

**Production and Evaluation of a Novel “Stiff Dough” for Diabetics
from the Incorporation of Bambara Fiber (*Vigna subterranea* (L.)
Verdc.) into Plantain Flour (*Musa* spp.)**

By

Ezeh Cherish Chioma

A project submitted to

The Department of Food Science and Technology

School of Engineering and Engineering Technology

**In partial fulfillment of the requirement for the award of Bachelor of Technology (B.Tech)
in Food Science and Technology.**

AUGUST, 2023.

TABLE OF CONTENT

Title page	i
Certification page	ii
Dedication	iii
Acknowledgement	iv
List of tables	v
List of figures	vi
Table of contents	vii
Abstract	viii
CHAPTER ONE	1
Introduction	1
1. Background of study	1
1.2. Problem statement	3
1.3. Justification of study	3
1.4. Aim and objectives	4
1.4.1. Main objectives	4
1.4.2. The specific objectives	4
1.5. Scope of study	4
CHAPTER TWO	5
Literature review	5

2.1.	Diabetes(<i>diabetes mellitus</i>)	5
2.1.2.	Types of diabetes	7
2.1.3.	Treatment of diabetes	8
2.2.	Origin of plantain	9
2.2.1.	Varieties of plantain	11
2.2.1.1.	Horn plantain	12
2.2.1.2.	French plantain	12
2.2.2.	Nutritional values of plantain	12
2.2.2.1.	Carbohydrates	13
2.2.2.2.	Fats	13
2.2.2.3.	Protein	13
2.2.2.4.	Vitamins and minerals	13
2.2.2.5.	Calories	14
2.2.3.	Health benefits	14
2.2.3.1.	Antioxidant – rich	14
2.2.3.2.	Excellent diabetic food	14
2.2.3.3.	Maintains blood pressure control	15
2.2.4.	Adverse effects	15
2.2.5.	Unripe plantain flour	16
2.3.	Origin of Bambara nuts(BN)	19
2.3.1.	Usefulness of Bambara nut	21
2.3.2.	Nutritional value of Bambara nut/proximate composition	22

2.3.2.1.	Carbohydrates	23
2.3.2.2.	Protein	24
2.3.2.3.	Lipids	25
2.3.2.4.	Minerals	26
2.3.2.5.	Phytochemicals	26
2.3.2.6.	Dietary fiber	27
2.3.3.	Bambara nut coat/testa	28
2.3.4.	Bambara nut fiber incorporation in unripe plantain flour to get a high fiber meal for diabetes.	29
2.4.	Fiber (dietary fiber)	30
2.4.1.	Health benefits of dietary fiber	31
2.5.	Meal (swallow)	31
CHAPTER THREE		34
3.1.	Materials and methods	34
3.1.1.	Procurement of materials	34
3.1.2.	Chemical, equipment's, and facilities	34
3.2.	Preparation of materials	34
3.2.1.	Production of unripe plantain flour	34
3.2.2.	Production of Bambara fiber	36
3.3.	Formulation of samples	37
3.4.	Analytical methods	39
3.4.1.	Proximate analysis	39

3.4.1.1.	Moisture content determination (oven - dry method)	39
3.4.1.2.	Determination of ash - content	40
3.4.1.3.	Crude fiber	41
3.4.1.4.	Crude fat	42
3.4.1.5.	Crude protein	43
3.4.1.6.	Determination of carbohydrate	45
3.5.	Sensory evaluation	45
3.6.	Statistical analysis	46
CHAPTER FOUR		47
Results and discussion		47
4.1.	Proximate nutrient composition.	47
4.2.	Sensory evaluation of a novel meal for diabetics from unripe plantain flour and bambara nut fiber.	54
CHAPTER FIVE		57
5.1:	Conclusion.	57
5.2:	Recommendation	58
REFERENCES		59
APPENDIX		68

LIST OF TABLES

Table 1: Recipe for Bambara nut fiber / Plantain flour blends.	39
Table 4.1: Proximate composition of unripe plantain flour and Bambara nut fiber(g).	53
Table 4.2: Sensory evaluation of a novel meal for diabetics from unripe plantain and Bambara nut fiber	56

LIST OF FIGURES

Fig 2.1: Picture of an unripe plantain (<i>genus musa</i>)	9
Fig 2.2: Picture of Bambara nut	19
Fig 3.1: Flow diagram of preparation of plantain flour	35
Fig 3.2: Flow diagram of preparation of Bambara nut fiber	36
Fig 3.3: Unripe plantain flour.	38
Fig 3.4: Bambara nut flour	38

ABSTRACT

The main objective of this study is the production and evaluation of a novel meal for diabetics using different blends of unripe plantain and Bambara nut fiber composite flour. Five different blends were formulated using 500:00, 450:50, 400:100, 350:150 and 300:200 of unripe plantain and Bambara nut fiber flour. The proximate and sensory properties were determined using standard procedures. The result obtained showed moisture content decreased significantly ($p \leq 0.05$) with increased level of Bambara nut fiber flour in the products as it decreased from 11.6% in sample A (500:00) to 9.67% in sample E (300:200), ash content shown that Bambara nut fiber flour significantly improves the ash content in the samples as it increased from 2.42% in sample A up to 2.87% in sample E (300:200). Novel meal formulation with higher Bambara nut fiber flour have the highest crude fiber content which ranges from 1.71% in sample A (500:00) to 7.40% in sample E (300:200). The protein content ranges from 2.44% in sample A up to 9.01% in sample E (300:200). The carbohydrate contents were significantly affected by Bambara nut fiber flour addition ($p > 0.005$) since the values were reduced by increase addition of kidney beans and reduced from 80.62% in sample A (500:00) down to 70.61% in sample D (350:150). The energy values ranged 1376 to 1443kcal. There were significant differences ($p < 0.05$) in all the sensory parameters among formulated blends. As sample with more Bambara nut fiber inclusion had a higher score in appearance, mouldability and taste while sample with 100% plantain flour scores highest in mouthfeel compared to the others blends. The study have showed that a novel meal for diabetics can be produced from unripe plantain and Bambara flour composite in ratio 300:200, for diabetics..

CHAPTER ONE

INTRODUCTION

1.1. Background study

Diabetes is a chronic health condition that affects millions of people around the world. It is a metabolic disorder that occurs when the body is unable to produce or use insulin properly, resulting in high blood sugar levels (ADA, 2021). Diabetes can be classified into two main types: Type 1 and type 2. Type 1 diabetes is an autoimmune disorder in which the body's immune system attacks and destroys the insulin-producing cells in the pancreas, resulting in a lack of insulin production while the Type 2 diabetes is a metabolic disorder in which the body does not produce enough insulin or does not use the insulin it produces effectively. Management of diabetes is critical to prevent complications and maintain good health (National Institute of Diabetes, 2021). Nutrition plays an important role in diabetes management, and a diet high in fiber is especially beneficial. Fiber which is known to slow the absorption of sugar into the bloodstream, which also helps keep blood sugar levels stable. Eating a variety of foods high in fiber, such as fruits, vegetables, legumes, and whole grains, can help people with diabetes maintain good health.

Unripe plantain which is a complex carbohydrate has been a part of diets around the world for centuries. Native to tropical regions, plantains have been a staple food in many cultures, providing a source of energy, vitamins, and minerals.

Unripe plantains is a major food for diabetes because they are and lower in sugar than ripe plantains, making them a great source of complex carbohydrates which is difficult to digest (Chukwu, 2016). But the major challenge with the unripe plantain swallow is that it undergoes retrogradation as soon as it cools which makes it difficult in forming a ball.

Bambara nut is a legumes that is still underutilized. It is a crop with great potential to sustain the dietary needs of both urban and rural communities [Anthony *et al.*, 2021. Bambara nut possess some good quality for use in the nutritional management of blood glucose likely for diabetes (Abdulrashid and Hassan, 2021). The understanding of the effects of food on these metabolic derangement play a vital role in the nutritional management of blood glucose levels for the prevention and management of diabetes mellitus (Russell *et al.*, 2016).

Bambara flour is a type of flour made from Bambara groundnuts, which are a legume native to the African continent. Bambara flour has been used in African cuisine for centuries, and is now gaining popularity in other parts of the world. It is often used in baking/ processing of a major food product known as “Okpa”. In the processing of Okpa , Bambara nut is usually milled and sieved to get the Bambara fiber. The flour is used in the production of Okpa while the fiber is a waste byproduct that is always thrown away or used as animal feed. The fiber content of Bambara flour is particularly high, and also a good source of dietary fiber composed of cellulose, hemicellulose, pectin and other complex

carbohydrates which have high binding properties. This makes it a great choice for those with diabetes and those looking to increase their daily fiber intake. In this work, blends of Bambara nut fiber and unripe plantain flour will be formulated

1.2. Problem statement

Most of the popularly known swallows in Nigeria contain much carbohydrate which makes them unsuitable for diabetics because of the potential impact of the swallow on blood sugar levels. Additionally, meals produced from unripe plantain flour quickly undergoes retrogradation as soon as it cools and this is a major problem in the use of unripe plantain flour as a meal. Bambara nut fiber has remained a waste generated from Bambara nut flour processing, and has not much value. Literature has shown that it has binding properties that could help reduce retrogradation, however, this has not been exploited in curbing this problem associated with unripe plantain cooked dough.

1.3. Justification of study

Incorporation of Bambara nut fiber into unripe plantain flour will go a long way in adding much fiber to unripe plantain flour and also help in retarding retrogradation of the cooked. This will also help in producing a meal that can compete favorably with other meals that contain high starch content, provide a

healthier and more enjoyable food option than what is currently available for diabetics.

1.4. Aim and objectives

1.4.1. Main objectives

The production and evaluation of a ” novel” meal for diabetes.

1.4.2. The specific objectives are:

1. To produce Bambara nut fiber.
2. To produce unripe plantain flour using the French variety of plantain.
3. To produce four blends of Bambara nut fiber and unripe plantain flour
4. To analyze the proximate compositions of the Bambara nut blends
5. To compare the quality attributes of the Bambara nut blends with the control that is 100% unripe plantain.

1.5. Scope of study

The scope of this work will cover the production of solid meal flour using unripe plantain flour and Bambara nut fiber. This work also covered the determination of the sensory evaluation and proximate compositions of the solid meal flour produced.

