampness content of an item, the more extended its time span of usability.

Ash content

It is the inorganic residue that remains after the organic material has been burned off that is referred to as ash of agricultural material (Pearson, 1976). Additionally, the remaining inorganic residue after the carbonaceous portion has been oxidized and evaporated, as well as other volatiles, are removed. Because of its abundance in ash, the ash content provides an estimate of the mineral elements in the food sample. A food material's ash content is important because the fixation and sort of minerals they contain, including their taste, appearance, surface, and solidness, impact the taste, appearance, texture, and overall stability of many foods. When it comes to using minerals to inhibit microorganisms' growth, the higher the mineral content, the better (Ayivor, Debrah, Forson, Nuviadenu, Buah Kwofie & Denutsui, 2011). To determine if ash is present in a food, you simply weigh the dry mineral residue of organic materials that have been heated to around 550 degrees Celsius (Pomeranz & Meloan, 1987).

Crude protein content

Protein is absolutely vital for both bodily growth and repair, as well as providing the body with energy. Because of their role in the body, proteins are often called the body's building blocks. Also, proteins serve other specialized purposes in the body. For example, enzymes are proteins that control chemical activity in living organisms (Mehas & Rodgers, 1997). A product's crude protein content is determined by measuring the total nitrogen content of the product and estimating the amount of protein contained within the product. Conventional measurement of nitrogen compounds in a product known as crude protein. In addition to being referred to as "crude" rather than "real" protein, the value derived by multiplying N by 6.25 is called "crude protein."

Crude fat content

Lipids are a class of substances that includes fats and oils, which are commercially significant (Abraham & Hron, 1992). They are responsible for increasing the palatability of food by retaining flavors, as well as for producing satiety as a result of the slow digestion of carbohydrates. Fatty acids are utilized as a wellspring of energy by all cells in the body, with the exception of erythrocytes and the nervous system. During times of famine, the brain makes use of ketones, which are acids that are derivatives of these acids. Nutritional fats aid in the retention and transportation of fat-dissolvable nutrients in the gastrointestinal system. Fat is a helpful and concentrated wellspring of energy, providing more energy per gram of body weight than the same amount of carbohydrate or protein. It also contains fat-soluble vitamins A, D, E, and K, as well as other nutrients (Tull, 1996).

Crude fibre content

Crude fibre is defined as materials that are indigestible to both human and animal organisms, according to theory. An insoluble substance is one that does not dissolve in dilute acid or alkali and is isolated under the same conditions (Pomeranz & Meloan, 1987). There are different degrees of indigestible cellulose, pentosans, lignins, and other components found in food, which is measured in raw fibre (Aurand et al., 1987). These fibres provide protection against colon cancer, diabetes, and cardiovascular disease, all of which are serious health concerns (Ponka et al., 2005). The remaining residue, which has been dissolved with 1.25% sulfuric acid and 1.25% sodium hydroxide, can be used to determine crude fibre content (Association of Official Agricultural Chemists, 1984).

Carbohydrate content

Carbohydrates are the more great bountiful and generally dispersed food component (Pomeranz & Meloan, 1987). Energy is crucial for cellular processes, and this 'protein sparer' keeps some of the protein reserved to fulfil its essential duties instead of serving as a fuel source. Protein and carbohydrate-rich foods are usually eaten together for this reason. All animals, including humans, rely on carbohydrates as their primary energy source. In addition to being isolated molecules, carbohydrates can also be physically and chemically bound to other molecules. A discrepancy between 100 and the sum of humidity, ash, crude protein, crude fat and crude fiber can be calculated in total carbohydrate content (Ponka, Fokou, Fotso, Achu & Tchouanguep, 2005; Akpapunam & Sefa-Dedeh, 1995; Onyeike & Oguike, 2003).

Factor Affecting Preference and Choice of Food

The decision of food is more complex than just liking or disliking a food product (Palojoki & Tuomi-Gröhn, cited in Adu-Gyamfi, 2018). Researchers such as Gains (1994), Randall and Sanjur (1981), Shepherd and Raats (1996), and Meiselman, Mastroianni, Buller, and Edwards (1998) have inspected commonly the variables that influence food inclination and have broadly categorized these factors into three namely: individual, food and environmental factors. Other researchers like Rozin and Volhmecke (1986) categorized these factors into biological, cultural, and individual factors. Individual factors age, sex, marital status, income level, and place of residence. Food characteristics add to sensory attributes such as taste, flavour, price, texture, health, and appearance whiles the environment depicts cultural, social, economic, and physical influences. Environmental factors include both internal and external physical elements such as ambience, décor, sanitation, staff, and proximity.

Individual factors

Socio-demographic variables like age, sex, occupation, education, religion the number of relatives, and the normal remittance each month have been found to impact food inclinations (Amuquandoh & Asafo-Adjei, 2013; Honkanen, Olsen, & Myrland, 2004; Shim, Gehrt & Holikova, 1999).

Tokuc, Ekuklu, Berberoglu, Bilge, and Dedeler (2009) affirm that age, sex, marital status, educational level, occupation, and household income largely influence the food preferences of customers in foodservice establishments. These factors have been identified as significant factors in clarifying varieties in food utilization in various settings, according to the experts. Kim, Kim, and Kandampully (2009) have concluded that three socio-demographic characteristics, which include sex, age, and education, influence customers' food choices. These researchers are not the only ones to make this conclusion, however. In the study conducted by Amuquandoh and Asafo-Adjei (2013), it was found out that except marital status all other socio-demographic characteristics (age, sex, education, and religion) have a significant relationship with tourists' preference for traditional foods in Ghana.

Physiologically, sex has an effect on food preferences. In many countries, male and female food preferences differ. Generally speaking, women tend to be more health-conscious than their male counterparts when it comes to nutrition. This is affirmed in a study on starchy food by Monteleone and colleagues, cited in Nti (2017) and fat spread by Bower, Saadat, and Whitten (2003) who set up special contrasts among males and females. In the two examinations, the food inclinations of females were noted to be health-related. Sex influences the assessment of quality and the physical environment, and these gender differences are linked up to the influence of stereotypes during gender role socialization (Ganesan-Lim, Russel-Bennet, & Dagger, 2008). Women favour fruits and vegetables over men, according to studies (Kleynhans, 2003). Others have discovered that there are no huge contrasts among people in Western culture when it comes to eating habits and food preferences, except for caloric intake (Sim, 2009). Men pay less attention to sales employees in settling on buy choices while ladies depend all the more intensely on the climate and service evaluation (Laroche, Saad, Cleveland, & Browne, 2000). Females are more likely to abstain from meat, be concerned about their weight, and prefer low-calorie foods, according to Rozin (2006).

Age is described as a powerful determinant of customers' behaviour which influences individual purchasing ability and preference (Neal, Quester, & Hawkins, 2002). According to research, age affects not only the amount of food consumed, but also the types of food and the eating location (Amuquandoh, 2011). Eating, including individual food preferences, change with age, subsequently from youth through youthfulness to adulthood (Amuquandoh & Asafo-Adjei, 2013). Ganesan-Lim, Russel-Bennet, and Dagger (2008) ascertained that age has a significant effect on the assessment made by customers. It was also found that customers' age was adversely related with the number and scope of their culinary investigations in Tse and Crotts's study (2005).

Reynolds and Hwang (2006) have observed that younger generations are noted for incessant eating out while more seasoned shoppers avoid attempting new cooking yet visit the foodservice industry as a form of socialisation. Younger clients dine out more because they always want to know about food trends and are always trying new ones (Kleynhans, 2003). Settembre (2013) found that adults aged 18-29 dine out more than they do at home. Customers aged 21-30 years (35%) and 31-40 years (31%), according to Lakos (2013), dine out more regularly. The percentage decreases as individuals get older. It is possible that older guests eat at a place in a restricted selection of dishes.

It is established that people with higher pay levels for the most part have advanced education levels and make different choices from those with lower income as well as education (Ganesan-Lim, et al., 2008). Those with higher education levels, according to Kivela and Crotts (2006), are more likely to have a higher-status occupation and to be older. Due to education, people learn a lot about foods, as food varieties are dependent upon restrictions and customs, and individuals travel more and attempt other customary food varieties because of the knowledge they have about them. Educational levels are related to nutrition knowledge by several investigators. Members with advanced education levels were more concerned about their health and more eager to learn about foreign cultures by eating local food (Lakos, 2013).

Socioeconomic elements including culture and religion have long been acknowledged as key variables influencing overall food intake. Food choices depend on culture and religion, therefore how we eat depends on the culture and religion we belong to (Chang, Kivela & Mark, 2010). It defines which foods are allowed and which are not in a particular group. It also describes how the group's "good" and "bad" foods are categorized. According to Prescott, Young, O'Neill Yau, and Stevens (2002), culture and religion also influence which foods and food potentials are acceptable in terms of their sensory properties. A cuisine can be distinguished by its basic foods, cooking techniques, as well as its flavor principles, according to Rozin (2006) A flavour principle is a grouping of seasonings that is characteristic of a variety of cuisines.

Some religions want specific foods to be avoided altogether, therefore proper preparation is required, like Halal and Kosher, or fasting or feasting is carried out (e.g., Ramadan). Because of these observed practices and limitations, customers' food habits can become stable and rigid, which can have an impact on food consumption in their homes (Carroll & Ahuvia, 2006). Islamic dietary rules have broadly distinguished permitted food from the unpermissible (prohibited). No matter where they go, Muslims must consume only halal food, even when traveling to foreign countries (Bon & Hussain, 2010). Hassan and Hall (2003) also found out that a vast proportion (82%) of Muslim customers visiting New Zealand would always look for halal food when traveling in New Zealand, and 39.6 percent expressed that they generally pre-arranged their suppers because of an absence of information on the accessibility of halal food in New Zealand.

When it comes to food preferences on vacation, according to Chang et al. (2010), the customers' culture-specific 'core eating behaviour' is a critical factor influencing their food preferences. Customers are by and large more able to acknowledge changes in auxiliary' food varieties (foods that are eaten widely and frequently but not daily) and 'peripheral' foods (foods that are eaten sporadically) while on vacation, but they are less willing to accept changes in 'core' foods (foods that are eaten every day) (i.e., staples that are consumed almost daily). The best research on eating behaviours and preferences, according to Kittler and Sucher's (2004) core and peripheral foods model, says that core foods are tightly linked to the culture and highly resistant to change while peripheral foods are easy to change and tailor to the changing tastes of society. Also, customers' personal food culture might effect their views of and opinions about foreign food, especially when it comes to flavour and cooking methods, according to Chang, Kivela, and Mak (2011). The research highlights the necessity of figuring out how cultural distance and culturally unique flavour principles influence consumer food consumption. This includes the importance of recognizing the cultural and cultural taste gaps between customers' home food culture and the local culture. To better understand the results, refer to the following information.

