RIVERS STATE UNIVERSITY
PORT HARCOURT

INVITRO ENZYME TECHNIQUE: AN ESSENTIAL TOOL IN FOOD ANALYSIS

AN INAUGURAL LECTURE

BY

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DEDICATION

To my LATE PARENTS
Chief Gilbert Kiin-Kabari
and
Mrs. Nnaanezia Grace Kiin-Kabari
For their parental love.

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PROTOCOL

The Vice-Chancellor and Chairman of this Inaugural Lecture,
Members of the Governing Council here present,
Deputy Vice-Chancellors (Administration and Academics),
The Registrar and Secretary to Council and Senate,
Other Principal Officers of the University,
Former Vice–Chancellors and Emerita Professors,
Former Deputy Vice–Chancellors,
Former Registrars,
Provost, College of Medical Science,
Dean of Postgraduate Graduate School,
Heads of Campuses of the University,
The University Orator,
Deans of other Faculties & Directors of Institutes and Centres
Heads of Department and Units,
Distinguished Professors and Members of Senate,
Dear Colleagues,
Other Invited Guests, Friends and Associates
Staff & Great RSU Students,
Gentlemen of the Press,
Ladies and Gentlemen.

1.0 PREAMBLE

My parts through life had been guided and molded by the Hands of the Almighty Father, the Creator of Heaven and Earth. As a child, I grew up very frail, however supported, surrounded and protected by parental love, because of this I was breast fed for 3 years and my father would not allow his only son to do any house chores. I started learning how to cook for myself, during my NYSC (1983/1984). Vice Chancellor Sir, I was supposed to be a spoilt child but for the intervention of God who directed my earlier steps of life towards Christianity and the activities in the Church. I enrolled in the choir, the Anglican Church in Bori, and became very active as a "Songito" in the church as at that time. One faithful day as I was studying the pages of the Bible as a young boy, I came across a quotation in the Bible – "The Great Commission" Matt. Chapter 28, 19 – 20.

> *Go ye therefore, and teach all nations, baptizing them in the name of the Father, and of the Son, and of the Holy Ghost.*
>
> *Teaching them to observe all things whatsoever I have commanded you: and, lo, I am with you always, even unto the end of the world. Amen.*

After going through the text, rehearsing and contemplating on the message contained therein I decided to leave the Anglican Church to join the Jehovah's Witness Organization because I felt they were the only group that was fulfilling that great commission – preaching the gospel from house to house and door to door. Bible study was compulsory and supported by tracks from Watch Tower and Awake both are publications of the Watch tower bible society of Pennsylvania, U.S.A. We started preaching Armageddon and that the world will end by

1975 following an imaginary calculations that six thousand years of human existence may come to an end by 1975. We failed to realize that nobody can predict God's plans and we could not reconcile that the Bible says that nobody knows the times, the hour and the date. The more I was persecuted the more I grew in faith and strength. As a matter of faith and conviction I decided not to go to Secondary School since the World will end in 1975. My father was not happy with me and he complained to every prominent persons from my area. The persecution continued until the Almighty Father intervened through an experienced headmaster, Chief Gbarazia (of blessed memory) who came to our house and said "Boy go to Secondary School and let Armageddon meet you in school" This statement became a turning point in my life because I decided to obey and started my academic journey in Birabi Memorial Grammar School (BMGS) in 1973 with one condition that I must be in the boarding house even though the distance from my house to the school was not upto 1km. After Secondary School, my career Choice - Food Science and Technology was based on the fact that I did not want to be a teacher and the determination to continue my education against my parent's wish. I got admitted into the then prestigious College of Science and Technology (CST) in 1979. I graduated in 1983 and was posted to Oyo State for National Youth Service Corp (NYSC). I did my primary assignment at Federal Government College Ogbomoso after being rejected by the International Breweries Ilesha. At the Federal Government College Ogbomoso, I was assigned to teach lower six Chemistry and upper six Organic Chemistry where I studied to teach because my knowledge of Chemistry was not enough to handle upper six organic Chemistry. I thanked the HOD Chemistry, Mr. Ajagbe who gave me all the supports and encouragements I needed. I returned from NYSC in 1984 and one of my maternal uncles who was working in NAOC in the Transport Department came to our house and my mother introduced me to him as her son who had just graduated from the University. My uncle asked, what did you study in the

University? And I simply and innocently answered with some degree of authority and confidence; Food Science and Technology. My uncle was furious and angry with me and said what is Food Science and Technology? What about Law, Medicine, Engineering etc and ended by saying, where will I go with such a course. I was embarrassed by my uncle's show of ignorance before the sister (my mother). That is why in this Inaugural lecture, I asked the question what is Food Science and Technology? In case we still have some people thinking like that or with the mindset of my late Uncle.

I started looking for job in all the companies in Rivers State and in Nigeria with my supervisor, Dr. E.O Denenu giving me reference letters, to no avail, but immediately I showed up at Post Primary School Board, I was recruited and posted to Okirika Grammar School (OGS) Okirika to teach Agricultural Science, Biology and Chemistry. Not satisfied, I continued my search for greener pastures. By 1985, I got employed at the Federal Polytechnic, Bauchi as a Technologist II in charge of Food Processing workshop and Food Analysis Laboratory, surprisingly I was given OND Food Analysis to teach in addition to my schedule as a Technologist. I worked in Federal Polytechnic, Bauchi up to 1990 where I was awarded the British Council Fellowship to study Food Analysis, Instrumentation and Laboratory Management under the British Council for Polytechnic Project. I returned from Bristol Polytechnic U.K in September 1990 and was reliably informed that the Food Science and Technology Department of Rivers State University of Science and Technology (RSUST) had been separated from Animal Science. I immediately applied as a Senior Technologist and was offered a temporary appointment which I accepted.

Here, I rose through the rank and file as a technical staff, acquiring all the laboratory skills and procedures that made me a Food Analyst. I was promoted to the rank of a Chief Technologist in 2003. After acquiring a Master Degree in Food

Science and Technology I applied for conversion and was interviewed and converted to the rank of Lecturer II in 2006.

Vice Chancellor Sir, my academic journey had not been a straight forward one, it can be likened to St. Paul Missionary journey. However, in all these, I have exhibited determination, hardwork. The Grace and Mercy of the Almighty Father had been upon me as a special or a miracle child. I am grateful to God for His protection and guidance which has brought about this Inaugural lecture today. It is not by might or power but only the Grace of God.

1.1 INTRODUCTION

Vice Chancellor Sir, permit me to start this lecture by defining terms that are commonly used today, providing new meaning and scope for better appreciation and understanding for the benefits of Humanity.

1.1.1 Definitions

Food: Food is defined as any substance which when eaten and absorbed by the body will produce energy, promote the growth and repair of body tissues or regulate these processes. It is usually of plant or animal origin and therefore contains essential nutrients that can help to achieve the functions stated above – produce energy, promote the growth and repair of body tissues or regulate them. In other words, food can be defined as a product derived from plants or animals that can be taken into the body to yield energy and nutrient for the maintenance of life and the growth and repair of body tissues. But I will increase the scope of the above definition, to include seafoods and edible insects that can be eaten into the body to yield the same results.

1.1.2 Nutrition

Nutrition is the Science of Food and Nutrients and other substances they contain, and of their actions within the body (including ingestion, digestion, absorption, transport, metabolism and excretion). A broader definition may include the social economic, cultural and psychological implications of food and eating.

1.1.3 Diet: Food and Beverages: A Person Eats and Drinks

We make food choices that will benefit, maintain and improve health. Food manufacturers and restaurant chefs have responded to selection of health promoting foods and beverages. In some cases, the health promoting foods may be natural, processed or prepared in a way that provides health benefits e.g. removal of toxic components or lowering of fats

content of foods/ingredients.
Diet play a key role as a risk factor for many chronic diseases often caused by over consumption such as cardiovascular diseases, obesity, cancer, dental diseases and other nutrient – deficient diseases caused by under consumption (e.g. Osteroporosis, Kwashiokor and Maramus). However, diet is only one risk factor, other determinants of health and well-being e.g. (Physical activity, sleep, drugs and alcohol abuse etc). Therefore, dietary habits i.e. what, when and how we eat also affect or influence our health.

1.1.4 Functional Foods

A functional food is a food claimed to have an additional function by providing new ingredients or more for existing ingredients. It is defined as foods that contain compounds that offer health benefits beyond the provision of basic nutrient such protein, carbohydrate, fat, vitamin and minerals, probiotic and fibre.

Examples of some conventional functional foods are given below:

a) Fruits: berries, kiwi, pears, peaches, apples, oranges, bananas.
b) Vegetables: broccoli, cauliflower, kale, spinach, tomatoes.
c) Nuts: Almonds, cashew, etc
d) Seeds: Chili seeds, flax seeds, hemp seeds, pumpkin seeds
e) Legumes: Black beans, chilies peas, navy beans lentils
f) Cereals – oats

Tomatoes are known to contain lycopene. Oats, for instance contain a type of fiber called beta-glucan which has been shown to reduce inflammation, enhance immune function and improve heart health. Similarly, fruits and vegetables are packed with antioxidants which are beneficial components that help protect against diseases.

1.1.5 Processed Foods

It is incorrect to assume that a product is "safe" because it is "natural" and toxic because it is "processed". The word processed, natural or minimally processed and ultra processed are often misunderstood. Processed by definition involves any conscious unit operations resulting in minor or major alterations in the natural shape, size form, sensory and chemical characteristics of a natural produce in order to change it into a more palatable and convenient form to eat. Most processed foods typically contain two or more ingredients normally used in household kitchen.

Vice Chancellor Sir, at this point, for those of us who belief strongly in nature or what may be called Nature's study, I make bold to say that there are foods that should be processed, before eaten, and those to be eaten raw. For instance, cassava must be processed to reduce intrinsic toxins, such as the cyanide, cowpea and soyabeans, infact all the beans must be soaked and given adequate heat treatment in order to eliminate or reduce protease inhibitors that are inherit in them.

Majority of the fruits and vegetables contain heat sensitive vitamins and antioxidants and to obtain maximum health benefits, nature made it that such fruits and vegetables should be eaten raw – unprocessed. Through Nature's study, a sequence of occurrence of fruits had been observed, where certain fruits handover to the next throughout the year providing a relay of occurrence as shown in Figure 1.

