UNIVERSITY OF CAPE COAST

GLYCAEMIC INDEX AND LOAD OF FONIO COMPOSITE BREAD

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BY

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DECLARATION

Candidate's Declaration

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

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

Name: Karim Ankrah Mohammed

Supervisors' Declaration

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

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

Name: Prof. (Mrs). Sarah Darkwa

ABSTRACT

Type II diabetes has been associated with glycaemic load and index of food due to the quantity or amount of carbohydrate available in such foods. Determination of glycaemic index and load of bread made from fonio cereal was the focus of the study. The study was conducted in Tamale Metropolis with four research objectives and two hypotheses. One hundred and three participants took part in the study, comprising ninety three sensory evaluation panellists and ten for glycaemic load test. True experimental research design was used and the samples were manipulated to see the needed effect. Fonio was successfully combined with white bread flour and whole wheat flour to come out with three different types of bread coded as 'F30', 'F50' and 'F70'. The sensory result revealed appearance, aroma, taste, Sweetness and texture for product 'F30' were all liked by the 93 respondents. In the case of product 'F50' and 'F70', the same findings were obtained as in the case of 'F30'. The study further revealed that 'F30', 'F50' and 'F70' all have low glycaemic load. In the case of glycaemic index, 'F70' had the least glycaemic index and this was followed by 'F50' and 'F30'. The proximate analysis on the fonio composite bread thus revealed that eight different nutrients were present in the formulated breads in different proportions. The nutrients were fat/oil, fibre, protein, dry matter, moisture, ash, Carbohydrate and glucose. Also, the study found out that there was no statistically significant difference between glucose level before and after consumption of the three fonio composite breads. There was statistical difference in terms of nutrients among the three developed fonio composite bread.

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DEDICATION

To my lovely parents Mr. and Mrs. Ankrah.

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INTRODUCTION

Globally cereal grains has been one major source of food for many people and it is used in several ways in food preparation such as cooking whole or milled into flour and used for other products. Bread is a product from flour and it is widely known and consumed by many consumers in the world. Bread is mostly produced using wheat flour so the use of fonio cereal flour in developing composite bread for consumption would be of great value to add to variety the of composite used in the production of bread and also increase the choices of consumers.

Due to variances that may result from diverse cooking and processing processes, a joint FAO/WHO Expert consultation paper emphasizes the need of determining the Glycaemic Index (GI) of indigenous foods owing to varying methods or processes of cooking that could have effects on a product (Aston, Gambell, Lee, Bryant & Jebb, 2008). Fonio is a cereal grain farmed in some areas in the Northern Region of Ghana. It is not widely known in the country but eaten in the area selected for this study to introduced composite fonio and to determine the glycaemic load and index of the products. This part of the thesis that is the introduction presents the background to the study, the problem statement, research objectives, and hypothesis, significance of the study, delimitation and limitation as well as organization of the study.

Background to the Study

Cereals constitute the major source of food for the world's population. The world is still reliant on grain crops and receives sustenance from it (Conklin & Stilwell, 2007), and the continent of Africa is not exempted

(Taylor, 2004). In most regions of the globe, an expanding global population mandates high grain production to meet the requirements of the masses, leading in the substitution of agriculture with agri-commerce (Jideani & Jideani, 2011). This has made people to move away from old-style to commercial crops, as well as non-conventional to marketable cereal crops (Jideani & Jideani, 2011). Important commercial crops such as wheat, barley, oats, and rye are considered cool-season cereals whereas rice, maize, sorghum, and millet, are considered as warm-season cereals (Ghatge, 2012, Ayodele & Mohammed, 2011).

Fonio is one of the earliest African grains, according to Chukwu and Abdul-Kadir (2008), and has been farmed many years over the arid Savannas of West Africa. However, Vietmeyer, Borlaugh, Axtell, Burton, Harlan, and Rachie (1996) indicated that, the plant has been really overlooked that is why it is known as Africa's "lost crop," and getting only a quota of the emphasis placed to maize, sorghum, and pearl millet. According to research, fonio is gaining recognition progressively, unearthed and estimated for more farmers being engaged in its cultivation and regarded for expansion as a cultivated species in near future (Ibrahim 2001).

Fonio (Acha) is a grain crop that originated in West Africa and belongs to the family *Graminaea* with its history, origin, spread, and genetic variation unknown. In West Africa, Gibon and Pain, (1985) commented on its long history and great significance. The crop is cultivated in variety of places such as Mali, Togo, Ghana, Nigeria, Sierra-Leone, Guinea Bissau, and also Senegal, Benin Republic and Cote d'ivoire (Gyang & Wuyep, 2005). There are two categories of fonio the white Fonio (*Digitaria exilis*) and the black

fonio (*Digitaria iburua*). The white fonio is more popular and grown in many areas than the black one.

In the West African Savannah region, fonio plays a pivotal role in the birth and evolution of old-style agriculture, nutrition, and indigenous medicine, in addition to other African traditional cereals (Adoukonou-Sagbadja, et al. 2007; & Henrard, 1950). The cereal fonio has been cultivated for a long time, and it is one of the earliest West African indigenous grains known by various names including "Acha", "hungry rice", "Ipouaga", "Feningué", "Findi", "Kansambahon", "Ova" in Benin, Burkina Faso, Nigeria, Guinea, Mali and Togo (Adoukonou-Sagbadja, 2010). Unfortunately it has continually been ignored by scientific research and growth packages in the sub-region.

In Ghana, fonio is farmed in the Northern region mostly in towns such as Zabzugu, Tatale, Yendi, Saboba and Chereponi. The cereal crop is mostly cultivated by the Chokosis and Kokomba people (Dokosi, 1977). It is called "Invoni by the Chokosis, the Konkombas call it "Kapui" and the Dagombas "Kabga". However, it is not known by all the ethnic groups in the region and cannot be found in other parts of the Northern Region or Ghana as a whole. Hence, it is not well known and thus underutilized. It is only well known in areas where the crop is being cultivated.

Fonio (Acha) is a cereal that is capable of thriving and produce seeds on poor soils with dangerous levels of Aluminum as compared to other crops, and it can be depended on in arid savannah environments, where brief rains are inconsistent (Ibrahim, 2001). Fonio (Acha) is occasionally viewed as the "grain of life" as it supplies nourishment early in the growing season, before

other crops are ready to harvest (Ibrahim, 2001). Though fonio contains very little amount of gluten content it has twenty amino acids which is good for human consumption and are lacking in other cereals such as rice, wheat, sorghum, and barley (Vietmeyer, Borlaugh, Axtell, Burton, Harlan & Sarwar, 2013). Nutritional security is very essential issue and increasing concern for most countries and fonio is capable of contributing to that effect (Asfaw 2006; Popkin, Adair, & Ng. 2012). Proximate analysis of fonio revealed the following nutritive value; 7.7% protein, 1.8% fat, 71% carbohydrate and 6.8% fibre (Oburuoga & Anyika, 2012).

Diabetes mellitus is a metabolic condition in which animals and humans are unable to use the accessible glucose from the meals they eat, causing blood glucose levels to rise over threshold values (Yadav, Rani, Singh, & Murari, 2015). Nearly 347 million people globally are affected with *Diabetes mellitus* and it is predicted the number could reach 592 million people (Gupta, Singh, & Lehl, 2015). *Diabetes mellitus* is basically classified into three types, Type 1 diabetes (autoimmune condition) this is caused by a lack of insulin (Esser, Legrand-Poels, Piette, Scheen, & Paquot, 2014). Type 2 diabetes is the most common form of diabetes mellitus and is highly associated with family history of diabetes, older age, obesity and lack of exercise. This type of diabetes occurs when the body cannot use the amount of insulin produced the way it should. People with type 2 diabetes are said to have insulin resistance. It used to be called adult-onset diabetes. This type of diabetes also affects kids and teens, mainly because of childhood obesity. Gestational diabetes is the third form, which affects only certain pregnant women (Baynes, 2015).

Diabetes mellitus is becoming more common across the world owing to a variety of factors including dietary changes, obesity, demography, ethnicity, and genetic susceptibility (Sivaprasad, Gupta, Crosby-Nwaobi, & Evans, 2012). Although various synthetic oral hypoglycaemic agents and insulin are available for the treatment and control of diabetes, they come with a number of drawbacks, including ineffective oral insulin intake, side effects, and toxicity from synthetic medicines (Surya, Salam, Tomy, Carla, Kumar, & Sunil, 2014).

Diabetes mellitus is on the rise across the world, revealing contemporary lifestyle patterns such as a high-calorie diet combined with less training activity. Another major cause of cardiovascular disease in the world is attributed to type two diabetes (World Health Organization 2012). It is acquired by humans as a result of our lifestyles. The prevalence of type 2 *diabetes mellitus* (T2DM) has a negative impact on individual health as well as a societal economic loss due to increasing health-care expenses.

An individual's pattern of meal consumption may result in the onset of type 2 diabetes especially foods that are high in carbohydrates are known to increase blood glucose (hyperglycemia) (Sheard, Clark & Brand-Miller, 2005). The source of energy for the body tissues is mainly from glucose and this is obtained from the consumption of carbohydrate foods. Thus, all digestible monosaccharaides, disaccharides and polysaccharides must ultimately be converted into glucose or process into glucose by various enzymes produced by the liver. Blood glucose levels in the body need to be kept relatively constant because of its significance in promoting proper cellular function.

Subsequent studies which shows prominence of high-protein diets which can lead to weight reduction other recent findings indicate that carbohydrates may be "worse than saturated fats" for dangers involved in cardiovascular disease (CVD). Dietary carbohydrates have gotten unfavourable press in the previous decade (Jakobsen, Dethlefsen, Joensen, Stegger, Tjonneland, & Schmidt, et al. 2010). These shifts in the environment have generated concerns regarding the quantity, and the kind of energy giving food that should be added in a healthy diet. It is believed that most of the energy giving foods (carbohydrates) meals consumed today are of poor quality, which may be linked to increase in blood sugar levels as well as low dietary fibre and calorie-dense) diets.

The term Glycaemic Index (GI), despite the fact that a simple numerical score that quantifies carbs' potential to raise blood glucose levels, it has become an accepted notion for categorizing carbohydrates, (Augustin et al., 2015). The after meal (postprandial) glycaemic reaction of a carbohydrate intake is tested against a benchmark food to determine its glycaemic index (Augustin et al., 2015). When the physiological impact of a carbohydrate is modified, the glycaemic index value is likewise immediately influenced (Bahado-Singh, Riley, Wheatly & Lowe, 2011). The postprandial glycaemic response of carbohydrates is influenced by a number of variables; particle size, processing techniques, starch type, and anti-nutritive elements found in food.

Foods' GI are measured on a scale between zero to one hundred. The GI values of carbohydrates have been categorised into three groups such as foods with GI values between 0 – 55 are considered low, foods with GI values between 56 – 69 are considered average and foods with GI values from 70 up

to 100 are regarded high Glycaemic Index foods. The glycaemic index of food has been discovered to be influenced by the cooking methods used in preparing the food (Aston, Gambell, Lee, Bryant, & Jebb, 2008).

Some carbohydrate meals cause insulin to react faster than others (Lin, Wu, Lu, & Lin, 2010). This might be related to changes in how quickly different meals release glucose into the bloodstream after consumption. The glycaemic index is a measure used to determine how quickly or slowly a carbohydrate item is transformed to glucose after consumption (Lavigne, Marrette & Jaques, 2000). Since there is a lack of understanding about the influence of fonio increasing sugar levels in human, the current study was conducted to construct and assess fonio composite breads, as well as estimate their glycaemic load and index.

Statement of the Problem

Fonio (*Digitaria exilis* and *Digitaria iburua*) are two cultivars of a minor cereal crop used in West Africa. Fonio is an essential food or food used during times of hunger. Its production is limited to a small number of indigenous groups for whom it has significant socio-cultural and economic importance. It is grown in the northern portion of Ghana by a collection of ethnic groups that live along the Eastern Corridor terrain.

Nutritionists continue to value fonio, it has two essential amino acids that are lacking in main cereals such as methionine and cysteine. These amino acids are very vital for the regular body processes of the human and deficient in major of the cereals that we consume daily hence the need to incorporate the cereal into products to enhance its utilization.

In addition, the crop is still undeveloped as a result of insufficient attention from research and extension agencies. The United States Academy of Sciences included fonio on a list of underutilized African tropical plants with potential economic value published in 1974. Little research on fonio still leaves the cereal crop underexploited and thus the potential value of the crop still underexploited. To buttress the underutilization of the cereal fonio, in the study of Chivenge, Mabhaudhi, Modi, and Mafongoya (2015), they said that fonio grain is one of Africa's "lost" crops, having been overlooked owing to lack of understanding of its nutritional potential by nutritionists and other researchers in general. Fonio is a cereal that many people do not have knowledge of hence underutilized in Ghana. A brief survey conducted by the researcher on fonio showed that fonio is not known by several people and thus not utilized by many people in Ghana.

The glycaemic index of several foreign cereals have been determined and documented but it is not the same with our Ghanaian cereal foods. Fonio is a cereal and can be eaten alone like other cereals such as corn or wheat. Fonio is usually added to other food ingredients to make dishes. It will be interesting to produce bread from fonio and compare it to ordinary plain bread and brown bread to see if it will contain less glucose and thus add little glucose to the blood when eaten; if it does so, then it could be recommended to diabetic patients who can enjoy fonio bread without any negative effect on their blood glucose level.

In the global context some studies were conducted on fonio which are very significant and needs to be mentioned to establish the need for this study. A study conducted in Nigeria was using fonio; induce postprandial blood

glucose and insulin responses in diabetics and non-diabetics subjects (Alegbejo, Ameh, Ogala, & Ibrahim, 2014). The study focused on the use of the cereal fonio on postprandial blood glucose of the respondents whereas this current study was about using fonio to develop composite product (bread) for both diabetic and non-diabetic patients.

Another study conducted in Nigeria by Ibrahim and Saidu (2017), looked at the effect of processed fonio (*Digitaria exilis*) grain on the blood glucose levels of induced Wistar Rat Model. A study was also conducted by Švec and Hrušková, (2018) in USA and this generally looked at the baking impact of wheat-fonio flour composites. They used a percentage composition of 2.5%, 5.0%, and 10.0% for the composites and their main focus was on the baking value of the wheat-fonio flour composites whereas this current study flour composites differ in percentages and also it is not focused on baking value of the composites but rather evaluates fonio composites for their glycaemic load and index for diabetic patients.

In the West Africa Sub Region, particularly Ghana a study was conducted by Eli-Cophie, Agbenorhevi, and Annan (2016). They determined the glycaemic index of five local foods and their suitability for diabetic patient's consumption. The staple foods used included *fufu* (locally pounded), *kenkey* (Ga), *banku, Tuo Zaafi* (TZ), and *fufu* (Processed powder). These studies though interesting and insightful looked at the cereal corn. The data gathered so far indicates some studies have been done on some fonio and some cereals with regards to determining the glycaemic index but not directly linked to development of composite and evaluating the glycaemic index and load for both diabetics and non-diabetics. Determining the glycaemic index of

fonio composite bread and its suitability for diabetic consumption will help compliment such efforts and data.

Purpose of the Study

The study's primary goal was to develop Fonio Composite Bread, determine its proximate composition as well as glycaemic index and glycaemic in order to recommend its suitability or non-suitability for diabetic patients'.

Objectives of the Study

The specific objectives of the study are to:

1. develop fonio composite bread using different proportions of fonio, wheat and polished wheat flour.
2. determine the sensory preference for the fonio composite bread.
3. determine the glycaemic index and glycaemic load of fonio composite bread.
4. determine proximate composition of the fonio composite bread.

Hypotheses

1. H_O: There is no statistically significant difference between glucose level before and after consumption of fonio composite bread.
2. H_O: There is no statistically significant difference in terms of nutrients among the three developed fonio composite bread.

Significance of the Study

This study is expected to contribute to the formulation of new recipes to the diets of diabetic patients and to the general public after developing the composite breads and determining the glycaemic load and glycaemic index in the products.

The discoveries from the research will provide data on glycaemic index and glycaemic load of fonio cereal which will be useful in making decisions on its consumption with regards to human health. It can go a long way to help consumers gain more from their choice of cereal grain foods. The study will complement to current works and serve as a reference material for other researchers who would conduct similar study on fonio cereal.

Delimitation

The study used specifically fonio in developing composite bread and not all types of pastry products to determine the glycaemic load and glycaemic index of the products and recommend for diabetic and non-diabetic patients. Also, nutritional components that were determined in the laboratory include carbohydrate, protein, fats, ash, moisture and fibre. The study was also carried out at the Tamale Teaching Hospital, where diabetic individuals were identified at the diabetic clinic.

Limitation

It was difficult to get a standardized document on fonio cereal food composite processing and preparation method used in the preparation of bread in Ghana. The method used in the production of the composite bread for the study may not be representative or standardized for other methods used by other people who prepare composite bread using different cereals. It was a challenge for the researcher to get participants willingly agreeing to take part in the study considering the restrictions.

Organisation of the Study

This thesis is organised in five major chapters. The first chapter deals with the background information related to the study, it also gives problem

statement, the purpose for which the study was conducted, followed by the objectives of the study and hypothesis. The chapter also looks at the limitations, delimitation and organization of the study. Chapter two of the thesis covers the literature aspect of the study which was grouped into conceptual and empirical review.

Chapter three focuses on the research procedure which comprised of the study design, study area, study samples, screening of participants, inclusion and exclusion criteria for participants and preparation of test samples. The chapter also discusses the proximate analysis of the fonio, ethical consideration, it also looks at how data was collected, processed and analysed. Chapter four covers the presentation and discussion of findings. The last chapter gives the conclusion, summary of the study, key findings, recommendations and suggestions for further study.