Food characteristics

Food is considered the most fundamental and most important factor affecting food choice and an integral part of the overall foodservice industry (Geissler & Rucks, 2011). According to Abdullah, Hamali, and Abdurahman (2011), fresh-tasting, natural, home-cooked tastes drive consumer demand around the globe. In countries as diverse as Nigeria, Brazil, Poland, and China, customer's favourite is authentic and natural-tasting food. In a study by Bon and Hussain (2010) focused on urban customers' taste preferences, attitudes, and behaviours, it was found that more than half (55%) of customers believe a fresh or natural flavour is what makes food taste delicious, followed by 'tastes as if it was made at home' (Bon & Hussain, 2010). This is analogous to the findings of an earlier study in which Cohen and Avieli (2004) reported that urban customers, first and foremost, wanted food that tastes as though it were made at home. These preferences for fresh, natural, or home-made tastes are one of the most significant challenges for food producers in the face of consumer behaviour (Bon & Hussain, 2010).

Food taste is known to be the most important feature of food attributes in several studies. Taste is perceived as a core element in food that greatly influences customer's purchase intention (Autun, Frash, Costen, & Runyan, 2010). Food is described as tasty when the freshness is associated with the crispness, juiciness, and aroma. According to a survey by Sukalakamala and Boyce (2007), those dining in restaurants said the two most important things in a dining experience were individual tastes and high-quality food. Perceptions of food based on personal preferences for taste, texture, and appearance had a much greater impact on foodservice establishments than previously thought. The same researchers have argued that taste and distaste are more important to younger consumers, while nutrition and health concerns are more important to older consumers.

Generally speaking, taste is found to be the most important determinant of food selection. Sweeteners, salt, and fat, for example, are ingredients that are over-consumed by the majority of customers, but which improve the taste of the product. Customers may even have expectations that unhealthy food (for example, fatty foods, sweeteners, and salt) will taste better than it actually does. According to Raghunathan, Walker Naylor, and Hoyer (2006), customers' opinions of the taste of food are greater for food that is marketed as harmful than for the identical food that isn't depicted as unhealthy. Sensory perceptions of appearance and taste can be enhanced by favourable descriptive menu names, much as they have been shown to influence food prices, food service attitudes, and repurchase intentions (Kim, Kim & Kandampully, 2009).

Fairness of the price, according to Namasivayam (2004), influences consumer reactions and purchasing decisions. Several scholars have also indicated price as a factor influencing customer preference (Cousins, Foskett & Gillespie, 2002; Gregoire, 2013). Price is the amount of money charged for a commodity, a competitive tool, and a primary element that affects customers' purchasing power (Gregoire, 2013). Bitner, Booms, and Tetreaut (1990) noted that the value for money from one foodservice industry to another or from one consumer to another also greatly affects the preference of a customer as well as the number of times the foodservice industry is patronised. According to Mensah (2009), in this context, food service only has revenue from price, which is dependent on meal quality, ambience, and service. According to Cousins et al. (2002), customers consider the quality of a meal with the price, therefore they look into the pricing of a meal before they decide to purchase food.

Namkung and Jang (2007) found that presentation was a major determinant of customer satisfaction in restaurants among food quality attributes. Appearance and presentation refer to how food is decorated and attractively garnish to please the eye. It is important to consider the final presentation of food, whether it is on a plate or a cafeteria counter. Customer psychology is affected by colour (Rosalin & Soetanto, 2006). You can use them to draw attention to the wide range of options available on the menu as well as to stimulate appetite. Add colour to your menu by incorporating garnishes, plate decorations, or colourful displays (Rosalin & Soetanto). Customers' preference is also influenced by the texture and shape of foods. Food texture can be described as soft, hard, crispy, crunchy, chewy, smooth, brittle, and granny (Rosalin & Soetanto, 2006). If you want your menu to be interesting and diverse, you need a good blend of flavours. Slightly sour or bitter flavours can be present on their own or in combination with sweet, sour, or salty flavours (Robinson, Borzekowski, Matheson, & Kraemer, 2007).

Origin of *Alchornea Cordifolia*

Alchornea cordifolia (Cordifolia Alchornea) (Schumach. and Thonn.) Euphorbiaceae species such as Müll. Arg (Euphorbiaceae) can be found in many parts of Africa, including central, western, eastern, and southern. Growing up to 5 meters tall, this multi-stemmed shrub or small tree can either climb or stand upright. Unisexual flowers are found on the plant, as well as sessile ones. There are 2 cup-shaped sepals and 8 stamens on the male flower, and a 2–4 lobed calyx on the female flower. Usually green or red, the fruit has three lobes and ovoid seeds (Noundou, 2012). As it grows, the plant develops a woody stem with many branches that bear leaves, and it becomes bushy. Their blades are 10–28cm in length and range from 6.5-16.5cm in width. They have a smooth blade and a few glands at the base (Timibitei et al., 2013). Below is a picture of an Alchornea cordifolia plant.

Figure 3: Picture of *Alchornea cordifolia* plant

Terpenes, sterols, flavonoids, glycosides and saponins have been identified in *Alchornea cordifolia* (Osadebe & Okoye, 2003). As well as the imidazopyrimidine alkaloids alchorneine and alchornidine as well as various guanidine alkaloids are identified in the leaves, roots and stem bark of this plant. In addition, there are flavonoids (approximately 2–3 percent), tannins (10 percent) as well as saponins (about 10 percent) (Mavar-Manga, Haddad, Pieters, Baccelli, Penge, & Quetin-Leclercq, 2008). Duke and Vasquez (1994) reported the presence of alchorneine, anthranilic acid, gentisinic acid, iso alchorneine, yohimbinein in the plant.

Ethno-medicinal Properties of Alchornea cordifolia

Alchornea cordifolia has been extensively studied for its antibacterial, antifungal, and antiprotozoal properties, just as its mitigating properties, with promising results. The pulped root is widely used in West Africa to treat venereal diseases. As well as being used to treat coughs and anaemia, dried leaves or roots can be smoked alone or in combination with tobacco. Branches and leaves are chewed for the same purposes, and leaf and root decoctions are widely used as a mouthwash to treat mouth ulcers, toothaches, and caries Agbor, Léopold & Jeanne (2004) use the root and stem bark to treat jaundice.

Ogungbamila and Samuelsson (1990) reported the use of the decoction of the plant leaf against gonorrhea in Nigeria and the infusion of the leaf has also been reportedly taken orally for urinary tract infection in Zaire (Muanza, Kim, Euler, & Williams, 1994). The decoction of the leaf as reported by Le Grand, (1989) is used for conjunctivitis in Senegal. For ringworm, the juice of the leaves and fruit is rubbed on the skin (Okeke et al., 1999). The plant leaf is used for treating an infected wound in Zaire (Muanza et al, 1994). The infusion of the dried leaf of *Alchornea cordifolia* is used for diarrhea in Zaire (Kambu et al, 1990; Muanza et al, 1994). The fresh chewed leaf juice of the plant is used for pneumonia in Sierra Leone (Macfoy & Sama, 1990). Analgesic, anti-inflammatory and antibacterial properties have been reported for it (Cesario, 1993).

Using an ethanol extract of the root, we were able to demonstrate that it significantly delayed the effects of histamine-induced bronchoconstriction, which was characterized by shortness of breath, in the guinea pig (Boampong, 1992). It was reported by Banzouzi et al. (2002) as well as Ayisi et al. (2003) that the crude extract's cytotoxicity was very small. Onion (Allium cepa L.) mitotic cell division was disrupted by alcohol extracts from root bark, stem bark, leaves, fruits, and seeds (Ayisi et al., 2003). ethyl acetate extract of *Alchornea cordifolia* leaves has antimicrobial activity against clinical and typed isolates of Pseudomonas aeruginosa, *Staphylococcus aureus, E. coli, and Candida albicans* according to a study by Adeshina et al (2010)

Studies on *Alchornea Cordifolia*

The great difference between this species and the other *Alchornea* species makes it the most studied species within that genus. This plant is found primarily in western to central Africa, in countries such as the Democratic Republic of the Congo, the Ivory Coast, Nigeria, and Ghana.

According to Ebi (2001), leaf extract (inhibition diameters ranging from 12 to 21 millimeters at 10 mg/L) had the highest antimicrobial activity when compared to methanolic stem bark, root bark, and leaf bark extracts, as well as further fractions. Additionally, he indicated that *Bacillus subtilis and Klebsiella pneumonia* bacterial strains, and fungal isolates *Aspergillus niger and Candida albicans*. albicans, were under attack. Fractionation methods revealed that the most powerful antibacterial substances in samples were phenolics, saponins, alkaloids, and terpenes.

Similarly, Obaji, Enweani, and Oli (2020) investigated the combined effects of *Alchornea cordifolia* and *Pterocarpus santalinoides* leaves extracts against selected multi-drug resistant diarrhoeagenic bacteria. In their research, the team found that using the methanol extract of the plant in a 5:5 ratio was effective against all the multi-drug resistant bacteria. There was evidence of potential synergistic activity between the Salmonella and *Alchornea cordifolia* combinations. Obaji, et al. (2020) discovered that identification of synergy implied the presence of antibiotic resistance modifying chemicals in those extracts. Also, Abdullahi, Nafiu, Adamu, and Aliyu (2020) assessed the antibacterial activity of the leaf extract of *Alchornea cordifolia* by determining the phytochemical constituents, antibacterial activity, and minimum inhibitory concentration of the leaf extract. The study shows that the aqueous and ethanol leaf extracts of *Alchornea cordifolia* obtained were found to contain phytochemical content and have antibacterial activity against *S. aureus, E. coli,* and *K. pneumonia*. According to Abdullahi and colleagues, the study has justified the use of *Alchornea cordifolia* in the treatment of some bacterial diseases in herbal medicine.

Scientists tested the plant's ability to kill germs. It was discovered that crude extracts of leaves and stems of *Alchornea cordifolia* have antibacterial action against gastrointestinal, cutaneous and respiratory infections. Crude extracts and pure compounds isolated from the extracts were tested using the micro-dilution assay against four Gram-positive and four Gram-negative bacterial strains for antibacterial activity. A variety of antibacterial activities were observed in the leaves, stems, and roots of *Alchornea cordifolia* against each of eight pathogens tested. Using *Alchornea cordifolia extracts*, the researchers found that the antibacterial activity may be due to the presence of isolated compounds. Therefore, Noundou and his colleagues believe that the observed effectiveness against gastrointestinal and skin infections as well as respiratory and urinary tract pathogens supports the traditional use for such disorders as well.