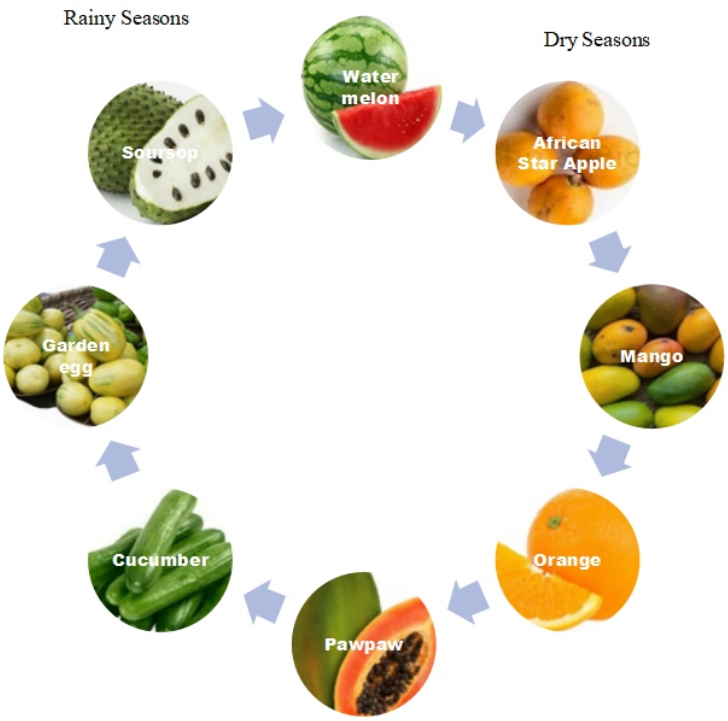

Fig. 1: Some Fruits in Nigeria and Season

2.0 WHAT IS FOOD SCIENCE AND TECHNOLOGY?

Food Science and Technology is the understanding and application of science to satisfy the needs of society for sustainable food quality, safety and security. At several Universities worldwide, degree programmes in Food Science and Technology have been developed in the past half a century. The aim of these courses had been to provide Food Science and Technology graduates the ability through multidisciplinary studies, to understand and integrate the scientific disciplines

relevant to food. They should be able to extend their knowledge and understanding of food through a scientific approach and to be able to apply and communicate that knowledge to meet the needs of society, industry and consumer for sustainable food quality, safety and security of supply. Food science is a coherent and systematic body of knowledge and understanding of the nature and compositions of food materials and their behavior under various conditions to which they may be subject while Food technology is the application of Food Science to the practical treatment of food materials so as to convert them into food products of different kinds, quality and stability and so packaged and distributed as to meet the needs of consumers for safe, wholesome nutritious and attractive foods.

2.1 OPTIONS AND SPECIALIZATION IN FOOD SCIENCE AND TECHNOLOGY

Food Science and Technology has a lot of branches and options which can be summarized as follows:

a) Food Microbiology and Biotechnology
b) Food Chemistry and Biochemistry
c) Food Processing and Packaging
d) Food Process Engineering
e) Food Analysis
f) Nutrition and Toxicology
g) Food Safety and Management

All the options and specializations are important and overlapping, you cannot specialize in any option without going through other areas. For instance, you cannot effectively do Food processing and Packaging without adequate knowledge of Food Chemistry, Food composition and the microorganisms associated with foods; the toxic components found in food. However, I will focus in Food Analysis because that is my area of specialization.

2.2 FOOD ANALYSIS

Food analysis is a discipline in Food Science and Technology dealing with the development, application and the study of analytical procedures/techniques for characterizing the properties of foods and their constituents. It is therefore, the resolution of the components of food into its proximate or ultimate parts; the determination of chemical elements or foreign substances or impurities. The practical way of investigation and solving these problem may adopt either a qualitative or quantitative approach depending on what is to be resolved. Various types of food samples may require analysis as part of a research programme; as a new product developed or as part of quality assurance programme for existing products. The nature of the food sample and the specific reason(s) for the analysis commonly dictate the choice of analytical methods. Speed, precision and accuracy are also key factors that determine the choice of methods.

2.3 ESSENTIAL TOOLS USED IN FOOD ANALYSIS

A tool can be a technique, method and/or equipment used in food analysis, such techniques may include;

a) Physical properties of food - a food physics which determines the size, shape, texture, viscosity etc.
b) Chemical properties techniques which include:
   Determination of proximate composition of foods – macronutrient determination in excess of 1%.
c) Invitro techniques – investigation of what happens when a food is ingested.
d) Instrumental techniques – involves the use of instruments/equipment in food analysis - e.g. moisture analysis, chromatography, spectrophometers, GC-MS, HPLC, AAS etc.
e) Micronutrient analysis – Determination of trace constituents of food – for quantities less than 0.01% of the simple.
f) Other specific techniques used for particular products, e.g.

Beer masters, electrophoresis etc.

g) Invivo techniques – involving the use of either human or rat as samples.

One major decision facing every food analyst is the choice of most effective method of carrying out a given analysis. In order to arrive at the right method, not only must food analyst be very familiar with the sequence of procedures of the various techniques and of the theoretical principles upon which they are based, but must also be conversant with the conditions under which each method is reliable. The Food analyst must again be aware of individual interference which may arise and must be capable of devising a means or added procedures in resolving such problems. The Food analyst will also be concerned with questions regarding the accuracy to be expected from given methods and in addition must not overlook such factors as time and cost of doing a particular analysis. The most accurate method of a certain determination may prove to be lengthy and time consuming, or may involve the use of expensive equipment and reagents. Therefore, a trained food analyst must choose methods though less exact but yield results of sufficient accuracy and time alongside the economy.

2.4 REASONS FOR FOOD ANALYSIS

Food analysis may be conducted for various reasons.

2.4.1 Process and Quality Control

This will change the processing steps involved whether it will result in product of acceptable composition or characteristics or can a processing step be modified to obtain a final product of acceptable quality. It can also change if the raw materials and finished product does not conform to specialization.

2.4.2 Government Regulations

Government regulations and recommendation are designed to maintain the general quality of food supply to ensure the food

industry provides consumers with food that are wholesome and safe, to inform consumers about the nutritional composition of food so that they can make knowledgeable choices about their diet, to enable fair competition amongst food companies and to eliminate economic fraud. There are a number of government agencies/departments responsible for regulating food quality in different countries these may include National Agency for Food and Drug Administration and Control (NAFDAC), Standard Organization of Nigeria (SON), The US Department of Agriculture (USDA), The National Maritime Fisheries Service (NMFS) and the Environmental Protection Agency (EPA).

2.4.3 Food Standard

Government agencies have specified a number of voluntary and mandatory standards concerning the composition quality inspection and labeling of specific food products. These standard includes.

a) **Mandatory Standards (Standard of Identify):** The regulations specify the type and amount of ingredients that certain foods must contain if they are to be labelled as such. For some food, there is a maximum or minimum concentration of a certain component that they must contain e.g. Peanut butter must be less 55% fat, fruit juice must not contain less than 30% of the fruit pulp. Ice-cream must be greater than 10% milk fat, tomatoes paste is not less than 30% of solid content etc.

b) **Standards of Quality:** Standards of quality have been defined for certain foods (e.g. canned fruits and vegetables) to set minimum requirements on the colour, tenderness, mass and freedom from defects.

c) **Standards of Fill-of-Container:** These standards state how full a container must be to avoid consumer deception, as well as specifying how the degree of fill is measured.

d) Voluntary Standards (Standards of Grade): A number of foods, including meat, dairy products and eggs, are graded according to their quality, e.g. from standard to excellent. For example, meats can be graded as prime, choice, select, standard etc according to their origin, tenderness, juiciness, flavour and appearance. There are clear definitions associated with these descriptors that products must conform to before they can be given the appropriate label. Specification of the grade of a food product on the label is voluntary, but many food manufacturers opt to do this because superior grade products can be sold for a higher price. The government has laboratories that food producers send their products to be tested and to receive the appropriate certification. This service is requested and paid for by the food producers, for example this function is carried out in Nigeria by National Agency for Food and Drug Administration and Control (NAFDAC).

2.4.4 Food Nutritional Labeling

Many countries make it mandatory for almost all food products to make standard nutritional label. It can also be called nutritional information. One of the major reason for including these regulations was so that consumers will be knowledgeable enough to make informed choices about their diet. Nutritional information may state the total calorie value as well as total fat (it cholesterol), carbohydrates, sugar and dietary fiber, proteins and vitamins and some minerals of nutritional importance. The label may also contain information about nutrient calories such as low fat, low sodium/ salt, high fiber, fat free, cholesterol free etc.

The label may also contain certain approved health claims based on links between specific food component and certain diseases e.g. calcium and osteoporosis, sodium and high blood pressure,

soluble fiber and heart diseases, cholesterol and heart disease. The information provided on the label can be used by consumers to plan a nutrition and balance diets to avoid over consumption of a particular food components linked with any health problems and to encourage consumption of foods that are beneficial to health.

2.4.5 Food Safety

One of the reasons for food analysis is to ensure that food is safe. It could be disastrous as well as being unpleasant to consumers if a manufacturer sold a product that was considered harmful or toxic. Food may be unsafe because it contains microorganisms that are harmful (e.g. listeria, *Salmonella*), toxic chemicals (e.g. pesticides, herbicides), and extraneous matter (e.g. glass, wood, metal insect). It is therefore important that manufacturers do everything possible to ensure that these harmful substances are not present or effectively eliminated. All these can be achieved by following good manufacturing practices regulations specified by government for specific food products and by having analytical techniques capable of detecting harmful substances – in such a case, analytical techniques of high sensitivity can be employed.

2.4.6 Food Quality Control

Due to the competitive nature of the food industry, food manufactures are continually trying their market-share and profits. Manufacturers must ensure that their products are of higher quality, less expensive and more desirable than their competitors, whilst ensuring that they are safe and nutritious. To achieve these standards, food manufacturers need analytical techniques to analyse food materials before, during and after the manufacturing process to ensure that the final product meets the desired standards. One of the most important concerns of food manufactures is to produce a final product that consistently has the same overall properties e.g. appearances, texture, flavor and shelf-life. Ideally a food manufacturer wants to take the raw

ingredients, process them to produce a product with specific desirable properties.

2.4.7 Research and Development

In recent years, there have been significant changes in the preferences of consumers for food that are healthier, higher in quality, lower cost and more exotic. Individual food manufactures must respond rapidly to these changes in order to remain competitive within the food industry. To meet these demands, they often employ a number of scientist including Food Scientist, whose primary objective is to carry out research that will lead to the development of new products, the improvement of existing products and the reduction of manufacturing costs. Many scientists working in universities, government research laboratories and large food companies carry out these basic research. Experiments are designed to provide information that leads to a better understanding of the role that different ingredients and processing operations play in determining the overall properties of foods. Research is mainly directed towards investigating the structure and interactions of food ingredients and how they are affected by changes in environment, such as temperature, pressure and mechanical agitation.

Scientists working for food companies or ingredients/raw materials suppliers usually carry out product development. Food scientists working in this area use their knowledge of food ingredients/raw materials, processing operation to improve the properties of existing products, or developed new products. In practice, there is a great deal of overlap between basic research and product development, with the basic researchers providing information that can be used by the product developers to rationally optimize food composition and properties. In both, fundamental research and product development, analytical techniques are needed to characterize the overall properties of

foods (e.g. colour, texture, flavor, shell-life etc) and to ascertain the role that each ingredient plays in determining the overall properties of foods. (Onwuka, 2018).

Vice-Chancellor Sir, permit me to introduced plantain – commonly consumed in various forms in the South-South, South-East and South-West geopolitical regions in Nigeria. This food commodity had been identified as a food store house. Therefore, my research focus was on unripe plantain (Plate 1).