Definitions of Terms

Cardiovascular disease (CVD) – this is referred to a group of disorders that affect the heart and blood vessels. It's commonly associated to fatty build-up in the arteries (atherosclerosis) and an elevated risk of blood clots.

Composite flour – A flour created by blending or combining different proportions of non-wheat flours with or without wheat flour, and used to make leavened or unleavened baked or snack goods.

Diabetes mellitus is a metabolic disorder, where animals and humans are unable to utilize the available glucose they obtain from foods they consume and thus results in elevation of blood glucose levels beyond threshold limits.

Disaccharides - Carbohydrates that yield two monosaccharide molecules on complete hydrolysis.

Fonio (Acha) – this is a cereal crop farmed in the West African origin and belongs to the family *Graminaea* with very little knowledge about its development, source, circulation and genetic diversity.

Hyperglycaemia – refers to blood sugar (glucose) levels that are too high associated with diabetes.

Insulin - is a hormone that aids in the regulation of blood sugar levels in the body.

In vivo – It refers to the tests, experiments, and procedures carried out by researchers in or on a whole live creature, such as a human, a laboratory animal, or a plant.

Monosaccharide – Simplest group of carbohydrate.

Polysaccharides – Class of carbohydrates whose molecules contain chains of monosaccharide molecules.

Postprandial – occurring or done after a meal, relating to the period after dinner or lunch.

CHAPTER TWO

LITERATURE REVIEW

The determination of this research was to develop Fonio Composite Bread, conduct proximate analyses and determine the glycaemic index, glycaemic load so as to recommend its suitability for diabetic patients' consumption in the Tamale Metropolis. The conceptual framework for the study is presented in this chapter. This is followed by review of literature relevant to the study including fonio, uses and importance of fonio in our diet, the nutritional value of fonio. It also presents literature on glycaemic load (GL) and glycaemic index (GI), Glycaemic index (glucose) and its associated diseases, classification of glycaemic index, the proximate analysis of fonio composite bread, product development and theoretical review. Similarly studies by other authors were reviewed.

Conceptual Framework on Fonio Composite Bread

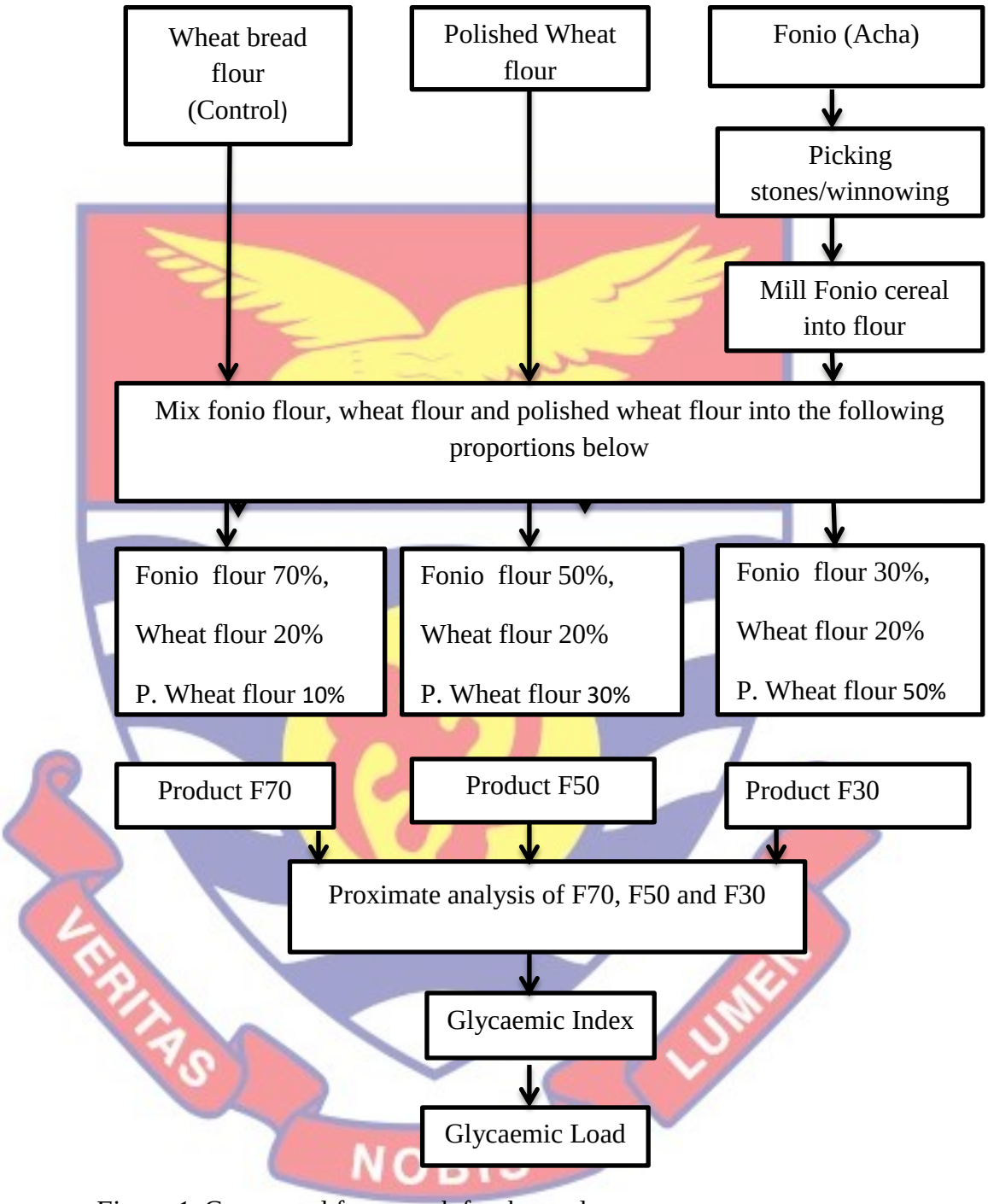

Figure 1: Conceptual framework for the study
Source: Researcher's Construct (2021).

Justification of the Conceptual Framework

The diagram shows the stages that Fonio cereal, whole wheat flour and polished wheat flour went through in the production of composite fonio bread.

The framework shows the stages at which various flours were mixed to obtain the composite flours which were used to produce the formulated fonio bread code named F70, F50 and F30. The fonio cereal was bought and winnowed to removed dirt and particles of stones from it, after which the cereal was then milled into flour. The whole wheat flour and the polished bread flour were bought from the market. The flours were then mixed into different proportions with fonio flour used intentionally to vary the various proportions since fonio was the main ingredient used for the composite bread developed. The control flour used in the study was the whole wheat flour hence this was 20% in all the three formulated flour composite. The quantity of white bread flour in the composition varied in all the three formulated composites depending on the total composition of fonio flour and the wheat flour used. The wheat flour was constant 20% in all the three formulated composite bread flours, hence the fonio flour quantity added to the wheat flour and the remaining quantity required to get 100% will be used for the polished wheat flour.

The composites flours were then used to produce three different bread samples and which was then sent to the University of Cape Coast Agricultural Science Laboratory for proximate analysis. The final stage of the conceptual framework was establishing the glycaemic index and load of the produced fonio composite breads by giving the baked samples to participants to consume and their blood glucose measured.

Glycaemic Index Concept

The glycaemic index (or GI) is a scale that values carbs on a scale of 0 to 100 on how much they elevate blood sugar (glucose) amounts upon dining. High-GI foods are those that are quickly metabolized (Glycaemic Index

Foundation 2017). The glycaemic index is a measurement of how fast and slow glucose levels rise in the blood. The word "glycaemic" means glucose in the blood. According to Jenkins, Kendall and McKeoun-Eyssen (2008), the measure of diet quality that compares a meal's high glucose impact to that of pure glucose (standard food) is termed as glycaemic index (GI). High GI meals include carbs that break down fast in the circulation, whereas low GI foods contain energy giving food that metabolize more slowly, releasing glucose into the bloodstream gradually.

A reduced glycaemic response is normally associated with a lower insulin demand, although this isn't always the case, and it can help with long-term blood glucose and cholesterol control (Atkinson, Forster-Powell & Brand-Miller, 2008). The insulin index may also be used to determine the insulin response to a specific meal. This has the benefit of immediately expressing whether changing or replacing diets to suit the individual conditions.

GI is being used to examine meals, unlike postprandial glucose level and oral glucose tolerance test, which offer information as to how someone manages the intake of accessible carbohydrates. Using weighted averages of individual items, the GI of mixed meals may be estimated and graded. It is a feature of the food that represents the quality of carbohydrate-containing foods as an index or percentage. A food's glycaemic index can be classified as low when it is less than fifty five (55) and considered medium when it is between fifty five and sixty nine (55–69), and finally considered high when it is more than seventy (70), (Glycaemic Index Foundation 2017).

Low-GI foods produce sugar into the blood slowly and steadily, resulting in more appropriate postprandial (after meal) blood sugar levels. The consumption diets that are high in GI enables blood glucose levels to rise more quickly, making it ideal for people suffering from hypoglycemia or it can be used for energy recovery after exercise (Freeman, 2005; Pawlak, Kushner & Ludwig 2004). Glycaemic response is influenced by the kind of energy giving food (amylose vs amylopectin), physical frame-up of starch molecules inside the diet, also the content of fat and protein, and organic acids or their salts in the meal (Wanjek, 2012; Bray, 2012).

Glycaemic index charts frequently include only one number for each product, yet variances can occur owing to variety, ripeness, cooking techniques, processing, and storage time. One clear example is potatoes within the same variety range from moderate to very high GI (Freeman, 2005; Kolata, 2012). Majority of glycaemic index values indicate little effect on blood sugar levels after two hours. After four hours, some individuals with diabetic conditions may have increased sugar levels (Chiu, Milton, Gensler & Taylor, 2007; Sheard, Clark & Brand-Miller, 2005).

Scientific data has revealed that those who ate a low-GI diet for a long time had a decreased risk of getting diseases such as heart disease, type two diabetes, coronary, and age-related mascular degeneration than those who do not eat low-GI foods (Chiu et al., 2007; Sadler, 2011). Raising systemic glycative stress, frequent glycaemic "spikes" or high blood sugar levels in meals may aggravate various disorders (Sheard, Clark, & Brand-Miller, 2005).

Significance of Glycaemic Index

Eating carbohydrate foods is important because it provides the body with the necessary energy required and when care is not taken to balance the nutrient in the body, it has its own consequences which can lead to devastating problems in future. It is therefore very imperative for us to know the glycaemic index of most of the foods that we consume especially the carbohydrates family to help us in our choice and balancing of food for a healthy life.

Foods with a reduced GI score have been demonstrated to be helpful with people with diabetes (Wolever, Vorster, Bjorck, Brand-Miller, Brighenti, Mann, Ramdath, Granfeldt, Holt, Perry, Venter, & Xiaomei 2003) and lower serum lipids in individuals with hypertriglyceridaemia (Wolever et al, 2003; Jenkins et al, 1988). The idea of glycaemic index (GI), firstly expressed by Jenkins et al., is an easy manner of describing starches based on their effect on postprandial glycaemic responses, unadulterated glucose signifies the "standard" and is comparable to a GI of 100. Carbohydrates with little GI values which are less than 55 are metabolized more slowly, resulting in a reduced rise in blood glucose as compared with those with a higher GI (Ajala, English, Pinkney 2013).

Comerford and Pasin (2016) are of the view that though the GI is important with regards to rising glucose levels, consideration must be given to nutritional content as well as food shape as they are also vital in inducing the metabolic state of these products. Notwithstanding the number of signs of the significance of low GI with regards to glucose rising effect Ludwig et. al, (1999) and Holt, et. al., (1997) opines that using GI as the only pointer to

define “healthier choice” foods has numerous limitations. Several variables, including quality of energy giving food, energy density of food, nutritional content, insulinemic response, acid levels, and the methods of cooking food, and varied food shapes has an impact in glucose response (GR).

Sports men and women and those with health problems, such as *diabetes mellitus*, should monitor their blood glucose levels often. Due to the necessity to balance our intake of sugar, diabetics need to consume foods that have low to moderate glycaemic sugar levels to manage their blood glucose levels (Ruth & Diane, 2003). Total carbohydrate is significantly more essential concern for athletes to endurance activity than the GI of the foods/diets chosen. Selecting low-to-moderate GI diets before physical exercise have a competitive advantage, since low GI foods result in increased fat oxidation rates (Stevenson, Williams, Mash, Phillips & Nute 2006).

Increased fat oxidation reduces the need for carbohydrates (CHO), allowing the fuel source to prolong. Furthermore, eating meals with a low to intermediate GI enhanced the supply of nonessential fatty acids during training and reduced reliance on intramuscular lipids during moderate - intensity physical activity (Trenell, Stevenson, Stockmann & Brand-Miller 2008). Relatively high GI meal or foods had little but significant benefit in terms of refilling glucose through restoring muscle glycogen post exercising (Dickinson, Hancock, Petocz, Ceriello & Brand-Miller 2008; Chen, Wong, Wong, Lam, Huang & Siu., 2008).

Determination of Glycaemic Index

The glycaemic index (GI) is a concept that classifies foods according to their glycaemic intensity. In other terms, GI is an assessment of

carbohydrate items' ability to raise blood glucose levels. It's computed by dividing the Incremental Area Under the Curve (iAUC) of a test food having the same quantity of carbohydrates by the incremental area under the blood glucose curve (iAUC) of a reference diet containing equal amount of carbohydrates. The glycaemic index (GI) is a method of ranking energy giving foods based on how fast or slowly they are broken down and raise blood sugar levels over a 2 hour period. The reference food that is usually employed for glycaemic index testing is glucose and white bread.

The extent of glycaemic response test is done at time intervals after a participant has taken a food sample and the blood samples taken for glucose test (Wolever et al., 2003). The area under which the curve increases is used as a denominator for each test item when evaluating GI of various carbohydrate foods. The reference meal is routinely monitored to provide for accuracy, per the accepted technique. Greater impact of GI is determined in the differences in the comparison food's glycaemic responsiveness rather than the variability in the test items (Brouns, Bjorck, Frayn, Gibbs, Lang, Slama, & Wolever 2005). Again, they acclaim that the testing of each participant in a GI determination study should repeat the reference food at least once. The calculation of glycaemic load (GL) is done by taking into consideration the glycaemic index (GI) and multiply it by the energy giving food (carbohydrate) content per serving. From examination of data from a number of independent studies of the same subject, it was clear that low glycaemic index and low glycaemic load diets are both linked to a decreased risk of T2D (Barclay et al. 2008). Buyers' tastes for low-GI items have shifted as a result of this.

Time intervals for Testing for Glycaemic Index

Individual foods must be tested to determine the glycaemic index, following a two-hour fast. Ten (10) or more healthy persons consume energy giving food (carbohydrates) equal to fifty (50) grams from the test meal, with a corresponding monitoring of the blood glucose levels in the period of two hours. The ten individuals eat the same quantity of energy giving food (carbohydrate) equal to fifty (50) grams and their blood glucose response is measured for a period of two hours (Glycaemic Index Foundation 2017).

The iAUC of the test meal is multiplied by 100 and divided by the iAUC of the reference (either glucose or white bread with 50g of accessible carbohydrate) (50). To assist decrease the error around the mean value, it is necessary to test the reference meals two to three times (Augustin, et. al. 2015). According to Health Canada (2013), they recommend collection of test at least two hours, with increasing frequency. They indicated that this can be done in 15-minute intervals and 30 minutes in the first hour in an orderly manner (Augustin, et. al. 2015).

The study conducted a fonio products glycaemic and allowed the participants to consume the products thirty minutes intervals for a continuous period of two hours interval in a day. This was to ensure the products consumed have started metabolizing into the bloodstream before the taking of the test till the two hours' period. The insulin release to a diet ought to be proportionate to the glycaemic effect postprandially. As a result, data on insulin quantities following the ingestion of the test food should be supplied to show that, when compared to the reference diet, the drop in blood sugar concentrations is not followed by abnormally elevated insulin levels (Health

Canada, 2013). To improve glycaemic management, the American Diabetes Association (ADA) recommends postprandial blood glucose self-monitoring in both gestational *diabetes mellitus* and pre-existing diabetes in pregnancy (American Diabetes Association, 2019).

Postprandial glucose and diagnosis of type 2 diabetes

The World Health Organisation has specified a number of diagnostic biomarker cut-offs with regards to type two diabetes. A person with diabetes is characterized as having a two-hour postprandial glucose level of more than 11 mmol/l on two different test occasions, according to the WHO (2012). Again, the World Health Organisation and the Pan American Health Organization considers 7.8–11 mmol/l of 2-hour blood glucose range to be a risk factor for type 2 diabetes (American Diabetes Association, 2019).

Also other associations such as The American Diabetes Association, South Africa Diabetes Association and the Japanese Diabetes Society have all accepted blood glucose levels of more than 8.6 mmol/l within 2-hour as a marker for gestational diabetes.

Glycaemic Index and Health

The FAO/WHO Expert Consultation Group on Carbohydrates in Human Nutrition advocated utilizing the classification of energy giving food (carbohydrates) as mild, medium, or high GI and to make nutritional decisions. A low-GI diet should consist mostly of meals high in non-starch polysaccharides (NSP). Non-starch polysaccharides, which are constituents of slowly digested carbohydrates, are beneficial in preventing sickness, specifically diabetes and other chronic disorders. Meals should not be selected only on the basis of their GI, as certain foods may have a low GI yet a high fat

content. As a result, the overall quantity of carbohydrate, amount and type of fat, fibre, and micronutrient content of foods should all be taken into account when determining whether or not a food is a healthy option (Pawlak, Kushner & Ludwig, 2004).