Ishola, Ashorobi, and Adoluwa (2008) and Umukoro and Aladeokin (2010) found that the anti-stress action of aqueous leaf and root extracts and the antidepressant outcome of hydroethanolic leaf extract in male Swiss albino mice were both mediated through interactions with dopamine, noradrenergic, and serotonergic receptors (Ishola, Agbaje, Akinleye, Ibeh, & Adeyemi, 2014). A number of leaf and root extracts, as well as isolated compounds, demonstrated significant anti-inflammatory activity in mouse ear oedema models, with leaf and root extracts displaying more prominent restraints than the calming indomethacin-control at portions of 90 mg/cm2 (Mavar-Manga, et al., 2008). According to earlier studies conducted on Swiss albino mice, a dose as low as 0.7 g/cm2 of methanolic-soxhlet leaf extract resulted in the best anti-inflammatory effect (Manga, Brkic, Marie, & Quetin-Leclercq, 2004). There was a significant difference in the percentages of inhibition between the polyphenolic and terpenoid fractions at 100 mg/Kg, with the polyphenolic fraction showing the highest percentages of inhibition at 100 mg/Kg; additionally, *Alchornea comosa* was screened for phytochemical content, with the highest percentages of inhibition obtained for the terpenoid fraction at 66.67 percent and 60 percent, respectively.

Kouakou, Schepetkin, Yapi, Kirpotina, Jutila, and Quinn (2013) investigated the immunomodulatory activity of polysaccharides isolated from the leaves of *Alchornea cordifolia*. They found that they were effective. There were six polysaccharide fractions isolated from the plant *Alchornea cordifolia*. Type II arabinogalactan was found to have significant immunomodulatory activity in fractions containing it. Individual components of *AP-AU*, including the parent fraction and its high-molecular-weight sub-fraction *AP-AU1*, were found to stimulate the production of NO and cytokines in human peripheral blood mononuclear cells, as well as in human and murine monocyte/macrophage cell lines, in vitro (Kouakou, et al., 2013). In addition to their anti-inflammatory and antioxidant qualities, water extracts from

Alchornea cordifolia leaves in traditional African folk medicine now have a molecular basis (Kouakou, et al., 2013).

A. cordifolia has also been reported to possess antioxidant properties. When given 2 g/kg of acetaminophen, Wistar albino rats were protected against acetaminophen-induced liver damage at dosages ranging from 200-300 mg/kg of extract (Olaleye, Adegboye, and Akindahunsi, 2006). This was accomplished through inhibition of glutathione S-transferases in both the liver and serum at optimal dosages of 200 mg/Kg and 400-500 mg/kg (Olaleye, Kolawole, & Ajele, 2007). Additionally, a stock solution at 5 mg/mL inhibited the DPPH radical by 92 percent, which was even higher than the vitamin E control at the same concentration (92 percent). Also of note, Kouakou-Siransy et al. (2010) reported that ethyl acetate and aqueous leaf extracts have antioxidant activity against the superoxide anion radical, with half-life values ranging between 4.1 and 13.4 micrograms per milliliter of solution in acellular and cellular in vitro systems, respectively. Osadebe et al. (2012) demonstrated another hepatoprotective mechanism in Wistar albino rats treated with ethyl acetate fraction of methanolic leaf extract at a dose of 300 mg/Kg, which was associated with a decrease in serum glutamate pyruvate transaminase levels after exposure to CCl4-induced hepatic damage. Osadebe et al. (2012) demonstrated another hepatoprotect

Additionally, Ajayi, Olasunkanmi, Agunbiade, Alayande, Aiyegoro, and Akinpelu (2020) investigated the antimicrobial properties of *Alchornea cordifolia* leaf extract against a panel of selected bacterial strains in addition to the above. As part of their research, the authors looked at antioxidant and phytochemical properties of plant constituents that were found to have bioactive effects. They discovered that the leaf extract of *Alchornea cordifolia* exhibited a range of antibacterial activities, depending on the concentration used. Testing for alkaloids, flavonoids, tannins, saponins, phenols, sterols, carbohydrates and terpenoids revealed that the plant contained all of these compounds as well as others. A total of three pathogens were tested, and the results of the study revealed that *Alchornea cordifolia* leaf extract, which possesses antioxidant properties, exhibited significant antimicrobial activity against all three pathogens (Ajayi, et al., 2020).

Recently, Kitadi et al. (2020) determined the mineral composition of *Alchornea cordifolia* (Schumach. & Thonn.) and other plants used in the management of sickle cell disease by traditional practitioners in Kwilu province and to evaluate their anti-sickling activity *in vitro*. The study found that twenty-three mineral elements, including Iron (Fe), Zinc (Zn), Magnesium (Mg), and Selenium (Se), were present in each of *Alchornea cordifolia* and the other two plants studied. The study reported that extracts of *Alchornea cordifolia* showed the capacity to prevent the sickling and the hemolysis of red blood cells (Kitadi, et al., 2020).

Chapter summary

This chapter reviewed literature related to the study. The literature reviewed mainly focused on the concepts of glyceamic index, glyceamic load and proximate analysis; factors affecting food preference and choice; and ethno-medicinal properties of *Alchornea cordifolia*. The review describes how glyceamic index and glyceamic load figures are obtained and how to interpret those figures. Also, the various components of proximate analysis were described. Specifically, the review explains how the moisture, ash, protein, fat, fibre, and carbohydrate contents of food are determined. Factors that influence food preference and choice were grouped under individual factors and food characteristics. The literature review concludes by outlining some studies on *Alchornea cordifolia.*

CHAPTER THREE

RESEARCH METHODS

Introduction

The methods and procedures used in the study are described in this chapter. Specifically, the chapter details the study design, study area, population, sample and sampling procedure, research instruments, data collection procedure as well as procedures for data management and analysis. Ethical issues are also discussed in this chapter.

Research Design

The experimental research design was used to explore the health and aesthetic benefits of using *Alchornea cordifolia* in preparing fufu (Amedahe, 2009). This kind of study involves manipulating one or more independent variables and applying them to one or more dependent variables in order to determine their impact on the latter. It is common for researchers to observe and record the effects of independent variables on dependent variables over a period of time, in order to arrive at a reasonable conclusion about the relationship between these two variables types. In fact, it's the only type that can test hypotheses relating to cause and effect.

As experimental investigations are inherently vulnerable to human error because of their dependence on controlled variables, experimental results are potentially inaccurate. It's possible that these mistakes will invalidate the experiment and the study being performed as a whole. Also, they may be costly and time-consuming. However, the principal advantage of the experimental approach to research design is that it provides the opportunity to identify cause-and-effect relationships. It usually involves the researcher manipulating conditions to determine their effect on behaviour.

Study Area

The study was conducted in Apewosika, a suburb in Central Region. Students and indigenes constitute members of the community. The study for the proximate analysis of the *Alchornea cordifolia* leaves, fufu made with cassava and plantain, fufu made out of cassava cooked with the *Alchornea cordifolia* leaves, and fufu made from cassava alone was conducted at the School of Agriculture Laboratory in the University of Cape Coast. The laboratory is well equipped with the necessary equipment to help carry out the analysis.

The determination of the glycaemic load of the fufu was carried out at the University of Cape Coast hospital on Campus. The hospital attracts patients from and around the University community. The various units in the hospital include the Outpatient's Department (OPD), wards, laboratory settings, and others.

Population

Population refers to all individuals of interest to the researcher. Breakwell et.al. (2006), explains population as a set of individuals (objects, subjects, events) that have common observable characteristics for which a researcher is interested. The rules for the incorporation of a unit in this study was depended on attributes of ten (10) and forty (40) respondents both males and females who are eligible for participation in the study of glycaemic load determination and sensory evaluation respectively. Consequently, the objective populace for the investigation was made up of persons interested to participate, free from glucose intolerance, knowledgeable about the test food, eaters, of fufu, and can evaluate its sensory characteristics. REVISE

Sample and Sampling Procedure

In this study, a total of ten (10) individuals (5 males and 5 females), aged between 18 and 40 years old who had no history of glucose intolerance were used for the glucose tolerance test. Forty participants (18 years – 40 years) were later used for the sensory evaluation of the three varieties of fufu produced. The ages of 18 years – 40 years were selected because, at that age, no parental concern is needed because they have the right to decide to be part or not of the experiment or test. University students at Apewosika community were used for the study. The purposive sampling method was embraced for the choice of the participants for the glycaemic load test and a convenient sampling technique for the sensory evaluation.

The sensory evaluation employed the discrimination and descriptive test methods. Discrimination test method was used because it uses a standard number of 25 to 40 participants. Descriptive test method was also used because of its standards to use participants who should be good eaters of fufu so as to score for the specific sensory characteristics needed to be known about the three (3) varieties of fufu produced. Households' variables were adopted to help select participants for the test. This helped to get information on students who eat fufu. Duo-trio test was employed to present the fufu samples, where three samples were presented, one being the reference food and one of the two left will be the same as the reference food.

With the glycaemic load test, 50g of dried ogyama leaves were cooked with 500g cassava for 15 minutes, 100g of plantain was cooked with 400g cassava for 15 minutes and 500g cassava only was cooked for 15 minutes. With this, each participant was given 50g of each variety of the test food to be eaten on three different days to check for the glycaemic responses. Also, 400g of the dried ogyama leaves was used to cook 2000g cassava for 20 minutes, 400g of plantain was cooked with 2000g of cassava for 20 minutes and 2000g of cassava only was also cooked for 20 minutes to test sensory characteristics of each of the test foods. The above combinations are tabulated below.

Preparation of fufu varieties for glycaemic load test

FUFU VARIETY	AMOUNT(G)	COOKING TIME
Cassava-Plantain	400g:100g	15 minutes
Cassava only	500g	15 minutes
Cassava-Ogyama	500g:50g	15 minutes

Preparation of fufu varieties for sensory evaluation test

FUFU VARIETY	AMOUNT(G)	COOKING TIME
Cassava-Plantain	2000g:400g	20 minutes
Cassava only	2000g	20 minutes
Cassava-Ogyama	2000g:400g	20 minutes

Research Instruments

A screening form, laboratory equipment, and questionnaire were utilized to gather information for the investigation. A self-developed screening form was used to screen participants for the glycaemic load. The screening form was partitioned into three areas. The principal section gathered data on participants' anthropometric characteristics (particularly, age, height, weight, and waist circumference). The second section recorded the results of the first and second oral glucose tolerance tests whereas the third section recorded the glycaemic responses of the participants to cassava-plantain fufu, cassava fufu, and cassava-ogyama fufu.

Laboratory equipment were used to carry out the proximate analysis of the three varieties of fufu. Specifically, weighing balance, hot oven, crucible, desiccator, hot furnace, round bottom flask, condenser, Soxhlet extractor, heating mantle, thimble, spectrophotometer, and flame photometer were utilized to decide the dampness, ash, protein, fat, fibre and carbohydrate contents of the three fufu varieties in that order.