Plate 1: Plantain Fingers

3.0 PLANTAIN – THE FOOD STORE HOUSE

Unripe plantain is a staple food in many tropical countries and an integral part of the traditional cuisines for centuries. This cuisine is not only delicious and widely acceptable but also have numerous health benefits and it is a nutritional powerhouse. It is rich in fiber and antioxidants. This is excellent source of dietary fiber containing both soluble and insoluble fiber which helps to promote digestive health, prevent constipation and also support healthy blood sugar levels. Additionally, unripe plantain contains antioxidants such as vitamin C and beta-

carotene which help protect the body from free radicals and oxidative stress.

Unripe plantain is used for glycemic control and weight management. The starch and fiber content in boiled unripe plantain makes them an excellent choice for individuals with diabetes or those trying to manage their blood sugar levels. The slow digestion of starch helps regulate blood sugar levels, thus preventing the spikes and crashes. Furthermore, the fibre content helps you feel fuller for longer period making unripe plantain an excellent addition to weight loss programmes. Unripe plantain contains probiotic fiber which helps feed the good bacteria in the gut promoting a healthy gut microbiome. A balanced gut microbiome is essential for strong immune system, proper digestion and even mental health.
Unripe plantain as a good source of essential minerals including potassium, magnesium and iron, calcium. Potassium helps to regulate blood pressure while magnesium and calcium for bone health aid energy production. Iron is essential for healthy red blood cells preventing anemia and fatigue.

3.1 MY CONTRIBUTIONS TO KNOWLEDGE

Vice Chancellor Sir, at this point, permit me to go through my contributions to knowledge using the invitro enzymes techniques as an essential tool in food analysis by asking the following questions.

a) Why should unripe plantain when exposed to oxygen changes colour, which also affect the plantain flour and plantain paste (amala). This change in colour is it caused by enzymatic reactions or ionic reaction? Can anything be done to prevent this colour change?
b) Another aspect that caught my attention is the recommendation of unripe plantain meals by medical personnel for patients having high blood sugar and related ailment. The question is that "why should unripe plantain meal be recommended since we know that unripe plantain

is starchy food and the end product of its digestion is sugar?

c) People know unripe plantain with the claims of containing so many minerals especially iron. In some cultures, immediately after delivery, (child birth); women are fed with unripe plantain meals (the plantain porridge, spiced pepper soup eaten with boiled plantain etc). The claim here is that it helps to restore the lost blood during child birth and promote fast recovery. The question here is how much of these minerals are bioavailable after injection? To prefer answers to these questions, the use of invitro enzyme technique became an essential tool.

d) Those of us from the Niger Delta region and coastal regions are used to eating shellfish as part of our traditional cursine. These shellfish (oyster, periwinkle, clam and whelk) are claimed to contain high protein and also a lot of minerals. If you eat any shellfish how much of this protein is in soluble fraction after digestion and available for absorption

4.0 EFFECT OF PRE-TREATMENT ON BROWNING OF PLANTAIN FLOUR PRODUCTS (AMALA)

Pretreatment have been used commonly to accelerate the drying of fruits. Blanching is another pretreatment that had been used to prevent enzymatic browning. Different drying method had been used previously for drying plantain fruits. However, these methods had been reported to affect physical, proximate, rheological and functional properties of unripe plantain flour. (Pacheol-Dalaye, *et al*., 2008). The end use of unripe plantain flour in food depends on the attractiveness of the colour. Enzymatic browning reactions which occurred during processing is one of the factors that affect plantain colour. This browning which occurs during processing in the presence of oxygen is due to the activities of the enzyme – polyphenol oxidase (PPO) also known as tyrosinase (Carbonaro and

Mattera, 2002). It is a copper containing enzyme that is widely found in plants. During enzymatic browning, polyphenol oxidase (PPO) catalysis lychoxylation of monophenol to diphenol and diphenol is then oxidized to quinones which will undergo polymerization to form brown pigment. It is therefore essential to pretreat unripe plantain slices during processing to prevent/arrest the browning which may affect the colour of the final product. Different chemical solutions such as ascorbic acid citric acid and sodium metabisulphite were used. Other chemicals used in this study are polyvinylpyrolidone, potassium citrate buffer (pH 4.2), 4-methylcatechile 3% hydrogen peroxide, 4% quaicol.

4.1 PREPARATION OF PLANTAIN FLOUR

The plantain fingers were washed, hand peeled and sliced into 3mm thickness, five hundred grams of the sliced plantain was blanched in 1.25% sodium metabisulphite solution for 15 min and another 500g of sliced plantain was blanched each in different concentration of citric acid and ascorbic acid (1-5%) for 10 min and finally another portion was blanched in water. Other procedures as illustrated in Figure 2 was followed

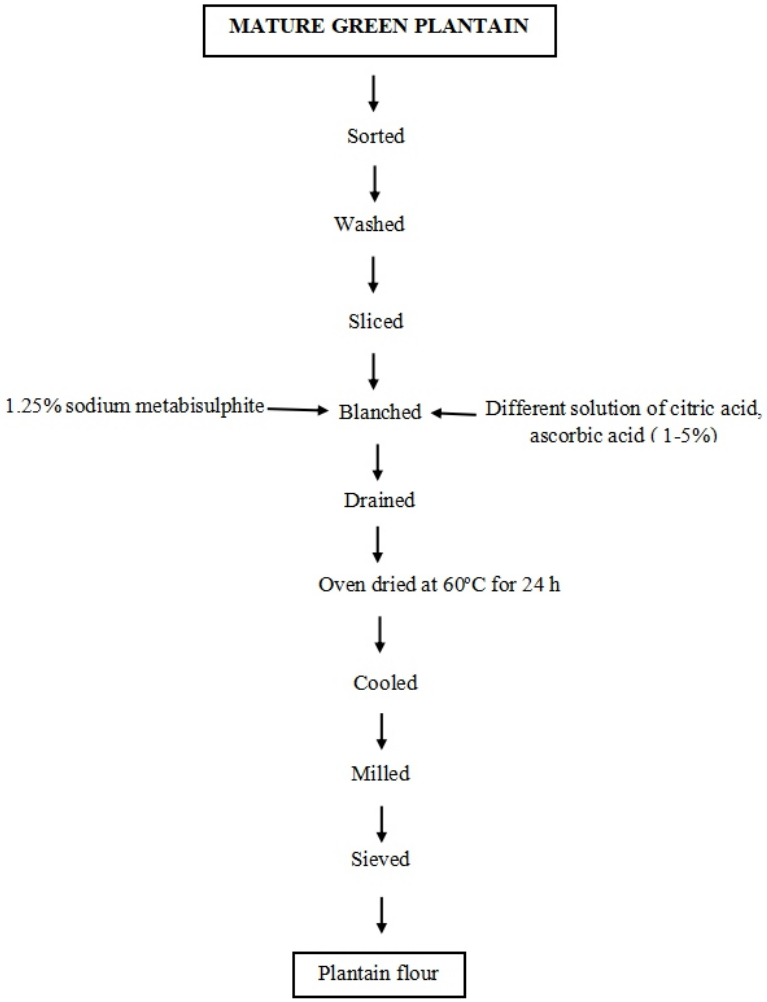

Fig. 2: Preparation of Plantain Flour

Plantain "Amala" was prepared using 20 gram of the plantain flour and gradually turned into 25ml of boiling water and stirred continuously for 2-3 min with a wooden spatula until the mixture gelatinized and form a paste called "Amala".

Browning index was determined using the method described by Walter and Purcell (1980) as modified by Omauru *et al*., (1990). Polyphenol Oxidase (PPO) was determined spectrophotometrically as described by Munoz *et al* (2006). Peroxidase Activity (PA) was also carried out using the method reported by Zhang *et al* (2006).

4.2 BROWNING INDEX

Browning index indicates the proportion of oxidized phenols present in a food simple (Jeong *et al.,* 2008). The results showed that 1% ascorbic acid (0.165) and 1% citric acid (0.157) had high levels of browning which significantly ($p > 0.5$) reduced with increase in the concentration. It also showed that there was no significant between 5% ascorbic acid and 5% citric acid when compared with the control (1.25% sodium metabisulphite) for the products as shown in Figures 3a and 3b.

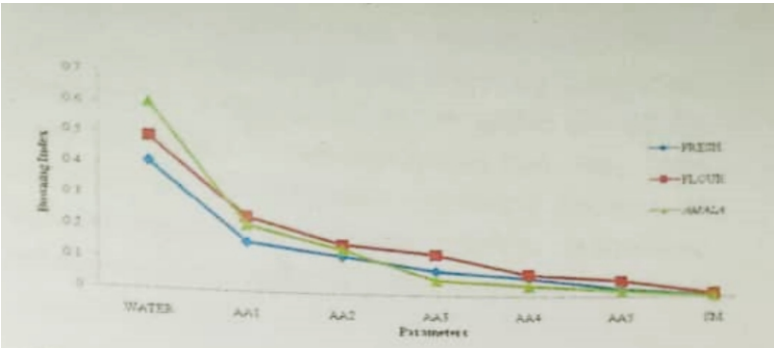

Fig. 3a: The Effect of Ascorbic Acid on Browning Index.

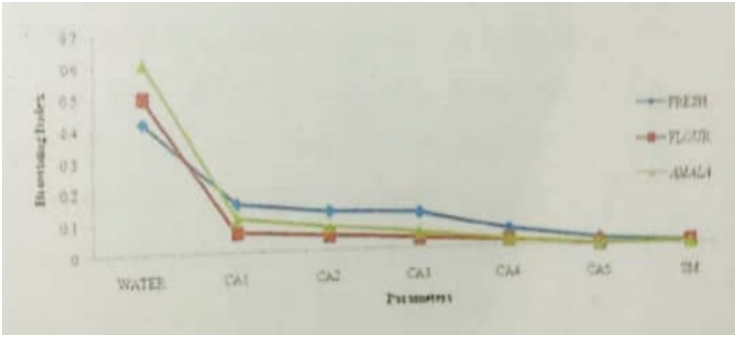

Fig. 3b: The Effect of Citric Acid on Browning Index.

Keys: AA1 = 1% Citric Acid, AA2 = 2% Citric Acid, AA3 = 3% Citric Acid, AA4 = 4% Citric Acid, AA5 = 5% Citric Acid, SM = Sodium Metabisulphite

4.3 POLYPHENOL OXIDASE (PPO)

The treatment was more effective in plantain 'amala' as compared to other samples – fresh and plantain flour. Blanching with water alone (control 2) could not effectively control browning reactions in the products; sodium metabisulphite appeared to be potent inhibitor for browning in plantain paste (amala).