GI and Diabetes

The occurrence of type two *Diabetes mellitus* (T2DM) has been widespread in recent years. Because T2DM is shortening people's lives and has become a major economic burden on countries throughout the world, it's critical to develop solutions to prevent and control the disease and its consequences. Several research have shown that diets with high glycaemic index increases healthy people risk of T2DM (Stevens et, al., 2002).

Diabetes mellitus is a chronic polygenic disorder which is characterized by decelerated sugar (glucose) uptake. Insulin insufficiency or inefficacy (peripheral insulin resistance) or a reduced insulin/anti-insulin ratio impede glucose metabolism, resulting in persistent hyperglycaemia and glycosuria (abnormal high levels of sugar in urine). Diabetes can cause high blood glucose levels because glucose appears in the bloodstream at a faster pace. Adjusting for factors such as age, Body Mass Index, family history, smoking, physical activity, alcohol consumption, and total energy intake, Sievenpiper, Jenkins, Whitham, and Vuksan (2002) found that the glycaemic index of a diet was connected completely with risk of developing type two diabetes.

However, because foods with low GI are often high in fibre and other nutrients that help to reduce diabetes risk factors like insulin resistance and obesity by improving insulin sensitivity and attempting to control body mass

by reducing fat accumulation, the GI of the food or diet may just be a dietary choice that helps to lower diabetes risk (T2DM). According to this study, diabetics require low to moderate glycaemic meals to control blood glucose levels due to the necessity to regulate blood glucose levels (Sartorelli & Cardoso, 2006).

Inherent or developmental risk factors for T2DM that cannot be changed by food and/or lifestyle modifications include the following, culture, family history, age, and gender. A variety of modifiable risk factors, on the other hand, play a critical role in the development of T2DM. Obesity and being overweight are the major causes of T2DM. People with a BMI of 30-35 had a 39-fold greater chance of having T2DM compared to those with a BMI of 23 (Hermansen et. al., 2006).

Glycaemic Index and Obesity

Studies have shown that the management of weight gain in adulthood can be reduced by eating a low-fat diet, high-protein, and complex CHOs diet. Diabetes and cardiovascular disease are both linked to obesity and insulin resistance. Not engaging in physical activity increases insulin insensitivity in muscle tissue. Obesity is closely linked to hyperinsulinemia, insulin resistance, and type 2 diabetes (Brand-Miller, Hayne, Petocz & Colaguiri, 2002; Lineback, 2005). Low GI meals may aid body mass loss by boosting fat oxidation at the expense of energy giving food (carbohydrates) oxidation and providing satiety.

Glycaemic Index and Hypoglycaemia

Hypoglycemia is characterized by a dangerously low blood glucose level. This happens when someone exercises without eating, if they have

diabetes and inject too much insulin, or if they eat insufficient food. Consuming a little sugar content or meals containing sugar generally improves a person's mood within 10-15 minutes. Jenkins, Wolever, Taylor, Barker, Fielden, and Baldwin, *et al* (1981) said that high glycaemic meals should be avoided since they might cause an insulin oversupply. Hyperinsulinemia produce a dip in blood glucose, which might result in a hypoglycaemic episode. Exercising is crucial in maintaining insulin response and blood glucose levels. Kaufman, Epport, Engilman, and Halvorson (1999) revealed that including lower GI items into diets decreased bouts of nocturnal hypoglycaemia.

Glycaemic Index and Coronary Heart Disease

In the world, Coronary Heart Disease (CHD) is the leading cause of mortality. As a result, nutritional solutions for preventing and managing this condition are hot topics. The study of fonio to know the glycaemic load and index is to add to searching for better solutions for diet issues that can lead to coronary heart diseases. The quantity and quality of energy giving food (carbohydrate) and fat in the food are the most important determinants in the establishment of CHD.

GI affects both postprandial hyperglycemia and postprandial insulinemia, both of which are independent risk factors for CVD. Higher levels of blood triglycerides (TG) and Low Density Lipoproteins (LDL) cholesterol, as well as lower levels of High Density Lipoproteins (HDL) cholesterol, have been related to high GI meals. High plasma LDL cholesterol and low HDL cholesterol levels induce atherosclerosis (Ludwig, 2002).

Glycaemic Index and Atherosclerosis

Atherosclerosis is a disease that mostly damages the arteries. The arteries that provide blood to the heart (coronary arteries), causes coronary heart diseases, myocardial ischemia, and myocardial infarction. It is believed that the risk factors of coronary include when CHO are substituted for saturated fats and also the quality of CHO affect CHD risk. This means that if high-GI carbohydrate diets are replaced with saturated fat, the risk of myocardial infarction (MI) rises. There was a non-significant negative relationship between GI and MI risk when low-GI CHOs were substituted, and there was no quantifiable impact when medium-GI CHOs were removed and replaced (Jakobsen, Dethlefsen, Joensen, Stegger, Tjønneland, Schmidt, Overvad, 2010).

Factors Affecting Glycaemic Response

Food preparation methods can alter the structure and the physicochemical properties of the food (Bahado-Singh et al., 2011) and thus affect its sugar response and subsequently its glycaemic index. A peer group study conducted in Ghana on some local foods such as fufu, kenkey, banku, and tuo-zaafi found that the processes and methods of cooking food affects the glycaemic index of the food item. However, they were not specific as to which unit and the level of effect on the product (Eli-Cophie, Agbenorhevi, & Annan, 2016).

According to studies, there is a lot of diversity in how food (carbohydrate) is digested, metabolized, and absorbed; this variance stems from the carbohydrate's source, content, and processing processes (Omoregie & Osagie, 2008; Granfeldt, Eliasson & Bjorck, 2000). In terms of metabolic

reactions, the structure of a carbohydrate is crucial. The accessibility and interaction of enzymes are influenced by their shape. Factors that influence the structure will also influence the metabolic response (Bjorck et al., 1994). Carbohydrates go through a lot of processing before they are ready for eating. The manner in which a carbohydrate item is processed has a significant impact on its overall qualities (Englyst et al., 2007), this has a substantial impact on the human body's physiological function. When the physiological impact of a carbohydrate is changed, the glycaemic index value is likewise immediately affected. Various variables like age and ripeness, as well as the presence of other anti-nutrients and macronutrients, impact GI levels in addition to processing and cooking techniques (Aston et al., 2008).

According to a study conducted by Hefni, Thomsson, and Witthöft (2021) in which they baked prototype products A, B, and C, they indicated that the bread making procedure or method decreased the content of total and non-resistant starch by up to 20% (p 0.001), while the content of resistant starch increased by up to threefold (p 0.001). The content of total dietary fibre was not affected. Brouns, et al., (2005) discovered certain relevant elements that impact glycaemic reactions and glycaemic index, such as grinding, degree of ripening, and heat treatment, in their study on the factors affecting glycaemic responses of foods and meals. Other factors influencing the glycaemic reactions of foods and meals include the kind of sugars added to the product, the type of raw material utilized, the type of monosaccharide bonds in carbohydrate, and the heating and cooling cycles. Grinding the fonio into flour, combining the composite flour with sugar, and heating the result during baking are some of the aspects that are strongly connected to Brouns, et. al.,

study. These are some of the elements that may have an impact on the fonio product.

Blood Sampling

Glucose quantities in blood can be tested from various parts of the human body. The veins, the arteries, and the capillaries might all be used to collect blood samples. The arteries are located deeper in the body and would have been the ideal place to take blood samples for glucose testing but because extracting arterial blood may pose a risk. Despite this, capillary blood closely resembles arterial blood in composition, making it a superior option to the more intrusive arterial blood (Brouns et al., 2005). To get enough blood from the participants for the study, they were asked to rub their fingers together for some time to make it warm for easy pricking and taking the drops of blood from their fingers for the test.

The rate of venous blood flow is influenced by the ambient temperature. Therefore, it is believed that blood samples collected from either the forearm or other parts (venous blood), may have the tendency of fluctuation in glucose level than capillary blood (Frayn, Whyte, Benson, Earl, & Smith, 1989). It is also believed that glucose concentration levels in the capillaries are greater than venous blood glucose concentrations, and this makes it simpler to notice extremely minor changes in blood sugar concentrations over time. Frayn et al., (1989) are of the view that blood samples taken from fingertip or earlobe is consequently more convenient and better for the measurement of glycaemic response in the estimation of GI (Wolever, Jenkins, Jenkins, & Josse, 1991).

Nature of Study Individuals

A person's insulin response and glucose tolerance impact the GI determination, which is a quantity of after-meal glucose reaction. As a result, there were worries about the physical condition of those taking part in GI investigations. Various researches, have attempted to provide an accurate viewpoint on the appropriate participant physiognomies for GI determination investigations.

Research conducted by Wolever, Nuttall, Lee, Wong, Josse, Csima, and Jenkins (1985) on “Predicting the proportional blood glucose response of varied diets using the white bread glycaemic index" revealed intra-individual variance in white bread glycaemic response. They discovered that normal healthy volunteers had within the individual variance in glycaemic response, but type two diabetes patients had less significant within individual variation than type one diabetes patients. As a result, Brouns et al. (2005) supported the use of apparently healthy individuals in the assessment of GI in order to improve accuracy.

Number of Study Individuals

The participants used for the research was based on the international accepted number for investigating glycaemic index and load of products. Many researchers used varied numbers from six to ten. A combined professional team, from FAO/WHO reported that the test foods should be repetitive in 6 or over to ascertain the GI of a food (FAO/WHO, 1998). However, in a report by Jenkins for the determination of glycaemic index in Hand-stretched Pizza, using the standard ISO method (ISO/FDIS 26642, 2000), ten participants were studied. According to the report, using the t-

distribution and assuming an average CV of within individual variation of iAUC values of 25%, n=10 sample size had 80% power to detect a 33% difference in iAUC with 2 tailed $p<0.05$ (Wolever et al., 2011). Brouns and his colleagues also recommended the use of ten individuals for an appreciable degree of precision (Brouns et al., 2005).

The Glycaemic Index Foundation (2017), opines feeding ten or more healthy people a portion of 50 grams of digestible energy giving food (carbohydrates) and then measuring the effect on their blood glucose levels over the next two hours. This is recommended by international standard method when conducting experiments on glucose levels in individuals.

Sensory Evaluation

The most important aspect of food business growth and development is influencing the senses of the customer on the food items to be sold. This is a major problem for nutritionists and dieticians developing healthier meals, for consumers. This is because our five senses influence our desire to purchase a particular product and not the other and at the end when the overall eating experience based on the senses is good it is termed good food. It is based on the inherent sensory characteristics in a person that is why individuals are utilized as test subjects to evaluate customer reaction as experienced through the five senses (Lawless & Heymann 2010).

Sensory assessment of food, according to Lawless and Heymann (2010), is a scientific process for provoking, calculating, examining, and deducing responses to items as experienced via the senses of sight, smell, touch, taste, and sound. Sensory assessment is a scientific approach for measuring human responses as they are experienced via the five senses.

Sensory assessment is an important aspect of the food creation process since it is the only way to predict how customers will react to food. The sensory test setting should be tightly controlled, and samples should be prepared and presented in a uniform manner so that panellists' perceptions of the food's quality are not influenced (Mihafu, Issa, & Moses, 2020).

Analytical and affective sensory tests are the two types of sensory tests. Affective tests are based on individual acceptance or preferences, whereas analytical tests are based on discernible distinctions. Difference tests (discriminative tests) and descriptive tests are the two types of analytical tests. Affective tests are either acceptance or preference tests, depending on the main aim of the investigation. The purpose of acceptance tests is to assess the degree of likeness, but the goal of preference testing is to determine which item is more liked (Lawless, & Heymann 2010; Brown 2008; Stone & Sidel 2004).

The Affective/Consumer Acceptance Test in sensory evaluation of products is also called the subjective method. This method is very useful for evaluating food satisfactoriness or preference by panel. This method requires a large number of respondents between fifty to one hundred and fifty (50-150) (Meilgaard, Carr, & Carr, 2007). Again, they opined that, the panelists may not be trained but selected based on previous use of product, economic social level and geographical area.

Many different tools are used for assessing how individuals appreciate food items and one of the most widely used sensory evaluation tool is the Hedonic Rating Scale (Lawless, & Heymann, 2010). The sensory evaluation tools come in different levels and they are all used in evaluating food and

some of them are the 9-point Hedonic scale, the 7-point Hedonic scale, and the 5-point Hedonic scale. The 9-point Hedonic scale ranges from "like a lot" to "dislike a lot" In practice, at least five points are recommended (Stone, Bleibaum, & Thomas, 2012). The affective or hedonic sensory evaluation permits a panel of seventy five (75) to one hundred and fifty (150) panellists to assess the level of liking product (Mihafu, Issa, & Moses, 2020).

Effect of Previous Meal

The previous meals taken by the participants, when care is not taken may influence the results of the study in the morning. The study conducted by Wormenor (2015) indicates that foods which are low in GI including dishes such as rice, fermented foods that are rich in fibre eaten during night-time may have effect on glucose tolerance to the next morning breakfast meal. In addition, Wolever, Jenkins, Ocana, Rao, and Collier (1988) opine that foods with low-GI eaten during supper reduce both acute postprandial blood glucose response to the dinner and the glycaemic response to the subsequent breakfast.

Reference Food

Reference food means the food which can be substituted in the diet for the food to which it is compared. The reference food items used in many experimental research of this nature are the white bread, a glucose beverage, or any other meal, provided the relationship between the substitute standard and either white bread or glucose could be established (Food and Agriculture Organization of the United Nations, 2012). Similar studies conducted by other researchers in different locations in connection with glycaemic load, glycaemic index used glucose as their reference food (Kouamé, et. al., 2017;

Eli-Cophie, Agbenorhevi, & Annan, 2016; and Venn, Kataoka, & Mann, 2014).

In the determination of GI, a standardized food which is referred to as the reference food is always used and measured against an experimental or test food. In the determination of GI over the years, several reference diets in different studies have been used. In the GI data base it is established that about ten diverse reference diets have been used in studies and some of them include the following food items: rice, whole barley bread, white bread, potato, glucose wheat chapatti arepa and bread. A study by Foster-Powell, Holt and Brand-Miller (2002) indicated that, the use of glucose and white bread was the most widely reference diet used.

Venn, Kataoka, and Mann (2014) in their study also cited the use of some dishes such as rice and sucrose in Chinese and European groups. They again indicated the use of both glucose beverage and jasmine rice as reference foods; again they mentioned that a glucose beverage and a breakfast cereal was used in their study as a reference food to test younger and older participants.

Cereals Used in the Production of Bread for the Study

Fonio (Acha)

Fonio Origin and Geographic Distribution

Fonio (*Digitaria exilis Stapf*) is recognized as West Africa's oldest indigenous cereal. Ghanaians call it fonio, while the Dogons of Mali call it potolo. Other names for fonio include hungry rice, hungry millet, afio, pini, fundi millet, hungry koos, and others. Fonio is mostly cultivated in West Africa, with Guinea being the primary farmers and consumers of the crop. It is

also cultivated in Ghana's northwestern area and other sections of Sub-Saharan Africa. Despite the fact that many people are unfamiliar with this cereal, it has a lot of potential to aid with food and nutrition security, which is especially important in these period of irregular climate change. The first person to recognize fonio as food was Berber explorer Ibn Battûta in the mid-14th Century in his "Voyage to Sudan" (modern-day Mali). He specified that, in these lands, coscoçoû (couscous) is prepared with foûni (fonio) "which is like mustard seeds", and adds strangely that "rice is harmful to Whites who eat it; fonio is better referenced." In the 19th Century, in his "Voyage to Timbuktu", the French explorer René Caillé mentions fonio, which he describes as "foigné" (a small grass species). This was in April 1827, as he approached the foothills of Fouta-Djalon in the Télimélé region of Guinea. Then, as he progressed further inland, crossing the regions of Kankan, Ouassoulou, Odienné and Tingrela, he frequently reiterated that fonio forms one of the staple foods of the inhabitants, who prepare it as a gruel or in the form of tau (nowadays called "tô") (Cruz & Béavogui, 2016; Jideani 1999).

Closer to our times, in the 1950s, the famous French agronomist Roland Portères wrote a monograph dedicated to it. He noted, recalling the work of Germaine Dieterlen, a French Africanist ethnologist, fonio's importance in the cosmogony of the Dogon people in Mali, where it is regarded as the first and oldest cultivated grain. "It is the image of the original atom whence the universe sprang." This cereal also plays a significant role in other traditional African societies like the Bassari in Senegal, the Coniagui in Guinea and the Bêtamaribê (Otamari people) in northern Benin (Cruz & Béavogui, 2016). In botanical terms, fonio is a glumaceous monocot of the

grasses family (Gramineae or Poaceae) and the genus Digitaria. Crabgrasses, which encompass hundreds of species, sometimes cultivated as fodder plants, but only three or four species are exploited for their grains (Cruz & Béavogui, 2016; Jideani 1999).

Growing Fonio

Fonio after sowing germinate within a week and grows faster and usually is ready to harvest in between two to four months. It grows well in a variety of soil types. Cruz and Béavogui (2016) found that it can grow in soils that are too poor as compared to other cereals (Jideani 1999).

Varieties of Fonio

The white fonio and the black fonio are the two most common kinds of fonio. White fonio is the most frequent kind used in culinary preparation across the world. In the West African countries such as Ghana, fonio is farmed in the Northern Region of Ghana typically in towns such as Chereponi and Saboba within the ethnic groups of Chekosis, Konkombas and Dagombas. It is called "Invoni by the Chekosis, the Konkombas call it "Kapui" and the Dagombas call it "Kabga". They primarily grow white fonio. With regards to the black fonio countries such as Benin, Mali Nigeria, Guinea, Niger, the northern part of Togo and Ghana grow it (Cruz & Béavogui, 2016; Jideani 1993). Below are the pictures of fonio plant, fonio seed in pulp of the two types of fonio.