Questionnaires were utilized to gather information on specific sensory characteristics of the three varieties of fufu. The questionnaire was divided into two sections. The first section collected data on the panellists' background characteristics (age and sex). The second section was made up of Likert scale items which required panellists to rate their acceptance of cassava-plantain fufu, cassava fufu, and cassava-ogyama fufu on a scale of 1–5 (1 means dislike very much and 5 means like very much).

Data Collection Procedure

Determination of Moisture Content and Dry Matter

Dampness content was controlled by gauging 10g of the sample into a porcelain crucible, heating in an oven at 105°C for 48 hours. The heated sample was then cooled in a desiccator, and then weighed. The distinction in the heaviness of the fresh and dried sample was partitioned by the heaviness of the new sample multiplied by 100.

%moisture

$$\frac{(\text{wt. of crucible + wt. of food sample}) - (\text{wt. of crucible + wt. of dry sample}) \times 100}{\text{Wt. of fresh sample}}$$ – Equ.1

The dry matter weight was expressed as a percentage of the fresh weight.

% Dry Matter = wt. of dry sample/ wt. of fresh sample x 100 - Equ.2

Determination of Ash Content

The ash content was measured by transferring dry samples in crucibles to a hot plate and charring them for a length of time sufficient for the smoke to dissipate. The samples were placed in a muffle furnace, which was set on fire at 550°C for eight hours. After being boiled, the test samples were allowed to cool in dessicators, and the weights were recorded. Ash was then calculated to be:

$$\% \text{ ASH} = \frac{\text{weight of ash}}{\text{Original weight of sample}} \times 100$$ - Equ.3

Determination of Crude Protein

Crude protein was determined using the Kjeldahl method as described by (Association of Official Analytical Chemists [AOAC], 2005). To digest the sample, concentrated sulphuric acid was added at 360℃ for 2 hours and neutralized using conc. sodium hydroxide. Boric acid and lithium sulphate catalyst were then added. Titre was against titrated against concentrated HCl. Percent nitrogen was calculated from the sample titre minus blank titre multiplied by molarity of HCl and then multiplied by 14.007 and divided by the sample weight in mg and finally multiplied by 100.

$$\%N = \frac{\text{(Sample Titre- Blank Titre) x Molarity of Hcl X 14.007 x100}}{\text{Sample weight (mg)}}$$

%Protein= %Nx6.25 - Equ.4

Determination of Fat Content

Fat was determined using the Soxhlet apparatus technique as depicted by AOAC (2005). Petroleum spirit (150 ml) was used for the extraction. Percentage fat was calculated from the weight of the extracted fat divided by sample weight multiplied by 100.

$$\text{CRUDE FAT (\%)} = \frac{\text{W (g)} \times 100}{\text{Sample Wt (g)}}$$

W= Weight of Oil - Equ.5

Determination of Fibre Content

Fibre was determined using the following reagents:

SODIUM HYDROXIDE, 1.25%

12.5g NaoH was dissolved in 700ml distilled water in a 1000ml volumetric flask and diluted to volume.

SULHURIC ACID, 1.25%

12.5g concentration of sulphuric acid was added to a volumetric flask containing 400ml distilled water and diluted to volume.

PROCEDURE

To this, 100ml of 1.25 percent sulphuric acid concentration was added and the mixture was allowed to boil for 30 minutes before being removed from the flask. Filtration was performed in a labeled sintered glass crucible after boiling. The residue was returned to the boiling flask, 100ml of the 1.25 % NaoH solution was added, and the mixture was cooked for 30 minutes.

After the boiling, the filtrate was cleansed with boiling water and methanol, and then filtered again. To weigh it, it was dried overnight in an oven heated to 105 degrees Fahrenheit. Over the course of five hours, the crucible was heated to 500 degrees. After cooling the crucible to room temperature in a desiccator, it was measured.

CALCULATION

% Crude fibre = weight loss through ashing x 100

Sample weight - Equ.6

Determination of carbohydrate Content

GLUCOSE SOLUTION

Stock solution: (1ml is equivalent to 0.25mg glucose), 0.250g D-glucose (dried in a vacuum oven at 70°c oven P_2O_5) was dissolved in water and diluted to 1 litre.

Working standards: a range from 0-20ml stock solution was pipette into 50ml flasks such that 2ml of each standard gives a range from 0-0.20mg glucose and diluted to volume.

1. ANTHRONE REAGENT (COLOUR FORMING REAGENT)

760ml conc H_2SO_4 was added to 330ml water in a boiling flask and kept cool while mixing. 1g anthrone, 1g of thiourea were added and dissolved using a magnetic stirrer. It was transferred to a dark bottle and left for 2hours before use. It was store at + 1°C

PROCEDURE

a. **EXTRACTION**

50mg of each of the milled samples were weighed into a 50ml conical flask with 30ml of distilled water. A glass bubble was placed in neck to simmer gently on a hot plate for 2 hours. It was latter topped up to 30ml and allowed to cool slightly. The solution was filter through a No. 44 Whatman paper into a 50ml volumetric flask and diluted to volume when cooled. The extract was prepared shortly before colour development. A blank was prepared by taking it through the same procedure

b. COLOUR DEVELOPMENT

Two (2ml) of each standard was pipetted into a set of boiling tubes. Two ml of the extract was pipetted and water blank into a boiling tube where guidelines and tests were dealt with the same way. Ten ml of anthrone reagent was quickly added and blended well in with the cylinder inundated in running tape water or ice shower. The cylinders were put in a beaker of bubbling water in a dim smoke cabinet and bubble for 10 minutes. The cylinders were then positioned in chilly water and permit to cool. The optical density was measured at 625nm or with a red filter using water as a reference. The standards were utilized to create a calibration graph, which was then used to calculate mg glucose in the sample aliquot (known volume). It was the same for blank decisions, which were deducted when required.

$$\text{Soluble carbohydrate (\%)} = \frac{\text{C (mg) x extract volume (ml)}}{\text{10 x aliquot (ml) x sample weight (g)}} \quad \text{- Equ.7}$$

Where C = carbohydrate concentration from the calibration graph.

Determination of Glycaemic Index and Glycaemic Load

An experienced laboratory technician from the University of Cape Coast hospital was involved in taking blood samples from participants of the study and reading results to reduce the chances of injury and infections to the participants after the procedure. For each meal or diet, we multiplied the mean glycaemic index by the number of grams of carbohydrate overall in the meal or diet to arrive at a glycaemic load (Nazar et al., 2016).

The glycaemic index and subsequently glycaemic load were determined using 10 participants. Brouns, Bjorck, Frayn, Gibbs, Lang, and Wolever (2005) recommend the use of 10 subjects in the determination of glycaemic index and compare the effect of cassava-plantain fufu, cassava fufu, and cassava-ogyama fufu on blood sugar levels as the third phase. The inclusion criteria were males and females between 18–40 years without any glucose intolerance while the exclusion criteria was diabetics or people living with glucose intolerance.

Preparation (Glycaemic Index)

- **Fasting Blood Sugar Test (FBST)**

Participants were informed to ensure 10-12 hour fast before the administration of the test as well as avoiding drinking alcohol. Their fasting blood sugar (FBS) were taken each day before administering the test and this was done by wiping the participant's fourth left finger with rubbing alcohol which was then pricked with a lancet to draw a drop of capillary blood. The one touch select glucometer with a strip inserted inside was used to collect the drop of blood to test for the fasting blood sugar.

- **Oral Glucose Tolerant Test (OGTT)**

Participants were given a glucose solution prepared from 50g glucose and 200ml water to be taken within a period of five minutes. The procedure for started at 8:00am and ended at 10:00am. A timer was then used to ensure that participants took the glucose solution within five minutes. An hour after drinking the glucose solution, a drop of capillary blood was taken from participants and tested for glucose. Blood samples from each participant was taken on the 60th, 90th, and 120th minutes as well to test for the glucose concentration. The Oral Glucose Tolerant Test (OGTT) was done twice on different days to ensure accuracy and precision.

Determination of Glycaemic Index of Test Foods

- **Test Foods**

Fresh cassava and plantain for the test foods were purchased at the Abura market. Cassava and plantain were peeled, cut into desirable sizes and washed. The peeled cassava and plantain were put in a saucepan and a desirable amount of water was poured on it and was put on fire to cook for 15 minutes. Cooked cassava and plantain were taken from the fire, and the liquid was poured away. The plantain was pounded and later added to cassava in a wooden mortar with a wooden pestle, the mixture was turned by hand and water addedtill it gradually became sticky. The mixture was then formed into round slabs in food packs and was taken to the participants. This procedure was used for the cassava fufu without the addition of plantain. Lastly, dried ogyama leaves were washed and placed on peeled fresh cassava, a desirable amount of water was added and cooked. The liquid was poured away and leaves on the cooked cassava were removed, the cassava was pounded until fufu of sticky texture was obtained.

The procedure for this test started at 8:00am and ended at 10:00am. Participants were given 50g of each test food (cassava-plantain fufu, cassava fufu and cassava-ogyama fufu) on three different occasions. A timer was used to ensure that participants eat the fufu within five minutes. A drop of capillary blood was collected from each participant an hour after consuming the fufu and analyzed for glucose. Glucose levels were measured in the participants' blood at 60, 90, and 120 minutes. This procedure was also done for all the three test foods.

Sensory Evaluation of Fufu Samples

The sensory evaluation test was carried out by using the same procedure that was used for preparing the test foods for the glycaemic index test. Panellists ate the test foods individually with fish light soup.

A self-developed questionnaire was utilized to gather information for the sensory evaluation. See appendix. A total of 40 panellists were selected. The inclusion criteria for selection were that participants should be consumers of fufu and were capable of evaluating the specific sensory characteristics of the food (Lawles & Heymann, 2010). The panel members were trained on the dos and don'ts of sensory evaluation.

Cassava-plantain fufu, cassava fufu and cassava-ogyama fufu was prepared for evaluation at 12:00 pm to 12:30 pm. Participants were selected and trained. Specific sensory characteristic like texture, colour, flavour, taste and overall acceptability were included on the questionnaire for participants to answer. Sensory evaluation question were rated on a scale of 1-5, where one (1) represented dislike very much, two (2) for dislike moderately, three (3) neither like nor dislike, four(4) like moderately and five (5) was like very much.