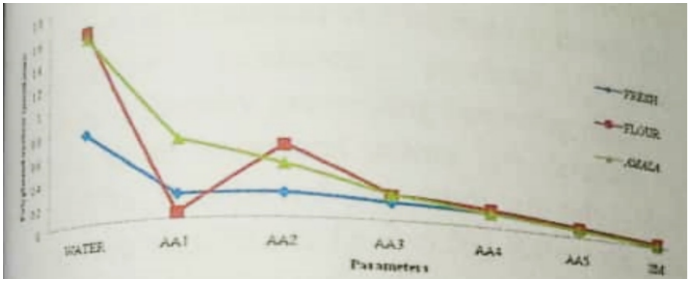

Fig. 4a: The Effect of Ascorbic Acid on Polyphenol Oxidase

Keys: AA1 = 1% Ascorbic Acid, AA2 = 2% Ascorbic Acid, AA3 = 3% Ascorbic Acid, AA4 = 4% Ascorbic Acid, AA5 = 5% Ascorbic Acid, SM = Sodium Metabisulphite

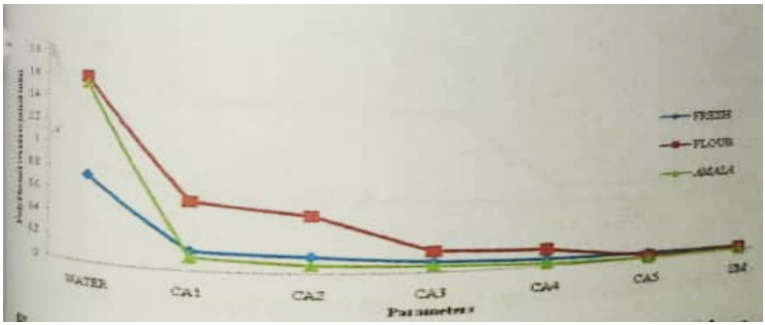

Fig. 4b: The Effect of Citric Acid on Polyphenol Oxidase

Keys: AA1 = 1% Citric Acid, AA2 = 2% Citric Acid, AA3 = 3% Citric Acid, AA4 = 4% Citric Acid, AA5 = 5% Citric Acid, SM = Sodium Metabisulphite

The results of PPO activity for fresh, plantain flour and plantain "amala" treated with different concentrations of ascorbic acid, citric and sodium metabisulphite solutions are shown in Figure 4a and 4b. It was observed that sample blanched with water had an increased level of PPO activity between fresh plantain, plantain flour and "amala". The PPO activity decreased significantly ($p < 0.05$) with increase in the concentrations of both ascorbic and citric acids. However, 5% citric acid solution compared favourable in inhibiting PPO activity in all products when compared with 1.25% sodium metabisulphite. The effort of ascorbic acid may be temporal because it can be oxidized irreversibly by the reaction of pigment intermediaries, endogenous enzymes and metals.

4.4 PEROXIDASE ACTIVITY

Figure 5a and 5b showed the result of peroxidase activity of

plantain products treated with different concentrations of enzymic acids. The results showed that plantain samples treated with sodium metabisulphite (0.016) and 5% citric acid (0.033) had the least peroxidase activity whereas plantain products treated with water had the highest peroxidase activity (0.16).

Results also revealed that 1% and 2% ascorbic acid solutions had the same level of enzyme activity. It was observed that plantain samples treated with ascorbic acid had more peroxidase activities than samples treated with citric acid in plantain "amala" which indicated that ascorbic acid did not inhibit enzyme activity in "amala". This may be due to the heat treatment given to plantain "amala" that oxidises ascorbic acid making it unstable.

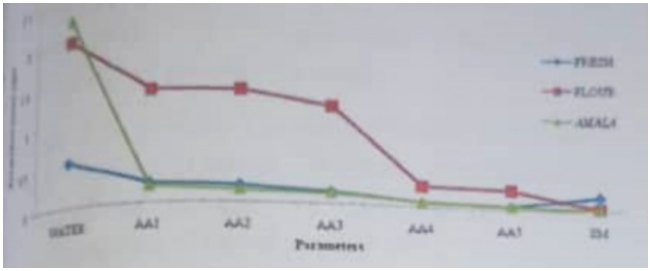

Fig. 5a: The Effect of Ascorbic Acid on Peroxidase Activity

Keys: AA1 = 1% Ascorbic Acid, AA2 = 2% Ascorbic Acid, AA3 = 3% Ascorbic Acid, AA4 = 4% Ascorbic Acid, AA5 = 5% Ascorbic Acid, SM = Sodium Metabisulphite

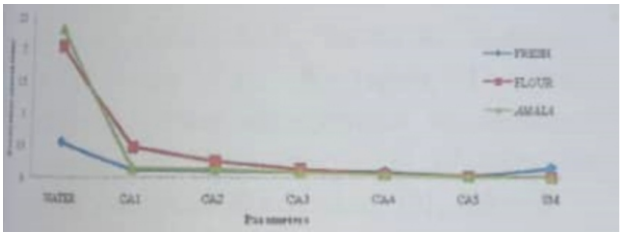

Fig. 5b: Effect of Citric Acid on Peroxidase Activity

Keys: AA1 = 1% Citric Acid, AA2 = 2% Citric Acid, AA3 = 3% Citric Acid, AA4 = 4% Citric Acid, AA5 = 5% Citric Acid, SM = Sodium Metabisulphite

According to Kiin-Kabari and Enyinda (2020) polyphenol oxidase (PPO) and peroxidase activity was effectively inhibited in plantain paste (amala) by sodium metabisulphite and citric acid which also resulted in production of browning and successfully led to the production of cream coloured amala. Ascorbic acid also was effective in the inhibition of PPO, Peroxidase activity and therefore browning was reduced in plantain amala.

5.0 THE POTENTIALS OF UNRIPE PLANTAIN IN FOOD FORMULATION

Musa paradiscaca as a functional ingredient in food formulation was investigated (Kiin-Kabari and Giami, 2015). Starch fraction and dietary fibre of unripe plantain flour as a functional ingredient in biscuit formulation is another way of promoting the consumption of functional food as recommended by world nutrition bodies to avert different health problems related to wheat consumption such as celiac diseases - a lifelong intolerance to wheat gluten characterized by inflammation of the proximal small intestine. A recent WHO recommendation is to reduce the overall consumption of sugars, and food that promotes high glucose response (WHO/FAO, 2003). A current trend in nutrition is the consumption of low carbohydrate diets, including slowly digested food products as well as increased intake of functional food (Huss and Martin, 2005). Though, a number of definitions have been given, the general opinion is that functional food is any healthy food similar in appearance to conventional food consumed as part of a usual diet and claimed to have a physiological benefit like health promoting or disease preventing properties beyond the basic functions of supplying nutrients (Summer and Mallusivela, 2011).

Vice Chancellor Sir, we studied the physiochemical and pasting properties of starches extracted from three cultivars of plantain grown in Nigeria (Cadaba, French horn and Agbagba) in order to ascertain the suitability in food formulations. Physiochemical properties such moisture content, swelling power, ash, amylose and amylopectin, pH and starch yield of three cultivars are shown in the Table I.

Table 1: Physicochemical properties of starch from three different cultivars of plantain

Parameter	French horn	Cadaba	Agbagba
Moisture content (%)	11.56 ± 0.05^{b}	12.86 ± 0.05^{a}	13.15 ± 0.020^{a}
Ash (%)	0.05 ± 0.03^{a}	0.29 ± 0.09^{b}	0.45 ± 0.02^{ab}
Swelling power (%)	9.48 ± 0.42^{a}	10.76 ± 0.72^{a}	10.10 ± 0.69^{a}
Solubility (%)	7.49 ± 1.70^{a}	3.55 ± 0.04^{b}	5.02 ± 0.76^{ab}
WBC (%)	65.50 ± 1.70^{a}	54.40 ± 0.14^{b}	62.90 ± 0.28^{a}
Amylase (%)	29.96 ± 0.14^{a}	30.66 ± 0.28^{a}	30.91 ± 0.21^{a}
Amylopectin (%)	70.04 ± 0.14^{a}	69.34 ± 0.28^{a}	69.09 ± 0.21^{a}
pH	4.46 ± 0.09^{a}	5.50 ± 0.14^{a}	4.70 ± 0.56^{a}
Starch yield (%)	15.00 ± 0.01^{a}	6.67 ± 0.02^{c}	13.30 ± 0.04^{b}

Mean ± SD of duplicate determinations. Values in the same row with different superscripts differ significantly ($P < 0.05$), WBC; Water Binding Capacity.

The results for pH was between 4.48 and 4.50 and moisture content of the extracted starch was low (11.56 to 13.15%) all indicating starches of good quality swelling power ranged from 9.48% (Agbagba) to 1.76% (Cadaba). Swelling power of starch based food is an indication of the strength of the hydrogen bonding between the starch granules. A good quality starch must have a low solubility and high swelling power (Zaakpa *et al.,* 2010, Eke-Ejiofor and Owuno, 2012). Amylose levels showed a range of 29.96% to 30.91%. Results for amylopectin

showed that Agbagba was significantly higher with a value of 70.04%.

5.1 PASTING PROPERTIES

The results of pasting properties are shown in Figures 6 and 7. Peak viscosity which is the maximum viscosity developed during or soon after the heating process is lower in Agbagba starch (133.50 RVU) and higher in French horn (163.17 RVU). Peak viscosity is a measure of the ability of starch to form paste on cooking. Adewole *et al* (2012) reported a value of 166.00 RVU for plantain starch which was comparable to the value obtained in French horn and Cadaba. These high viscosities showed that the starches formed the pastes on cooking with a corresponding pasting temperature of 86.05 and 85.95°C for French horn and Cadaba respectively. Therefore, peak viscosity is an indication of the strength of the paste which is formed from gelatinization during food processing.

Trough values ranged from 85.08 to 135.00 RVU. French horn gave the highest trough (hold value. The holding strength of a paste is the ability of the granules to remain undisrupted when the starch is subjected to a period of constant high temperature and material stress, this hold period is often compared by a breakdown in viscosity. The breakdown was higher in Agbagba (48.42 RVU) and least in French horn (28.17 RVU). The ability of starch to withstand shear thinning or breakdown in viscosity is of high industrial significance. Final viscosity is used to predict and determine the textural quality of foods. It showed starches from the samples studied will produce a more cohesive pastes.

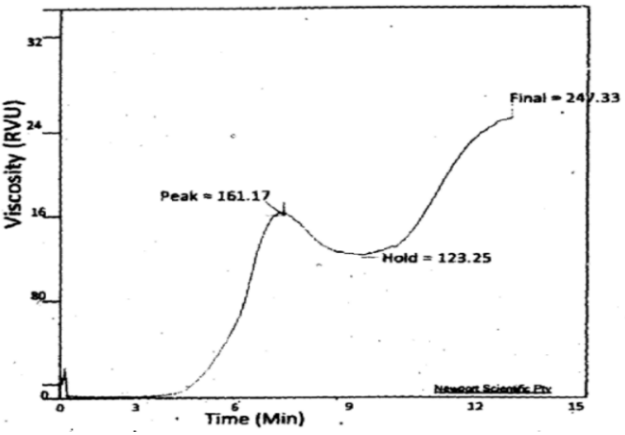

Fig. 6: Pasting curve of Cadaba plantain starch.