Figure 3: Fonio Plant

Figure 2: Fonio seed in pulp

Figure 4: White Fonio (*Digitaria iburua*)

Figure 5: Black Fonio (*Digitaria exilis*)

Nutritional and Health Benefits of Fonio (Acha)

Fonio is gaining popularity not in Africa alone but the world due to the health benefits it gives. Fonio is also referred to as the "the hungry rice" and is sometimes pounded and eaten as a side dish or sometimes mixed with little water to create a hot cereal, which is sometimes served in a gourd in some traditional African homes (Adainoo 2021; & Jideani 1993). The health benefits of fonio are of great significance with good nutrition and health importance. Fonio is high in food fibre, it has protein, carbohydrates, fats/oil, vitamins, and many minerals including iron, calcium, magnesium, and potassium, as well as vitamins like folic acid and vitamin B3. Fonio also has a minimal calorie, fat, and salt content (Adainoo 2021; & Jideani 1993).

According to Adainoo (2021) the following benefits can be derived from fonio: Dietary fibre; fonio is a cereal with high fibre content and a low carbohydrate level. White whole fonio has approximately 20% more digestible fibre than black whole fonio. Furthermore, the high fibre content of fonio aids digestion. Fonio carbohydrates are easily digestible and the fibre helps the meal pass through the digestive tract quickly. Furthermore, fonio intake may aid weight loss due to its high fibre and low carbohydrate value. This is not to imply that fonio burns fat; there's no proof of it. With regards to dietary fibre Ballogou et. al., (2013), proximate analysis results indicated 11.3 crude fibre in fonio.

According to Anderson et al. (2009), the high fibre content that is found in fonio may be beneficial for persons who want to lose weight because fibre has no calories but produces a “full” sensation due to its water-absorbing abilities, as well as helping to lessen the risk of several malignancies, particularly colon cancer. This hypothesis is based on the fact that insoluble fibre speeds up the removal of waste from the body.

Proteins are essential nutrients for the body’s growth and development. Amino acids are present in fonio which can be used in building the body unlike many other cereals which lack many of these amino acids. These amino acids in fonio are of greater quality than those found in rice, wheat, maize, and other grains. The use of legumes with fonio would raise the diet's protein content to that of an egg, if not higher. This is possible because legumes are high in lysine, which fonio lacks.

Furthermore, fonio is high in methionine and cysteine (Sulphur-containing amino acids), all of which are proven to be beneficial to skin, hair, and nail health. Methionine has an anti-aging impact on the skin and slows down the aging process. Methionine strengthens the nails and prevents hair loss. Cysteine aids wound healing and maintains skin health. Cysteine appears to have a function in detoxification, according to research (Jideani 1999). Gluten proteins are not present in Fonio. As a result, it is a fine cereal to eat if you have celiac disease (an autoimmune disease that causes the immune system to attack gluten as if it is a bacterium and could lead your body digesting itself).

Fonio is high in zinc, a mineral that is necessary for children's optimal growth and development. Even when boiling, fonio has higher zinc content than maize (Jideani, 1999). Folic acid is abundant in fonio, making it a great source of vitamins. Folic acid is a crucial vitamin that the body needs for brain development. It is a necessary vitamin for expectant mothers. Folic acid protects unborn infants from neural tube problems. Folic acid also aids in the development of mental wellness and the prevention of depression. Vitamins B1, B2, B3, and B6 are found in fonio and are necessary for regular bodily processes. Fonio has similar carbohydrate, fat, protein that make up a cereal. It has the chance of producing and adding energy to the body. It can produce steady energy throughout the day.

For diabetes patients, it is great food for diabetic patients because it has a lower amount of glycaemic percentage. Since fonio is absorbed gradually it can reduce the effects of blood sugar. Fonio is full of insulin qualities that help in managing blood sugar levels in the body. Fonio is low in GI and a great

benefit to diabetic people. Also according to Jideani (1999), traditionally, fonio has been a good diet for diabetics and women who have just given birth. Again, Jideani (1990) is of the view that fonio is one of the most nutritious and delicious African grains.

Structure of (Fonio) Acha Grain

Fonio (Acha) grains are rather tiny, has a weight between 0.6 and 0.7 grams per 1,000 grains. The husk (glume), an exterior protective covering that constitutes up to 24 percent of the total weight of the grain and measures between 1.6 and 1.8 mm long and around 0.8 mm broad, surrounds the grain. The pericarp and a layer of aleurone cells, which are the initial endosperm tissues, make up the exterior structure of caryopsis. The aleurone layer and the starchy endosperm are found in the endosperm of Acha grains. Below is a picture of the fonio grain:

Figure 6: Fonio grain

The endosperm, which measures between 2 and 13 meters and is a major reserve tissue in Fonio (Acha) grains, is the bulkiest component, as it is in most cereals (Chinwe, Ojukwu, and Jackson 2015). Fonio (Acha) grain is utilized in a range of cuisines for both home and special events; as a special food (delicacy): Acha may be included into a number of meals, including

porridge and couscous. It can be prepared in a variety of ways with fish, meat, lentils, or vegetables. It is typically grown by women in West Africa and eaten as a special delicacy at weddings and other occasions (Chinwe, Ojukwu & Jackson 2015).

Fonio is used to make bread and other pastries, and it is a rich source of protein. Grains might be beneficial to cookies, crackers, and popcorn. The gluten-free flours acha and iburu may be used to manufacture a wide range of biscuits and snacks (Ayo and Nkama, 2003). Whole Acha grains are used to prepare non-traditional culinary products such as a weaning food, when used as weaning food it is recommended by physicians for diabetic patients due to its low bulk density (Jideani, 1990).

Fonio (Acha) is also used for preparing drinks: the grain is used in the production of traditional beer. The Acha grains may be ground into flour and used to prepare traditional beverages. The Lambas of northern Togo make a renowned beer (tchapalo) from white fonio. As a Primary Cereal: It may be eaten as a breakfast cereal. It is one of the most essential grains for morning cereal in several regions of Ghana, Sudan, and Ethiopia. Fonio is a light, easy-to-digest cereal that can be used in a wide range of cereal-based dishes, making it a good choice for gluten-free, health-conscious, or baby-food products (Chinwe, Ojukwu & Jackson 2015).

The grains are used as animal feed for animals reared in the house. The grains are readily digested and hence the following animals can eat it without any problem; cattle, sheep, goats, donkeys, and other ruminant animals. Because of its high methionine concentration, it is a prized feed for monogastric animals, particularly pigs and poultry (Adoukonou-Sagbadja,

2010). Animals are also fed, the straw and chaff. People in Nigeria's Hausa area and the Benin Republic make couscous (cuisine) (wusu-wusu) consisting of both varieties of fonio. The Akposso and Akebou tribes of southern Togo make a meal called fonio with beans that is only eaten on rare occasions. It's used to make porridge, rice, and for baking bread in Ghana. The gluten-free cereal is also high in protein. The husk is used as a cooking fuel in the home. For building houses or walls, the straw is often shredded and mixed with clay. It's also used to make ash for potash or to produce heat for cooking.

Wheat

Wheat (*Triticum aestivum*) is the most essential and strategic cereal crop. Wheat is used by most people in the world and nearly two billion people's in the world use it as staple (36% of the world population) (Braun, Atlin, & Payne 2010). Wheat is the most extensively planted crop in temperate areas, and it is used to feed both humans and livestock. Wheat is classified as a cereal grain. Its adaptability and high yield potential, as well as the gluten protein component, which offers the viscoelastic properties that, allow dough to be turned into bread, pasta, noodles, and other meals, have contributed to its success. Wheat has contributed significantly to human civilisation and enhanced global and regional food security. On a worldwide scale, it offers roughly 19% of the calories and 21% of the protein requirements of daily human requirements (Braun, Atlin, & Payne 2010).

Wheat is cultivated in thousands of types across the world today, with the majority requiring fertile soil and a temperate environment. The Midwestern part of United States of America and the southern prairie area of Canada, among other places in North America, provide optimal growing

conditions for high-quality wheat. China, India, France, and Russia are among the other significant wheat producers. Wheat is more widely used in baked products than any other cereal grain. Wheat is popular because of the gluten that it develops when wheat is combined with water. Raised bread is difficult to fathom without gluten.

Wheat is also popular due to its mild, nutty taste. Wheat kernels are the seeds of the wheat plant, and they are processed into flour. The kernels can be regarded as a form of grass seed since cereal grains are members of the grass family. In fact, as a wheat field begins to develop, it resembles lawn grass. The endosperm, germ, and bran are the three primary components of wheat kernels. To get white flour from wheat it is the endosperm which is milled, while whole wheat flour comprises all three components of the kernel. Because it contains the complete wheat kernel, whole wheat flour is called a whole grain product. The bulk of the kernel is made up of endosperm. It is the whitest portion, mainly because it is largely made up of starch (usually 70–75%). The starch is encased in protein pieces (Braun, Atlin, & Payne 2010).

Whole wheat Flour

Graham flour is a kind of whole wheat flour. This type of flour contains all the three sections of the kernel—bran, germ, and endosperm—it is a whole grain product. Whole wheat flour is available in a variety of granulations, ranging from coarse to fine. The bran and germ are heavy in oil, and the oil can react with oxygen and oxidizes to rancid off flavours hence it has a shorter shelf life than white flour. We have soft red wheat flour and hard red wheat flour. Mostly it is the hard red wheat flour that is used in producing flours on regular basis. The hard red wheat flour has a high protein level

between 11–14 percent or more. However, its gluten content is not much as compared to bread flour. This is due to a number of factors. Whole wheat flour has sharp bran particles that actually slash through gluten strands as they develop. Furthermore, the bran and germ, which do not produce gluten, provide a significant amount of protein in whole wheat flour (Salunkhe & Despande 2001).

Finally, gluten formation is hampered by components found in wheat germ. This implies that whole wheat flour-based yeast-raised doughs and baked products will differ from white flour-based doughs and baked goods. Considering the cohesiveness, whole wheat bread doughs are less cohesive and 100% whole wheat bread is denser and durable than bread doughs flour, and coarser than white bread. It also has a deeper colour and a stronger flavour. Bakers frequently combine roughly one-quarter to one-half part whole wheat flour to one part bread or high-gluten flour to please clients who are unfamiliar with the strong flavour of whole wheat flour bread (Salunkhe & Despande 2001).

Nutritional value of wheat flour

Glutenin and gliadin are two major gluten-forming proteins found in the endosperm of wheat kernels. Glutenin and gliadin produce strands of gluten when flour is combined with water, which are vital in the construction of baked foods. Many cereals are used in baking however, the wheat cereal grain is the most common cereal used in baking bread and this has enough glutenin and gliadin to produce high-quality gluten for bread production. The wheat germ is the plant's embryo. Protein, lipids, B vitamins, vitamin E, and minerals are all abundant in wheat germ. As the germ sprouts, these nutrients

are critical. While germ protein does not produce gluten, it is a high-quality food in terms of nutrients (Braun, Atlin, & Payne 2010).

The bran is the wheat kernel's protective outer layer. Although white wheat, which has a light bran colour, is sometimes available, it is generally darker in colour than the endosperm. In any instance, the bran contains a lot of nutritional fibre. In reality, bran contains roughly 42% dietary fibre. It also has a high protein, lipid, B vitamin, and mineral content (Braun, Atlin, & Payne 2010). The cross section of wheat grain picture presented below:

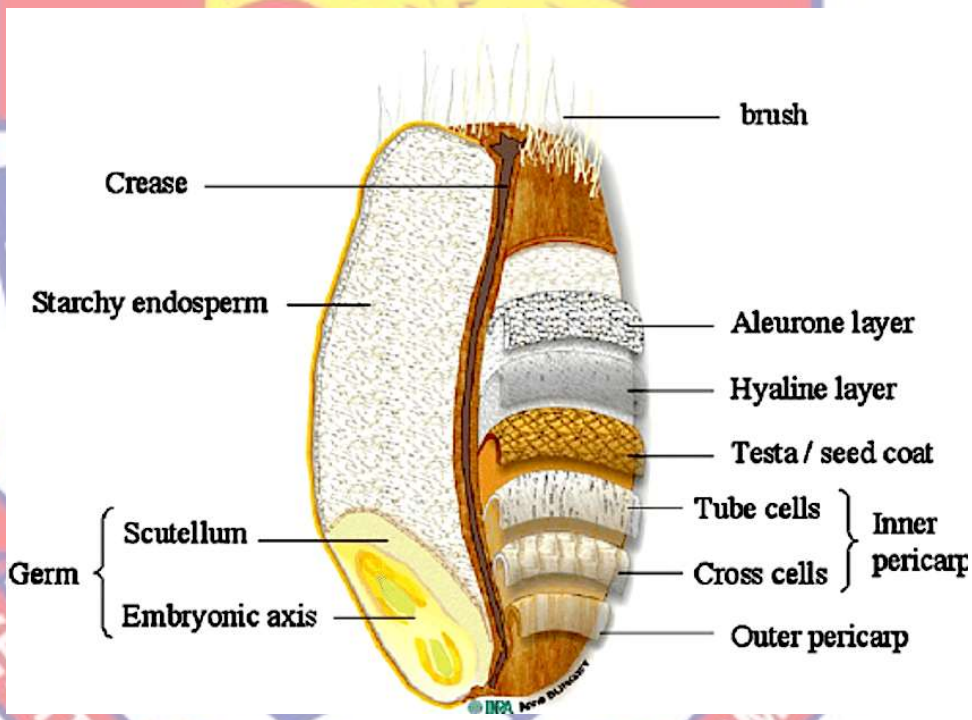

Figure 7: Cross section of wheat grain

Polished Wheat bread flour

According to Sivasankar (2002), refined wheat is wheat which through milled process discards the seeds and chaff. Although this wheat is more durable, the grinding process makes many of the nutrients and fibres in the wheat decrease. The products which are made from refined wheat are white rice, wheat flour, white bread, and various breads.

White flour is made from the endosperm, which is the whitest component of the kernel and is processed into white flour. Polished wheat flour comprises predominantly starch in the crushed endosperm, although additional natural components in white flour alter its qualities. Starch and protein are the two most important components of polished wheat flour. Majority of the flour (68–76%) is made up of starch. Polished wheat flour contains little grains or granules of starch. During the milling process or when flour is kept under moist circumstances, some starch granules are destroyed. When this happens, amylase breaks down a little quantity of starch into sugars that yeast can easily ferment.

The quantity of sugar certainly contained in flour is <0.5% which is hardly sufficient for optimal yeast fermentation. Most yeast dough formulations incorporate sugar or a source of amylase. Protein chunks (6–18%) function as a cement to keep starch granules in place in the endosperm. Glutenin and gliadin, the gluten-forming proteins, account for approximately 80% of the proteins in endosperm. Enzymes including amylase, protease, and lipase are among the other proteins included in polished wheat flour (Shewry, 2009; & Sivasankar, 2002).

The moisture content of flour is usually between 11 and 14 percent. Flour is prone to fungal and mold development, flavour alterations, enzyme activity, and insect infestation when moisture level exceeds 14%. Flour must be stored correctly, covered, and in a cold, dry location for these reasons. Gums (2–3%), particularly pentosans, are another kind of carbohydrate found in flour (Shewry, 2009). Pentosan gums are present in white flour in such little amounts, it's easy to miss their relevance. They do, however, play a vital role

in flour. A tiny amount of pentosan gums contributes significantly to batters and doughs consistency since they absorb 10–15 times their weight in water. Small levels of gluten appear to interact with wheat flour, increasing its strength and structure (Shewry, 2009). A good source of obtaining soluble dietary fibre can be found in pentosan gums, according to Shewry (2009). Although white flour contains just a little quantity of lipids (1–1.5%), oil, and emulsifiers, they are required for optimal gluten formation. Wheat oil, on the other hand, oxidizes quickly and goes rancid, decreasing the shelf life of flour. While stale flour is neither harmful or unhealthy, it does have a discrete false aroma that can be avoided by properly keeping the flour well and utilizing it as soon as possible.

Inorganic particles and mineral salts make up ash, which is found naturally in wheat kernels. Iron, copper, potassium, sodium, and zinc are all present. Ash stimulates yeast fermentation by delivering minerals to yeast, in addition to providing required minerals to the diet. The flour takes on the colour of ash, which is gray. Polished wheat flour, on the other hand, has a low ash content (less than 0.6 percent) when milled properly, since ash is concentrated in the bran layer, which is separated from the endosperm when white flour is milled (Shewry, 2009).

CHAPTER THREE

METHODOLOGY

The aim of this study was to develop fonio composite flour and process the flour into composite bread; determine the glycaemic load and glycaemic index of the bread and if low recommend it for diabetic patients. The chapter discusses the research procedure used. Specifically, the scope of this chapter covered the study design, study area, study samples, screening of participants, inclusion and exclusion criteria for participants and preparation of test samples. The chapter also discusses proximate determination, ethical consideration and data collection, data processing and analysis

Research Design

The true experimental research design was used for the study. According to Shadish, Cook, and Campbell (2001) an experiment is "a study in which an intervention is deliberately introduced to observe its effects" (p. 12). The true experiment was conducted as follows; first by the use of laboratory experiment for proximate analysis, secondly using discriminating testing to sensorily evaluate the formulated breads and thirdly testing for blood glucose in the participants. According to Yang & Lee (2019) sensory descriptive analysis includes trained panels discriminating and describing both qualitative and quantitative sensory aspects of items.

The 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 for determining their effect on behaviour. This research design was deemed ideal for the study because fonio cereal flour was used to produce three different composite breads. The

glycaemic load, glycaemic index and the nutritional components in the bread or baked products were determined.