Data Management

Data that was collected from the participants and the panellists was protected in a local drawer in the researcher's supervisor's office. The data was coded, and uploaded. Together with the pictures of proximate analysis procedure taken, these were sent into the email and dropbox account of the researcher and encrypted with a password that was created for the study. The analysis continued immediately after the data collection. The data analyzed was protected on the researcher's laptop with a password. Also, a softcopy was uploaded to the email and dropbox accounts created for purposes of the study as well as an external drive for backup purposes. Used strips stained with blood samples and needles were disposed into the hospital's hazard container by the laboratory technician to help ensure proper disposal.

After the final thesis is submitted and the researcher graduates successfully, all information and pictures of the study will be finally destroyed or deleted from the email and dropbox account and the memory card formatted.

Data Analysis

The data was analyzed with Excel and SPSS version 24 and the results were presented in tables and charts. Descriptive statistics were employed to analyze the anthropometric characteristics of the participants. The components of cassava-plantain fufu, cassava fufu, and cassava-ogyama fufu were analyzed using descriptive statistics. Glycaemic indices of the three varieties of fufu were analyzed with a one-way ANOVA and subsequently, descriptive statistics were employed to present the glycaemic loads.

Also, descriptive statistics were employed to analyze the effect of the three varieties of fufu on blood sugar levels. Specifically, the glycaemic responses of the participants to the reference food and test foods (cassava-plantain fufu, cassava fufu, and cassava-ogyama fufu) were plotted as graphs. Participants' acceptability of the three varieties of fufu was also analyzed using descriptive statistics while an independent sample t-test was used to test the hypothesis. In all the analyzes, statistical significance was set at 95 percent (that is $p<0.05$).

Ethical Issues

Research morals is a bunch of good standards against which the actions of scientists (researchers) are judged (Singleton, Straits, and Straits, 1998). The Institutional Review Board of the University of Cape Coast granted ethical approval (UCC-IRB) for the study. A letter of introduction was also acquired from the Department of Vocational and Technical Education, which was then sent to the School of Agriculture Laboratory (UCC) and the University of Cape Coast Hospital, requesting authorization to carry out the research. On the other hand, participants were required to provide informed consent, which means that they were adequately informed about the type of information expected from them, why the information was sought, how it would be used, how they would be expected to participate in this research, and how it would affect them directly and indirectly. Participants were informed of the study's aim before they began. They were assured of confidentiality where all information they provided would be used purely for academic purposes and for anonymity, their names would not be associated with the responses. Panellist ID provided on the questionnaire was made up of random numbers. Blood samples taken from participants for the glucose tolerance test were discarded right after the results were recorded.

It was additionally disclosed to the members that, support in the investigation was not to expect any monetary or non-monetary gain or loss.

Chapter summary

The methods and procedures used by the study were detailed in this chapter. First of all, the design adopted to conduct the study was described. Also, the study area, population, sample and sampling procedures, and research instruments were described. Very importantly, this chapter also detailed the laboratory procedures used to collect data and espoused the techniques that were employed to analyse the data and why they were used. The chapter concludes by explaining the ethical procedures followed.

CHAPTER FOUR

RESULTS AND DISCUSSION

Introduction

This chapter is a presentation and discussion of the results of the study. The results are presented according to the objectives of the study. Thus, the presentation has been organized under the following headings: proximate analysis of test foods, the glycaemic load of test foods, the effect of test foods on blood sugar level, and sensory evaluation of test foods. The results have been presented in tables and charts. The discussion of results was done by comparing the findings to those of past studies, drawing similarities and disparities among them.

Anthropometric characteristics of participants

Some anthropometric characteristics of participants were measured to ascertain participant's general health status. These characteristics were age, height, weight, body mass index (BMI), and waist circumference. The participants were between the ages of 20 to 40 years with a mean age of 30 years. Also, they had an average waist circumference of 35 inches. These indicate that they are all adults. They had an average BMI of 28.5, ranging from 20.8 to 35.4. According to the World Health Organization (WHO) Classification, an adult with a BMI of 18.5 to 24.9 is considered healthy while a BMI of 25.0 to 29.9 is considered overweight. Based on these classifications, most of the participants of the study were overweight as presented in Table 1.

Table 1: Anthropometric characteristics of participants

	Age (years)	Height (cm)	Weight (kg)	BMI (kg/m^2)	Waist circumference (inch)
Minimum	20.0	150.0	61.0	20.8	32.0
1st Quartile	26.0	161.0	70.9	26.9	32.9
Median	27.5	163.7	76.3	28.1	34.5
3rd Quartile	33.5	174.9	93.3	30.6	37.5
Maximum	40.0	186.3	102	35.4	39.5
Mean	29.6	167.2	79.7	28.5	35.2
Std. Deviation	6.004	11.0743	13.1	3.8	2.6568
Standard Error	1.899	3.5020	4.1441	1.2010	.8401
Sample (n)	10	10	10	10	10

Source: Dadzie (2021)

Objective 1: Proximate analysis of cassava plantain fufu, cassava fufu, and cassava ogyama fufu

The first objective of the study was to determine the proximate composition of different varieties of fufu to know their nutrient content. Initially, samples of sun-dried and oven-dried ogyama leaves were analyzed to determine the moisture, ash, protein, oil, fibre, and carbohydrate contents. Also, the proximate analysis was conducted on boiled cassava alone and cassava boiled with ogyama leaves. The results of these analyzes showed that the carbohydrate contents of the sun-dried ogyama leaves and oven-dried ogyama leaves were similar (65.1% and 65.4% respectively. Also, it was observed that sun-dried ogyama leaves had a moisture content of 48.2 percent, and similarly, oven-dried ogyama leaves had a moisture content of 48.5 percent. Again, both samples had similar fat and fibre contents but slightly different protein contents. While sun-dried leaves had a protein content of 20.7 percent, oven-dried ogyama leaves have a protein content of 21.1 percent.

The moisture content of cassava alone was 63.6 percent. The protein, fat and fibre contents were 2.7 percent, 0.14 percent, and 2.4 percent respectively whereas its carbohydrate content was 94 percent. Findings showed that the addition of ogyama leaves made no significant changes to the nutrient content of cassava. Rather, there were slight increases in the moisture, protein, and fat contents. These are presented in Table 2.

Table 2: Proximate composition of Ogyama leaves and cassava

Sample	**Moisture (%)**	**Ash (%)**	**Protein (%)**	**Fat/Oil (%)**	**Fibre (%)**	**CHO (%)**
Sun-dried leaves	48.17	4.26	20.71	1.26	8.73	65.05
Oven-dried leaves	48.54	3.64	21.05	1.27	8.69	65.35
Cassava alone	63.62	0.72	2.70	0.14	2.45	93.99
Cassava + sun-dried leaves	63.79	0.64	2.74	0.22	2.44	93.96

Source: Dadzie (2021)

The moisture, ash, protein, oil, fibre, and carbohydrate contents of cassava plantain fufu, cassava fufu, and cassava ogyama fufu were ascertained. The results presented in Table 3, show that cassava plantain fufu and cassava ogyama fufu contained a similar carbohydrate content (80.0% and 80.5% respectively). Cassava fufu however had the highest carbohydrate contents (86%). Cassava-ogyama fufu though lower in carbohydrate, had the highest fibre content (3.8%) while cassava fufu with the highest carbohydrate content, had the least fibre content (1.6%). Both cassava-plantain fufu and cassava fufu contained similar oil content of about 1.6 percent whereas cassava-ogyama fufu had an oil contents of 1.1 percent. Also, all three fufu varieties contained different amounts of protein. Cassava fufu had the least proportion of protein (9.7%). Cassava ogyama fufu contained 13.5 percent protein and cassava plantain fufu contained 14 percent protein. All three varieties contained a similar amount of moisture and ash (about 73% of moisture and about 1% of ash).

Table 3: Nutrient content of different types of fufu

Sample	Moisture (%)	Ash (%)	Protein (%)	Fat (%)	Fibre (%)	CHO (%)
Cassava plantain fufu	74.09	1.23	14.04	1.68	3.04	80.0
Cassava fufu	73.91	1.08	9.73	1.61	1.59	85.98
Cassava ogyama fufu	73.59	1.06	13.52	1.13	3.82	80.46

Source: Dadzie (2021)

Objective 2: Glycaemic load of the cassava plantain-fufu, cassava fufu, and cassava-ogyama fufu

The second objective of the study was to determine the glycaemic load of cassava plantain fufu, cassava fufu, and cassava ogyama fufu. The incremental area under the curve (IAUC) for the reference food, as well as the test foods, was first calculated using the trapezoid rule **state the rule**. Also, the glycaemic indices of the various test foods were determined.

Incremental area under the curve of reference food and test foods

The incremental area under the curve of the reference food glucose was 732.5. That of the reference foods (cassava-plantain fufu, cassava fufu, and cassava-ogyama fufu) were 661.5, 709.9, and 627.5 respectively. A one-way analysis of variance (ANOVA) was conducted and the results indicated a statistically significant difference (F=4.29, p=0.011). A Tukey post hoc test revealed that a statistically significant difference in the means existed only between the reference food and cassava ogyama fufu (p=0.013). These are presented in Table 4.

Table 4: Incremental area under the curve of reference food and test foods

	Glucose	Cassava plantain-fufu	Cassava fufu	Cassava ogyama-fufu
Mean	732.45	661.50	709.95	627.45
Std. deviation	101.21	59.06	66.05	52.97
Std. error	32.01	18.68	20.89	16.51
Minimum	642	578	602	566
Maximum	968	780	827	720
95% CI	660.1 – 804.9	619.3 – 703.8	662.7 – 757.2	589.6 – 665.3
F=4.287; p=0.011				

Source: Dadzie (2021)

Multiple comparisons

		Mean diff.	Sig.
Reference food (glucouse)	Cassava plantain fufu	70.95	0.144
	Cassava fufu	22.50	0.898
	Cassava ogyama fufu	105.00*	0.013
Cassava plantain fufu	Reference food	-70.95	0.144
	Cassava fufu	-48.45	0.449
	Cassava ogyama fufu	34.05	0.720
Cassava fufu	Reference food	-22.50	0.898
	Cassava plantain fufu	48.45	0.449
	Cassava ogyama fufu	82.50	0.069
Cassava ogyama fufu	Reference food	-105.00*	0.013
	Cassava plantain fufu	-34.05	0.720
	Cassava fufu	-82.50	0.069

Source: Dadzie (2021)

* The mean difference is statistically significant at 0.05 level

Glycaemic indices of test foods

According to Brand-Miller, Hayne, Petocz, and Colagiuri (2003), foods with values of 55 or less (≤ 55) have a low glycaemic index, foods with 56 to 69 have a medium glycaemic index and 70 or more (≥ 70) are classified as foods with high glycaemic index. The glycaemic index of cassava plantain fufu was 73.9, that of cassava fufu and cassava ogyama fufu were 78.3 and 54.8 respectively. Thus, cassava plantain fufu and cassava fufu can be classified as high glycaemic foods while cassava ogyama fufu is a low glycaemic index food. An analysis of variance revealed that the difference in the mean glycaemic indices of the three staples is statistically significant (F=43.805, p=0.000). This is presented in Table 5.