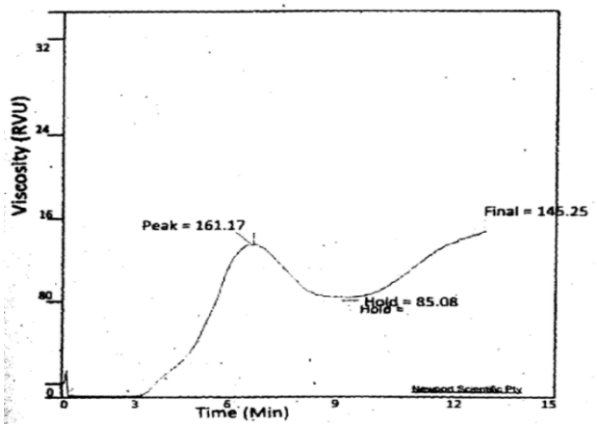

Fig. 7: Pasting curve for Agbagba plantain starch.

Finally, it was observed that the extracted starch from cultivars possess good physicochemical and pasting properties and could be utilized in plantain based foods and pharmaceutical products. Starch from French horn cultivar had a better yield and lower value of breakdown viscosity indicating a more stable paste formulation (Kiin-Kabari *et al*., 2014)

5.2 STARCH FRACTIONS

Starch fractions and dietary fibre were determined on unripe plantain flour using invitro enzymes technique. The total starch was determined according to the method described by Goni *et al* (1997) using α - amylase enzymes and glucose assay kits and glucose concentration was converted to starch by multiplying by a factor of 0.9. Resistant Starch (RS) was also done using pepsin and α - amylase enzymes. The digestible starch was taken as the difference between the Total Starch (TS) and Resistant Starch (RS) i.e. digestible starch = total starch – Constant Starch as reported by Frei *et al*., (2001) and modified by Capriles *et al*., (2008). Dietary fibre was determined according to AOAC (2012) method using Bovine-Pancrease, pepsin and amyloglucosidase enzymes.

The total starch in plantain was observed to be 38.42% with a high resistance starch of 19.49%, while digestible starch was 11.93%. Unripe plantain starches had been shown to have small concentrations of free sugars and rapidly digestible starch. The dietary fibre content of unripe plantain flour was 23.77%. This showed that resistance starch has an interesting relationship with dietary fibre. The higher the resistance starch, the higher the dietary fibre. Also Reihiman *et al* (2004) observed that dietary fibre in human nutrition lowers serum cholesterol, reduces the risk of heart attack and other metabolic diseases. The bulking effect of fibre in the diet, especially on the stool volume, softness, frequency and regularity of elimination are thought to be due to high water binding capacity of fibre (Okaka *et al* (2002). See Table 2.

Table 2: Starch Fractions and Dietary Fibre of Wheat/Plantain Biscuit (%)

Blends	Resistance Starch	Digestible Starch	Total Starch	Dietary Fibre
A	12.06 ± 0.005^{d}	25.07 ± 0.007^{b}	37.13 ± 0.007^{c}	12.03 ± 0.18^{f}
B	9.42 ± 0.002^{f}	23.06 ± 0.003^{d}	32.48 ± 0.004^{d}	21.19 ± 0.27^{c}
C	10.25 ± 0.003^{c}	24.63 ± 0.006^{c}	34.88 ± 0.0006^{b}	21.9 ± 0.26^{d}
D	13.34 ± 0.008^{b}	24.63 ± 0.006^{c}	38.29 ± 0.008^{bc}	18.29 ± 0.23^{c}
E	13.28 ± 0.007^{c}	26.77 ± 0.009^{a}	40.05 ± 0.009^{a}	22.17 ± 0.42^{b}
F	19.49 ± 0.009^{a}	11.93 ± 0.001^{c}	31.42 ± 0.004^{c}	25.77 ± 0.94^{a}

Keys:
A = 100% WF and 0% PF, B = 90% WF and 10% PF, C = 80% WF and 20% PF, D = 70% WF and 30% PF, E = 60% WF and 40% PF. F = 0% WF and 100% PF
where WF = Wheat Flour
PF = Plantain Flour

5.3 PLANTAIN FLOUR IN FOOD FORMULATION

The utilization of plantain flour in biscuit productions was done using different levels of substitution of wheat flour with plantain flour. (10%, 20%, 30% and 40%) with few contents (100% wheat flour and 100% plantain flour). The samples were labelled from A – F. Proximate composition, physical properties, starch fractions and dietary fibre were determined on the products from various levels of substitution of wheat/plantain flour blends.

The proximate composition of the biscuit is presented in Table 3

Table 3: Proximate Composition of Biscuit Prepared from Wheat/Plantain Flour Blends (%)

Samples	Moisture	Ash	Fat	Protein	Total CHO
A	11.80 0.07a	1.91 0.01a	11.08 0.04a	9.91 0.28a	68.75 0.64d
B	10.97 0.09d	1.81 0.02a	11.02 0.28a	8.24 0.19b	70.93 0.42c
C	1.061 0.01bc	1.39 0.01b	10.56 0.08bc	6.05 0.07c	72.21 0.25c
D	10.49 0.07b	1.33 0.02b	9.81 0.08c	4.55 0.49d	73.41 0.58b
E	10.18 0.07b	1.28 0.03bc	9.47 0.02c	3.80 0.14d	75.26 0.014a
F	10.18 0.05b	1.18 0.02c	9.10 0.07d	3.30 0.14d	76.12 0.18a

Keys:
A = 100% WF and 0% PF, B = 90% WF and 10% PF, C = 80% WF and 20% PF, D = 70% WF and 30% PF, E = 60% WF and 40% PF. F = 0% WF and 100% PF
where WF = Wheat Flour
PF = Plantain Flour

The moisture content ranged from 10.18% (Sample E and F) to 11.80% (sample A) Crude protein and fat content were observed to decrease significantly with increase in plantain flour added, while carbohydrate content increased. The ash content which is an important parameter ranged from 1.91% to 1.18% showing a decrease with increase in the level of substation with plantain flour. The physical properties such as weight, diameter, height, thickness (width) and spread ration decreased with increase in the level of plantain flour when compared in the control (Sample A)
The results for starch fractions and dietary fibre of biscuit produced from different levels of substitution of wheat flour with plantain flour are presented in Table 4.

Table 4: Physical Characteristics of Biscuit from Wheat / Plantain Flour

Blends	Diameter (cm)	Thickness (cm)	Weight (g)	Height (cm)	Spread ratio
A	3.80 ± 0.015^{a}	6.80 ± 1.40^{a}	3.46 ± 0.08^{a}	0.50 ± 0.009^{a}	12.33 ± 0.10^{a}
B	3.70 ± 0.14^{ab}	6.05 ± 0.23^{b}	3.39 ± 0.06^{ab}	0.40 ± 0.007^{a}	12.23 ± 0.07^{a}
C	3.60 ± 0.13^{b}	5.85 ± 0.18^{b}	3.31 ± 0.04^{b}	0.30 ± 0.006^{c}	12.27 ± 0.09^{a}
D	3.55 ± 0.10^{b}	5.95 ± 0.21^{b}	3.24 ± 0.03^{c}	0.30 ± 0.006^{c}	12.24 ± 0.6^{a}
E	3.45 ± 0.07^{bc}	$5.90 \pm 0.21b$	3.21 ± 0.01^{c}	0.20 ± 0.001^{d}	12.18 ± 0.04^{b}
F	3.35 ± 0.07^{c}	5.60 ± 0.15^{c}	3.20 ± 0.01^{c}	0.20 ± 0.001^{d}	11.15 ± 0.1^{c}

Keys:
A = 100% WF and 0% PF, B = 90% WF and 10% PF, C = 80% WF and 20% PF, D = 70% WF and 30% PF, E = 60% WF and 40% PF. F = 0% WF and 100% PF
where WF = Wheat Flour
PF = Plantain Flour

The percentage total starch was significantly higher in 100% wheat flour (Sample A) compared to other samples. However, total starch decreased with increase in plantain flour with the lowest (38.24%) recorded in Sample F. Resistant starch was observed to increase from 8.96% to 19.49% with increase in the level of supplementation of plantain flour whereas digestible starch (DS) deceased from 38.17% (Sample A) to 18.93% (Sample F). Unripe plantain starches have been reported to have small concentration by free sugars and rapidly digestible starch (Rainburk *et al.,* 2004). The dietary fibre content of the biscuit increased from 12.03% (Sample A) to 25.77% (Sample F). This showed a progressive significant increase between the samples with increase in the level of plantain flour added (Kiin-Kabari and Giami, 2015). These observation is beneficial in human nutrition, because a lot of researchers had shown the importance of dietary fibre in the diet (Nugent, 2005, Rebman *et al,* 2004).

5.4 INVITRO STARCH HYDROLYSIS AND PREDICTION OF GLYCEMIC INDEX

Invitro starch hydrolysis and prediction of glycemic index in amala and plantain based products (Kiin-Kabari and Giami, 2016). Invitro starch hydrolysis had been identified as a simple or in expensive experimental method used in estimating glycemic response of carbohydrate meals after ingestion (Praya *et al.,* 2002; Dona *et al.,* 2010). These findings helped in reducing the use of human beings and avoiding the complexities associated with human management involved in invitro experimental designs. Various studies have demonstrated the influence of different nutrients in foods on starch hydrolysis. These nutrients include protein content (Chung *et al.,* 2008). Resistant starch (Fioc *et al*., 2003; Deepa *et al.,* 2010). Moisture content (Lynch *et al.,* 2007), Phosphorus content (Woda *et al.,* 2008; Absat *et al.,* 2009). All these factors had been found to affect starch digestibility. When raw starch granules are gelatinized during heating, the disruption of starch sometimes increases its susceptibility to enzymatic degradation. In many starchy foods the resistant starch is not fully gelatinized during processing either due to limited water or insufficient heating.

The post prandial response of foods containing raw or partially gelatinized starches have become the subject of interest in recent years because slowly digested carbohydrates are generally considered to be beneficial for the dietary management of metabolic disorders including diabetes and hyperlipidemia (Brand-miller, 2003; Lehmann and Robin, 2007).

In Nigeria, plantain (*Musa paradisiaca*) is a popular food commodity and a cheap source of carbohydrate. An important contribution of plantain (unripe) fruit is the Glycemic Index (GI) which compares equal quantities of carbohydrate and provides a measure of carbohydrate quality and not quantity

(Liu *et al.,* 2000). Unripe plantain has also been reported to contain high slowly digestible starch with a low glycemic index (GI) high content of resistant starch and dietary fibre (Okafor and Ugwu, 2013; Kiin-Kabari and Giami, 2015).

The international table of glycemic index and load showed that unripe plantain has a glycemic index of 40 ± 4. Since low glycemic index foods release glucose at a slower rate compared to high glycemic index foods, unripe plantain flour has the potential to slow down the rate of starch hydrolysis in plantain based products.

Based on the potentials of unripe plantain flour, already discussed, it is now necessary to look at the utilization of unripe plantain flour in food formulation and also to determine how such inclusion may affect the predicted glycemic index. The following plantain based products were investigated – plantain 'amala', cookies, bread and cake.