CHAPTER TWO

LITERATURE REVIEW

2.1. Diabetes (*Diabetes mellitus*)

Diabetes also known as “*Diabetes mellitus*” is defined as a metabolic disorder of multiple etiology characterized by chronic hyperglycemia with disturbances of carbohydrate, fat and protein metabolism; resulting from defects in insulin secretion, insulin action, or both [Alhassan *et al.*,2018] . Diabetes happens when the body is not able to take up sugar (glucose) into its cells and use it for energy. This results in a build up of extra sugar in your bloodstream. Mismanagement of diabetes can lead to serious consequences, causing damage to a wide range of the body's organs and tissues including the heart, kidneys, eyes and nerves. Most questions usually asked by diabetics is “why their blood glucose levels are always high?”. This is because, the process of digestion includes breaking down the food eaten into various different nutrient sources. When carbohydrates is eaten (for example, bread, rice, pasta), the body breaks this down into sugar (glucose). When glucose is in the bloodstream, it needs a key to help get into its final destination where it's used, which is inside your body's cells. This help or "key" is insulin. Insulin is a hormone made by the pancreas, an organ located behind the stomach. The pancreas releases insulin into the bloodstream and the Insulin acts as the “key” that unlocks the cell wall which allows glucose to enter the body’s cells. Glucose provides the energy tissues and organs need to properly function. For diabetes, the pancreas does not make any insulin or enough insulin or the

pancreas makes insulin but the body's cells don't respond to it and can't use it as it normally should. If glucose can't get into the body's cells, it stays in the bloodstream and the blood glucose level rises. And there have been an increase in records of diabetics patients in the world.

According to Adumaya *et al.*, 2012, the prevalence of diabetes mellitus rose by 49% between 1990 and 2000(Begum *et al.*, 2014). In 2012, diabetes resulted in 1.5 million deaths worldwide, making it the 8th leading cause of death. Brand Miller (2004) stated that, more than 80% of diabetic deaths occur in low- and middle-income countries. In Nigeria, the prevalence is 8-10% (Brand Miller *et al.*,2003). Nigeria has the greatest number of people living with diabetes in Africa, which is currently estimated to be approximately 1.7 million and may increase to 4.8 million by 2030 (Adumaya *et al.*,2012). Although, diabetes is not a curable disease, dietary measures are very important and are inevitable to maintain an ideal body weight, control the blood sugar level and prevent acute and long-term complications. The intake of low glycemic foods potentially contributes to a significant improvement of the condition.

The glycemic index is a relative ranking of carbohydrates in foods on a scale of 0-100, according to how they affect blood glucose levels after eating (Bourns *et al.*, 2005).The concept of the glycemic index was developed to provide a numeric classification of carbohydrates in food, which is useful when glucose tolerance is impaired. Carbohydrate-containing foods have a range of effects on the blood

glucose level; some foods cause a rapid rise and others do not (CDC,2002). Meal planning with the glycemic index involves choosing foods that have a low or medium glycemic index. Food with a high glycemic index raises blood glucose more than food with a medium or low glycemic index (Chutkan *et al.*,2012). Low glycemic index foods produce gradual rises in blood sugar and insulin levels, due to slow digestion and absorption and have been proven to be beneficial for health (Bourns *et al.*, 2005).

Adjusting food choices towards the selection of mainly low glycemic index foods is most helpful for people attempting to prevent or control type 2 diabetes or to diminish the effect of insulin resistance (Davidson *et al.*,2017). A low glycemic index diet appears to improve overall blood glucose control in people with type 1 and 2 diabetes mellitus.

2.1.2. Types of diabetes

There are differences types of diabetes which includes:

Type 1 diabetes: This type is an autoimmune disease, meaning the body attacks itself. In this case, the insulin-producing cells in the pancreas are destroyed. Up to 10% of people who have diabetes have Type 1. It's usually diagnosed in children and young adults (but can develop at any age). It was once better known as "juvenile" diabetes. People with Type 1 diabetes need to take insulin every day. This is why it is also called insulin-dependent diabetes.

Type 2 diabetes: With this type, the body either doesn't make enough insulin or the body's cells don't respond normally to the insulin. This is the most common type of diabetes. Up to 95% of people with diabetes have Type 2. It usually occurs in middle-aged and older people. Other common names for Type 2 include adult-onset diabetes and insulin-resistant diabetes.

2.1.3. Treatment of diabetes

Treatments for diabetes depend on the type of diabetes, how well managed the blood glucose level is and the other existing health conditions.

Type 1 diabetes: When diagnosed with this type, the patient must take insulin every day because the pancreas no longer makes insulin.

Type 2 diabetes: If one have this type, the treatments can include medications (both for diabetes and for conditions that are risk factors for diabetes), insulin and lifestyle changes such as losing weight, making healthy food choices and being more physically active.

Oral medications and insulin work in one of these ways to treat your diabetes:

Stimulates the pancreas to make and release more insulin, slows down the release of glucose from the liver (extra glucose is stored in the liver), blocks the breakdown of carbohydrates in the stomach or intestines so that the tissues are more sensitive to (better react to) insulin, helps rid the body of glucose through increased urination.

2.2. Origin of plantain



Fig 2.1: Picture of an unripe plantain (*genus Musa*) (Encyclopaedia Britannica)

Plantain is a common name for a herbaceous plants of the *genus Musa*, it was classified formally as *Musa Acuminata*, *Musa Balbisoana* or *Hybrids Musa Acuminataz Balbisoana* depending on their genomic constitution (balell John ,2000) gave the archaic scientific name *Musa paradisiacal* which is no longer used. Most plantain come from the hybrid AAB and ABB cultirar group all members of the genus. *Musa* are indigenous to tropical regions of South east Asia and Oceania including the making Archipelago. (Brian and Allan 1985). Plantains are a major food staple in West and Central Africa, Central America, the Caribbean islands, and northern, coastal parts of South America (Clifton,2016).

Plantains are a versatile food, and can be cooked in a variety of ways. They can be boiled, fried, mashed, or baked. Plantains are also used to make chips, breads, and cakes. Plantains are an important source of nutrition for many people, providing essential vitamins and minerals. They are high in fiber, potassium, and vitamin A, and are a good source of energy. It is a nutritious and versatile food, and is becoming increasingly popular in the United States and Europe. Plantains are a staple food in many parts of the world, and their importance is likely to continue to grow in the future.

Plantain is a carbohydrate source. Its utilizable protein content as percentage of calorie ingestion is higher than sago and cassava, but is much lower than other staples such as maize, rice, and wheat. On per gram consumed basis, plantain's essential amino acid concentrations are very low, even lower than cassava.

Cooked green plantain (and cooked green banana) has a low GI, unlike potatoes and many grains. Plantain contains very little β -carotene. The vitamin C content of plantain is very similar to those of sweet potato, cassava, and potato.

According to EFC (2019), Plantains contain complex carbohydrates capable of replacing glycogen and important vitamins, particularly B6 and C, and minerals (potassium, calcium, magnesium, and iron). Plantain fruit is composed mainly of water (around 75 percent) and carbohydrates (around 32 percent). It contains several vitamins, including A, B, and C, and is very low in protein and fat but rich in minerals, particularly potassium (around 400 mg/100 g). It is cholesterol free,

high in fiber, and low in sodium. Chemical composition varies not only among cultivars but also according to climatic and other conditions.

Plantains, being starchier than bananas, can be eaten ripe or unripe, but many countries have developed commercial processes to provide a wide variety of products from both fruits (in several cases, green bananas can also be used): puree, flour, jam, jelly, chips, crisps, flakes, dried, catsup, relishes or spreads, preserves, vinegar, and even wine. Plantain flour, both from green and ripe fruit, has a great industrial potential and, enriched with sugar, powdered milk, minerals and vitamins, and artificial flavoring, is much used in baby foods. All told, bananas and plantains represent more than 25 percent of the food energy requirements of Africa (Frison and Sharrock, 1999).

Plantains in the yellow to black stages can be used in sweet dishes steam-looked plantains are considered a nutritious food for infants and the elderly. Plantains are also dried and grouped into flour it is an important food stuff that constitute, water of about 1062%, proteins 55%, Fat 1.15%, Carbohydrates 81.6% and Ash 3.01%.

2.2.1. Varieties of plantain

There are two general varieties of plantains: the horn plantain and the French plantain.

2.2.1.1. Horn plantain

Horn plantain is a type of herbaceous perennial plant that is native to the Mediterranean region. It is a member of the plantain family, and is known for its long, thin leaves and its clusters of yellow flowers. Horn plantain is often used in traditional medicine, as it is believed to have medicinal properties. It is also used in cooking, as its leaves can be used to make a variety of dishes. Horn plantain is an easy to grow plant, and can be found in many gardens.

2.2.1.2. French plantain

French plantain is a type of plantain that is native to the Caribbean and Central America. It is a large, starchy fruit that is closely related to the banana. French plantains are typically larger and less sweet than other varieties, and have a firmer texture when cooked. They are often used in savory dishes, such as stews, soups, and curries, as well as in desserts and fried snacks. French plantains are also a popular ingredient in Caribbean cuisine, where they are often boiled, mashed, or fried.

2.2.2. Nutritional values of plantain

One cup of boiled green plantains (137g) provides 166 calories, 1.5g of protein, 40g of carbohydrates, and 0.1g of fat, Plantains are an excellent source of vitamin C, fiber, and vitamin B6 (Malia, 2021).

2.2.2.1. Carbohydrates

Plantains provide a healthy dose of carbohydrates. One cup of boiled green plantains has 40 total grams of carbs, with nearly 4 grams of fiber and just 3 grams of natural sugar. As plantains ripen, fiber content goes down and sugar content increases. Plantains are high in resistant starch, which gives them a low glycemic index (of about 38.5 for ripe raw plantains to 44.9 for boiled unripe plantain).(Oladela and Williamson, 2016).

2.2.2.2. Fats

Plantains are naturally low in fat but easily absorb the oil they are cooked in.

2.2.2.3. Protein

Plantains are not a significant source of protein. A medium plantain has less than 2 grams.