Table 5: Glycaemic index of test foods

	Cassava plantain fufu	**Cassava fufu**	**Cassava ogyama fufu**
Mean	73.92	78.32	54.83
Std. deviation	11.47	9.90	9.18
Std. error	3.63	3.13	2.90
Minimum	65.71	71.24	48.26
Maximum	82.13	85.40	61.40
95% CI	60.4 – 88.1	66.8-95.8	41.1-67.0

Source: Dadzie (2021)

F=43.805, p=0.000

Glycaemic load of test foods

As the name suggests, glycaemic load measures the relative glycaemic impact of a typical dish. Foods with a glycaemic load less than or equal to 10 (≤ 10) are considered as low glycaemic load foods, those with a glycaemic load 11-19 are classified medium glycaemic load foods whereas foods with a glycaemic load greater than or equal to 20 (≥ 20) are considered high glycaemic load foods (Venn, et al, 2006). Cassava fufu had the highest glycaemic load (31.3), followed by cassava plantain fufu (29.6) and cassava ogyama fufu (19.2). Given that cassava plantain fufu and cassava fufu had a glycaemic load greater than 20, it is concluded that cassava plantain fufu and cassava fufu are high glycaemic load foods while cassava ogyama fufu is a medium glycaemic load food. This is presented in Table 6 according to (Venn, et al, 2006).

Table 6: Glycaemic load of test foods

Test food	Glycaemic load	Classification
Cassava plantain fufu	29.56	High
Cassava fufu	31.33	High
Cassava ogyama fufu	19.19	Medium

Source: Dadzie (2021)

Objective 3: Effect of cassava plantain fufu, cassava fufu, and cassava ogyama fufu on blood sugar level

Oral Glucose Tolerance Test (OGTT) was carried out on participants twice to determine participants' glycaemic response to glucose (the reference food). The Fasting Blood Sugar (FBS) level, as well as fluctuations in participants' response to carbohydrates in both tests, were plotted. In the first OGTT, the average FBS was 5.4mmol/L. After administration of glucose, the average peak of glycaemic responses for all participants was observed at the 60th minute (6.6mmol/L). This dropped to 6.3mmol/L at the 90th minute and further to 5.6mmol/L at the 120th minute. For the second OGTT, the average FBS for the ten participants was 4.96mmol/L. After the glucose administration, the average peak of glycaemic responses was observed at the 60th minute (6.3mmol/L), the same as the first OGTT. The average glycaemic responses dropped slightly at the 90th minute (6.2mmol/L) and further to 4.6mmol/L at the 120th minute. This result is presented in Figure 1.

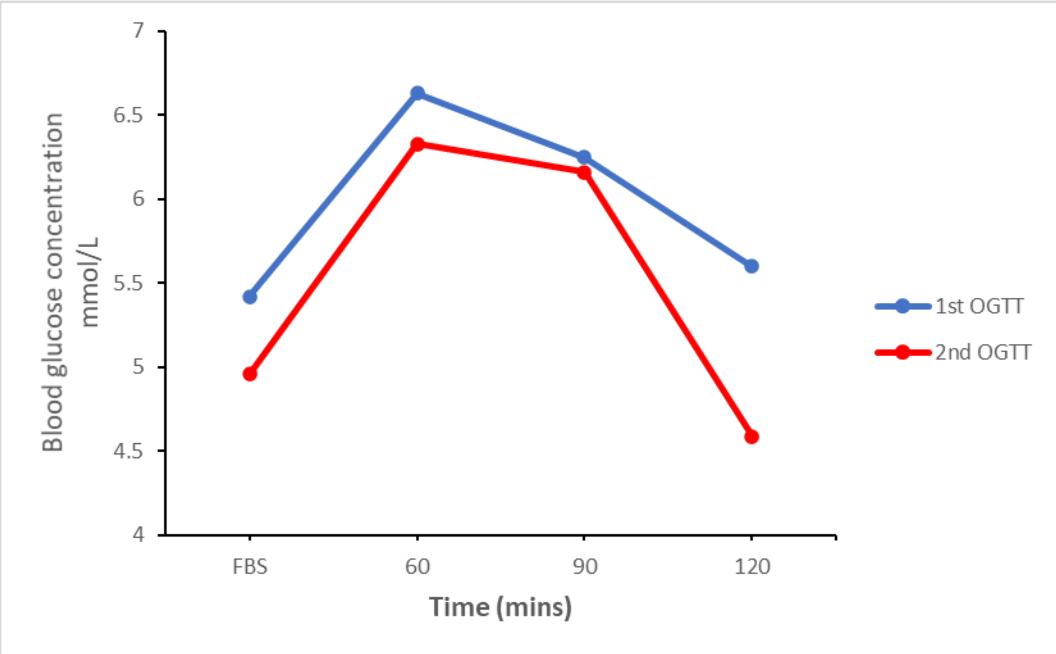

Figure 1: Glycaemic response to glucose

Source: Dadzie (2021)

The participants' glycaemic response to the test foods is shown in Figure 2. For cassava-plantain fufu, the FBS was 5.44mmol/L. The average peak of glycaemic responses was observed at the 90th minute (5.6mmol/L) before declining at the 120th minute (5.46mmol/L). For cassava fufu, the FBS was higher (5.73mmol/L). Unlike cassava-plantain fufu, the average peak of glycaemic responses for cassava fufu was observed at the 60th minute (6.25mmol/L) before an eventual decline to 5.68mmol/L at the 120th minute. With cassava ogyama fufu, the FBS was very similar to that of cassava plantain fufu (5.48mmol/L). The average glycaemic responses for the ten participants declined to 5.31mmol/L at the 60th minute, 4.99mmol/L at the 90th minute, and finally to 4.96mmol/L at the 120th minute (see Figure 2).

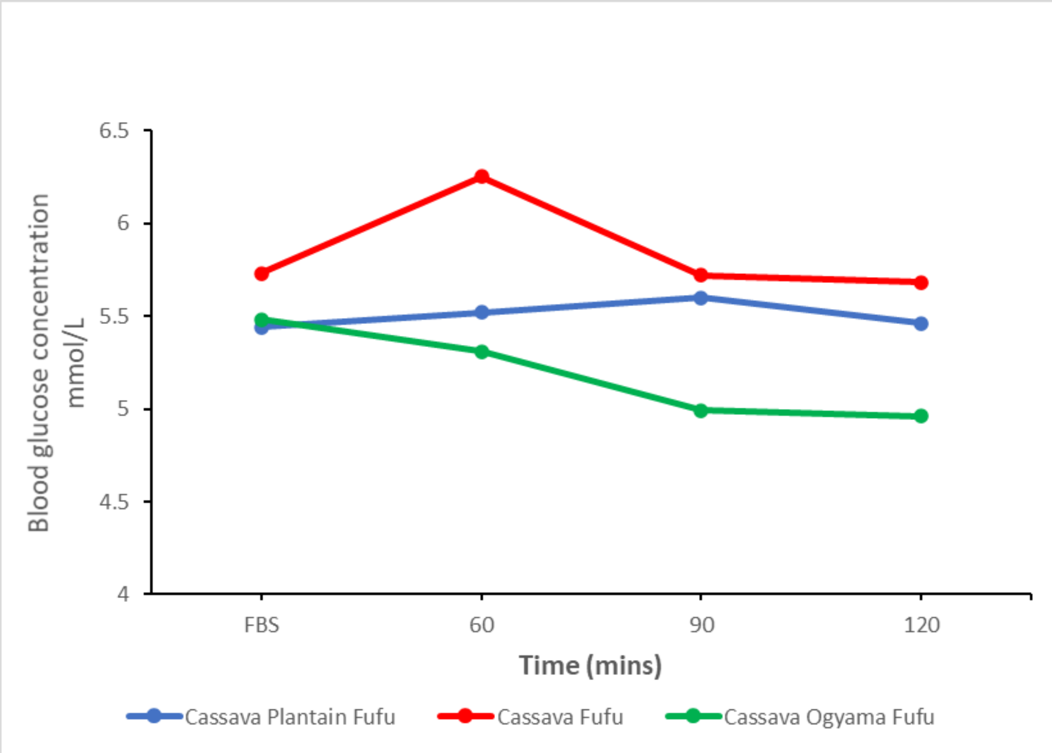

Figure 2: Glycaemic response to test foods

Source: Dadzie (2021)

Objective 4: Sensory evaluation of the acceptability of cassava-plantain fufu, cassava fufu, and cassava-ogyama fufu.

Sensory evaluation was conducted on the three test foods (cassava plantain fufu, cassava fufu, and cassava ogyama fufu). The evaluation focused on the colour, taste, aroma/flavour, mouthfeel, and after taste. Forty panellists sensorilly evaluated the test foods. Their background characteristics (age and sex) are presented in Table 7. About one third of the panellists were aged between 21-25 years and 26-30 years (35% and 30% respectively). Also, a quarter (25%) were between the ages 36-40 years while 10 percent were aged 31-35 years. Concerning their sex, more than half (57.5%) were females.

Table 7: Age and sex of panellists

Background characteristic	Frequency	Percentage
Age (years)		
21-25	14	35.0
26-30	12	30.0
31-35	4	10.0
36-40	10	25.0
Sex		
Male	17	42.5
Female	23	57.5

Source: Dadzie (2021)

Cassava plantain fufu (CPF) was the most acceptable fufu variety in all regards (ie, colour, taste, aroma, mouthfeel, and after taste). Concerning colour, aroma/flavour, and mouthfeel, cassava ogyama fufu (COF) was preferable to cassava fufu (CF). This is presented in Figure 3.