5.4.1 Product Formulations

"Amala" is a common plantain paste produced by stirring in hot water (1:4 $^{w}/_{v}$) until a smooth paste was formed using the method reported by Kiin-Kabari *et al.,* (2015).

Other baked products investigated include, cookies and cakes.

Cookies were produced from 85% plantain flour and 15%. Bambara groundnut protein contributed as described by Arisa *et al*., (2013), with modification, as reported by Kiin-Kabari and Giami (2015).

The butter method described by Ogazi (1984) was used with modification. Bread was produced using 70% wheat flour, 20% plantain flour and 10%. Bambara ground protein concentrate as recommended by Kiin-Kabari *et al* (2015). After mixing the resultant batter was scaled (500g), proofed for 20 minutes and baked at 180^{o}C for 45 mins

Cake was also produced for 70% wheat flour, 20% plantain flour and 10% Bambara ground protein concentrate using the creamy

method of blending. Half of the composite flour were mixed with all the fat for 2 min to obtain a creamy dough before the remaining composite flour and other ingredients were added, more water was added gradually and mixing continued until the dough was soft and greasy. The dough was moulded shaped and baked in the oven at 200°C for 15 min.

5.4.2 Invitro Starch Digestion Rate and Prediction of Glycemic Index (PGI)

The starch digestive rate (hydrolysis) for plantain products (amala, cookies, bread and cakes) were expressed as the percentage of total starch hydrolase over time intervals of 30 min. 60 min, 90min and 120 min of incubation. The hydrolysis index (HI) was derived from the ratio between the areas under the hydrolysis curve of the various products developed and the reference sample (Glucose).

From the Hydrolysis Index (HI) obtained, the Predicted Glycemic Index (PGI) was calculated using the equation established by Goni *et al* (1997).

$$PGI = 39.7 + 0.548HI.$$

$$HI \frac{\text{AUC of product}}{\text{AUC of reference sample}} x \frac{100}{1}$$

Where AUC = Area under the Hydrolysis Curve.

Table 5: Total Starch (TS), Resistant Starch (RS) and Digestible Starch (DS) of Plantain Products

Sample	Total starch (%)	Resistant starch (%)	Digestible starch (TS – RS) (%)
Plantain flour	51.51[c]	5.22[a]	46.29[c]
Amala*	64.33[b]	4.99[a]	59.34[b]
Cookies*	63.53[b]	3.30[b]	60.23[b]
Bread+	68.34[a]	0.94[c]	67.40[a]
Cakes+	70.62[a]	2.95[b]	68.45[a]

a,b,c Means bearing the same superscript within the same column do not differ significantly ($P < 0.05$)

Key:

* = 85% plantain flour and 15% Bambara groundnut protein concentrate.

+ = 70% wheat flour, 20% plantain flour and 10% Bambara groundnut protein concentration.

The result showed that total starch of plantain starch was low (51.51%) which also indicated a low digestible starch of 46.29% as shown in Table 5, which also resulted in a high resistant starch value of 5.22%. Similar values of 4.99% was also observed in plantain 'Amala'. These values are significantly different from the low resistant starch observed in cakes and bread. This observation may be attributed to the fact the heat treatment applied in both cases may not be significant to fully gelatinized the starch granules making it resistant to α amylase digestion. It may also contain high dietary fibre which cannot be digested by the human enzymes.

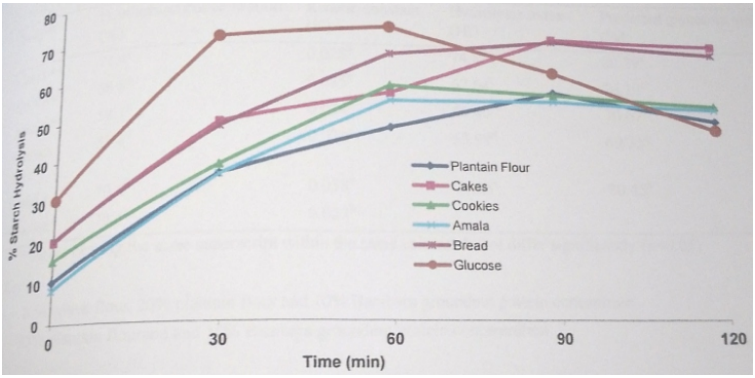

Fig. 8: Rate of Starch hydrolysis of Plantain Product

5.4.3 Rate of Starch Hydrolysis

Starch hydrolysis curve for plantain products are presented in Figure 8.

The products followed the pattern of enzymatic digestion except glucose that got to plateaus earlier at 60 mins. Plantain flour, amala and cookies had their maximum hydrolysis of 51.4%, 55.1% and 56.8%, respectively at 90 mins while cakes and bread displayed maximum hydrolysis of 71.4% and 70.8% respectively also at 90 min.

The equilibrium concentration (C), Kinetic constant (K), Hydrolysis Index (HI) and Predicted Glycemic Index (PGI) of plantain products as shown in Table 6.

Table 6: Equilibrium concentration (C), Kinetic constant (K), Hydrolysis Index (HI) and Predicted Glycemic Index (PGI) of plantain products

Sample	Equilibrium concentration (%)	Kinetic constant (K),	Hydrolysis Index (HI)	Predicted Glycemic Index (%)
Cakes+	71.4^{b}	0.028^{a}	74.85^{a}	80.79^{a}
Cookies*	66.8^{b}	0.025^{a}	62.64^{c}	74.10^{c}
Amala*	58.1^{c}	0.024^{b}	56.40^{bc}	70.67^{b}
Plantain flour	53.4^{d}	0.028^{a}	43.98^{d}	59.35^{c}
Bread+	70.8^{b}	0.038^{a}	74.25^{a}	80.45^{a}
Glucose	78.4^{a}	0.023^{b}	-	-

a,b,c,d means bearing the superscripts within the same column do not differ significantly ($p<0.05$)

Key:

+ = 70% wheat flour, 20% plantain flour and 10% bambara groundnut protein concentrate.

* = 85% plantain flour and 15% bambara groundnut protein concentration

The equilibrium concentration (C) was higher in cakes (71.4%)

and bread (70.8%) which indicated no significant difference. The Kinetic constant (K) of the various products showed very low values between 0.0274 (amala) to 0.038 for bread and 0.028 for cake. These low values suggest generally higher resistance to enzymatic hydrolysis (Kiin-Kabari and Giami, 2016).

Jaisut *et al* (2009) had earlier observed direct influence of both K and C parameters on the starch hydrolysis of brown rice. The highest Hydrolysis Index (HI) of 74.85% was observed in cakes and 74.25% in bread which resulted in higher Predicted Glycemic Index (PGI) of 80.79% for cakes and 80.45% for bread. These values were significantly different from that obtained for 'amala' with Hydrolysis Index (HI) of 56.40%, PGI 70.67% and cookies with HI values of 62.64% and PGI of 74.10%. The lowest HI of 43.98% and PGI of 59.35% was recorded in plantain flour results showed that the more plantain flour in the product formulation, the lower the HI which subsequently led to a reduced Predicted Glycemic Index.
Although PGI for white bread had been reported to be 94.61% (Capriles *et al.,* 2008). Compared to 80.45% obtained for composite plantain bread in this study. These results showed the more plantain flour the less the glycemic index.

6.0 MINERAL BIOAVAILABILITY USING IN-VITRO ENZYME DIGESTION

The plantain samples were subjected to invitro enzymatic digestion with pepsin plus pancreatin according to the method described by Ikeda (1990). Enzymes solutions containing 16mg pepsin (Cat No P6587) and 3.5 ml of 0.06N HCL, 1.0g sodium chloride make upto 100ml deionized water was prepared. Another solution containing 1.6g of pancreatin (Cat No P1750) dissolved in phosphate buffer (pH 7.5) and made upto 100 ml with same buffer was also prepared. In a test tube, 20ml of pepsin enzyme solution was added to 0.5g of the sample. The closed test tube was shakened and incubated at

37°C for 3 hours. Immediately after peptic digestion, pH was adjusted to 8.0 using phosphate buffer. Toluene was added to prevent the growth of microorganism. Pancreatin solution (25 ml) with deoxicholate (1.0%) was then added to the digestion mixtures and samples was subsequently incubated for 20 hours at 37°C. After digestion, the suspensions was placed in ice-cold vessel and classified by centrifugation at 10,000 rpm for 20 mins. The supernatants obtained were subjected to mineral analysis using the atomic absorption Spectrophotometer (AAS). The percentage soluble fraction was calculated from the total mineral content and the mineral content after enzyme digestion. The data obtained were analysed using of Analysis of variances (ANOVA) with SPSS 16.0 software version 2007.

6.1 TOTAL MINERAL COMPOSITION

Total mineral (dry weight) composition of three banana and plantain hydrides are shown in Table 7.

Table 7: Total Mineral Compositions (mg/100g) of Three Banana Hybrids and Three Plantain Hybrids

Samples	Ca	Na	K	Mg	Fe	Zn
A	257.23^{d}	496.34^{a}	1925.89^{a}	140.89^{b}	29.19^{a}	0.93^{a}
B	165.70^{c}	121.67^{f}	1650.28^{c}	116.65^{f}	8.13^{d}	0.71^{b}
C	285.64^{c}	309.93^{c}	1407.89^{d}	119.55^{e}	20.88^{b}	0.36^{c}
D	448.19^{a}	143.19^{d}	741.42^{e}	150.53^{a}	7.50^{e}	0.41^{d}
E	326.67^{b}	363.57^{b}	1655.02^{b}	138.83^{e}	27.31^{a}	0.41^{d}
F	136.88^{f}	131.93^{e}	1163.74^{c}	129.47^{d}	9.56^{c}	0.55^{e}

a – f means with the same superscript with the column are not significantly different ($p>0.05$)

Key:

A = FHIA 17; B = FHIA 21; C = FHIA 34; D = Ogoni Red; E = two fingers; F = Agbagba;

Ca = Calcium; Fe = Iron; K = Potassium; Mg = Magnesium; Zn = Zinc; Na = Sodium.

The highest total sodium (496.34 mg/100g) potassium (1925.89 mg/100g), iron (29.19mg/100g) and zinc (0.93mg/100g) was recorded by FHIA 17 banana hybrid and least total sodium (121.6mg/100g) in FHIA 21 banana hybrid, Ogoni red gave the highest amount of calcium (448.19mg/100g).

6.2 SOLUBLE MINERALS

The soluble composition in the plantain and banana hybrid are shown in Table 8.