The composite flour was prepared by the researcher and used in a well reputable bakery in the Tamale Metropolis to produce the three different types of bread for testing. The test bread was measured against a reference food (glucose) to find the glycaemic index. The test foods and reference food were given to 10 healthy humans and examined for their blood sugar (glycaemic load). Additionally, the test foods and the reference food was given to the same group to enable easy comparison of the changes that resulted from eating the food. The test must be carried out in living humans or in vivo owing to certain factors that hamper or impact the digestion and assimilation of food in the human body. The testing was carried out based on the standardized method required.

The Study Area

The Tamale Metropolitan Assembly was founded in 2004 by the legislative instrument (LI 2068) that raised the then Assembly which was Municipal to the status of Metropolis. In the country currently there are six Metropolitan Assemblies and it is one of them. The northern part of Ghana comprising the Upper East, Upper West, North East, Savannah, and Northern Regions have only one Metropolis, which is the Tamale Metropolitan Assembly. Tamale is the metropolitan capital city as well as the Northern Region's regional capital.

The Metropolis has a total estimated land area of 646.90180sqkm, accounting for around 0.9 percent of the northern region's total land area (Ghana Statistical Service, 2010). The Metropolis is located between the latitudes of 90 16 and 90 34 North and the longitudes of 00 36 and 00 57 West. The Metropolis is made up of 115 different settlements. The majority of rural settlements have extensive swaths of land suitable for agronomic activity, and they serve as the metropolis' food basket. The population of the city is estimated to be at 233,252. (Ghana Statistical Service, 2010). This equates to 9.4 percent of the northern region's overall population.

Figure 8: Map of Northern Region

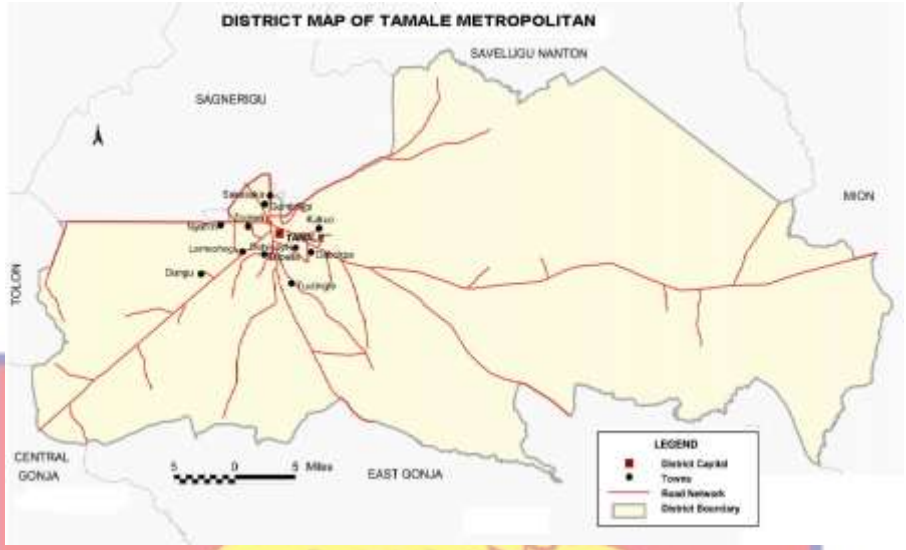

Figure 9: Map of Tamale Metropolis

Population

The study population was made up of individuals from the Tamale Metropolitan area where the study was conducted. According to Tannor, (2014), the study population is the group that the research seeks out or aims to examine in order to solve the problem. Again, he added that a population does not necessarily refer to people; the population may be finite or infinite.

Sample and Sampling Procedure

The study sample size used was one hundred and three (103) comprising ten (10) non-diabetic patients who were purposively selected for postprandial testing to determine the glycaemic load of the composite bread consumed whereas ninety-three (93) participants were selected for sensory evaluation of the fonio composite bread. Since it was a new product, it is recommended that 75 to 150 people could be used for the sensory evaluation (Mihafu, Issa, % Moses, 2020). The participants were trained about the sensory characteristics they were going to evaluate to enable them execute the test and report their experience on the screening form appropriately.

At the beginning of the study 110 participants were expected, however 7 participants did not complete the study due to reasons best known to them. Hence calculating the retention rate for the study was 94%. This means that majority of the expected participants took part in the study and few representing 6% were not able to adhere to the study restrictions and hence they were exempted from the study.

The ten (10) non-diabetic patients were used in accordance with the international standard method, which states that the glycaemic index (GI) value of a diet is determined by feeding a portion of 50 grams of digestible (available) carbohydrate to ten or more healthy people. Then measuring the glucose effect over the following two hours [(Eli-Cophie, Agbenorhevi, & Annan, 2016; Morgan, Shelagh, Hampton, & Frost, 2011)]. To satisfy the international standard the ten non-diabetic patients' health status were confirmed by a practising nurse at Tamale Teaching Hospital to ensure that they were healthy before taking part in the study. The 10 people were asked to fast for a period of 12 hours prior to visiting the hospital and a professional nurse took their blood samples and measured the blood glucose level with the aid of a glucometer. The ninety-three (93) participants were also used for the affective or hedonic sensory evaluation because; this method permits a panel of seventy five (75) to one hundred and fifty (150) panellists to assess the level of liking a product (Mihafu, Issa, % Moses, 2020).

The purposive sampling technique was used because it is ideal for selecting the participants who are non-diabetic patients. Purposive sampling, according to Oliver (2006), is a type of non-probability sampling in which the researcher makes decisions about who should be included in the sample based

on a variety of criteria such as respondents' specialist knowledge of the research issue, or capacity and willingness to participate in the study. It is worth noting that a thoroughly screened panellist, effective training, as well as adequate statistical interpretation and controls, when properly implemented, may give several benefits and serve as a foundation for making informed judgments about food products (Drake, 2007).

The sensory evaluation of the items was done with the use of a five-point hedonic scale with the following indications "liked a lot" to "disliked a lot" (Sample of the sensory evaluation form can be found in appendix 'D'). The determination of how much people like a particular food by Hedonic Rating Scale is one of the most extensively used sensory evaluation tool (Lawless, & Heymann, 2010). The 9-point Hedonic scale, 7-point Hedonic scale, and 5-point Hedonic scale are all used in practice. The 9-point Hedonic scale ranges from "like a lot" to "dislike a lot". At least five points are recommended in practice (Stone, Bleibaum, & Thomas, 2012). However, for the sake of this study, the five-point hedonic scale was used.

Sampling Fonio (Acha)

The white fonio was used because of its wide cultivation and usage in the areas of production such as Saboba, Chereponi and Yendi areas in Ghana. Fonio was bought from the producers at Chereponi to ensure that the right cereal is obtained and also to avoid any tendency of purchasing adulterated fonio.

Screening of Participants

The participants used for the study were dully screened to determine their health status before taking part in the glycaemic load test. The researcher

asked participants about their current health status with regards to treatment of gastrointestinal disorders and *Diabetes mellitus* in recent times. Participants willing to take part in the study were used to ensure their commitment to the guidelines towards the success of the experiment at the various stages of collecting data from them. Fasting blood sugar levels were used to establish the subjects' diabetes status.

In determining diabetic conditions of individuals' their blood glucose level which is less than 140 mg/dL (7.8 mmol/L) is considered normal, whereas a blood glucose level of more than 200 mg/dL (11.1 mmol/L) after two hours is considered diabetic. Prediabetes is defined as a blood sugar level of 140 to 199 mg/dL (7.8 to 11.0 mmol/L). Participants screening was done with the help of a registered professional nurse in Tamale Teaching Hospital. The participants fasting blood sugar levels were tested and they were within 4.9 - 6.4 mmol/L. This demonstrates that none of the test subjects was prediabetes or was diabetic. The participants were asked whether they were taking medications for gastrointestinal disorders or *Diabetes mellitus* which might have a bearing on the test results.

Participants anthropometric profiles of body weight were taken in kilogramme (kg) and height (m), including age and gender. The Body Mass Index is a simple calculation using a person's height and weight. The Body Mass Index (BMI) was calculated using the formula BMI = weight/height × height or BMI=kg/m^2 where kg is a person's weight in kilograms and m^2 is the height in meters squared. A BMI of 25.0 or more is overweight, while the healthy range is 18.5 to 24.9. The BMI was calculated to exclude participants' who were obese. The BMI of the participants ranged between 18.5 – 22.2

which meant that they were normal and could take part in the study (Glycaemic Index Foundation, 2017).

Participants' previous night meal eaten and the time they ate their previous last meals were taken and recorded. This was done purposively to determine what meals were taken and also to ensure that complete metabolism had taken place before the test was carried out. This was done in Tamale Teaching Hospital with the assistance of a medical practitioner.

Participants who were pregnant, nursing, or suspected of having food allergies were also evaluated. The study excluded participants who had a history of gastrointestinal problems, *diabetes mellitus* metabolic condition, or any cardiovascular disease (CVD), pregnancy, or breastfeeding. To avoid difficulties from ingesting the composite food items from the fonio, participants with a history of illness were excluded from the study. Sample of the screening form is presented as appendix 'E'.

Inclusion Criteria

1. The study considered participants who were healthy and did not have any ailment recently and in the past. Also, using the BMI results of the participants who are not morbidly obese were permitted to take part in the study
2. The study considered participants who were within the ages of 18 to 60 because they were within the working class range and were matured enough to take decisions on their own and may not have needed parental consent before taking part in the study. The aged were not included because they could have been suffering from some aging ailments.

3. Consideration was given to both genders to take part in the study.
4. The study participants who would have had to travel far distances to the testing centre were excluded to avoid delays in coming or absenteeism.

Exclusion Criteria

Due to the nature of the study which required strict adherence to guidelines, participants willing to take part in the study were taken through orientation to enable them know what exactly was to be done. They were reminded of the necessity of following the research's instructions. Before arriving at the test site, participants were told not to eat anything late in the night nor in the morning. Morgan, Shelagh, Hampton, and Frost (2011) hypothesize that eating a high evening energy giving food will result in an increase in postprandial glucose when compared to the same in the morning, and that the postulated high glycaemic excursions in the evening could be mitigated by lowering the meal's glycaemic index (GI).

Participants were asked to refrain from smoking or drinking during the research period. They were also told not to engage in any vigorous exercise in the days leading up to the tests. Although exercise is good for regulating blood glucose levels, according to Marni, Pam, Glen Ronald, Sonja, and Michael (2013), an individual's blood glucose levels often rises during, and especially after, brief, very intense exercise. This is due to increases in glucose production that outnumber increases in glucose disposal. Acute physical activity can also raise muscle glucose (Malkova, Evans, Frayn, Humphreys, Jones, & Hardman 2000).

Participants who were exempted from the study was based on the following:

1. Participants who were not healthy, morbidly obese with or without diabetes.
2. Participants who did not know fonio and its products and could not take it and were not willing to take part in the study.
3. Participants' ingestion experience of cereals or specifically fonio was sought and those allergic to it.
4. The aged and also participants within 18 and 60 years with history of cardiovascular diseases, hepatitis or any known metabolic disorder.
5. Participants or individuals on medications such as cough mixtures that could influence the results.
6. All incomplete questionnaires were excluded and where the first (i.e. fasting) blood-glucose concentration of any participant was above normal he/she was also excluded.
7. Participants who were engaged in intensive physical exercise were exempted.

Data Collection Instruments

Kjeldahl apparatus: this was used to determine protein during the proximate analysis of the composites.

Soxhlet apparatus: this was used to determine the amount of fats/oil during the proximate analysis of the composites.

Glucometer: this device was used to measure the amount of sugar (glucose) in the blood of the participants for the study.

Crucibles: this was a ceramic container used to heat the composite products in an oven to determine the ash and moisture content.

Fibretec equipment: this was used to determine crude fibre during proximate analysis in the laboratory.

Desiccator: the desiccator was used for the final cooling and drying of the bread composite that was heated to determine the moisture content in it.

Mixing bowl: the mixing bowl was used to mix the composite flours for baking in the bakery.

Weighing scale: the weighing scale was used to measure the weight of the composite breads in grams for each participant during the glucose testing.

How glucometer was used

The glucometer and the strips were purchased from a registered pharmaceutical shop and tested by a registered nurse in the diabetic clinic in Tamale Teaching Hospital to ensure standardized device used and accuracy in reading of results when blood samples were taken. No blood or control solution was applied to the test strip before it was inserted into the glucometer device. The test strip container was tightly closed to protect the strips from been affected by moisture. Unused test strips were stored in the original container with the cap closed. The date on the test strips container was checked before used to ensure that the test strips were not expired. The test strips and the glucometer were stored in a cool dry place.

Prior to piercing participants the nurse used warm soapy water to wash her hands and dried them thoroughly. The test strip has two ends and one edge was metallic and the other end edge was designed yellow. She then inserted the metallic end of the test strip into the glucometer and then turned it on. A flashing drop symbol appeared before the piercing was performed. The finger where the lancing device was used was squeezed gently to help blood flow for

the testing. The yellow edge of the test strip was used to touch the blood drop. When a flashing hourglass symbol appeared, the finger was removed from the test strip. The result appeared with an arrow that showed the amount of the glucose in the blood. Clotted blood drop could not be used because the device read it as error. The glucometer target ranges are colour-coded; a test result with an arrow pointing to blue indicates that the test result was above the target range, green indicates that the test result was within the target range, and red indicates that the test result was below the target range. If the test result was outside this range, the results will flash. This implies that the flashing occurs just when your blood glucose level is over or below the preset range.

Data collection procedure

Collection of data for the study was done in three different processes. The first was collected using a self-developed hedonic sensory evaluation form, the second one was collected using a self-developed screening form in the hospital for the glycaemic test and the third one was the laboratory test results on the various fonio composite breads obtained from the University of Cape Coast School of Agriculture Laboratory. The sensory test was repeated three times with different composite breads using ninety-three participants within 2 hours 30 minutes in a day.

The participants were grouped at Dabokpa Technical Senior High School Catering Department and were administered with the developed fonio samples. The participants were taken into the food laboratory where each one was put in a booth to ensure independent evaluation of the samples. The laboratory had good lighting, well ventilated, clean work surfaces, enough

space for erecting stands or booths for participants as well as good running water. The fonio product code named F70 was assessed first followed by F50 and then F30 was assessed third. This procedure was used to ensure that participants do not come the following day with a different taste experience with other foods or change in weather condition which may interfere with the sensory evaluation characteristics of the participants being used.

A screening form for evaluating the fonio breads was developed, comprised of three sections. The first section consisted of bio data, the second section was on anthropometric profiles, prior health history, last meals consumed the night before and the time they were eaten, and lastly, alcohol consumption of participants. The third section was made up of a table used to record time of consumption of fonio composite bread, the sugar concentration in mmol/L every thirty minutes (30mins) interval after consumption of fonio composite bread within a period of two hours (2hrs). This was carried out for three days on each participant.

A questionnaire was prepared and it was made up of open and closed ended questions to give participants enough opportunity to provide more information about the study. Prior to administering the questionnaires each was given a unique code to use for the testing of the different composite fonio bread. The screening questionnaires were collected each day after the activity and given back to same participants on the day of continuation of testing the samples until completion. The participants were identified by their unique codes while tasting or evaluating the fonio composite bread samples.

Proximate Analysis of Composite Fonio Bread

The fonio composite samples were packed in a zip lock bag, kept in an Eskimo Ice Chest container and sent to the University of Cape Coast School of Agriculture Laboratory for the determination of proximate composition of the three different fonio products formulated. The following analysis were carried out; determination of carbohydrate, moisture, ash, fibre, fat, and protein using AOAC methods (AOAC, 2008).

Determination of Moisture Content (AOAC 2008)

Porcelain crucibles were dried in an oven and then weighed. About 10-12g of the fonio composite bread was placed in the oven-dried crucible and weighed. To achieve even heat dispersion, the crucible containing the sample was distributed around the oven's base. After that, it was maintained in an oven temperature of 105^{o}c for two hours in a day. The crucible containing the sample was cooled in a desiccator for an hour, and weighed. The % water loss by the sample was then used to compute the moisture content. The % moisture content in the fonio composites flour was calculated using the formula below.

Moisture content (%) = $\frac{W2-W3(g)}{W2-W1\ (g)}\ x\ 100$ 1

Where,

W1 = weight of crucible

W2 = weight of crucible and sample of fonio flour composites before drying

W3 = weight of crucible and sample of fonio flour composites after drying.

Source: AOAC (2008)

Determination of Ash Content (AOAC 2008)

For ash content determination, an empty crucible was weighed and 10g of the fonio flour composite was placed in the weighed crucible and it was

then placed in an oven and heated gently for about sixty minutes at 105°c. It was then transferred into a furnace and heated at a temperature of 550°c until all the carbon particles were burnt. This was done overnight. The crucible containing the ash was then cooled in a desiccator and weighed. The amount of ash in the sample was then determined as a percentage of the original composite flours. The following formula was used to compute the percentage:

$$\text{Ash content (\%)} = \frac{Weight\ of\ ash}{initial\ weight\ of\ fonio\ composite}\ x\ 100 \quad \ldots\ldots\ldots\ldots 2$$

Source: AOAC (2008)

Determination of Protein (AOAC 2008)

For protein determination, the amount of protein in food is computed using the nitrogen content of the meal. Protein was determined using the Kjeldahl method involving digestion, neutralization or distillation, and titration. About 0.2g of the fonio composite product was measured in a 100ml Kjeldahl flask and digested at 360°c for two hours after 4.4ml of digestion reagent had been added. A blank was prepared; without the sample. The digests were placed into a 50ml volumetric flasks and brought up to volume.