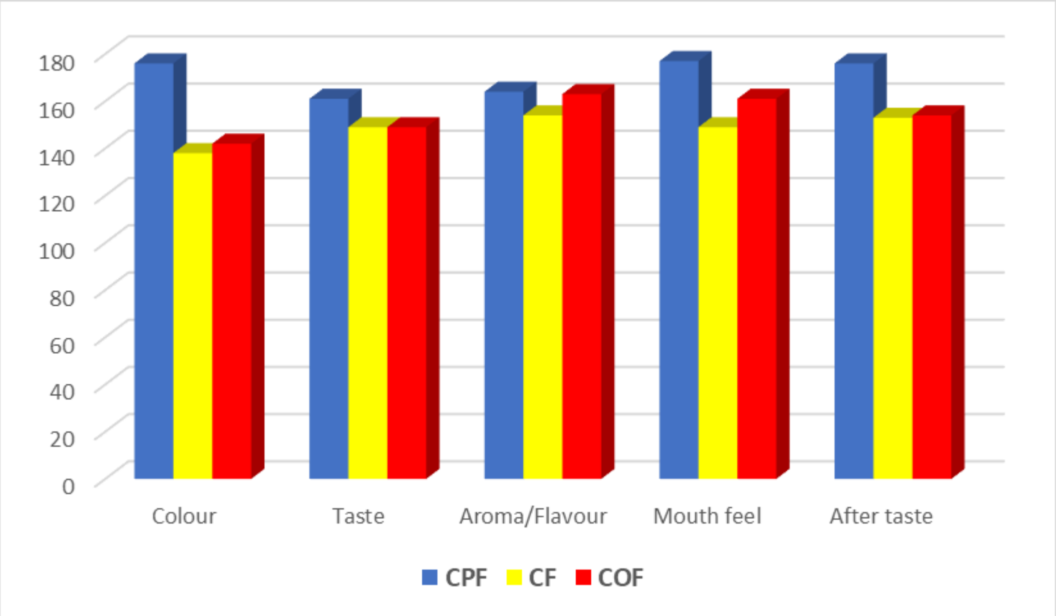

Figure 3: Sensory evaluation of test foods
Source: Dadzie (2021)

Overall acceptability of cassava plantain fufu, cassava fufu, and cassava ogyama fufu

The overall acceptability of the three types of fufu was ascertained. The panellists rated their acceptability of the foods on a scale of 1-5 (where 1 means dislike very much and 5 means, like very much). The results revealed that all the panellists liked cassava-plantain fufu. A third of them very much liked cassava fufu while 25 percent moderately liked it. While another third (33.3%) were undecided, 8.3 percent indicated that they moderately dislike cassava fufu. Concerning cassava-ogyama fufu, three-fourths (75%) moderately liked it and an additional 8.3 percent said they liked it very much. These results are presented in Table 8.

Table 8: Overall acceptability of cassava plantain fufu, cassava fufu, and cassava ogyama fufu

	(1) Dislike very much (%)	(2) Dislike moderately (%)	(3) Neutral (%)	(4) Like moderately (%)	(5) Like very much (%)
Cassava-plantain fufu	-	-	-	50.0	50.0
Cassava fufu	-	8.3	33.3	25.0	33.3
Cassava-ogyama fufu	-	-	16.7	75.0	8.3

Source: Dadzie (2021)

The individual scores for the different varieties of fufu concerning their acceptability were summed to determine the most acceptable variety. The results, presented in Figure 4, indicate that cassava-plantain fufu was the most preferred because it scored the highest. According to the results, cassava-ogyama fufu was more acceptable than cassava fufu.

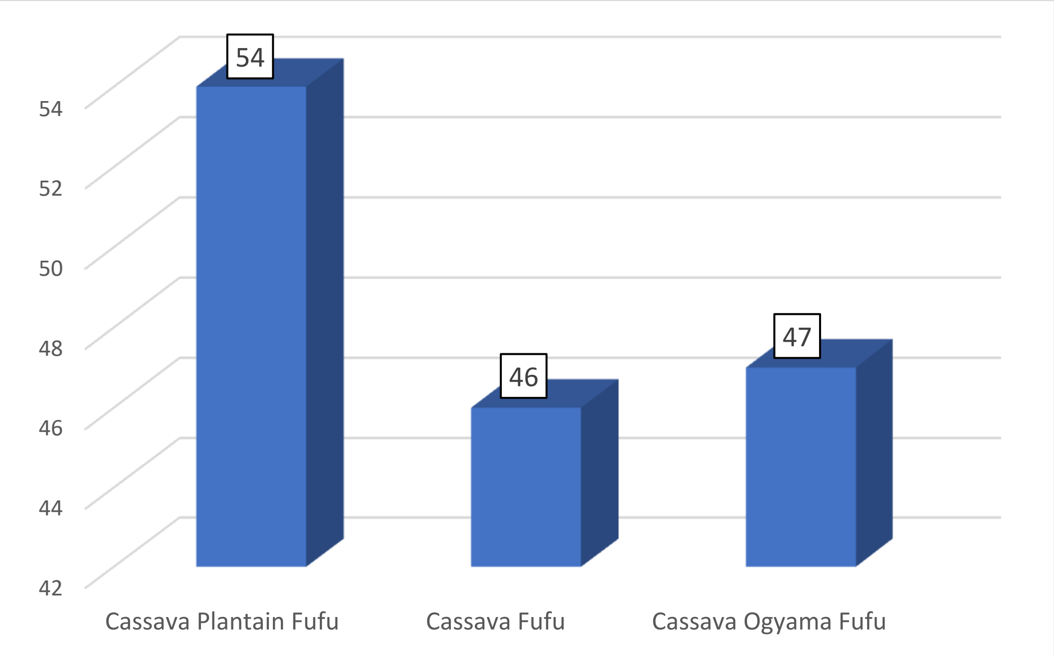

Figure 4: Overall acceptability of cassava plantain fufu, cassava fufu, and cassava ogyama fufu

Source: Dadzie (2021)

Validation of hypothesis

The hypothesis which guided the study was that there is no statistically significant difference between cassava plantain fufu and cassava ogyama fufu. An independent sample t-test was used to test this hypothesis. Specifically, the test was conducted to ascertain whether the difference between the overall acceptability of cassava-plantain fufu and cassava-ogyama fufu was statistically significant. On a scale of 1-5 (where 1 means dislike very much and 5 means, like very much), cassava plantain fufu and cassava ogyama fufu were rated 4.5± 0.52 and 3.9 ± 0.51 on average. The difference between the means was 0.583 which was found to be statistically significant given that t(38)=2.755, p=0.012. Therefore, the hypothesis that there is no statistically significant difference between cassava-plantain fufu and cassava-ogyama fufu was rejected. This result is presented in Table 9.

Table 9: Independent sample t-test of cassava plantain fufu and cassava ogyama fufu

Fufu variety	**N**	**Mean**	**Std. Deviation**	**Std. Error Mean**
Cassava plantain fufu	40	4.500	0.5222	0.1508
Cassava ogyama fufu	40	3.917	0.5149	0.1487

t-test for Equality of Means

T	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference
2.755	38	.012	0.5833	0.2117	0.1443 – 1.0224

Source: Dadzie (2021)

Discussion

The protein content of cassava-plantain fufu was 14.0 percent, cassava fufu was 9.7percent and that of cassava ogyama fufu was 13.5percent. A high protein content is a desirable quality feature in food product development (Singh, Kumar, Sabapathy, & Bawa, 2008). This is because protein is an indispensable nutrient which through the supply of amino acids is involved in many biological processes (Journel, Chaumontet, Darcel, Fromentin & Tomé, 2012). Also, low protein intake is reported to be a cause of undernutrition

(Bain et al., 2013). The protein content recorded in this study is slightly higher than what some researchers reported. For example, Olapade, Babalola, and Aworh (2014) reported that cassava flour contains 7.13 percent of protein. Also, a study on the nutritional composition of fufu analog flour produced from cassava root and cocoyam tuber, Bamidele, Fasogbon, Oladiran, and Akande (2015) reported similar findings. Other studies, on the other hand, reported higher protein contents. Ndife, Kida, and Fagbemi (2014) reported high content of about 24.56 protein while Ubbor and Akobundu (2009) recorded 26.25 percent for cassava.

Olapade, et al. (2014) reported 91.3 percent carbohydrate content for cassava flour which is slightly higher than what was found in this study. In a related study, Bamidele et al. (2015) found that the carbohydrate content of cassava flour ranged from 80 – 87.2 percent. Among the three test foods used in this study, cassava fufu had the highest carbohydrate content. The presence of plantain or ogyama in the other fufu varieties could probably explain why their carbohydrate content was lower.

The glycaemic response of a food is influenced by the amount and availability of dietary fiber. There is evidence that dietary fiber helps to increase or improve satiety by extending and lengthening stomach emptying and glucose absorption. In this way, fiber has an important effect in lowering the glycaemic index of a diet.

The FAO and WHO (1998) suggested that individuals should plan and centre their meals on foods that have low glycaemic indices to avoid chronic diseases which include coronary heart disease, obesity, and diabetes.

Slow cooking techniques such as baking and steaming, as opposed to certain fast cooking methods such as boiling, pressure cooking, and microwave cooking, often result in lower glycaemic index values than these quick cooking methods. Steaming is a technique of cooking that takes time since it involves constantly boiling water and allowing it to vapourize and turn into steam. The steam then transfers heat to the meal in close proximity, thus cooking the dish. Even though the food is kept separate from the boiling water, it is in direct touch or contact with the steam, which results in a softer texture to the finished product. Because steaming is a leisurely way of preparing food, the majority of the nutrients in the meal are maintained. Quick-cooking methods like boiling usually result in a higher gelatinization of starch resulting in disruptions of the amylose and amylopectin ratios making it easy to be broken down by digestive enzymes (Yeboah, Agbenorhevi, & Sampson, 2019). This quick method of cooking could account for the reason why the test foods had high glycaemic index figures.

Acceptability of food is dependent, among other factors, on the sensory attributes of the food. Food taste is known to be the most important feature of food attributes in several studies studies (Abdullah, Hamali & Abdurahman, 2011; Bon & Hussain, 2010; Hemmerling, Asioli, & Spiller, 2016; Kamphuis, de Bekker-Grob, & van Lenthe, 2015). Taste is perceived as a core element in food that greatly influences customer's purchase intention (Autun, Frash, Costen, & Runyan, 2010). In this study, it was found that colour, taste, aroma, mouthfeel, and after taste significantly affected the acceptability of the test foods. This agrees with reports from past studies. For example, Abdullah, Hamali, and Abdurahman (2011) posited that fresh tasting, natural, home-cooked tastes drive consumer demand around the globe while Bon and Hussain (2010) reported that more than half of customers believe a fresh or natural flavour is what makes food taste delicious.

Chapter Summary

The results for the test foods were analysed and discussed individually based on each research question. Research question one and two were analysed using descriptive analysis. A one-way analysis of variance was also used to test for research question three and four, and an independent sample t-test was used to test for the research hypothesis based on specific sensory characteristics.

CHAPTER FIVE

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

Introduction

This chapter summarizes the study's results. In this chapter, conclusions are made based on the results and are discussed in detail. The study's results are also used to make recommendations, and proposals for future research are made in response to the findings.