Table 8: Soluble Fraction (Minerals) after In-vitro Digestion of plantain and Banana Hybrids with Pepsin and Pancreatin

Samples	Ca	Na	K	Mg	Fe	Zn
A	213.01^{c}	272.27^{a}	1161.02^{b}	102.60^{c}	13.42^{a}	0.39^{b}
B	147.08^{e}	68.97^{f}	1331.71^{a}	74.48^{d}	29.49^{f}	0.48^{a}
C	209.98^{d}	188.67^{c}	1150.76^{c}	108.68^{b}	10.85^{b}	0.31^{f}
D	334.52^{a}	122.55^{d}	770.51^{e}	45.22^{f}	4.34^{d}	0.36^{d}
E	305.27^{b}	266.95^{b}	969.13^{d}	63.84^{e}	9.62^{c}	0.31^{f}
F	130.28^{f}	115.52^{e}	481.65^{f}	120.84^{a}	3.35^{e}	0.38^{e}

a – f means with the same superscript with the column are not significantly different ($p>0.05$)
Key:
A = FHIA 17; B = FHIA 21; C = FHIA 34; D = Ogoni Red; E = two fingers; F = Agbagba;
Ca = Calcium; Fe = Iron; K = Potassium; Mg = Magnesium; Zn = Zinc; Na = Sodium.

The results showed that Ogoni red had the highest digestible calcium (334.52mg/100g), FHIA 17 had the highest amount of digestible sodium (272.27mg/100g) followed by two fingers (266.94mg/100g) and FHIA 34 (188.67mg/100g). Potassium and iron (1161.01mg/100g) and (13.42 mg/100g) were higher in FHIA 17. This results showed a significant difference ($P < 0.05$)

in iron, calcium, potassium, magnesium and in all the hybrids (Kiin-Kabari and Agoha, 2018).
Percentage bioavailable minerals.

Table 9: Percentage (%) Bioavailable of Minerals in Banana and Three Plantain Hybrids

Samples	Ca	Na	K	Mg	Fe	Zn
A	82.80^{d}	54.85^{f}	60.28^{e}	72.82^{e}	54.97^{c}	41.93^{f}
B	88.76^{c}	56.68^{e}	80.69^{b}	63.84^{d}	40.46^{d}	67.60^{e}
C	73.51^{f}	60.87^{d}	81.74^{a}	90.90^{a}	51.96^{b}	86.11^{b}
D	74.63^{e}	92.89^{a}	66.20^{c}	42.41^{f}	57.86^{a}	87.80^{a}
E	93.44^{b}	73.42^{c}	58.55^{f}	32.57^{e}	35.22^{e}	75.60^{c}
F	95.59^{a}	80.50^{b}	64.96^{d}	93.33^{b}	35.04^{f}	69.09^{d}

a – f means with the same superscript with the column are not significantly different ($p>0.05$)
Key:
A = FHIA 17; B = FHIA 21; C = FHIA 34; D = Ogoni Red; E = two fingers; F = Agbagba;
Ca = Calcium; Fe = Iron; K = Potassium; Mg = Magnesium; Zn = Zinc; Na = Sodium.

The percentage bioavailable minerals are presented in Table 9. The results showed that calcium showed a range from 73.51% to 95.59% sodium had a range from 54.85% to 80.50% with plantain hybrid have a better bioavailability compared to banana. For potassium, the value ranged from 58.55% to 81.74% with banana hybrid showing more mineral released and available. Agbagba showed 93.30% of magnesium to be bioaccessible with the lowest value of 32.57% in two fingers. Although, the total zinc contents of banana and plantain hybrid were low, the percentage bioavailability ranged from 41.93% to 87.80% (Ogoni Red).

Iron had been associated with unripe plantain. However, the

percentage soluble fraction were low ranging from 35.04% obtained in Agbagba to 57.86% (Ogoni Red). Bioavailability of minerals is affected by the presence of some metal agents on the solubility of mineral elements (Ekcohn *et al*, 2017). Availability could be enhanced with processing method that releases the effect of phytic acid which binds metals such as CA, Zn and Fe and thus increasing the bioavailability. (Chaoui *et al*., 2013; Eltayeb *et al*., 2007).

6.3 BIOAVAILABILITY AND MINERAL BALANCE

Bioavailability and mineral balance of cookies produced from processed from seseame seed flour blender (Akusu *et al*., 2020). The same invitro techniques and fermentation was used to access;

a) The level of antinutrients and the fermentation to determine the effects of these antiminerals on mineral bioavailability.
b) To look at fermentation as a processing method on mineral bioaccessibility. Antinutrient investigated include phytic acid using the method of Hassan (2011). Total phenol content was determined using the method described by Singleton *et al* (1966) and oxalate was determined using the method of AOAC (2012).

6.3.1 Fermentation

The seseame seeds were dehulled, boiled in water for 6 hours and cooled. The cooked seeds were placed in a plastic container with a tight lid and scaled. The samples were allowed to fermentation at $35 \pm 2^{o}C$ for 7 days, and oven dried at $80^{o}C$ for 12 hours to stop the fermentation process. Samples were milled and sieved (30 mesh) to obtain fermented seseame flour. Other processing methods adopted includes, germination, toasting, boiling and using raw (control). Development and production of cookies using the different methods and formulations were done. Invitro bioavailability of cookies. Peptic digestion followed by titatable acidity and pancreatic digestion were used to determined mineral both the total mineral and soluble

fractions. Bioavailability was calculated using the equations below:

Bioavailability % $\frac{Y}{Z} x \frac{100}{1}$

where Y = mineral content of bioaccessible fractions (mg/100g)

Z = total mineral content (mg/100g)

Mineral balance was calculated as follows;

100 – Bioaccessible mineral (%).

Table 10: Mineral Balance (%) of Cookies Produced from Wheat/Processed Seseame Seed Flour Blends

Cookies	Zinc	Copper	Calcium	Magnesium	Iron
WRSC1	33.832^{f}	29.797^{n}	67.399^{c}	36.419^{j}	21.698^{g}
WRSC2	8.307^{q}	34.725^{o}	63.263^{d}	39.971^{h}	18.675^{i}
WRSC3	13.863^{n}	40.195^{m}	25.431^{i}	41.760^{g}	6.488^{o}
WRSC4	29.958^{g}	24.768^{q}	28.449^{g}	42.182^{g}	16.157^{j}
WDSC1	10.810^{p}	84.923^{b}	15.642^{k}	45.095^{d}	10.084^{n}
WDSC2	2.622^{r}	56.772^{k}	10.907^{m}	46.292^{c}	26.483^{f}
WDSC3	45.364^{c}	7.856^{s}	74.946^{a}	44.265^{e}	46.555^{d}
WDSC4	59.399^{a}	56.052^{k}	69.115^{b}	45.254^{d}	66.474^{b}
WCSC1	47.042^{b}	81.557^{c}	70.384^{b}	39.953^{h}	74.870^{a}
WCSC2	38.144^{e}	79.120^{d}	15.351^{k}	44.571^{e}	3.759^{q}
WCSC3	17.980^{m}	10.001^{r}	2.323^{p}	11.878^{j}	13.005^{l}
WCSC4	13.651^{n}	63.859^{j}	32.718^{f}	10.185^{k}	35.206^{e}
WFSC1	25.837^{h}	71.139^{f}	6.519^{o}	42.188g	47.966^{c}
WFSC2	41.716^{d}	67.883^{h}	11.605^{l}	44.296e	1.183^{s}
WFSC3	42.071^{d}	73.237^{e}	28.999^{g}	43.519^{f}	5.061^{p}
WFSC4	25.006^{i}	86.336^{a}	23.460^{j}	43.244^{fg}	19.165^{h}
WGSC1	2.144^{r}	44.078^{l}	26.833^{h}	43.677^{f}	2.096^{r}
WGSC2	11.799^{o}	39.874^{m}	5.421^{o}	43.641^{f}	12.532^{m}
WGSC3	18.426^{l}	36.243^{n}	32.867^{f}	43.765^{f}	6.966^{o}
WGSC4	23.670^{j}	66.046^{i}	26.262^{h}	49.078^{b}	14.288^{k}
WFC	22.976^{k}	70.459^{g}	42.262^{e}	97.458^{a}	27.203^{f}

Value bearing different superscript in the same column differ significantly ($P<0.05$).
Key:
WRSC = Wheat: Roasted Seseame Cookies
Samples WRSC1, 2, 3 and 4 (95:5, 90:10, 85:15 and 80:20), respectively
WDSC = Wheat: Defatted Seseame Cookies
Sample WDSC 1, 2, 3 and 4 (95:5, 90:10, 85:15 and 80:20), respectively
WCSC = Wheat: Cooked Seseame Cookies
Sample WCSC 1, 2, 3 and 4 (95:5, 90:10, 85:15 and 80:20), respectively
WFSC = Wheat: Fermented Seseame Cookies
Sample WFSC 1, 2, 3 and 4 (95:5, 90:10, 85:15 and 80:20), respectively
WGSC = Wheat: Germinated Seseame Cookies
Sample WGSC 1, 2, 3 and 4 (95:5, 90:10, 85:15 and 80:20), respectively
WFC = Wheat Flour Cookies 100%

6.3.2 Mineral Balance

The mineral balance of cookies produced from wheat and seseame seed flour blends are shown in Table 9 above. Mineral balance for Zn, Cn, Ca, Mg and Fe ranged from 2.14% to 59.40%, 7.86% to 86.34%, 2.32% to 74.95%, 39.96% to 97.55% and 3.76% to 74.80%, respectively. Cookies with high mineral balance is an indication of low bioaccessibility of that specific mineral. Cookies with 5% fermented seseame seed flour recorded highest percentage of bioaccessible zinc and magnesium.

7.0 PROTEIN DIGESTIBILITY AND MINERAL BIOAVAILABILITY OF SOME SELECTED SHELLFISH (KIIN-KABARI, *et al.*, 2020).

Shellfish are excellent source of protein and a good source of

minerals such as calcium, sodium, phosphorous and iron (Kiin-Kabari *et al.,* 2017). Molluscs to a large extend include gastropods (periwinkles, whelks, snails) and bivalves (clams, oysters and others), shellfish are excellent source of protein to both riverine communities and the entire population at large (Tayo *et al.,* 2008). Periwinkles had been reported to contain as much as 60.93% protein. Studies had reported that consumption of oysters, clams, periwinkles and whelks can address the serious problem of micronutrient deficiency. However, the usefulness of shellfish as a source of protein and minerals for human may be limited by the actual amount of these minerals protein are available for absorption and utilization.

Shellfish are rich in essential micronutrients such as calcium, (129.18mg/100g), magnesium (31.19mg/100g), potassium (71.13mg/100g). iron (10.90mg/100g) and zinc (1.31mg/100g) as reported earlier by Obande *et al*., (2013). Kiin-Kabari *et al* (2017) observed a high protein values of 13.96%, in whelks and clams and 13.31% in oysters and high ash content of 14.02% was shown in whelks with a corresponding high magnesium, calcium, potassium and sodium. Oyster with a value of 286.22m/100g was shown to be the richest source of phosphorus (Kiin-Kabari *et al*., 2017).
Vice Chancellor, the question is how much of these protein is digestible and absorbed by the body. To resolve this problem, we used the invitro protein digestion techniques to find out and determine the percentage of proteins digestible by intestinal enzymes, making it available for absorption by the human body.