2.2.2.4. Vitamins and Minerals

Plantains contain iron, vitamin C, vitamin B6, folate, potassium, magnesium, copper, and vitamin A. According to the USDA, a cup of plantains provides 12.5 milligrams of vitamin C, which is about 15% of one's daily recommended intake. Plantains contain folate, which is a vital nutrient for women trying to conceive. Nearly 20% of the daily recommended intake is gotten from a cup of cooked plantains.

2.2.2.5. Calories

One cup of boiled green plantains (137g) provides 166 calories, 96% of which comes from carbs, 3% from protein, and 1% from fat.

2.2.3. Health Benefits

The resistant starches and micronutrients in plantains offer several health benefits, especially when plantains are consumed with minimal processing.

2.2.3.1. Antioxidant-rich

Plantains contain a high concentration of antioxidants. Antioxidants are substances that aid in the fight against free radicals, which cause oxidative damage in the body. According to one study, the peels and flesh of plantains contain flavonoids and polyphenols, both essential antioxidants. Antioxidants are vital because they aid in treating metabolic illnesses such as diabetes, cancer, and heart disease.

2.2.3.2. Excellent diabetic food

When boiled, unripe plantains have a low glycemic index (GI) of 45 due to their high resistant starch content. Resistant starch is a form of carbohydrate that does not break down into sugar in the small intestine but instead goes into the large intestine, where fermentation occurs. Resistant starch does not elevate blood glucose levels since it is not digested in the small intestine, making it suitable for

managing diabetes. Fermentation in the large intestine also helps glycemic management by encouraging the growth of “good” gut flora. It is a good meal for managing diabetes because it has minimal sugar; their low carbohydrate content combined with relatively high energy content makes them suitable for managing this disease. It makes it a good choice, especially if other fibers and protein-rich foods like green vegetables are added, hence an excellent choice to avoid diabetes.

2.2.3.3. Maintains blood pressure control

Plantains are high in potassium, a mineral that aids in the treatment of hypertension. One large green plantain can give around 44 percent of the daily potassium requirement. Unripe plantain’s low sodium level makes them ideal for hypertensive people.

2.2.4. Adverse Effects

The resistant starch in plantains may make them difficult to digest. Green, raw plantains are especially high in resistant starch. If one is not used to eating a lot of fiber, plantains can cause discomfort like gas, bloating, and constipation, so I’m order to avoid that, Increase your intake slowly, allow plantains to ripen fully, and cook before eating to reduce digestive distress. Plantains are popular among packaged foods as well and can be found as dried or fried plantain chips. You can eat plantains when they are green or yellow. The level of ripeness will determine

the type of starch and the consistency of the plantain. Green plantains contain more resistant starch, while yellow, fully ripe plantains contain more natural sugars.

2.2.5. Unripe plantain flour

Plantains are a staple food in many parts of the world, particularly in tropical regions where they are widely cultivated. Unripe plantains have a high starch content, which makes them a good candidate for use in flour production. In recent years, there has been growing interest in the use of unripe plantain flour as a gluten-free alternative to wheat flour in food products. One of the main advantages of unripe plantain flour is its high starch content. This makes it an excellent source of energy, providing a slow and sustained release of glucose into the bloodstream. Additionally, unripe plantain flour is a rich source of dietary fiber, which helps to regulate digestion and improve gut health. Another advantage of unripe plantain flour is its low glycemic index (GI) value. Foods with a low GI value are absorbed more slowly into the bloodstream, which helps to regulate blood sugar levels and reduce the risk of type 2 diabetes.

There have been several studies investigating the potential health benefits of unripe plantain flour. For example, a study by Adebayo *et al.*, (2020) found that unripe plantain flour has a high antioxidant content, which may help to protect against oxidative stress and prevent the development of chronic diseases such as cancer and heart disease. Similarly, a study by Akanji *et al.*, (2018) found that

unripe plantain flour has anti-inflammatory properties, which may help to reduce the risk of inflammation-related diseases such as arthritis and allergies. In terms of its use in food products, unripe plantain flour can be used as a gluten-free alternative to wheat flour. This makes it a suitable option for people with celiac disease or gluten intolerance, who cannot tolerate gluten-containing foods. Additionally, unripe plantain flour can be used as a binding agent in food products, helping to improve the texture and structure of baked goods and other products. And one of the main challenges of using unripe plantain flour is its flavor. Unlike wheat flour, which has a mild and neutral flavor, unripe plantain flour has a strong, earthy flavor that may not be to everyone's taste. To address this issue, many manufacturers mix unripe plantain flour with other flours, such as cassava flour or corn flour, to reduce its strong flavor. Unripe plantain flour is a promising alternative to wheat flour, with potential health benefits and a range of applications in food products. Nevertheless, further research is needed to fully understand its potential and to develop new uses for this versatile and nutritious ingredient.

However, in the preparation of a meal, plantain flour is found to undergo retrogradation certain periods of time after cooking dough preparation.

Retrogradation is known as a natural process that occurs when starch molecules in food undergo structural changes during cooling, resulting in the formation of a crystalline structure. This process can affect the nutritional quality, texture, and

flavor of foods made with starchy ingredients such as unripe plantain flour.

Though unripe plantain flour is known for its high fiber content, low glycemic index, and potential health benefits for people with diabetes, the retrogradation process can cause the starch in the unripe plantain flour to become more resistant to digestion, which can affect its glycemic response and reduce its nutritional value. To mitigate the effects of retrogradation in unripe plantain flour, several studies have investigated different processing techniques, such as heat-moisture treatment, acid hydrolysis, and enzyme modification. These methods have been shown to reduce retrogradation and improve the nutritional and functional properties of unripe plantain flour. But this report will be centered on the use of Bambara nut fiber to reduce retrogradation in the meal to be produced, which is a cheaper method / procedure to follow to make it affordable for the masses.

Several factors though have been found that influence the retrogradation of plantain flour, including the type of plantain used, the processing method, and the storage conditions, but processing techniques such as heat-moisture treatment can help to mitigate these effects and improve the functionality of the flour in the preparation of diabetic-friendly swallows.

2.3. Origin of Bambara nuts (BN).



Fig 2.2: Picture of Bambara nut (Source: Besthomediet, 2018)

Bambara groundnut (*Vigna subterranea* (L.) Verdc.), is classified under the family *Leguminosae*, sub-family *Faboidea* and genus *Vigna*. It is an indigenous leguminous African crop that is grown across the continent (Olanipekun *et al.*, 2012). It is commonly found in Nigeria and known locally as; “Okpa” (Igbo), “Epa-roro” (Yoruba) and “Kwaruru” or “Gurjiya” (Hausa). There are seven varieties of Bambara groundnut which is mainly recognized by their seed-colour or design, including black, red, cream/black eye, cream/brown eye, cream/no eye, speckled/flecked/spotted purple and brown (light or dark) (PGBG, 2011).

Bambara groundnut (*Vigna subterranea* (L.) Verdc) a legume indigenous to Africa is cultivated across the semi-arid sub-Saharan Africa region (Hillocks *et al.*, 2012). It is a hardy crop and has been recognized as an important nutritious food source when food is scarce (Mbosso *et al.*, 2020). This could be attributed to

its climate-smart features, including its ability to fix nitrogen, and to grow under adverse environmental conditions such as poor soils and drought (Myes *et al.*, 2019; Paliwal *et al.*, 2020). This nutrient-dense legume is sometimes termed a “complete food” due to its balanced macronutrient composition. Bambara groundnut contains ~64.4% carbohydrate, 23.6% protein, 6.5% fat, and 5.5% fiber and is rich in minerals (Azman *et al.*, 2019). It is relatively underutilized compared with major cash crops and has often been associated with small-scale, subsistence farming, with women being the major producers and processors (Mbosso *et al.*, 2020; Mubaiwa *et al.*, 2018). The utilization constraints of Bambara groundnut include the knowledge gap in improved seed system, agronomic practices, processing, and utilization.

Bambara groundnut, an underutilized African legume, has the potential to contribute to improved food and nutrition security, while providing solutions for environmental sustainability and equity in food availability and affordability. The crop has advantages over more favored species in terms of nutritional value and tolerance to adverse environmental conditions (FAO, 2001; Mkandawire, 2007). Bambara groundnut is an annual crop, which resembles groundnut (*Arachis hypogaea*) in both cultivation and habitat. It is one of the five most important protein sources for many Africans (Chittaranjan, 2007). This paper discusses the potential role of Bambara groundnut in contributing to enhanced dietary and planetary sustainability, with emphasis on areas that span the value chain: from

genetics, nutrition, processing, production and utilization, through to its socioeconomic potential. Bambara groundnut is a sustainable, low-cost source of complex carbohydrates, plant-based protein, unsaturated fatty acids, and essential minerals (magnesium, iron, zinc, and potassium), especially for those living in arid and semi-arid regions. As a legume, Bambara groundnut fixes atmospheric nitrogen to improve soil fertility. It is resilient to adverse environmental conditions and can yield on poor soil. Despite its impressive nutritional and agroecological profile, the potential of Bambara groundnut in improving the global food system is undermined by several factors, including resource limitation, knowledge gap, social stigma, and lack of policy incentives. Multiple research efforts to address these hurdles have led to a more promising outlook for Bambara groundnut; however, there is an urgent need to continue research to realize its full potential.

2.3.1. Usefulness of Bambara nut

The traditional use of Bambara groundnut seeds in treatment/management of several ailments is remarkable and presents a gap for detailed study on the therapeutic and pharmaceutical value of the crop (Harris *et al.*, 2018). Jideani and Diederick (2014) reported that the medicinal role of Bambara groundnut is mainly based on information obtained from communities in several parts of Africa and the world where this crop is reportedly responsible and useful for treatment of various ailments. For example as a treatment /management for diarrhea, a

mixture of Bambara groundnut seeds and water from boiled maize are consumed. To alleviate the nausea associated with pregnancy, pregnant women chew and swallow Bambara groundnut seeds (Olanipekun *et al.*, 2019). Other prophylactic and therapeutic use of Bambara groundnut seeds includes protein deficiency, kwashiorkor, venereal diseases, polymenorrhea (roasted BGN seeds are used), internal bruising, and cataracts (mixture of water and crushed BGN seeds are used (Olanipekun *et al.*, 2019).