The extraction process was done using distillation apparatus. Distilled water was used to flush the distillation apparatus for about fifteen to twenty (15-20) minutes; After completing the flushing of the equipment, five (5) milliliters of boric acid indicator solution was put into a 100ml conical flask and positioned underneath the distillation apparatus's condenser, with the condenser's tip entirely fixed in the solution of boric acid. A small quantity of the sample digest was placed in the chamber through the trap funnel. To begin distilling, 10ml of alkali mixture was added, and about 50ml of the distillate collected.

The distillated solution was titrated against 0.1N HCl until the colour of the solution became green and the indicator returned to its original colour (wine red). The sample titre value was subtracted from the digestion blanks in the same way. Hence in calculating the nitrogen and protein content, the titre values obtained were used. The conversion factor of 6.25 was used to multiply the nitrogen content using the formula below:

$$\text{Total \% Nitrogen (\%N)} = \frac{(\text{Sample titre value} - \text{Blank titre value}) \text{ X } 0.1 \text{ x} 0.01401 \text{ x } 100}{\textit{sample weight X } 10} \quad \ldots 3$$

% Protein = %N x 6.25

Source: AOAC (2008)

Determination of Fat/Oil (AOAC 2008)

The lipid content was determined using the Soxhlet extraction method. About 10-12g of milled fonio composite samples were weighted into a thimble and placed in a Soxhlet extractor with a capacity of 50ml was cleaned, dry and kept in a 250ml round bottom flask and a milled fonio composites was measured and then transferred to the Soxhlet extractor. A 150ml of petroleum spirit was introduced to the flask or the Soxhlet extractor. The sample was extracted for 6 with the help of a heating mantle. The flask was removed and heated in an oven for 2 hours at 60°C. The empty flask had been weighed before the extraction and weighed after cooling in a desiccator. The fat/oil proportion was determined as follows:

Calculation

$$\text{Crude Fat (\%)} = \frac{\text{W (g)} \times 100}{\text{Sample (g)}} \quad \ldots\ldots\ldots\ldots 4$$

Where W is Weight of Oil extracted

Source: AOAC (2008)

Determination of Crude Fibre (AOAC 2008)

For determination of the crude fibre content 12.5g of NaoH was dissolved in a 700ml of distilled water in a 1000ml volumetric flask and 12.5ml concentrated Sulphuric acid added and made up to volume. An amount of 1g of fonio composite sample was measured and placed in a boiling flask. The concentrated Sulphuric acid solution was then heated for 30 minutes and filtered in a sintered glass container after the boiling. The deposit was poured into the boiling flask, along with 100ml of the 1.25% NaoH solution, which was boiled for 30 minutes again. After the boiling, the residue was filtered and washed with boiling water and methanol. The container was weighed after being dried in an oven at 105°C for 12 hours. The following day the container was kept in a furnace at 500°C for four hours and later progressively cooled in a desiccator at room temperature and weighed.

Calculation

$$\text{Crude fibre (\%)} = \frac{\text{weight loss through ashing}}{\text{Sample weight}} \times 100 \quad \ldots\ldots\ldots\ldots 5$$

Source: AOAC (2008)

Determination of Carbohydrate (AOAC 2008)

For the determination of soluble carbohydrate content a glucose stock solution was dried in a vacuum oven at 70◦cover P_2O_5. The substance obtained was then dissolved in water and diluted to 1liter. Standardized procedure was followed hence a stock solution of 0 – 20ml was prepared and this was pipetted into 50ml flasks such that 2ml of each standard gave a range from 0-0.20mg glucose and this was then diluted to capacity.

For the preparation procedure a concentration of H_2SO_4 of quantity 760ml was added to water quantity of 330ml in a boiling flask while mixing.

A magnetic stirrer was used to add and stir to dissolve 1g anthrone, 1g thiourea. After dissolving the mixture was poured into a dark bottle and allowed for 2 hours before used. The remaining was stored at + 1°C.

Procedure Extraction

A 50ml conical flask was weighted and 50mg of milled fonio composite sample was added to 30ml of distilled water. A glass bubble was inserted in the neck to simmer slowly on a hot plate for 2 hours. A distilled water of quantity 30ml was used to top up periodically and after sometime it was removed from the hot plat and allowed to cool slightly and later filtered through a No.44 Whatman filter paper into a 50ml volumetric flask. The extract was prepared shortly before a colour developed. A blank solution was prepared using the same procedure.

Colour Development

Two milliliters (2ml) of the standard solutions together with 2 milliliters (2ml) of extract and water blank was pipetted into a set of hot tubes. Both standards and samples were given the same treatment. Anthrone solution of 10ml was added quickly to the mixture and the tubes submerged in flowing tap water. The tubes were then placed in a beaker of hot water and boiled for 10 minutes in a dark fume cabinet.

The tubes after boiling for ten minutes were submerged in cold water again and allowed to cool in the dark room. The optical density was measured at 625nm using water as reference. The standards were utilized to create a calibration graph, which was then used to calculate the aliquot sample glucose. The blank determination was processed the same way, with subtraction if needed.

Soluble carbohydrates (%) = $\frac{\text{C (mg)} \times \text{extract volume (ml)}}{10 \times \text{aliquot (ml)} \times \text{sample wt (g)}}$ 6

Where C = carbohydrate concentration from the calibration graph

Source: AOAC (2008)

Data Collection Procedures

Pre-Test/Pilot Testing

- Ten non-diabetic participants were selected from the study area and trained for the pre-testing.
- Consumption experience of participants about the product was sought before the product was given to them to evaluate using the discriminative testing.
- A prototype fonio composite bread in different sizes and shapes were developed and presented to them to evaluate.
- The glucometer for testing glucose was bought from a registered pharmaceutical agent and standardized before use in the Tamale Teaching Hospital for reliability in test results.

Formulation of Fonio Composite Bread

A completely randomized design (CRD) with three (3) treatments, wheat flour, fonio (Acha) and polished wheat flour was used for the study. Fonio flour was combined with whole wheat flour and polished wheat flour in different proportions as shown in table 1 to develop three types of fonio composite breads namely F30, F50 and F70.

Table 1: Fonio Composite Bread formulation Ratio

Product	Fonio (Acha) Flour (%)	Whole Wheat Flour (%)	Polished wheat Flour (%)
F70	70	20	10
F50	50	20	30
F30	30	20	50

Source: Researcher's Construct (2021)

Recipe for Preparation of F70 Composite Bread

Ingredients

500g Flour (Fonio 70%, Wheat 20% and polished wheat flour 10%)
5g Yeast
20g Sugar
50g Margarine
2 tsp Salt
300ml Liquid (water)
2tsp Nutmeg

Method

- Right quantities of all the dry ingredients were weighed (flour, yeast, sugar, nutmeg and salt) into a large mixing bowl and mixed together.
- A well was made in the centre and 300ml of water gradually added and mixed well. When the dough became a little stiff, 1-2 table spoon full of water was added and mixed well.
- The dough was placed on a work surface, flour sprinkled on it and kneaded for about 10 to 15 minutes.
- The satin-smooth dough was then cut into the required sizes and gently moulded into oval shapes.
- The rolled shaped dough was placed on a baking sheet and covered with cling film and left to rise for 1 to 2 hours until it doubled in size.
- The dough was baked in an oven at 220^{o}c for 25-30 minutes until golden brown colour and cooled on a wire rack.

The same procedure was used to bake F50 and F30 bread using 100g of their composite flour as shown in table 1.

Fasting Blood Sugar (FBS)

To determine the fasting blood sugar (FBS) of participants, a careful selection and screening of non-diabetic individuals was done. The participants' capillary blood was taken by pricking the individuals with a lancet and used the strips to take drops of the blood to examine for the FBS. The Accu-Check Instant glucometer was fast and gave results within five (5) seconds after taking the blood drops.

The participants were advised to eat latest between 6pm to 8pm the day before the test and come to the testing centre the following day between 6am to 8am so that the 12 – 14 hrs fast was achieved. Participants on arrival were scrutinized well to ensure that each participant had undergone 12-14 hours fast prior to taking the test. In line with a study conducted by Pandolfo, Messina and Russo (2021) instructed participants not to eat but fast overnight and come over for the testing. They also instructed the participants to keep their usual dietetic habit and take dinner between 7pm to 8pm and the test usually started between 7am and ended at 9:30am daily.

Glucose/Reference Test

In this study the food used as reference diet was glucose and this was given to each participant at the centre to consume before running the test. A glucose solution of 50g was prepared and given to each participant to drink accompanied by a bottle of water (volume, 175ml). The glucose solution was taken within three (3) to five (5) minutes and each participant was timed to

ensure an accurate interval of thirty (30) minutes was obtained before the next test was taken.

The moment each person finished drinking the glucose solution, the time was recorded, and after 30 minutes later, all of the participants' capillary blood was drawn and tested for glucose. Blood samples were obtained continuously from all participants between the hours of 6am and 8am and ended between 10am and 10:30am at the intervals of 30 minutes, 60 minutes, 90 minutes and 120 minutes, and the glucose concentration in mmol/L was measured.

This activity lasted for two hours with the participants staying at the premises to ensure that they did not engage in any intensive physical activity during the testing period. A participant then left the premises where the testing was done after the two hours period and returned after two days for the next testing. However, before participants left the testing premises they were reminded of the various restrictions they needed to adhere to, so as to continue participating in the study. Hodges, et al. (2019), in a study used similar conditions of restriction on participants to ensure effective data collection. Participants were advised to stay away from any strenuous activity for two days before attending each session as well as fasting overnight prior to visiting the hospital for a session.

Sample Foods

The participants were given the sample foods after two days of consuming and testing a particular product sample. This was done continuously with all the three samples. The participants were made to undergo 12-14 hours fast prior to taking the test samples. They were equally

reminded of the various restrictions to abide by to enable them take part in the study. They were asked to desist from smoking and drinking alcohol during the study period that they were testing. Participants were asked to report between the hours of 6am to 8am and ended between 10am to 10:30am at the intervals of 30 minutes, 60 minutes, 90 minutes and 120 minutes as well. The blood glucose concentration in mmol/L of participants were taken at these time periods.

The participant's last meal and time the meal was taken in the previous day was requested for and recorded, to enable the researcher keep an accurate check on the time participants took their last meals.

Testing participant's blood glucose levels required pricking their thumbs to get blood drop to place on the glucometer in order to obtain the sugar level readings. To prick their thumbs I had to clean them with a piece of cotton wool soaked in alcohol. They were then pierced with a sharp needle (lancet). The place pierced was then squeezed for blood drop to be obtained and the inserted strip in the glucometer was used to pick the blood to determine the FBS level in mmol/L. The time each participant's FBS was measured and appropriately recorded. The blood drop was quickly picked to prevent clotting and avoid errors in the glucometer readings.

Portion Size of Reference Food given to Participants

Portion size of reference food differs from product to product based on the amount of glucose it may produce that will be equivalent to 50g of the commercial glucose produced (Lin et al. 2010). Hence, the portion sizes of the products were calculated to ensure that the size of the fonio bread produced

had enough carbohydrate (glucose) up to 50g when consumed by the participants. The calculations were based on the following:

From the proximate analysis carried out, 100g of the fonio bread F30, contained 34.6534667 glucose. To find the amount of F30 that would contain 50g of glucose, the following equation was used if $\begin{matrix} 100g & = & 34.6534667 \\ xg & = & 50 \end{matrix}$ therefore $\frac{50}{34.6534667} \times 100$ the results was =144g and this was what was given to each participant with respect to product F30 to get a glucose equivalence of 50g.

For product F50 with 100g bread proximate results containing 32.1368 glucose was calculated using the following equation $\frac{50}{32.1368} \times 100$ therefore the results was =156g and this was what was given to each participant with respect to product F50 to get a glucose equivalence of 50g.

For product F70 with 100g bread proximate results containing 32.1401 glucose was calculated using the following equation $\frac{50}{32.1401} \times 100$ therefore the results was =156g and this was what was given to each participant with respect to product F70 to get a glucose equivalence of 50g.

Purity Test of Reference Food (Glucose)

To ensure the purity of the glucose bought from the pharmacy and used as reference food, sample was sent to the University of Cape Coast Chemistry Laboratory for purity testing. The results of the purity test obtained from the laboratory was 98.62% glucose, approximately 99%. This certifies that the

glucose used in this study as the reference food was pure and comparing the results from the test foods with it provided reliable results.

Ethical Consideration

Ethical clearance was obtained from the University of Cape Coast Institutional Review Board prior to data collection for the study. Consent was obtained from each individual participant prior to data collection. Participants were given the right to drop out of the study anytime they wanted with no problem. Privacy and confidentiality of participants responses were well-maintained throughout the study. All Covid-19 health and safety protocols were observed during the collection of the data.

Data Analysis and Presentation

The data were analysed using IBM-SPSS software for Windows by using the appropriate statistical tools for each research objective. The demographic data for the study was analysed using mean, standard deviation, frequency and percentage. The result was presented in tables for easy interpretation and discussion. The first research objective on the development of bread from fonio was accompanied with photos used in the discussions.

The research experiments conducted, frequency and percentages were used to present responses from the sensory evaluation of the three formulated fonio bread. The third research objective was analysed using the Trapezoid rule to calculate the area under the curve for blood glucose level in the consumed test foods. The one-way ANOVA was used to compare difference in the means of the level of nutrients to bring out their significance for research objective four and for testing the two hypotheses. The Repeated Measures ANOVA was used to analyse the glucose level of the participants

before and after consuming the formulated breads whereas the one-way ANOVA was used to analyse the nutrients found in the fonio breads.

CHAPTER FOUR

RESULTS AND DISCUSSION

The chapter presents the data and results collected from participants and results of chemical analysis carried out in the laboratory. The chemical analysis was carried out on the three formulated fonio breads that used wheat and polished wheat flour. The formulated breads had varied percentages of the components used in the formulations as detailed in the materials and equipment section in the Methodology of this write up.

The results presented are in two main parts. The first part presents the demographic characteristic of the respondents/participants. The second part presents the result which focused on the research objectives and the hypotheses. Findings have also been discussed and supported with relevant literature that had been reviewed in this study.

Demographic Characteristics of Respondents

The demographic characteristics of the respondents are presented in Table 2 and deals with the age, gender and level of education of the respondents.

Table 2: Demographic Characteristics of Respondents

		Frequency	Percent
Age	18-27 28-37 38-47 48-60	mean = 23.12 SD = 4.1	
Gender	Female	36	38.7
	Male	57	61.3
	Total	93	100
Level of education	JHS	15	16.1
	Not educated	2	2.2
	SHS	10	10.8
	Tertiary	66	71
	Total	93	100

Source: Field survey, Mohammed (2021)

The demographic characteristic of the respondents is presented in Table 2. The total number of respondents was 100 but 7 out of this number presented incomplete questionnaires, thus leaving 93 respondents for the study. This gave a response rate of 94%. The mean age and standard deviation of the participants were 23.12 and 4.1 respectively. The male participants were far more than the female participants by 21. The excess number of male participants was about 23% with respect to the total participants in the study. In terms of the participants educational status, four categories of educational levels were identified in the study. The least 2 (not educated) of the participants did not have any formal education. A total of 66 participants representing a percentage of 71% had tertiary education. It was impressive to note that almost all the participants were formally educated.

Research Objective One: **Develop fonio composite bread using different proportions of fonio, wheat flour and polished wheat flour.**

Composite breads from fonio were successfully formulated from the combinations of different proportions of fonio flour, wheat flour and white flour. The concept has been presented in Chapter Three of this thesis and had been discussed thoroughly about the various formulations used in obtaining the composite fonio breads. The formulated breads are presented in Figure 10, 11 and 12. The breads from the fonio composites had been code named as F30, F50 and F70.

Figure 10: Fonio bread with 70% fonio, 20% whole wheat and 10% polished wheat flour.

Figure 11: Fonio bread with 50% fonio, 20% whole wheat and 50% polished wheat flour.

Fi*gure 12*: Fonio bread with 30% fonio, 20% whole wheat and 50% polished wheat flour.

Research Objective Two: **Conduct sensory evaluation of the fonio composite bread.**

The sensory evaluation results on the fonio composite bread are presented in Tables 3, 4 and 5. The sensory evaluation results was based on 'appearance', 'aroma', 'texture' 'sweetness' and 'overall acceptability'. Each of the three tables represents a particular formulation based on the quantity of fonio flour, whole wheat flour and polished wheat flour.

Table 3: Results on F70

Attribute	Characteristic	Frequency	Percentage
Appearance	**like a lot**	**43**	**46.2**
	like a little	**37**	**39.8**
	neither like nor dislike	**5**	**5.4**
	dislike a little	**5**	**5.4**
	dislike a lot	**3**	**3.2**
	Total	**93**	**100**
Aroma	**like a lot**	**22**	**23.7**
	like a little	**49**	**52.7**
	neither like nor dislike	**21**	**22.6**
	dislike a little	**1**	**1.1**
	dislike a lot	**0**	**0**
	Total	**93**	**100**
Texture	**like a lot**	**47**	**50.5**
	like a little	**27**	**29**
	neither like nor dislike	**1**	**1.1**
	dislike a little	**11**	**11.8**
	dislike a lot	**7**	**7.5**
	Total	**93**	**100**
Sweetness	**like a lot**	**33**	**35.5**
	like a little	**40**	**43**
	neither like nor dislike	**8**	**8.6**
	dislike a little	**9**	**9.7**
	dislike a lot	**3**	**3.2**
	Total	**93**	**100**
Overall acceptability	**like a lot**	**28**	**30.1**
	like a little	**48**	**51.6**
	neither like nor dislike	**6**	**6.5**
	dislike a little	**9**	**9.7**
	dislike a lot	**2**	**2.2**
	Total	**93**	**100**

Source: Field survey, Mohammed (2021)

F70 Composite Fonio Bread (Table 3)

In terms of appearance of the formulated bread F70, majority of the panellist representing 86% did like the formulation's appearance of F70. The aroma of bread gives it nice fragrance and this attracted people around when bread was being baked. The aroma was one of the attributes evaluated in this

study. Majority of the panellist 71 representing 76% did like the aroma of F70. The texture as one of the parameters for assessing the sensory nature of the formulated products showed; 80% of the panellist liking the texture of F70 whereas little above 19% did not like F70 bread.