7.1 INVITRO PROTEIN DIGESTIBILITY

The protein was determined in all the shellfish samples using the AOAC (2012) standard method. Invitro protein digestibility sample was determined by the method of Monsour and Yusuf (2002). The samples (250mg) was suspended in 15ml of 0.1N HCL in a glass tube. Pepsin enzymes (1.5mg) was introduced

into the suspension at 37°C and shakened intermittently for 3 hours. The solution was neutralize with 0.5N sodium hydroxide and then treated with 4mg of pancreatic enzyme in 7.5ml of 0.2ml phosphate buffer (pH 8.0) containing 0.5ml sodium acid. The mixture was shaken gently at 37°C for 24 hours. The solids was separated by centrifugation at 4000 rpm for 30 min and washed with water (5x30ml) and filtered with Whatman No. 1 filter paper. The residue was dried in the oven at 100°C and analysed for nitrogen using the popular Kjeldahl method. The protein digestibility was calculated using the formular.

$$\% \text{ protein digestibility} = \frac{\text{Nitrogen of samples} - \text{Nitrogen of Residue}}{\text{Nitrogen of sample}} x \frac{100}{1}$$

The results for invitro protein digestibility of the shellfish investigated are presented in Figure 8.

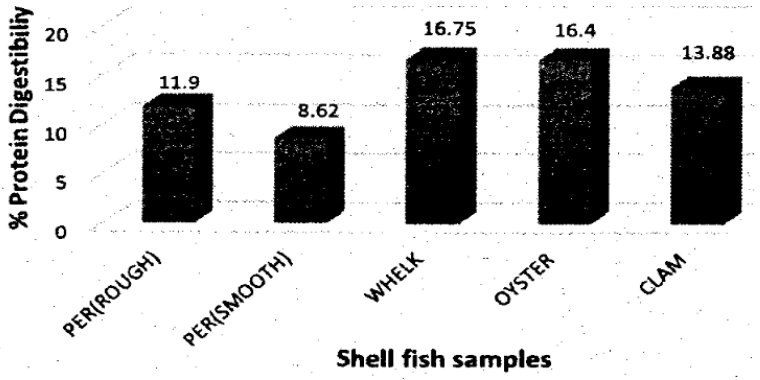

Fig. 9: Percentage protein digestibility of some selected shellfish

The protein digestibility of shellfish was 11.9, 8,62, 16.75, 16.64 and 13.88% for periwinkles (rough), periwinkle (smooth), whelk, oyster and clam, respectively as shown in Figure 9. These showed that proteins in oyster and whelk were more digestible than periwinkles and clam. Invitro protein digestibility provides a useful, and reliable tool for estimating protein nutritional quality. The nutritional quality of protein is related to its amino acid composition, digestibility and the ability to supply the essential amino acids in the amount required the species consuming the protein (Endres, 2001). It can be used to screen raw materials and to evaluate the effect of various processing methods on protein quality. A significant advantage of the invitro technique is that it is cheaper and farer is takes less time to predict the digestibility of the protein in the sample, unlike protein digestibility measured by animal feeding which is expensive and time consuming.

7.2 MINERAL BIOAVAILABILITY OF SHELLFISH USING INVITRO TECHNIQUE

The mineral bioavailability of shellfish (clams, periwinkles, oysters and whelk) were determined using the same invitro enzyme digestion techniques to show the soluble fraction of the minerals found in shellfish. The procedures and approach are the same earlier plantain studies.

7.3 PERCENTAGE MINERAL BIOAVAILABILITY OF SELECTED SHELLFISH

The bioavailability of calcium, iron, sodium, zinc, magnesium and potassium ranged from 58.80 - 84.30%, 33.85 – 47.87%, 21.90 – 96.60%, 31.45 – 62.06%; 69.00 – 99.50% and 80.80 – 97.40% respectively, with periwinkle (smooth) recording the highest value and clam the lowest. Bioavailable magnesium was 96.40, 93.20 and 94.80%, for periwinkle (rough), whelk and oyster, respectively.

Lower concentrations of bioavailable sodium (21.90%) and

iron (33.90%) was absorbed in whelk while higher bioavailable calcium (84.30%) was observed in periwinkle rough as presented in Table 11.

Table 11: Percentage Mineral Bioavailability of Selected Shellfish (%)

Shellfish	Na	Fe	K	Zn	Ca	Mg
Oyster	92.90^{b} ± 0.01	40.80^{c} ± 0.04	94.80^{c} ± 0.06	31.50^{e} ± 0.15	61.80^{c} ± 0.43	69.00^{e} ± 0.00
Clam	96.60^{a} ± 0.15	35.20^{d} ± 0.11	80.80^{e} ± 0.04	62.10^{a} ± 0.00	53.00^{e} ± 0.08	99.00^{b} ± 0.01
Periwinkle (rough)	92.10^{c} 0.00	42.60^{b} ± 0.02	96.40^{b} ± 0.02	46.20^{b} ± 0.11	84.30^{a} 0.04	80.70^{d} ± 0.03
Periwinkle (smooth)	91.20^{d} 0.02	± 47.9^{a} ± 0.21	97.40^{a} ± 0.10	41.60^{c} ± 0.07	71.20^{b} 0.03	± 97.20^{c} ± 0.02
Whelk	21.90^{e} ± 0.01	33.90^{e} ± 0.02	93.20^{d} ± 0.04	37.90^{d} ± 0.09	58.80^{d} 0.00	± 99.50^{a} ± 0.01

Values are mean standard deviation of triplicate samples. Mean values bearing different superscript within the same column differ significantly ($p<0.05$).

Key:
Na = Sodium, Fe = Iron, K = Potassium, Zn = Zinc, Ca = Calcium, Mg = Magnesium

Clams was high in bioavailable sodium (96.60%) and zinc (62.10%) while periwinkle (smooth) was high in available, iron (47.90%) and potassium (97.40%). Shellfish in general had high mineral bioavailability except for iron and zinc which was below 50%. The low bioavailability of zinc and iron in the shellfish samples could be attributed to interactions of the iron with protein and/or other food components thereby hindering its absorption.

8.0 CONCLUSION AND RECOMMENDATIONS

8.1 CONCLUSION

Vice Chancellor Sir, in this inaugural lecture, I have given clarity on issues such as processed and unprocessed foods and that nature had provided that certain foods should be processed in order to derive maximum benefits from them. That we should as a matter of fact, eat fruits in season.

(a) I have highlighted the discipline Food Science and Technology and enumerated the various branches of specialization and options.

(b) I reviewed Food Analysis as an important branch of Food Science and Technology enumerating the purpose or reasons why we do Food Analysis either for food process control, nutrition labelling, government regulation for food safety, consumer protection and Research and Development.

(c) I also reviewed various analytical techniques used in Food Analysis to characterize the overall production of food and to ascertain the role of raw materials, ingredients, processing condition and control played in the overall quality of food products.

Leveraging on invitro enzyme techniques as an essential tool in food analysis, I focused on the following:

i) Polyphenol oxidase and peroxidase activities were effectively inhibited in processed plantain amala by 1.25% sodium metabisulphite and 5% citric acid which also resulted in the prevention of browning and successfully lead to the production of creamy plantain paste (amala).

ii) Unripe plantain flour showed higher resistant starch and dietary fibre which makes it slowly digestible. When incorporated in products formulation such as biscuit

production, the total starch decreased with increase in the level of unripe plantain flour while resistant starch and dietary fibre increased upto 19.49% and 25.77%, respectively in biscuit samples. However, biscuit prepared with 80:20 wheat/ plantain flour blend was acceptable with regards to aroma, texture, color and overall acceptability. Therefore, unripe plantain flour can serve as a functional ingredient in biscuit production.

iii) It is also concluded that the addition of unripe plantain flour in baked products lowered the rate of hydrolysis and the corresponding predicted glycemic index.

iv) It was observed that the plantain based products developed (bread, cakes, cookies and "amala") was high in potassium, iron and phosphorous and low in sodium. However, not all the minerals detected in the products were bioavailable when digested enzymatically into soluble absorbed form. The Ca/P for cakes and bread is high and can serve as a good source of calcium and phosphorus which is considered essential for bone formation and maintenance. Products with high minerals balance is an indication of low bioavailability.

v) Protein digestibility of selected shellfish showed that oyster and whelk had more digestible protein than periwinkles and clams. Whelk recorded the highest bioavailable magnesium (99.50%) followed by clam (99.00%), clam also showed significant high zinc bioavailability. Low concentration of sodium (21.90%) and iron (33.90%) were observed in whelk while higher in available calcium (84.30%) and potassium (96.40%) was observed in periwinkle (rough). Therefore, invitro enzyme techniques had shown that not all the minerals detected were available for absorption after digestion.

8.2 RECOMMENDATIONS

Vice Chancellor Sir, there are a lot of indept research findings that had been scientifically conducted to develop products if commercialized will have developmental or positive impact on the economy lying waste in the shelves of various university libraries. I therefore recommend that:

a) industries, companies and investor should liaise with relevant organs of the Universities to ensure that these findings are effectively harness, coordinated and utilized for the benefits of humanity.
b) there are a lot of rumors and questions that need clarification and possible answers about food. Some of these questions are observatory which may be personal without any scientific test and evaluations. Again this create a wrong signal to the public about food, diet and nutrition. I would suggest that Government, the Nigerian Institute of Food Science and Technology (NIFST) and the Council NIFOST to regulate and sensitize the public through advocacy providing professional advice on such issues.

c) the study of Food and Nutrition should be made compulsory for girls and women (wives or anybody), whose responsibility seem to be relatively involved with the choices of diet for households. The knowledge of food and nutrition will guide them in the selection of food materials and preparation for optimum health benefits. For instance, women go to the market and buy buckets of rotten tomatoes, boiled and used for food, they forget to realize that once toxins are produced in the rotten tomatoes, no amount of heat treatment may destroy the toxins. Again, a situation whereby women purchase vegetable fats/ oils that solidifies or sleeps at room temperature, many people do not realize that there is no much difference between room temperature in Nigeria and body temperature. Women melt

the fat and use it to fry or cook. On consumption, the saturated fat will certainly solidify and cloth the arteries restricting normal blood flow. The resultant effect is cardiovascular disorder. Therefore, our women/girls and anybody changed with the responsibility of food for the people should have a basic knowledge of Food and Nutrition.

d) finally, there is need for inter disciplinary collaboration in Research Techniques so that errors or limitations in any can be corrected, elaborated by the other; making Research outputs more enhance and comprehensive.

8.3 ONGOING RESEARCH PROJECTS

Vice chancellor Sir, let me use this opportunity to inform you that there are some on-going
research projects at different stages of completion.

1. **Thermal bacteriology and canning.** This involves the canning of periwinkle using different solutions. See Plate 2. The canning operation was done in 2023, and we are now doing storage studies to determine the shelf life.

Plate 2: Labelled Canned Shellfish

2. **Dehydration and rehydration of shellfish.** This involves the drying, packaging of selected shelf fish found in our environment, and also to determining the most effective packaging materials that will provide the best nutritional result on rehydration.

3. **Production of low-carb swallow:** It involves the use of food wastes such as unripe plantain peels, water melon peels, tigernut residue etc with a binder to produce a nutritionally acceptable low-carb swallow. All nutritional and sensory characteristics will be studied.

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