The producing communities use bamabara groundnut in many ways. Each community has its own way of preparing Bambara groundnut for use. Where it is used for food, the seeds are ground into flour and used to prepare soup, porridge and various fried or steamed food such as ‘akara’, ‘moi-moi’ and ‘okpa’. The fresh pods are also boiled with salt and pepper and eaten as snack. Dry seeds are equally roasted with salt and eaten as snack. Some communities believe that the black coloured variety has spiritual healing effect. They use the variety for medicinal purposes. Because Bambara groundnut ranks higher in market value than other legumes like cowpea and peanuts, it is used during ceremonies as gifts in some communities.

2.3.2. Nutritional Value of Bambara nut/Proximate composition

The proximate composition of Bambara grains has been found to vary with cultivar and growing locations (Table 1). In general, protein (9.60–40.0%) and

carbohydrate (42.0–70.0%) represent the major components of Bambara groundnut, whereas ash (2.90–5.37%), fiber (3.41–6.85%), and fat (4.30–7.24%) contents are relatively low. The low fat contents of pulses such as Bambara groundnut is expected because it is generally low in fat when compared with oil seeds such as soybean and peanuts (Oyeyinka & Oyeyinka, 2018). Although inherent differences in grains may affect proximate composition, growing conditions may affect the composition of Bambara groundnut. For instance, some authors found that five different Bambara groundnut genotypes grown under the same conditions showed similarity in their composition (Oyeyinka & Oyeyinka, 2018).

Balanced Macronutrient Composition

2.3.2.1. Carbohydrates

Carbohydrates are the most abundant macronutrient in Bambara groundnut, accounting for up to 64.4% of the total dry weight of the seed (Azman et al., 2019). The majority of the carbohydrate fraction is complex oligosaccharides and polysaccharides, of which starch accounts for up to 49.5% of the total carbohydrates. The reported starch content of Bambara groundnut seeds varies considerably (22 to 49.5% of dry seed weight), depending on genetic and environmental factors, stage of maturation, and method of analysis (Oyeyinka and Oyeyinka, 2018). Amylose represents 19.6–35.1% of the total starch content, while the rest of the constituents consist primarily of amylopectin and a small

quantity (1–2%) of protein, lipid, and ash. Raw Bambara groundnut has a higher proportion of slowly digestible starch (SDS) and resistant starch (RS) than rapidly digestible starch (RDS), implicating poor digestibility. Nonetheless, cooking can substantially increase the RDS fraction, thereby improving digestibility and carbohydrate availability (Xin Lin *et al.*,2020).

2.3.2.2. Protein

The protein content of Bambara groundnut ranges from 9.6 to 40% (Nwadi *et al.*,2020), with an average value of 23.6% (Azman *et al.*,2019). This variation is also attributed to differences in genetic background, growing conditions, and analytical techniques used for estimation (e.g., nitrogen conversion factor) (Mubaiwa *et al.*,2018, Boye *et al.*,2010). Storage proteins are the predominant protein fractions in Bambara groundnut, of which vicilin is reported to be the major constituent, followed by legumin). High protein content is a desirable trait in foods, but the importance of protein quality, which is determined by both amino acid composition and protein digestibility, should not be overlooked. Variability in amino acid profile between cultivars of Bambara groundnut is evident. In general, most studies report glutamic acid to be the most abundant amino acid in Bambara groundnut, suggesting its potential to be isolated for use as a flavoring agent. Out of the essential amino acids, leucine and lysine are present at a higher concentration while methionine is the lowest (Xin Lin *et al.*,2020). Phenylalanine, valine, histidine, and isoleucine were also reported to be

present in high concentrations, while tryptophan has been found to be the limiting amino acid (Oyeyinka *et al.*,2019, Yao *et al.*,2015). Its lysine-rich, methionine-poor composition makes Bambara groundnut a good complementary protein source to cereals, which are often deficient in lysine but rich in methionine. The in vitro protein digestibility (IVPD) of raw and cooked Bambara groundnut varies between 70 and 81% and 82 and 87.5%, respectively (Xin Lin *et al.*,2020). The increase of IVPD after cooking is attributed to the destruction of heat labile antinutritional factors (ANFs) and fragmentation of native proteins into smaller polypeptides, subsequently improving enzyme accessibility and protein bioavailability.

2.3.2.3. Lipids

There is considerable variation (1.4 and 9.7%) in the reported values of lipid content in Bambara groundnut (Adebowale *et al.*,2011, Yao *et al.*,2015). The majority of fatty acids in Bambara groundnut are unsaturated, predominated by oleic and linoleic acids (omega-6) (Yao *et al.*,2015, Adeleke *et al.*,2017). Palmitic acid is the third most abundant fatty acid, and linolenic acid (omega-3) is present at a low concentration. While having high unsaturated fatty acid content is appealing from a consumer health perspective, it increases the susceptibility of fats to oxidation and rancidity. Therefore, the end uses should be taken into consideration when selecting the desirable trait of lipid composition.

Rich in Essential Micronutrients

2.3.2.4. Minerals

The most abundant minerals in Bambara groundnut are potassium, magnesium, phosphorus, zinc, and iron (Xin Lin *et al.*,2020). Azman *et al.*,(2019), reported that the levels of these minerals were higher than those found in commonly consumed legumes such as chickpea and mung bean, but they vary by cultivar and growing conditions. The presence of ANFs in the seeds can adversely affect the bioavailability of the minerals. Gwala *et al.*,(2020) reported that the concentration and bioaccessibility of calcium, magnesium, iron, and zinc in Bambara groundnut seeds were influenced by factors such as storage period, processing method, location of mineral in the seeds (testa or cotyledons), and the degree and strength of mineral chelation. Despite being a relatively good source of these minerals, it is unlikely that the dietary needs of individuals can be met through consumption of Bambara groundnut alone.

2.3.2.5. Phytochemicals

Bambara groundnut seeds contain phytochemicals such as flavonoids and tannins. These compounds are usually found in the seed coats and are more abundant in seeds with dark or red-colored seed coats. A positive correlation between darkness of seed coat and total phenolic compounds has been established (Tsamo *et al.*,2018). Mubaiwa *et al.*,(2019) reported an abundance of the flavonoids epicatechin and catechin in raw and cooked red seed,

respectively. Catechin and epicatechin can polymerize to form proanthocyanidins, also known as condensed tannins, which have been associated with nutraceutical properties, such as antioxidant, cardioprotective, antitumor, and neuroprotective properties (Rauf *et al.*, 2018). Antioxidant properties have been reported in brown and red Bambara groundnut seeds, levels of which were comparable with commonly consumed legumes, but inferior to the powerful antioxidant ascorbic acid (Nyah *et al.*, 2015, Nyah *et al.*, 2017). Despite the positive health outcomes associated with consumption of phytochemical compounds, their anti-nutritional implications should not be overlooked.

Other Important Functional Properties

2.3.2.6. Dietary Fiber

Bambara groundnut contains appreciable levels of dietary fiber in the form of RS and non-starch polysaccharides. The concentration and composition of dietary fiber are influenced by maturity stage and processing methods (Yao *et al.*, 2015). Total dietary fiber content of Bambara groundnut ranges from 1.4 to 10.3%, of which insoluble fiber represents a higher fraction than soluble fiber (Azman *et al.*, 2019). The relatively high proportions of SDS, RS, and dietary fiber in Bambara groundnut reduce the rate of digestion and lower the postprandial glycemic response, rendering Bambara groundnut a low glycemic index (GI) food (Oyeyinka *et al.*, 2017). From one point of view, it is advantageous to encourage the consumption of low GI foods as these confer numerous health

benefits, e.g., lowering postprandial blood glucose and insulin levels, regulating appetite, and reducing the risks of obesity and other non-communicable diseases. Conversely, the increased consumption of flatus-causing non-starch polysaccharides has been associated with irritable bowel (Mohammed *et al.*, 2015). More importantly, from a nutritional security point of view, non-digestible dietary fibers can bind to minerals and form a physical barrier to digestive enzymes, thus reducing the bioavailability of essential minerals (Rousseau *et al.*, 2020).

2.3.3. Bambara nut coat/tests

The testa, or coat, of the Bambara groundnut seed is an important component of the crop and is rich in fiber. The fiber content of the Bambara groundnut testa has been the subject of numerous studies aimed at understanding its composition and potential uses. In this article, we will discuss the fiber content of the Bambara groundnut testa, its composition, benefits, and potential applications.

The Bambara groundnut testa is composed of several different components, including polysaccharides, proteins, and lignin. The polysaccharides in the testa are primarily composed of cellulose and hemicellulose, which are the main structural components of plant cell walls. These polysaccharides provide the testa with its strength and rigidity, allowing it to protect the embryo inside. The proteins in the testa are believed to play a role in seed germination and help regulate the water and nutrient supply to the embryo. Lignin is a complex

polymer that provides additional strength and rigidity to the testa and is also believed to play a role in seed germination (Ngupta and Tripathi, 2019). The fiber content of the Bambara groundnut testa is primarily composed of cellulose and hemicellulose, with smaller amounts of lignin. The fiber content of the testa varies depending on the variety of Bambara groundnut, but it is generally between 30 and 50% of the total weight of the testa (Kokwaro, 1976).

This high fiber content makes the Bambara groundnut testa an excellent source of dietary fiber, which is essential for maintaining a healthy digestive system

2.3.4. Bambara nut fiber incorporation in unripe plantain flour to get a high fiber meal for diabetes.

The production of a meal for diabetes has become increasingly important in recent years. This report will explore the potential benefits of incorporating Bambara nut fiber and unripe plantain into such a meal and investigate the production of the meal itself. Bambara nut and unripe plantain have emerged as potential ingredients for diabetes use. Bambara nut, which is native to Africa, is rich in protein, fat, and dietary fiber which help to reduce postprandial glucose level. Additionally, it is also rich in minerals, vitamins, and antioxidants which can help to protect the body from oxidative damage. Unripe plantain, on the other hand, contains dietary fiber, minerals, and vitamins which can help to reduce postprandial glucose level. Furthermore, it also contains substances such as phytosterols, flavonoids, and polyphenols which can help to reduce the risk of

cardiovascular diseases. These two ingredients can be used to create a meal for diabetes which can help to reduce postprandial glucose level and improve the overall health of diabetics. In this article, research will be carried out based on the potential benefits of incorporating Bambara nut fiber into unripe plantain to get a successful meal preparation. Due to the high prevalence of diabetes in Nigeria, there is a need to develop food solutions that can help to manage the disease. Incorporating these two food sources to get a meal could be an effective way of managing diabetes. Furthermore, the meal could provide a convenient and cost-effective dietary option for people with diabetes, as it is easily prepared and can be consumed on the go. Further research should be conducted to assess the efficacy of the novel meal in managing diabetes.