Summary

The study was experimental research that explored the health and aesthetic benefits of *Alchornea cordifolia* (ogyama) in preparing cassava fufu. Specifically, in the study, cassava-plantain fufu, cassava fufu, and cassava-ogyama fufu were analysed to determine their moisture, ash, protein, oil, fibre, and carbohydrate content. Also, the study determined the glycaemic index and glycaemic load of cassava plantain fufu, cassava fufu, and cassava ogyama fufu; and compared the effect of the three fufu varieties on blood sugar level. Finally, the study conducted a sensory evaluation of the acceptability of cassava-plantain fufu, cassava fufu, and cassava-ogyama fufu. Attributes evaluated included colour, taste, aroma/flavour, mouthfeel, and after taste of the different varieties of fufu.

The study was guided by the hypothesis that there is no statistically significant difference between cassava-plantain fufu and cassava-ogyama fufu. Self-developed questionnaires were used to gather data for the sensory evaluation. Both descriptive (frequencies and means) and inferential statistics (one-way analysis of variance and independent sample t-test) were employed in the analysis of the data with a statistical significance set at 95 percent (that is, $p<0.05$).

Key Findings

1. Cassava fufu had the highest carbohydrate content while cassava-plantain fufu and cassava-ogyama fufu had a slightly lower carbohydrate content than cassava fufu.
2. There was a statistically significant difference in the incremental area under the curve (IAUC) of the reference food and test foods, particularly, between the reference food and cassava-ogyama fufu.
3. Cassava plantain fufu and cassava fufu had high glycaemic indices while cassava ogyama fufu is a low glycaemic index food. Also, cassava plantain fufu and cassava fufu had high glycaemic load whereas cassava ogyama fufu had a medium glycaemic load.
4. There was a statistically significant difference in the glycaemic indices of the test foods (cassava plantain fufu, cassava fufu and cassava ogyama fufu).
5. Findings showed that participants' glycaemic response to the reference food and test foods was different.
6. Cassava-plantain fufu was the most preferred in terms of colour, taste, aroma, mouthfeel, and after taste. Also, concerning the overall acceptability of the different fufu varieties, cassava-plantain fufu was the most acceptable probably because it is the fufu commonly eaten in most homes while cassava fufu was the least acceptable.

7. Finally, the hypothesis that there is no statistically significant difference between cassava-plantain fufu and cassava-ogyama fufu was rejected because the findings revealed otherwise.

Conclusions

Cassava plantain fufu and cassava fufu have high glycaemic indices as well as high glycaemic loads. On the other hand, cassava ogyama fufu has low glycaemic index and medium glycaemic load. Cassava-ogyama fufu was not the most preferred fufu variety however, it was preferable to cassava fufu. The findings of the study highlight the importance of all the sensory features of food and not merely the nutritional components alone. Thus, nutrition alone is not sufficient to compel people to make a demand for a particular food. The food's sensory features (taste, aroma, colour, mouthfeel, etc.) also play a significant role.

Recommendations

These recommendations are based on the study's findings:

1. The consumption of cassava-ogyama fufu can be recommended more often to diabetics who wish to continue enjoying "fufu" while they manage their health condition since it has a relatively low glycaemic load. The use of "ogyama" leaves should be encouraged among households to use them in food preparation.
2. More recipes of foods with *Alchornea cordifolia* leaves should be developed by stakeholders in the hospitality, food product development, or food manufacturing sectors such as the department of VOTEC (UCC) so that several varieties of meals will be prepared using "ogyama" leaves can be made available to consumers to choose

from. This will help to reduce the intake of too much glucose in our body.

3. The glycaemic index and loads of cassava, plantain, and ogyama leaves should be investigated.

Suggestions for Further Studies

1. Timing for testing can be spread below and above the 90^{th} and 120^{th} minutes respectively
2. Further studies can be done on ogyama and other carbohydrate foods

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APPENDICES

APPENDIX A

QUESTIONNAIRE

UNIVERSITY OF CAPE COAST

COLLEGE OF EDUCATION STUDIES

FACULTY OF SCIENCE AND TECHNOLOGY EDUCATION

DEPARTMENT OF VOCATIONAL AND TECHNICAL EDUCATION

SENSORY EVALUATION QUESTIONNAIRE

The purpose of this evaluation is to collect data to examine the nutritional contents of three varieties of fufu. These are cassava plantain fufu (CPF), cassava fufu (CF), and cassava ogyama fufu (COF). The study is for academic purposes hence, your candid response will be of immense help to the study. Any information given would be for the intended purpose and be assured that your identity will not be revealed under any circumstance.

Date: ……………………… Panellist

ID………………….

Background Information of Respondent

1. Please tick [ ] your age range.

Age (years): 15-20 [ ] 21-25 [ ] 26-30 [ ] 32-35 [ ] 36-40 [ ] 41-45 [ ] 46-50 [ ]

2. Please circle your gender

Gender: Male Female

INSTRUCTION FOR THE EVALUATION

1. Please take a sip of water before tasting.

2. Assess the varieties of fufu samples in the order presented that is from left to right.

3. Please remember to rinse your mouth with water and spit it into the cup provided before tasting each of the samples.

4. With a tick, score each fufu sample using the numbers 1-5 to grade the attribute of each sample according to your preference of the three varieties of fufu in the table below.

Dislike very much =1, Dislike moderately =2, Neither like nor dislike=3, Like moderately=4, Like very much =5

Coded sample	Colour	Taste	Aroma/ Flavour	Mouth Feel	After Taste	Overall Acceptability
CPF						
CF						
COF						

Comments:

……………………………………………………………………………………

……………………………………………………………………………………

……………………………………………………………………………………

……………………………………………………………………………………

Thank you for your participation.

APPENDIX B

SELF DEVELOPED SCREENING FORM

UNIVERSITY OF CAPE COAST

COLLEGE OF EDUCATION STUDIES

FACULTY OF SCIENCE AND TECHNOLOGY EDUCATION

DEPARTMENT OF VOCATIONAL AND TECHNICAL EDUCATION

SELF-DEVELOPED SCREENING FORMS FOR SELECTING PARTICIPANTS

Background information of participants

1. Name of participants
2. Gender:
3. Age:

History of Glucose intolerances of participants

2. Have you ever been diagnosed of diabetes? Yes / No
3. If yes which hospital?
4. When was this done (date)?

History of Allergies of Participants

5. Have you ever experienced allergies to cassava, plantain and ogyama leaves?
6. Are you allergic to any of these common vegetables used to prepare soup?
    a. Tomatoes
    b. Pepper
    c. garden eggs
    d. onions

APPENDIX C

ADVERSE REACTION REPORTING FORM

UNIVERSITY OF CAPE COAST

COLLEGE OF EDUCATION STUDIES

FACULTY OF SCIENCE AND TECHNOLOGY EDUCATION

DEPARTMENT OF VOCATIONAL AND TECHNICAL EDUCATION

ADVERSE REACTION REPORTING FORM

Background information of participants

1. Name of participants
2. Gender:
3. Age:

History of Adverse reactions of Participants

Do you have any of the following adverse reaction? If yes, underline the type of reaction

a. Headache
b. Itching
c. Temperature
d. Running nose
e. Redness of eyes
f. Any other reaction? If yes specify………

APPENDIX D

SUGAR PROFILE FORM

UNIVERSITY OF CAPE COAST

COLLEGE OF EDUCATION STUDIES

FACULTY OF SCIENCE AND TECHNOLOGY EDUCATION

DEPARTMENT OF VOCATIONAL AND TECHNICAL EDUCATION

TOPIC: HEALTH AND AESTHETIC BENEFITS OF ALCHORNEA CORDIFOLIA IN CASSAVA FUFU

Background characteristics

1. Age (in years) …………………
2. Height …………………
3. Weight …………………
4. Waist circumference …………………
5. BMI …………………

Glycaemic Response to Glucose

1st Oral Glucose Tolerance Test

Date: ……………………………… Time: ………………

FBS	60th minute	90th minute	120th minute

2nd Oral Glucose Tolerance Test

Date: ……………………………… Time: ………………

FBS	60th minute	90th minute	120th minute

Glycaemic Response to Test Foods

Cassava Plantain Fufu

Date: ……………………………… Time: ………………

FBS	60th minute	90th minute	120th minute

Cassava Fufu

Date: ……………………………… Time: ………………

FBS	60th minute	90th minute	120th minute

Cassava Ogyama Fufu

Date: ……………………………… Time: ………………

FBS	60th minute	90th minute	120th minute

APPENDIX E

IRB CLEARANCE

UNIVERSITY OF CAPE COAST

INSTITUTIONAL REVIEW BOARD SECRETARIAT

TEL.: 0558093143 / 0508878309
E-MAIL: irb@ucc.edu.gh
OUR REF: UCC/IRB/A/2016/1021
YOUR REF:
OMB NO: 0990-0279
IORG #: IORG0009096

1ST JULY, 2021

Ms. Anne-Marie Dadzie
Department of Vocational and Technical Education
University of Cape Coast

Dear Ms. Dadzie,

ETHICAL CLEARANCE – ID (UCCIRB/CES/2021/16)

The University of Cape Coast Institutional Review Board (UCCIRB) has granted Provisional Approval for the implementation of your research "***Health and Aesthetic Benefit of Using Alchornea Cordifolia in Preparing Cassava Fufu***" This approval is valid from 1st July, 2021 to 30th June, 2022. You may apply for a renewal subject to submission of all the required documents that will be prescribed by the UCCIRB.

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

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

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

Yours faithfully,

Samuel Asiedu Owusu, PhD
UCCIRB Administrator

ADMINISTRATOR
INSTITUTIONAL REVIEW BOARD
UNIVERSITY OF CAPE COAST

APPENDIX F

INTRODUCTORY LETTER

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

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

University of Cape Coast
Cape Coast

Our Ref: VTE/IAP/V.1/156

24th November, 2020

The Head
University of Cape Coast Hospital
UCC

Dear Sir/Madam

INTRODUCTORY LETTER

We have the pleasure of introducing to you **Anne-Marie Dadzie** who is an M.Phil student of this Department and working on the thesis topic **"Health and Aesthetic Benefit of using Alchornea Cordifolia in Preparing Cassava Fufu".**

Currently, she is at the data collection stage of her research work and is requesting to use your hospital facility to carry out Glycemic Response among respondents after they have eaten the fufu.

Thank you.

Yours faithfully,

Dr. Augustina Araba Amissah
HEAD OF DEPARTMENT

APPENDIX G

PICTURES OF PROXIMATE ANALYSIS AT THE SCHOOL OF AGRICULTURE LABORATORY, UCC


JENWAY

APPENDIX H

PICTURE OF PROXIMATE ANALYSIS: HEATING ACID SOLUTION

APPENDIX I

PICTURES FOR GLYCEAMIC INDEX

APPENDIX J

PICTURE FOR GLYCEAMIC INDEX PARTICIPANTS WITH SUPERVISOR

APPENDIX K

PICTURES FOR SENSORY EVALUATION