The sweetness of F70 was disliked by few (13%) of the panellist whereas those who liked the sweetness of the product a little and a lot formed the majority panellist 79%. On the overall acceptability of F70, most of the panellist representing 82% liked the product F70 whereas few of the panellist representing 12% did not like the product F70 after evaluating it sensorily. The overall acceptability was liked by majority 82% of the respondents. This means that the product F70 was largely accepted.

Table 4: Result on F50

Attribute	Characteristic	Frequency	Percentage
Appearance	like a lot	44	47.3
	like a little	36	38.7
	neither like nor dislike	10	10.8
	dislike a little	3	3.2
	dislike a lot	0	0
	Total	**93**	**100**
Aroma	like a lot	42	45.2
	like a little	37	39.8
	neither like nor dislike	5	5.4
	dislike a little	6	6.5
	dislike a lot	1	1.1
	Total	**93**	**100**
Texture	like a lot	44	47.3
	like a little	16	17.2
	neither like nor dislike	13	14
	dislike a little	16	17.2
	dislike a lot	2	2.2
	Total	**93**	**100**
Sweetness	like a lot	28	30.1
	like a little	43	46.2
	neither like nor dislike	12	12.9
	dislike a little	6	6.5

Table 4:Cont

	dislike a lot	2	2.2
	Total	**93**	**100**
Overall acceptability	like a lot	45	48.4
	like a little	31	33.3
	neither like nor dislike	11	11.8
	dislike a little	6	6.5
	dislike a lot	0	0
	Total	**93**	**100**

Source: Field survey, Mohammed (2021)

F50 Composite Fonio Bread (Table 4)

Table 4 presents the responses of the 93 panellists that have sensorily assessed the F50 product. The parameters for the sensory evaluation were appearance, aroma, sweetness, texture and overall acceptability. With respect to the appearance of F50, only 3 panellists disliked the product a little whereas majority 80 of the panellist did liked the product. In the case of the of the aroma for F50, the least number of panellist that disliked it was only one person and in the case of the panellists that liked the product 'a little' and 'a lot' were 37 and 42 respectively. It can therefore be concluded that most of the panellists liked the aroma of F50. The texture of the product was neither liked nor disliked by 13 panellists whilst those who disliked the texture of F50 a little were also 16. However, the frequency counts for like a little and like a lot were 16 and 44 respectively; hence, it can be said that F50's texture was generally liked by the panellists.

The Sweetness was another attribute that was evaluated and it revealed 71 panellist representing 76% did liked the sweetness of the product whereas few (8) of the panellist representing 9% did not like the sweetness of the product. It can be concluded that majority of the panellists liked the Sweetness of F50. The overall acceptability of F50 was liked by majority 76 of the panellist and this represents 82%.

Table 5: Result on F30

Attribute	Characteristic	Frequency	Percentage
Appearance	like a lot	32	34.4
	like a little	31	33.3
	neither like nor dislike	2	2.2
	dislike a little	17	18.3
	dislike a lot	9	9.7
	Total	**93**	**100**
Aroma	like a lot	30	32.3
	like a little	42	45.2
	neither like nor dislike	8	8.6
	dislike a little	9	9.7
	dislike a lot	4	4.3
	Total	**93**	**100**
Texture	like a lot	30	32.3
	like a little	28	30.1
	neither like nor dislike	9	9.7
	dislike a little	12	12.9
	dislike a lot	14	15.1
	Total	**93**	**100**
Sweetness	like a lot	26	28
	like a little	48	51.6
	neither like nor dislike	5	5.4
	dislike a little	12	12.9
	dislike a lot	2	2.2
	Total	**93**	**100**
Overall acceptability	like a lot	24	25.8
	like a little	39	41.9
	neither like nor dislike	13	14
	dislike a little	14	15.1
	dislike a lot	3	3.2
	Total	**93**	**100**

Source: Field survey, Mohammed (2021)

F30 Composite Fonio Bread (Table 5)

The appearance of F30 was disliked by 26 panellists representing 28% whereas majority 63 panellists representing 68% liked the appearance of the product. Out of the total of 93, 72 of the panellists either like the product a little or a lot in terms of the aroma. Only nine panellists disliked F30 and eight

also were not certain on which measuring scale to go for with respect to the aroma of the product.

The texture of F30 was disliked a lot by 14 panellists and liked a little by 28 panellists. The persons that liked the texture of F30 a lot were 30. It can be concluded that 58 of the panellists liked the texture of the F30. The Sweetness of F30 was confirmed by 74 counts which were like a little and like a lot. This shows that 80% liked the sweetness of the product F30. The overall acceptability of F30 was liked by 68% and few representing 18% did not accept product F30. This means that product F30 was accepted by many of the panellist in the sensory evaluation.

Table 6: Post hoc Analysis of differences in means

Comparisons of glucose levels	Diff. Means	Lwr	Upr	P. Adj
Glucose-Before. Exp.	0.823	-0.003	1.648	0.051
F30-Before. Exp.	0.830	0.005	1.655	0.048
F50-Before. Exp.	0.958	0.132	1.783	0.016
F70-Before. Exp.	0.648	-0.178	1.473	0.188
F30-Glucose	0.008	-0.818	0.833	1.000
F50-Glucose	0.135	-0.690	0.960	0.990
F70-Glucose	-0.175	-1.000	0.650	0.974
F50-F70	0.310	-0.515	1.135	0.822
F30-F70	0.183	-0.643	1.008	0.970
F30-F50	-0.1275	-0.9526	0.6976	0.9920

Source: Field survey, Mohammed (2021)

The post Hoc analysis to confirm the mean differences in glucose level before the experiment and after the experiment for the three different formulations is presented in Table 6. The P. Adj. glucose level for the three formulations before the experiment was in the range of 0.016 and 0.188. Comparing the results to the alpha value of (0.05) it is not significant. Comparing the products formulated with the reference food shows an increase which is higher than the alpha value of (0.05) hence significant. The values for

comparing between the formulated products were also higher than the alpha value hence significant. The post Hoc analysis confirms comparisons of glucose levels of products formulated and reference food and that comparing between formulated products had higher values than the alpha and hence significant difference in their glucose values.

Research Objective Three

Determine the glycaemic index and glycaemic load of fonio composite bread.

In achieving the third research objective, the glycaemic index was calculated based on the fonio composite bread and later used to calculate the glycaemic load. The fonio composite bread was formulated and their glycaemic indices and loads for the F30, F50 and F70 are presented in Table 7.

Table 7: Glycaemic Index and Load of Fonio Composite Bread

Formulation	Glycaemic Index	Carbohydrate	Glycaemic Load
F30	1.75	85.38	1.49
F50	1.77	84.59	1.50
F70	1.39	82.57	1.15

Source: Field survey, Mohammed (2021)

The result in Table 7 shows that F30 product had 1.75 for the glycaemic index and that of its glycaemic load was 1.49. In the case of F50, the glycaemic index load 1.77 and that of glycaemic load was 1.50. The glycaemic index for F70 was 1.39 while that of its glycaemic load was 1.15. Comparing the glycaemic loads of the various breads it is obvious that F70 had the least glycaemic load value and F50 had the highest glycaemic load value. This means that in selecting products which will have less effect in raising glucose levels in our blood product F70 will be the best followed by product F30.

Research Objective Four

Conduct proximate analysis of fonio composite bread

In conducting the proximate analysis of the three fonio composite breads, the products were analysed in the University of Cape Coast School of Agriculture Laboratory using the appropriate reagents and procedures. The results from the analysis are presented in Table 8.

Table 8: Results of Proximate Analysis of Fonio Composite Breads

Sample	% DM	% Moisture	% Ash	% Protein	% Fat/Oil	% Fibre	% CHO	% Glucose
F30	71.29	28.71	0.86	13.17	0.69	2.72	82.57	34.65
F50	72.46	27.54	1.32	10.29	1.16	2.65	84.59	32.14
F70	75.72	24.28	0.84	9.87	1.62	2.29	85.38	32.14

Source: Field survey, Mohammed (2021)

Table 8 shows that the samples from the three fonio composite breads all contain moisture, ash, protein, fat/oil, fibre, carbohydrate (CHO) and glucose. The nutritional composition in the formulations varied from product to product. With reference to the dry matter, the least figure recorded was for F30 and the highest F70. The variations in the DM values for the three products were not wide. The difference between the least and the highest value recorded was 4.43%. The moisture content of all three products were below 30%, the least value being 24.28% and the highest value was 28.71%. The difference in the range was 4.43%. The ash content in percentage of the formulations was low in product F70 and F30 whereas product F50 had the highest percentage in ash content.

Product F30 had the most protein and the least F70, however, difference between the two was only about 3. The amount of fat/oil found in

the fonio breads were equally low compared to other nutrients that were found in the three formulations. The least figure was for F30 and the highest one was F70. The fibre of the three products were also low between 2.29% and 2.72% with a variation of only 0.43%. The CHO content of the formulations were quite high but did not vary much, between 82.57% and 85.38%. The least recorded value was for F30 and the highest was for F70. The amount of glucose found in the breads ranged from 32% to 35%. The highest amount of glucose found was in F30 and the least found was for F70 and F50.

Hypothesis One

H_0: There is no statistically significant difference between glucose level before and after consumption of the three (F30, F50 & F70) composite breads

In testing the hypothesis on the glucose levels of the participants before consuming the formulated bread and after, blood samples of the participants were taken and read on a glucometer. Glucometer readings for each participant before and after consuming the formulated breads were taken. The significant value from the Repeated Measures ANOVA was compared to the alpha value of 0.05. The descriptive result after testing the hypothesis with Repeated Measures Analysis of Variance (ANOVA) within groups have been presented in Tables 9 and 10 for analysis.

Table 9: Descriptive result of glucose level before and after consumption of Fonio composite bread

Characteristics	Formulation	N	Mean	Std. Deviation	Std. Error
Glucose level before consuming Fonio Bread	F30	10	5.1100	.55867	.17667
	F50	10	4.9400	.48580	.15362
	F70	10	5.0500	.46963	.14851
	Total	30	5.0333	.49364	.09013
Glucose level after consuming Fonio Bread	F30	10	6.2950	.72512	.22930
	F50	10	6.4000	.67165	.21239
	F70	10	6.0700	.45717	.14457
	Total	30	6.2550	.62261	.11367

Source: Field survey, Mohammed (2021)

The results presented in Table 9 were in two sections. The first session was the blood glucose level of the participants before consuming the formulated breads and the second session was the blood glucose levels of participants after the consumption of the bread. The results showed that the mean value of the participants' glucose levels before consuming the breads were almost the same. The mean value for F50 was 4.9 and that of the other two formulations (F30 and F70) were 5.1 and 5.1 respectively. It can therefore be assumed that the glucose level of the participants before consuming the formulated breads were the same. The results also confirmed that the glucose levels of participants were normal taking into consideration the standardized normal levels.

In a similar vein, the glucose level of the participants did rise by about one mean in reference to the glucose level of the participants after consuming the bread. The mean value of F30 was 6.3 and that of F70 was 6.1. The highest glucose mean value was for persons that consumed F50 with a value of 6.4. Figure 13 thus shows the pictorial view of how the blood glucose rose after consuming the three developed breads.

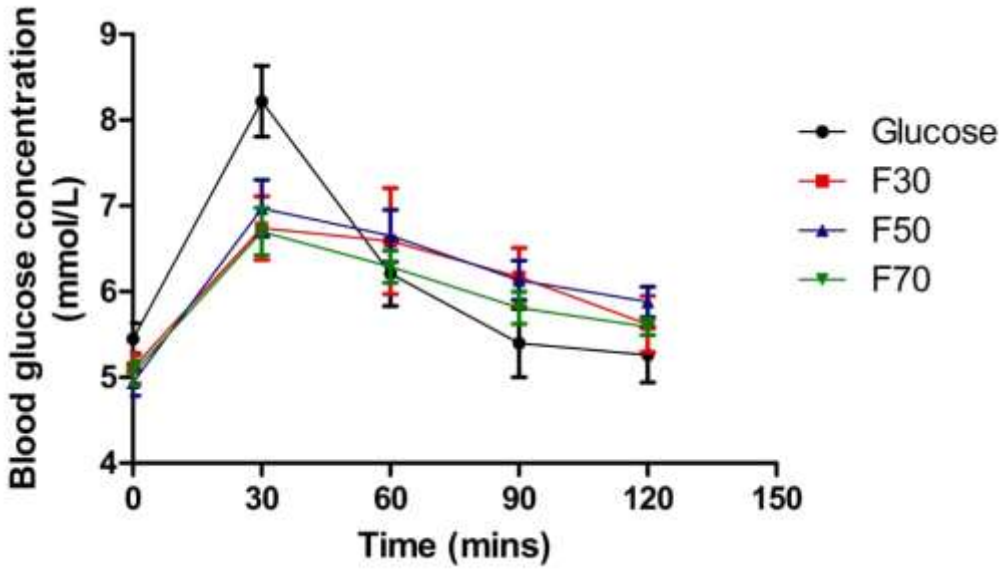

Figure 13: Blood glucose time curve after each product

The Repeated Measures ANOVA results as presented in Table 10 showed that the sum of mean squares between groups and within groups was less than that within groups with respect to the glucose level before consuming fonio bread. The same scenario did happen after the consumption of the formulated bread. The sum of squares between groups was 0.57 and that of within groups was 10.7. In comparing the significant value to the alpha value of 0.05, the glucose level before consuming the test foods, the value was higher than the alpha value. In the case of the glucose level after consuming the test foods, it was also higher than the alpha value (0.05); ($p>0.05$). It can therefore be concluded that there was no statistically significant difference in blood glucose levels, before and after the fonio breads were eaten. Hence, the researcher failed to reject the null hypothesis. This means that there is no statistically significantly difference between the glucose level before and after consumption of the three (F30, F50 & F70) fonio composite breads.

Table 10: ANOVA Result of glucose level before and after consumption of Fonio bread

		Sum of Squares	Df	Mean Square	F	Sig.
Glucose level before consuming Fonio Bread	Between Groups	.149	2	.074	.290	.750
	Within Groups	6.918	27	.256		
	Total	7.067	29			
Glucose level after consuming Fonio Bread	Between Groups	.569	2	.284	.719	.496
	Within Groups	10.673	27	.395		
	Total	11.242	29			

Source: Field survey, Mohammed (2021)

Hypothesis Two

H_0: There is no statistically difference in terms of nutrients among the three developed fonio composite bread

The second hypothesis which sought to test for significance or otherwise of nutrients composition in the composite bread was tested by comparing the significant value to the alpha value of 0.05. Four different nutrients were found and their values computed and tested using one-way ANOVA. The test were repeated in triplicate to ensure that the values read/taken during the laboratory analysis were correct. The results have been presented in Tables 11 and 12.

Table 11: Nutrients among the three Developed Fonio Composite Bread

		N	Mean	Std. Deviation	Std. Error
%DM	F70	3	75.72430	.309854	.178894
	F50	3	72.46000	.297085	.171522
	F30	3	71.28538	.261280	.150850
%Moisture	F70	3	24.27570	.309854	.178894
	F50	3	27.54000	.297085	.171522
	F30	3	28.71462	.261280	.150850
%Ash	F70	3	.83571	.002771	.001600
	F50	3	1.31976	.024224	.013986
	F30	3	.86067	.008519	.004918
%Protein	F70	3	9.86819	.129981	.075045
	F50	3	10.28678	.217517	.125584
	F30	3	13.16688	.203526	.117506
%Fat and	F70	3	1.62418	.005646	.003260
Oil	F50	3	1.16087	.008385	.004841
	F30	3	.68764	.009440	.005450
%Fibre	F70	3	2.28806	.022150	.012788
	F50	3	2.64620	.054778	.031626
	F30	3	2.71787	.024279	.014017
%CHO	F70	3	85.38386	.119636	.069072
	F50	3	84.58638	.242118	.139787
	F30	3	82.56694	.191390	.110499

Source: Source: Field survey, Mohammed (2021)

The result in Table 11 with respect to the Dry matter (DM) indicates that the mean results ranged from 71.29 and 75.72, 'F70' had the highest dry matter and content the least was for 'F30'. The Moisture content in F70 was less than the other two products (F50 and F30). The Ash present in the three formulations showed product F50 with the highest Ash content and the product with the least Ash was F70. The protein found in the three formulations showed F30 has the highest protein and the least was product F70. The fats and oil found in the three formulated products during the test showed the highest amount of oil was in product F70 whilst F30 had the least amount of fats and oil. In the case of the Fibre in the three formulated breads; product F30 has the highest in fibre whilst product F70 had the least amount of fibre in it. The carbohydrate found in the formulated breads revealed F70 had

the highest carbohydrate and the least carbohydrate among the three formulated breads were in product F30.