2.4. Fiber (Dietary fiber)

Dietary fiber is found in whole grain cereal and fruits and vegetables. Fiber is made up of the indigestible parts or compounds of plants, which pass relatively unchanged through our stomach and intestines. Fiber is mainly a carbohydrate. The main role of fiber is to keep the digestive system healthy. Other terms for dietary fiber include 'bulk' and 'roughage', which can be misleading since some forms of fiber are water-soluble and aren't bulky or rough at all.

2.4.1. Health benefits of dietary fiber

The digestive system is lined with muscles that massage food along the digestive tract – from the moment a mouthful is swallowed until the eventual waste is passed out of the bowel (a process called peristalsis). As dietary fiber is relatively indigestible, it adds bulk to our faeces and keeps the digestive system healthy. It is also important for other body functions (such as: lowering blood cholesterol, keeping our weight under control, stabilizing glucose (which is important if one has diabetes), reducing the risk of other conditions (such as heart disease and some cancers). Once diagnosed with diabetes, it requires the eating of a diet high in fiber which slows glucose absorption from the small intestine into the blood. This reduces the possibility of a surge of insulin – the hormone produced by the pancreas to stabilize blood glucose levels.

2.5. Meal (Stiff dough)

Nigerian meal is a type of traditional Nigerian cuisine that consists of a variety of dishes made from different types of dough. The most common type of meal is made from a fermented corn flour called eba, which is mixed with water and cooked until it forms a thick paste. Other types of meal include fufu, which is made from cassava or yam flour, and amala, which is made from yam flour. All of these types of meals are usually served with a variety of soups and stews, such as egusi, ogbono, ewedu, and okra. The most popular types of meal include Fufu, Eba, Amala, Semolina, and Pounded Yam. Fufu is made from cassava or plantain

flour, boiled and pounded into a smooth paste. It is usually served with a variety of stews, soups, and sauces. Eba is made from a combination of cassava and plantain flour, boiled and pounded into a thick paste. Semolina is made from wheat flour, boiled and pounded into a thick paste. It is usually served with a variety of stews, soups, and sauces. Pounded Yam is made from yam, boiled and pounded into a thick paste. It is usually served with a variety of stews, soups, and sauces. The Nigerian meal is an important part of the Nigerian diet, and is enjoyed by people of all ages.

Nigerian meal dishes are a great source of carbohydrates and provide essential vitamins and minerals. They are also a good source of dietary fiber, which helps to promote healthy digestion, and can help to reduce cholesterol levels.

Additionally, these dishes are low in fat and calories, making them an ideal choice for those looking to maintain a healthy weight. They are a great source of energy, which can help to improve overall physical performance.

A critical part of managing diabetes lies in maintaining a healthy diet. Eating healthy is important for everyone, especially people living with diabetes, as it plays a key role in ensuring that blood sugar and body weight are in check.

Given that the Nigerian diet is starch-heavy by nature, it is critical to deliberately maintain a diet. Endocrinologists and nutritionists alike would agree that the rules of thumb are to eat a fiber-rich diet with whole, unprocessed foods such as nuts, fruits and vegetables; observe a low-carb and low-sugar diet; drink lots of water,

avoiding alcohol and smoking. While staying within healthy limits, it is possible as a Nigerian living with diabetes to eat well. Contrary to popular notions, one does not have to eat restrictive or boring meals. Foods that nourish the body can and should be enjoyed.

CHAPTER THREE

3.0. MATERIALS AND METHODS

3.1. Procurement of Materials

The materials i.e. the matured dried unripe plantain (*musa paradisiaca*) and Bambara groundnut (*Vigna subterranea L. Verdc*) were purchased at Relief market, Owerri, Imo state.

3.1.2. Chemicals, Equipment, and Facilities.

The chemicals used in the research work were sourced from New Concept Analytical Laboratory at Obinze, Owerri, Imo state, as well as the equipment and facilities used.

3.2. Preparation of materials

3.2.1. Production of Unripe plantain flour

The unripe plantain was traditionally processed into flour, this, was achieved by peeling the unripe plantain, washing, slicing the pulp into small round pieces and drying them for 48 hours at 60°C using the cabinet dryer. The dried pulp was then grounded with milling machine, sieved and stored.

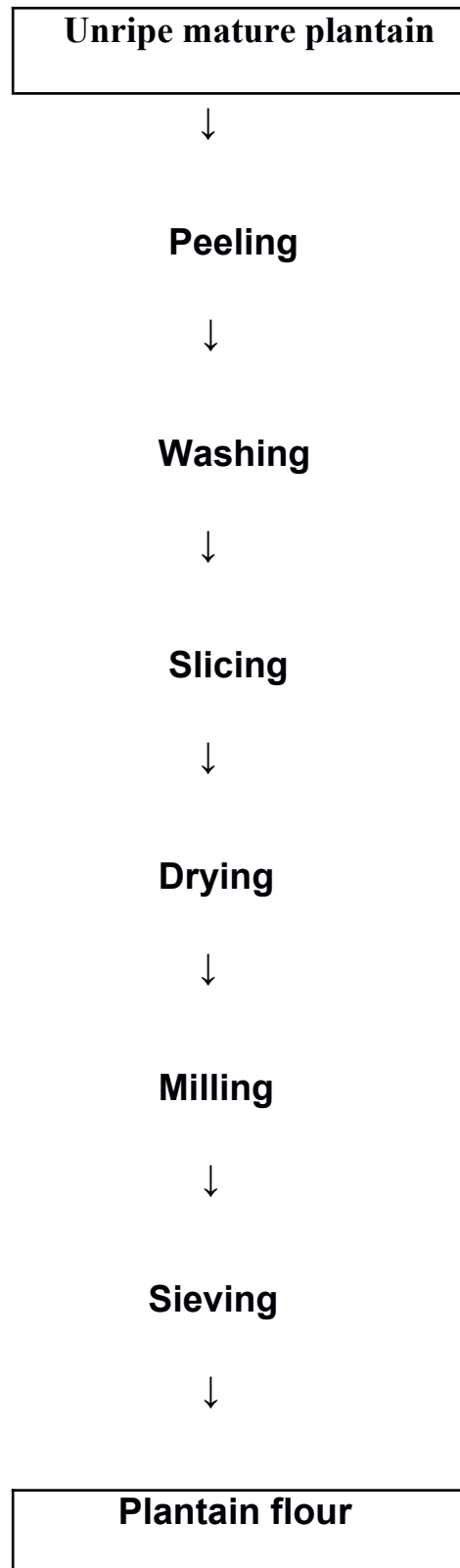
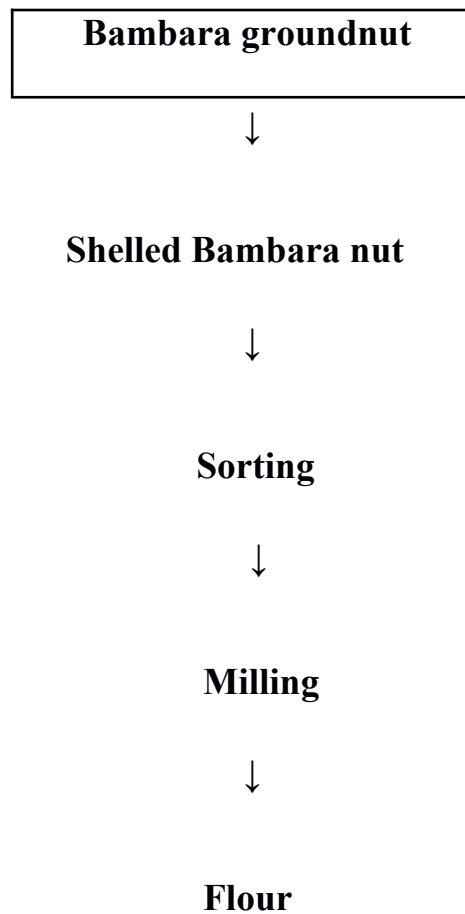


Figure 3.1: Preparation of plantain flour.

3.2.2. Production of Bambara nut fiber

Bambara nut fiber was obtained by removing the hard outer shell of the seeds.

The seed kernel was then milled to produce a fine powder , after which it was sieved to separate the fiber from the Bambara nut flour. The fiber was then packaged and stored.



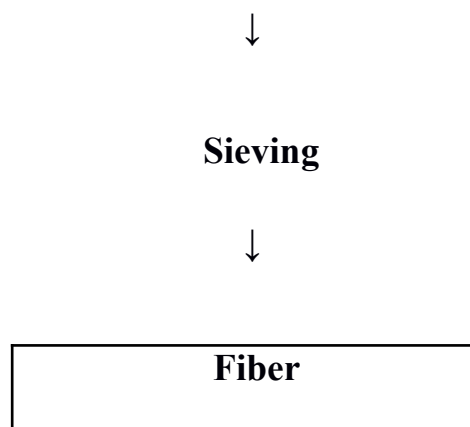


Figure 3.2: Preparation of Bambara nut flour

3.3. Formulation of unripe Plantain flour (UPF)– Bambara nut fiber (BFN) blends.

The UPF and BFN was mixed at different proportion (100:0,90:10,80:20,70:30, and 60:40) which was done manually. For blend 90:10, 500g of the UPF was measured using a measuring scale into an uncontaminated dried bowl. Thereafter, 50g of BFN was measured as well into another uncontaminated dried bowl. The two flours was then poured into a stainless pot and the flour was mixed manually. The mixing was done for 10 minutes in other to ensure homogeneity of the flours. The procedure was employed in preparation of the remaining blends i.e. for 80:20 (400g of UPF and 100g of BFN was mixed together using the same method); For 70:30 (350g of UPF was mixed together with 1500g of BFN); For 60:40 (300g of UPF was mixed together with 200g of BFN); But for 500:0 which is the control, 100% of UPF was used in order to determine the improvement in nutrients of the main flour in this research.



Fig 3.3: Unripe plantain flour (Source: Luis ,2023)



Fig 3.4: Bambara nut flour (Source: Zhengzhou, 2023)

Table 1: Recipe for Bambara nut fiber / plantain flour blends

Sample	UPF(g)	BFN(g)
UPF1	450	50
UPF2	400	100
UPF3	350	150
UPF4	300	200
Control	500	0

3.4. Analytical methods

The following analysis were carried out on the different samples:

3.4.1. Proximate analysis

Proximate composition was determined after bringing the samples to uniform size by the official methods of analysis of the association of official analytical chemists, 17th edition AOAC (2003) Arlington Virginia.

3.4.1. 1. Moisture Content Determination (Oven - Dry Method)

The aluminium or plastic dishes were washed thoroughly and placed to dry in the oven at 110 °C. They were put inside the desiccator to cool and each disc was weighed. The food sample were mixed, the laboratory sample was put in the weigh dish, the weight of the dish plus weight of the undried sample were taken (in duplicate). The samples were placed in the moisture oven to dry at 70° - 80°c

for 2 hours and at 100° - 135°c (usually 105°c) for the next 4 hours or until the weight was constant. The samples were cooled in the desiccator and the dried weight of the sample plus the dish was taken. The moisture content was then calculated as described in the equation below:

$$\text{MC (\%)} = \frac{W_2 - W_3}{W_2 - W_1} \times 100\% \quad \text{.....}$$

eqn(1)

$$W_2 - W_1$$

where,

Mc = Moisture content

W_1 = Initial weight of empty crucible

W_2 = Weight of crucible + food sample before drying.

W_3 = Final weight of crucible + food sample after drying.

3.4.1.2. Determination of Ash Content

2-5g of finely ground dry sample was accurately weighed into a tared or porcelain crucible. The samples were then charred on a heater or bunsen flame inside a fume cupboard to drive off most of the smoke. The sample were then transferred into a preheated muffle furnace at 550°c, then it was left at that temperature for 2 hours or until a white or light gray ash results when the residue is black in colour. It was then moistened with a small amount of water to dissolve salts, then dried in an oven, the ashing process is then repeated again. Then cooled in a desiccator and reweighed.

Calculation:

$$\% \text{ Ash (dry basis)} = \frac{\text{Weight of ash}}{\text{Weight of original food}} \times 100 \dots\dots\dots \text{eqn(2)}$$

$$AC = \frac{W_3 - W_1}{W_2 - W_1} \times 100$$

where,

Ac= Ash content % (dry basis)

W_1 = Initial weight of empty crucible

W_2 = Weight of empty crucible + food sample before drying and/or ashing.

W_3 = Final weight of crucible + ash.

3.4.1.3. Determination Of Crude Fiber

Crude fiber was determined as described by AOAC,2003. About 2g of thoroughly mixed food sample (W_0) was weighed and transferred into a porous crucible. Then the crucible was placed into a Dosi- fiber unit and the valve was kept in” OFF” position. After that 150mL of preheated H_2SO_4 solution (0.1281) was added, some drops of foam-suppress was also added to each column. The cooling circuit was then opened and the heating elements (power at 90%) was also turned on. When the solution started boiling, the power was reduced to 30% and left for 30 minutes. The valves were then opened for drainage of acid and rinsed with distilled water thrice to completely ensure the removal of acid from the sample.

The same procedure was used for the alkali digestion by using KOH (0.223m) instead of H_2SO_4 . The samples were dried and cooled in a desiccator and weighed (W_1). The same sample crucible was then kept in a muffle furnace at $55^\circ C$ for 3-4 hours. Then cooled in a desiccator and weighed again (W_2). The fiber content was then calculated as shown in equation below;

Calculation:

$$\% \text{ crude fiber} = \frac{W_1 - W_2}{W_0} \times 100 \quad \dots\dots\dots \text{eqn(3)}$$

3.4.1.4. Crude Fat

Crude fat will be determined by the AOAC (2003). The dry extraction method used for fat determination consisted of extracting dry sample with some organic solvent, since all the fat material e.g. fats, phospholipids, sterols, fatty acids, carotenoids, pigments, chlorophyll, etc. Are extracted as crude fat. Fat was determined by intermittent soxhlet extraction apparatus. Crude was determined by ether method using soxhlet apparatus.

Approximately 5g of moisture free sample was wrapped in filter paper, and placed in fat free thimble and then introduced into the extractor tube. The weight of the clean and dried receiving flask was taken and filled with petroleum ether and fit into the apparatus.

After 4 - 6 siphoning, the ether was allowed to evaporate and the flask was disconnected before the last siphoning. The flask was transferred into a water bath to evaporate ether, then the flask was placed in the oven at 105°C for 2 hours and cooled in a desiccator. The flask and its content were then weighed. The quantity of oil obtained will be expressed as percentage of the original sample to be used using equation (iii) given below:

$$\text{Crude fat (\%)} = \frac{\text{Weight of ether sample}}{\text{Weight of sample}} \times 100 \quad \dots\dots\dots \text{eqn(4)}$$

3.4.1.5. Crude Protein

The crude protein was determined by AOAC (2003).

Reagents:

- a) 0.1 MHCL (standard)
- b) Concentrated sulphuric acid.
- c) Sodium hydroxide solution 40% w/w
- d) Digestion mixture: potassium sulphate (K_2SO_4) and copper sulphate ($CuSO_4$).
- e) Boric acid: Dissolve 40g of boric acid in sufficient distilled water and make the volume up to to 1000mL
- f) Indicator: Methyl red.

Procedure:

Protein in the sample was determined by kiedahl method. 0.5 - 1.0g of dried sample was weighed and put in a digestion flask. 10 - 15mL of concentratd H_2SO_4 and 8g of digestion mixture i.e. $\text{K}_2\text{O}_4 : \text{CuSO}_4$ (8:1). The flask was swirled around in order to mix the contents thoroughly under a running tap water. The content in the flask was then placed on a heater to start digestion till the mixture becomes clear (blue - green in colour). The digest was then cooled and transferred into a 100mL volumetric flask and made up to mark with distilled water. 10mL of the digest was distillated in a markan still distillation apparatus added with 100mL of 0.05M NaOH through the same way, and distillated for 10 minutes, the ammonia (NH_3) was collected using 20mL of 4% boric acid solution as $\text{NH}_4^+ \text{OH}^-$ in a conical flak with few drops of modified methyl red indicator. The distillate was then titrated against standard 0.1MHCL solution till the appearance of pink colour. A blank was also run through all steps above. Percent crude protein content of the sample was calculated by using the following formula:

Calculation:

% Crude protein = $6.25 \times \%N$ (*correction factor).

$$\%N = \frac{(S - B) \times N \times 0.014}{\text{Weight of the sample} \times V} \times 100 \quad \dots\dots\dots \text{eqn(5)}$$

Weight of the sample $\times V$

where,

S = Sample titration reading

B = Blank titration reading

N = Normal of HCl

D = Dilution of sample after digestion

V = Volume taken for distillation

0.014 = milli equivalent weight of nitrogen

3.4.1.6. Determination of Carbohydrate

The total Carbohydrate content of the sample was the percentage remaining after the moisture, ash, lipid, fiber, and protein contents have been removed.

Mathematically, it is given as:

Total Carbohydrate = 100 - (% protein + % lipids +% ash content +% Fiber + % Moisture content).eqn(6)

3.5. Sensory Evaluation

Sensory evaluation was carried out on the reconstituted cooked dough, using a nine - point hedonic scale. Twenty semi- trained man panelists was used to access the cooked dough. They were asked to indicate their preference for the samples in terms of taste, mouldability, mouthfeel, aroma and overall acceptability with 7-9 being the highest which is:

Like extremely.	9
Like very much.	8
Like moderately.	7
Liked slightly.	6
Neither liked nor Disliked.	5
Disliked slightly.	4
Dislike moderately.	3
Dislike very much	2
Disliked extremely.	1

3.6. Statistical Analysis

All experiments were conducted in triplicate. All data obtained were subjected to statistical analysis of variance (ANOVA) using SPSS version 24.0. Mean values was compared using Turkey's Test ($p > 0.05$) to find out any statistical difference.

CHAPTER FOUR

RESULT AND DISCUSSION

4.1. Proximate Nutrient Composition

In Table 4.1 as shown in the results obtained from the proximate analysis of novel stiff dough for diabetics using different blends of unripe plantain and Bambara nut fiber composite flour. The results obtained regarding the proximate composition of the stiff dough shows its nutritional potential, as a result of the higher content of proteins, raw fibers, fats, carbohydrate, and ash (minerals). The result obtained showed substitution of unripe plantain flour with Bambara nut fiber flour significantly improves the nutritional compositions.

The moisture content of the samples decreased significantly ($p \leq 0.05$) with increased level of Bambara nut fiber flour in the products as it decreased from 11.6% in sample A (500:00) to 9.67% in sample E (300:200). The low moisture content of all the meal produced is an indication of longer storage as high moisture content aids microbial activities oxidation – reduction processes and fungal growth. The moisture content of the entire meal in this work was lower than the report of Asaolu *et al.* (2012) whose report ranges from 12.60-17.11%. The moisture content estimates directly the water content and indirectly the dry matter of the samples. According to Singh, Sandhu, & Kaur, (2015), flours with moisture content less than 14% can resist microbial growth and hence storage stability. Therefore, the moisture content of the flour samples which falls between 0 - 10% is within the range acceptable for effective flour storage for further processing

without the risk of microorganism contamination. The moisture content of the formulations were within the acceptable limit of not more than 10% for long term storage of powder products. Moisture content and water activity have been reported to have great effects on the keeping quality and shelf life of foods as it served as an indicator of shelf life stability; increase in moisture content enhances microbial contamination and chemical reactions that could lead to reduction in the food quality and stability.