Table 12: ANOVA Result of the nutrients in the Composite Bread

		Sum of Squares	Df	Mean Square	F	Sig.
%DM	Between Groups	31.739	2	15.870	188.524	.000
	Within Groups	.505	6	.084		
%Moisture	Between Groups	31.739	2	15.870	188.524	.000
	Within Groups	.505	6	.084		
%Ash	Between Groups	.446	2	.223	1002.222	.000
	Within Groups	.001	6	.000		
%Protein	Between Groups	19.352	2	9.676	274.798	.000
	Within Groups	.211	6	.035		
%Fat and Oil	Between Groups	1.316	2	.658	10316.914	.000
	Within Groups	.000	6	.000		
%Fibre	Between Groups	.318	2	.159	116.942	.000
	Within Groups	.008	6	.001		
%CHO	Between Groups	12.649	2	6.325	173.175	.000
	Within Groups	.219	6	.037		

Source: Field survey, Mohammed (2021)

The one-way ANOVA results presented in Table 12 was about the nutrient composition and other contents in the composite breads. This shows all the four nutrients and other contents were significant with values 0.00 each. The alpha value to compare the significant value to was 0.05. In comparing the Significant value of the four nutrients, it can be concluded that the p -value was less than the alpha value ($p<0.05$). The result therefore is significant. The null hypothesis was therefore rejected in favour of the alternative hypothesis. This means that there was statistical difference in terms of nutrients among the three developed fonio composite bread.

Discussion of Results

This section presents findings and discusses into detail results supported with literature. The possibility of using fonio in combination with whole wheat flour and polished wheat bread flour to make bread was successful. The bread contains most of the nutrients needed by the body. The dieting patterns of the people in the Tamale Metropolis were gradually changing in view of white colour jobs that mostly compel people to leave home early. This has called for people to eat breakfast early and bread mostly form part of the breakfast. The demand for bread in the market may increase the price of the commodity. Introducing fonio bread into the market could help stabilize the cost of ordinary bread or 100% wheat flour bread.

The introduction of fonio bread into the market may provide consumers with variety to select from. The new bread that has been formulated did not only come with a new name but the nutritional composition of the bread was very welcoming. The nutritional content found was similar to that found by Adainoo (2021) who reported low dietary fibre in a similar product. Adainoo (2021) found the fibre content to be about 20% which was far higher than what was found in this study. The amount of fibre in the three types of composite was about 3% (for F30 & F50) and this was the highest value fibre obtained among the three formulated fonio breads and the least being 2.3% in F70.

A food for that matter bread can attract the attention of consumers through it sensory attributes such as aroma and appearance. Potential consumers are likely to use the aroma of bread to judge if it would be tasty, good or otherwise. Bread in nearby areas could have the aroma all over the

area and thereby draw people's attention. At times the appearance of the bread could attract a person especially its colour. The use of aroma and appearance were some of the sensory characteristics to test the sensory nature of the developed bread and as a way to know their overall acceptability. The overall acceptability of the formulations was also liked by the respondents. What this means is that a lot of people would prefer to eat the fonio breads that have been developed to eating the usual wheat flour bread.

The third research objective revealed that the glycaemic index of F30, F50 and F70 were all comparatively low. In determining the glycaemic load of any food, the glycaemic index and the available carbohydrate in that food are considered. The low glycaemic index found in the fonio bread would lead to slower rise in blood glucose when eaten as Ajala, English and Pinkney (2013). Thus consumption of fonio bread would not contribute much to rise in blood glucose of consumers. The chances of developing diabetes as a result of consuming the fonio bread was therefore very low based on the findings of this study.

The glycaemic load is the actual end result that could tell if a given food has serious consequences on the individual when consuming that food. Increase in the prevalence of diabetes in Ghana has become a common a matter of public health concern, it is therefore important that foods that help to control blood sugar are identified and communicated to the general public. Type II diabetes occurs as a result of the consumption of high glycaemic load or glycaemic index foods. It is therefore important that the findings of this study is communicated to health personnel with consumers to help manage diabetic and other related health conditions.

The first hypothesis tested in the study showed that there was no significant difference between glucose level before and after consumption of the three (F30, F50 & F 70) fonio composite breads. This result thus indicated that the participants were healthy and the consumption of the test food (Fonio composite breads) had no significant change in their blood sugar level. Consumption of the fonio bread therefore has no negative influence on the blood sugar levels of consumers compared to the polished wheat bread in the market.

With regards to the second hypothesis, the nutrients accessed were found in significant levels in the fonio breads as was earlier being reported by Oburuoga and Anyika (2012) in fonio. The nutrients found in the bread alone without using any beverage alongside may still be good enough for the body. For instance, the presence of carbohydrate was enough to provide the required calories of energy for the body to undergo its chores. The protein found was also good for the replenishment of the worn out tissues and keep the body in shape or form.

The baking values of some of the nutrients tested in the fonio formulated fonio products were established. According to a study conducted by Hefni, Thomsson, and Witthöft (2021) in which they baked prototype products A, B, and C, they indicated that the bread making procedure or method decreased the content of total and non-resistant starch by up to 20% (p 0.001), while the content of resistant starch increased by up to threefold (p 0.001). The content of total dietary fibre was not affected. Comparing the baking effect of their products with this study; it is clear that the fibre content in percentage increased a little above the raw flour product, it was also clear

that the carbohydrate percentage increased in F70, F50 and reduced in F30 after baking. This means that baking has an effect on some of the product nutrient as it is evidential in my products and that of Hefni, Thomsson and Witthöft, (2021).

The results of Ballogou et. al., (2013), proximate analysis of protein indicated 11 maximum whereas with this study the proximate analysis of protein results was 9. This means that there was a significance difference of two values comparing the results obtained from the proximate analysis conducted by Ballogou et al., (2013). This can therefore be attributed to geographical settings since this current study formulations and testing was done in Ghana.

Also the energy present in fonio has been investigated by Jideani and Akingbala (1993) and they found 19400 KJ/kg. Ballogou et al. (2013) established fonio carbohydrate 91% and when compared with this study proximate analysis results of 90% carbohydrates; it gives an impression that the test results in different geographical locations can be altered due to situations that prevails in the area of study.

CHAPTER FIVE

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

Summary

Food is one of the essential commodities of humans that cannot be ignored. Breakfast as one of the first meals in human daily feeding and it makes humans gain the needed energy to carry out the day's task. Bread is found in most homes in Ghana because bread from different formulations often flood the Ghanaian market. The current study sought to introduce another formulation of bread which is not already available to the Ghanaian populace.

Fonio as the major component in the current formulations was produced and necessary sensory and proximate analysis carried out. Fonio was considered as the best cereal to use in varied ratios due to its low level of gluten. The proximate composition of fonio made it the best choice of locally available cereal to use. The formulation ratio using fonio was 30%, 50% and 70% and the remaining percentages were wheat flour and polished wheat flour. Three different formulations were developed and coded to solicit a fair judgment from the panellist used for the sensory evaluation.

Type II diabetes is associated with the glycaemic load of foods and this is also related to the quantity or amount of carbohydrate in such foods. It was therefore necessary to determine the glycaemic index and load of the formulated bread from fonio cereal. The research work was specifically guided by four research objectives and two hypotheses. The relevant conceptual framework was developed to give a clear direction to the study. Empirical literature review was reviewed to support the study.

The study was carried out in the Tamale Metropolis of the Northern Region of Ghana with one hundred and three (103) participants. Ten participants were for blood glucose test and 93 participants for sensory evaluation. The participants in the glycaemic index and load tests were considered healthy per World Health Organization's standard as required. The inclusion criteria were detailed in the Methodology section thesis.

A true experimental research design was adopted to enable the samples to be manipulated. Fonio was fed to the participants and their blood glucose level measured with a glucometer. The proximate analysis of the formulated breads was carried out in the laboratory. The second part of the data collected was on sensory analysis on the fonio composite bread carried out by the selected participants and subsequently determined by ten of the participants' glucose levels after consumption of the fonio composites bread. The results were analysed with the appropriate statistical tools and presented in Tables and Figures and used for the discussion and conclusion.

Key Findings

The first research objective was to develop fonio composite bread using different proportions of fonio and wheat flour. The results established that it was possible to develop acceptable bread from a mixture of fonio, whole wheat flour and polished wheat flour. The composite bread samples were coded 'F30', 'F50' and 'F70' based on the percentage of fonio flour they contained.

The second research objective was to conduct sensory evaluation on the composite fonio bread. The appearance, aroma, texture, sweetness and overall acceptability of all three types of fonio composite bread were liked by

all 93 respondents though there were variations in the scores obtained. However, the variations obtained from the number of participants that accepted the sensory characteristics were not statistically significant.

Glycaemic index and glycaemic load of the composite fonio bread was the focus of the third research objective. All the fonio composite bread samples F30, F50 and F70 had low glycaemic load. In the case of glycaemic index, F70 had the least glycaemic index followed by F30 and F50 (F70 > F30 > F50). The three types of fonio composite bread can therefore be consumed with the least effect on blood glucose which causes Type II diabetes provided the accompanying foods do not have much sugar in them.

The fourth research objective was conducted to determine the proximate composition of the fonio composite breads. The content of dry matter, moisture, ash, protein, fat/oil, fibre and carbohydrate differed in the three formulations with fibre being very low in the three formulations.

With regards to the first hypothesis there was no statistically significant difference between glucose level before and after consumption of the three (F30, F50 & F70) fonio composite breads. With regards to the second hypothesis there was statistically significant difference of nutrients proximate composition of the three developed fonio composite bread.

Conclusions

The main focus of the study was to developed fonio composite bread and determines the glycaemic index and load of newly developed fonio composite bread and test two hypothesis. The fonio composite breads were successfully developed by combining fonio, wheat flour and polished wheat flour to obtained three different products code named F70, F50 and F30 and

used for sensory evaluation and the results showed that the three formulated fonio composite bread were acceptable to most of the participants.

The glycaemic index and glycaemic load of fonio composite bread were determined and the results showed three formulated fonio breads had low glycaemic indices and loads, hence good for consumption with least effect on blood glucose rising. The following nutrients protein, carbohydrates, ash and fats and oil were tested for and they were present in different proportions.

The descriptive result after testing the hypothesis with Repeated Measures Analysis of Variance (ANOVA) and the result between and within groups showed that glucose levels before and after consumption of fonio composite breads to be higher than the alpha value of 0.05 ($p>0.05$). There was therefore no statistically significant difference in blood glucose levels before and after consumption of the fonio breads.

The one-way ANOVA results showed four different nutrients significantly presents with values 0.00 which were less than the alpha value of 0.05 ($p<0.05$). The null hypothesis was therefore rejected in favour of the alternative hypothesis. Thus there were statistically differences in the level of the nutrients among the three formulated fonio composite breads.

Recommendations

Recommendations have been made in relation to the findings in the current study. The first recommendation was to the Food and Nutrition Departments in Cape Coast University students to explore other ways to utilize and market the developed bread from fonio in collaboration with the researcher. The university community is a big market on its own which could serve a pilot pending the bigger market outside the University of Cape Coast.

The study conducted sensory evaluation of the three formulations and the parameters used were all accepted. The sample size in determining this was small though enough to draw conclusion for this study. It is therefore recommended that a market test of the samples be carried out involving a large number of participants.

The glycaemic index and loads of the formulations were low therefore their consumption could be encouraged among diabetic patients. Dieticians in the diabetic clinics could be used to introduce the consumption of F30, F50 and F70. Also, physicians could put some diabetic patients on the consumption of the new formulations for about six months and examine their general health conditions. The statistical difference in the nutrients found in the three formulations could be explored further to see their impact on the consumers.

Suggestions for Further Studies

The study recommended that the scope of the current study be expanded to other regions of Ghana; and the nutrients as well as the composition of the bread be varied with the baking method also changed.

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APPENDICES

APPENDIX A

PROXIMATE OF CEREALS FLOURS

PROXIMATE OF CEREALS FLOURS

Sample	% DM	% Moisture	% Ash	% Protein	% Oil	% Fibre	% CHO
P Wheat Flour	87.13425	12.86575	0.43529	13.71299	1.00219	0.44914	84.40038
P Wheat Flour	87.04678	12.95322	0.49455	13.79671	1.09659	0.45693	84.15522
P Wheat Flour	86.77369	13.22631	0.57126	13.98562	1.00325	0.44121	83.99865
Wheat Flour	88.52581	11.47419	1.30522	11.62585	1.12549	1.69106	84.25238
Wheat Flour	88.45539	11.54461	1.39048	11.73942	1.19866	1.71254	83.95890
Wheat Flour	88.35000	11.65000	1.41705	12.14512	1.19022	1.68695	83.56066
Fonio	89.67667	10.32333	0.39944	8.45306	0.42463	0.35821	90.36466
Fonio	89.61412	10.38588	0.48730	8.45017	0.45215	0.36599	90.24439
Fonio	89.75826	10.24174	0.37825	8.67499	0.46933	0.35113	90.12631

APPENDIX B

COMPOSITE FLOUR PROXIMATES

COMPOSITE FLOUR PROXIMATES							
Sample	% DM	% Moisture	% Ash	% Protein	% Fat/Oil	% Fibre	% CHO
F70	89.97198	10.02802	0.56262	10.62080	0.69276	2.00318	86.12064
F70	90.01464	9.98536	0.57297	10.23479	0.70216	1.89650	86.59358
F70	90.10615	9.89385	0.57448	10.14259	0.69866	1.96523	86.61904
F50	89.62262	10.37738	0.56842	11.33340	0.92877	2.72300	84.44640
F50	89.52962	10.47038	0.55107	11.04402	0.92155	2.56987	84.91349
F50	89.60051	10.39949	0.58900	11.13480	0.91254	2.64235	84.72132
F30	89.31051	10.68949	0.58674	14.36230	1.10464	2.92027	81.02604
F30	89.21263	10.78737	0.56334	14.37897	1.11548	2.85697	81.08524
F30	89.19292	10.80708	0.56400	14.47270	1.09986	2.91547	80.94798

APPENDIX C

COMPOSITE BREADS

COMPOSITE BREADS								
Sample	% DM	% Moisture	% Ash	% Protein	% Fat/Oil	% Fibre	% CHO	% Glucose
F70	75.93343	24.06657	0.83858	9.96907	1.63005	2.28800	85.27430	32.0413
F70	75.36832	24.63168	0.83305	9.72151	1.62369	2.31024	85.51151	32.3131
F70	75.87114	24.12886	0.83551	9.91400	1.61879	2.26594	85.36576	32.0659
F50	72.79089	27.20911	1.33488	10.53312	1.16983	2.65529	84.30688	32.0104
F50	72.21617	27.78383	1.29182	10.12117	1.15958	2.69587	84.73156	32.3389
F50	72.37295	27.62705	1.33258	10.20605	1.15321	2.58745	84.72071	32.0611
F30	71.58632	28.41368	0.86495	13.39510	0.68220	2.70995	82.34780	34.2067
F30	71.11638	28.88362	0.85086	13.00419	0.69854	2.74512	82.70129	34.9660
F30	71.15344	28.84656	0.86620	13.10136	0.68218	2.69854	82.65172	34.7877

APPENDIX D

SENSORY EVALUATION FORM

Tray Number:……..….

Bio Data

1. Gender: Male [ ] Female [ ]
2. Level of Education: Not Educated [ ] JHS [ ] Secondary School [ ] Tertiary [ ]
3. Date of birth: ……..... Age……

In front of you is one sample. Overall acceptability the sample and tick (√) how much you like or dislike each of the characteristics. You can Overall acceptability the sample more than once. Please take water after tasting each sample.

PRODUCT "A" "F70"

	Appearance	Aroma	Texture /mouth-feel	Sweetness	Overall acceptability
Like a lot					
Like a little					
Neither like nor dislike					
Dislike a little					
Dislike a lot					

PRODUCT "B" "F50"

	Appearance	Aroma	Texture /mouth-feel	Sweetness	Overall acceptability
Like a lot					
Like a little					
Neither like nor dislike					
Dislike a little					
Dislike a lot					

PRODUCT "C" "F30"

	Appearance	Aroma	Texture /mouth-feel	Sweetness	Overall acceptability
Like a lot					
Like a little					
Neither like nor dislike					
Dislike a little					
Dislike a lot					

Thank you

APPENDIX E

GLYCAEMIC LOAD SCREENING FORMS

Bio Data Date:……

Time:……

1. Unique code :……..
2. Gender: Male [ ] Female [ ]
3. Level of Education: Not Educated [ ] JHS [ ] Secondary School [ ] Tertiary [ ]
4. Date of birth: ……..... Age……
5. Height:……
6. Weight:…… BMI [ ] Normal: [ ] Abnormal: [ ]

Diabetic/health history of participants

7. Glucose level without taking product sample: ……. Non diabetic: [ ] Pre-diabetic: [ ] Diabetic: [ ]
8. Do you have past or present history of any of the following conditions: Cancer:[ ] Diabetes:[ ] Gastrointestinal disorder: [ ] Hepatitis: [ ]

Other guidelines for participating in the study

9. Do you smoke or take alcohol? Yes[ ] No[ ]
10. Are you pregnant or breastfeeding? Yes[ ] No[ ]
11. Previous meal taken: …… Time:……
12. Did you eat this morning before coming? Yes[ ] No[ ]

Base on the responses from 1-12 indicate: Qualified for study: [ ]

Disqualified for study:[ ]

Record of glucose level after taking developed fonio bread samples

DAY ONE	**Time Interval for Record of Glucose Level**			
SAMPLE "A" "F70"	30min	60min	90min	120min
Time				
DAY TWO	**Time Interval for Record of Glucose Level**			
SAMPLE "B" "F50"	30min	60min	90min	120min
Time				
DAY THREE	**Time Interval for Record of Glucose Level**			
SAMPLE "C" "F30"	30min	60min	90min	120min
Time				

Thank You

APPENDIX F

PROCESSES THROUGH BAKING OF COMPOSITE BREADS

Three Composites Bread Baked

Product F30

Product F50

Product F70

APPENDIX G

PROXIMATE ANALYSIS AT UCC LABORATORY

APPENDIX H

GLUCOSE TESTING

APPENDIX I

SENSORY EVALUATION PROCESS