The ash content which is an indication of its mineral content, shown that Bambara nut fiber flour significantly improves the ash content in the samples as it increased from 2.42% in sample A up to 2.87% in sample E (300:200) but all the meals produced contained ash content value which are within the limit recommend for diabetic food which suggests that it is a good source of minerals (Ahmed *et al.*, 2019). However, values obtained in this study were comparable higher to that reported in other studies; 2.06% – 3.8% (Matos *et al.*, 2009), 2.37% (Appiah *et al.*, 2011) and 2.8% (Lim, 2012) respectively. This observation is in agreement with that of (Appiah *et al.*, 2011) which observed an increase in the ash content of fermented maize- Bambara nut fiber flour blends. The increase in the ash content could be attributed to the reduction in carbohydrate content of the sample, thereby increasing other dry matter. The increase in ash content as Bambara nut fiber flour composition increased could be an indication that the minerals present in the samples were released from the chelated complex compound through the

activities of microorganisms, since ash content is an index of the mineral content of food.

The meal formulation with higher Bambara nut fiber flour have the highest crude fiber content which ranges from 1.71% in sample A (500:00) to 7.40% in sample E (300:200) which is in agreement that those reported for unripe plantain: Bambara nut fiber flour by Okanlawon (2000) and this could be attributed to the dry nature of Bambara nut fiber flour. The result of the current study contradicts with Ndife *et al.*, 2016 who found that fiber content in plantain-bambara nut Composite flour as 3.29-5.73%. Biniyam 2013 recorded higher fiber content in Composite flour made with unripe plantain and Bambara nut fiber flour (10.50-16%). Increased fiber content can help with waste passage by expanding the inside walls of the colon, making anti-constipation more efficient, lowering cholesterol levels in the blood, and lowering the risk of various cancers. Fiber is one of the essential component that are often used to develop enriched foods as a consequence of their demonstrated functionality which contributes to the great offer of competitive functional foods in the market. Fiber is considered an efficient protective agent for a wide variety of illnesses, including cardiovascular disease, colon cancer and constipation. In order to increase the consumption of fiber, the American Dietetic Association (ADA) recommended the inclusion of a variety of grains, mushrooms, vegetables, and fruits for an active and healthy life. Also, the increase in the fiber content can be an added advantage in the production of novel meal as this can

counterbalance the hydrophilic nature of plasticized starches which leads to improved handle-ability and general mechanical properties of the product.

The fat and oil content in this study were significantly improved with increased Bambara nut fiber flour substitution as it increased from 1.20% in sample A (500:00) up to 2.66% in sample E (300:200). The result obtained was lower when compared with the results of Okanlawon (2000) whose result showed plantain – Bambara nut fiber Composite flour with fat content of 12.50%. There are a significant differences ($p>0.005$) in values obtained for Fat contents as Bambara nut fiber flour addition significantly improves the fat content of the samples. Meals with moderate fats have been reported to be good as flavour enhancers and useful in improving palatability when incorporated in foods (Aiyesanmi & Oguntokun, 2019). Since Bambara nut fiber flour has a higher fat content than plantain flour, the rise in crude fat content in this study may be attributed to increasing the Bambara nut fiber flour. The moderate fat content of the samples is an indication that they could be stored for a long period without the problem of peroxidation which is a major cause of fat instability.

The protein content result showed a significant difference ($P>0.05$) between the meal produced with more Bambara nut fiber flour than those produced with lesser percentage or no Bambara nut fiber flour. The protein content ranges from 2.44% in sample A up to 9.01% in sample E (300:200). The variation may probably be due to variation in organic matter contents of these samples, as appreciable amount of nitrogen in the samples occurs in organic form. The results obtained for

the protein compares favorably with the value reported by Sahito et al. (1998) for plantain-soybean (10.88%). Foods rich in protein content are of great nutritional importance in developing countries such as Nigeria where there is a prevalence of protein malnutrition (Okpala & Okoli, 2011). Protein is required by children for growth, repair, and maintenance of the body. It also acts as enzymes and hormones and maintains fluid, electrolyte and acid–base balance, and strong immune system (Mahan & Escott-Stump, 2018). Proteins act as carriers for other nutrients such as lipids, vitamin A, iron, sodium, and potassium (Mahan & Escott-Stump, 2018).

The carbohydrate contents were significantly affected by Bambara nut fiber flour addition ($p>0.005$) since the values were reduced by increased addition of bambara nut fiber flour and reduced from 80.62% in sample A (500:00) down to 70.61% in sample D (350:150). The result showed that the meals are rich sources of carbohydrate. The high carbohydrate content of the meal blends indicates that it could be used in managing protein-energy malnutrition, since there is enough quantity of carbohydrate to derive energy from in order to spare protein, so that protein can be used for its primary function of building the body and repairing worn out tissues rather than as a source of energy (Butt & Batool, 2020).

The energy values ranged 1376 to 1443 kcal, it is well know that the energy content is affected by the proportion of fat, protein and carbohydrate therefore the Bambara nut fiber sample had the lowest energy value. These blends therefore provides low energy less than 400 kcal/100g which gives about 17.30% of the daily

energy intakes recommended for a 70 kg person. Therefore, these blends may be considered a new food product with low energy diet that not only increases the supply of some compounds, but with added healthy biological activities. Hence the use in edible film production will contribute to a wide varieties of the available one

Table 4.1: Proximate composition of unripe plantain flour and Bambara fiber (%)

Sample code	Unripe plantain: Bambara groundnut	Moisture (%)	Ash (%)	Fiber (%)	Fats (%)	Protein (%)	Carbohyd.(%).	ENERGY
A	500:00	11.62 ^a ±0.152	2.42 ^e ±0.100	1.71 ^e ±1.000	1.20 ^e ±0.001	2.44 ^e ±0.100	80.62 ^a ±0.010	1435.96 ^d ±0.000
B	450:50	11.06 ^b ±0.152	2.47 ^d ±0.100	2.42 ^d ±1.000	1.40 ^d ±0.010	4.88 ^d ±0.010	77.78 ^b ±0.100	1436.31 ^c ±0.110
C	400:100	10.89 ^c ±0.100	2.59 ^{bc} ±0.100	5.00 ^c ±1.000	2.55 ^b ±0.000	6.31 ^c ±0.049	74.18 ^c ±0.001	1443.61 ^a ±0.100
D	350:150	10.76 ^d ±0.608	2.52 ^c ±0.100	6.78 ^b ±0.100	1.84 ^c ±0.100	7.51 ^b ±0.141	70.61 ^d ±0.010	1376.86 ^e ±0.000
E	300:200	9.67 ^e ±0.100	2.87 ^a ±0.100	7.40 ^a ±0.100	2.66 ^a ±0.001	9.01 ^a ±0.010	71.13 ^e ±0.001	1441.69 ^b ±0.210

Values are mean scores± Standard deviation of triplicate. Data in the same column bearing different superscript differ significantly (p < 0.05)

Sensory evaluation of novel stiff dough for diabetics from unripe plantain and Bambara nut fiber.

The result of the sensory score of the sample in Table 4.3. The 4 novel meal for diabetics from unripe plantain and Bambara flour were subjected to a panel of 20 semi-trained judges comprising male and female using 9-point Hedonic rating scale. Sensorial attributes viz., appearance, taste, mouldability, aroma and mouthfeel are shown in Table 4.3. There were significant differences ($p < 0.05$) in all the sensory parameters among formulated blends. The sample with more Bambara nut fiber inclusion (BFN) had a higher score in appearance, mouldability and taste while sample with 100% plantain flour scores highest in mouthfeel compared to the others blends. In the sensory analysis, the Mouldability scores was lowest (4.80) in sample A (500:00) and highest in sample E (300:200) the sample was rated highest by panelists probably because its texture appears mouldable and people tend to like such Sivasankar, (2009) observed that Bambara nut fiber owing to its high water and oil absorption can be easily moulded into shapes.

The 100% Bambara flour sample was preferred most in terms of mouthfeel over other blends because the plantain flour used in sample E helped in imparting some flavour on the flake. This result is consistent with the findings of Ibe and Orabuike, (2009).

The novel meal for diabetics from unripe plantain and Bambara flour produced was highly desirable in appearance, aroma, taste and mouth feel thus indicating

that it could compete favourably with other types of flakes that are sold locally. It was also more appealing to the sensory panel that may have a natural affinity for flakes prepared from the beans, since the crop is readily available in the study area.

Table 4.3: Sensory evaluation of novel stiff dough for diabetics from unripe plantain and Bambara nut fiber.

*Values are mean scores $\pm$ Standard deviation of 20 panelists

Sample code	Unripe plantain: Bambara groundnut	Mouldability	Aroma	Appearance	Taste	Mouthfeel
A	500:00	4.80 ^c $\pm$ 1.96	6.20 ^c $\pm$ 2.00	7.40 ^d $\pm$ 0.50	6.50 ^a $\pm$ 2.17	7.20 ^a $\pm$ 2.17
B	450:50	5.40 ^d $\pm$ 0.88	6.50 ^d $\pm$ 1.23	7.00 ^e $\pm$ 1.70	5.95 ^d $\pm$ 1.24	6.50 ^e $\pm$ 1.24
C	400:100	5.80 ^c $\pm$ 1.28	5.60 ^c $\pm$ 1.00	7.60 ^b $\pm$ 1.00	5.65 ^e $\pm$ 0.13	6.60 ^c $\pm$ 0.13
D	350:150	7.70 ^b $\pm$ 0.89	7.50 ^b $\pm$ 2.20	7.50 ^c $\pm$ 2.00	6.00 ^c $\pm$ 0.20	6.85 ^b $\pm$ 0.20
E	300:200	8.53 ^a $\pm$ 1.34	8.00 ^a $\pm$ 1.05	7.800 ^a $\pm$ 1.10	6.60 ^a $\pm$ 1.23	6.55 ^d $\pm$ 1.23
LSD _(0.05)						

*Data in the same column bearing different superscript differ significantly ($p < 0.05$).

CHAPTER FIVE

CONCLUSION AND RECOMMENDATION

5.1: CONCLUSION

The study have shown that the addition of Bambara nut fiber flour to unripe plantain flour improves the nutritional quality of novel meal without substantial changes in the sensory properties. The use of Bambara nut fiber thus has the potential to combat protein-energy malnutrition and micronutrient deficiencies in developing countries. The novel meal composition of 300:200 (unripe plantain: Bambara nut) provided the optimum nutritional qualities in terms of ash, fats, fiber and protein and therefore, the inclusion of Bambara nut fiber flour in plantain-based confectioneries will increase the home and industrial consumption of these crops in developing countries. It is therefore recommended that flour blends of unripe plantain and Bambara nut fiber in ratio 300:200, be used to produce of novel meal for diabetic people. In conclusion, with proper selection and combination, it is possible to use local household foodstuff to formulate multimixes that can be used as novel meal for diabetic persons. The consumption of enriched blends should be encouraged due to its high protein content and acceptable functional properties. In vitro, digestibility may be a subject of further research as well as shelf stability of the flours. Glycemic response of consumer, economics of large scale production and marketing strategies are recommended.

5.2: RECOMMENDATION

Base on the findings of this research work, the following recommendation were made.

1: Further, the effect of the Bambara nut fiber flour on storage stability of the flours may also be investigated.

Further study is thereby recommended on the microstructural analysis of the new product.

, further studies can be done on the antinutritional composition in order to increase its market potential in the market.

2. The microbial quality of the composite flour produced needs to be ascertain in further studies.

3. The composite flour produced should be stored in air-tight containers to prevent clumping of the powder.

REFERENCE

- Abdulrashid Mohammed, Hassan Daniel Mhya (2021). Evaluation of phytochemical constituents, proximate contents and glycemic index of Bambara groundnut (*Vigna subterranea L. Verdc*) varieties grown in Northeastern Nigeria. Vol.15(2), pp. 22-27.
- Adebayo, R. A., Adeyemo, O. O., & Arojojoye, K. O. (2020). Phytochemical and functional properties of unripe plantain (*Musa paradisiaca*) flour. Journal of Food Science and Technology, 57(7), 2671-2679.
- Adebayo-Oyetoro, A., Shotunde, A., Adeyeye Samuel, A., & Ogundipe, O. (2017). Quality evaluation of millet-based fura powder supplemented with Bambara groundnut. International Journal of Food Science, Nutrition and Dietetics, 6(3), 358–362. <https://doi.org/10.19070/2326-3350-1700063>
- Adebowale, Y.A, Schwarzenbolz U, Henle T. Protein isolates from Bambara groundnut (*Voandzeia Subterranean L.*): chemical characterization and functional properties. Int J Food Prop. (2011) 14:758–75.doi:10.1080/10942910903420743 [CrossRef Full Text](#) | [Google Scholar](#)
- Adeleke, O.R, Adiamo O.Q, Fawale O.S, Olamiti G. Effect of processing methods on antinutrients and oligosaccharides contents and protein digestibility of the flours of two newly developed bambara groundnut cultivars. Int Food Res J. (2017) 24:1948–55. Available online at: [http://www.ifrj.upm.edu.my24%20\(05\)%202017/\(15\).pdf](http://www.ifrj.upm.edu.my24%20(05)%202017/(15).pdf)[Google Scholar](#)
- Adumanya, O.C., A.A. Uwakwe, S.C. Onuoha, O.B. Odeghe, G.A. Obi-Adumanya and P.C. Nwachukwu, 2012. The proximate analysis and sensory evaluation of “Okpa” prepared with fluted Pumpkin and Scent leaves. Can. J. Scient. Ind. Res., 3: 175-178.
- Ahmed, O., Jimoh, K; Olatidoye, O (2019). Evaluation of physicochemical and rheological characteristics of soybean fortified yam flour. J. App. Biosci. 13 703-706.
- Aiyesanmi, G. and Oguntokun, H (2019) Exploring the nutritional potential of wild and underutilized legumes. Compr. Rev. Food Sci. Food saf. 8(4), 305-331
- Akanji, M. A., Oluwafemi, O. S., & Ojokoh, A. O. (2018). Nutritional and antinutritional compositions of unripe plantain (*Musa paradisiaca*) flour.

International Journal of Food Science and Nutrition Engineering, 8(4), 243-248.

Akubor, P.I and Ukwuru M . U 2003. “Functional properties of Soy flour and Plantain flour blends”. Plants Food. Human. Nutrition, 58: 1-12.

American Diabetes Association (2021). Diabetes Basics.Retrieved from <https://www.diabetes.org/diabetes>.

Anderson J.W, Baird P, Davis R.H Jr, et al. 2009, [Health benefits of dietary fiber](#)_, Nutrition Reviews, vol. 67, no.4, pp.188-205

Ansley Hill (2021). Health benefits of Bambara nut fiber.

Anthony, I., Oladele, A.K., & Adeyeye,E.I. (2021). Bambara Nut (*Virgna subterranea* L. Verdc) Seed: A Review on its Nutritional and Health Benefits . Foods , 10(20, 369.

AOAC (2003). Official method 996.06 “official methods of analysis of AOAC” (17th ed.). Gaithersburg, Maryland, USA: AOAC International Press.

Appiah O; Amugo, CI; Eka, OU (2011). Chemical composition of yam beans (*Sphenostylis stenocarpa*). Trop. Sci. 30, 59–63

Asian Journal of Agriculture and Food Sciences (ISSN: 2321 – 1571) Volume 03 – Issue 01, February 2015. Asian Online Journals (www.ajouronline.com)

Asaolu , M.F., Fawale , S.O.,& Ogunlakin,G.O. (2012). Proximate composition and physio-chemical of unripe plantain (*Musa paradisiaca*) flour. International Journal of Biology , Pharmacy and Applied Sciences, 1(5), 660 - 672.

Azman Halimi R, Barkla BJ, Mayes S, King GJ. The potential of the underutilized pulse Bambara groundnut (*Vigna subterranea* (L.) Verdc.) for nutritional food security. J Food Compos Anal. (2019) 77:47–59. doi: 10.1016/j.jfca.2018.12.008

Bamshaiye OM, Adegbola JA, Bamishaiye EI. Bambara groundnut: an under-utilized nut in Africa. Advances in Agricultural Biotechnology. 2011;1(1):60-72.

- Begum, S.A., R. Afroz, Q. Khanam, A. Khanom and T.S. Choudhury, 2014. Diabetes mellitus and gestational diabetes mellitus. *J. Paediatr. Surg. Bangladesh*, 5: 30-35.
- Besthomediet (2018). Bambara Groundnut - Health benefits of Bambara groundnut (Okpa).
- Boye J, Zare F, Pletch A. Pulse proteins: processing, characterization, functional properties and applications in food and feed. *Food Res Int.* (2010) 43:414–31. doi: 10.1016/j.foodres.2009.09.003 [CrossRef Full Text](#) | [Google Scholar](#)
- Brand-Miller, J.C., 2004. Postprandial glycemia, glycemic index and the prevention of type 2 diabetes. *Am. J. Clin. Nutr.*, 80: 243-244.
- Brand-Miller, J.C., S. Hayne, P. Petocz and S. Colagiuri, 2003. Low-glycemic index diets in the management of diabetes: A meta-analysis of randomized controlled trials. *Diabetes Care*, 26: [2261-2267](#).
- Britannica, The Editors of Encyclopaedia (2023). “Plantain”. *Encyclopedia Britannica*
- Brouns, F., I. Bjorck, K.N. Frayn, A.L. Gibbs, V. Lang, G. Slama and T.M.S. Wolever, 2005. Glycaemic index methodology. *Nutr. Res. Rev.*, 18: 145-171.
- Burkitt, D.P., 1983. The Development of the Fiber Hypothesis. In: *Dietary Fiber*, Birch, G.G. and K.J. Parker (Eds.). Applied Science Publishers, London, UK., ISBN-13: 978-0853341789, pp: 21-27
- Butt H and Batool, L (2020) Quality evaluation of plantain -African yam bean flour blends and sensory properties of its cooked (amala) paste. *Res. J. Food Sci. Nutr.* 3, 31-40
- CDC., 2002. Diabetes: Disabling, deadly and on the rise (at a glance series). National Centre for Chronic Disease Prevention, Centre for Disease Control Prevention (CDC), U.S. Dept. of Health and Human Services, Atlanta, GA., USA.
- Chittaranjan, K., 2007. *Genome Mapping and Molecular Breeding in Plants*. Vol. 3, Springer-Verlag, Berlin Heidelberg, New York

- Chukwu , N.(2016). Unripe Plantain and Diabetes: A Review . International Journal of Diabetes & Metabolic Disorders, 1(1), 1-3.
- Chutkan, R., G. Fahey, W.L. Wright and J. McRorie, 2012. Viscous versus non viscous soluble fiber supplements: Mechanisms and evidence for fiber-specific health benefits. J. Am. Acad. Nurse Pract., 24: 476-487.
- Cleveland clinic (2021). An overview on diabetes. 9500 Euclid Avenue, Cleveland, Ohio 44195 | [800.223.2273](tel:800.223.2273) | .
- Clifton.P., Keogh.J. (2016). Plantain and banana. [Encyclopedia of Food and Health](#).
- Davidson, G. I., Eze ,N.M., Onyeke ,N.G. and Oooh, N.P., (2019). Nutritional Composition and Glycaemic Index of Standardized Traditional Bambara Nut, Corn and Yam-Based Dishes Consumed in the Nsukka Local Government Area of Enugu State, Nigeria. Pakistan Journal of Nutrition, 18: 677-685.
- Davidson, G.I., H.N. Ene-Obong and C.E. Chinma, 2017. Variations in nutrients composition of most commonly consumed cassava (*Manihot esculenta*) mixed dishes in South-Eastern Nigeria. J. Food Qual., Vol. 2017.
- Ejike CC, UKa NK, Nwachukwu SO. Diabetes and pre-diabetes in adult Nigerians: Prevalence, and correlations of blood glucose concentrations with measures of obesity. Academic Journal. 2015;9(3):55-60.
- F.A.O. (1987). Roots, tubers, plantains and bananas in animal feeding (D. Machin and S. Nyvold, editors). Animal Production and Health paper No. 95. Rome. pp289.
- FAO, 2001. A global mapping system for Bambara groundnut production. Agricultural Information Management Series No. 1, Food and Agriculture Organization of the United Nations, Rome, Italy.
- Filli,K. B., Nkama, I., & Jideani, V. A. (2013). The effect of extrusion conditions on the physical and functional properties of millet-bambara groundnut based fura. American Journal of Food Science and Technology, 1(4), 87–101. <https://doi.org/10.12691/ajfst-1-4-5>
- Frison, E. A., and S. L. Sharrock. "Introduction: The Economic, Social and Nutritional Importance of Banana in the World." In *Bananas and Food*

Security, edited by C. Picq, E. Fouré, and E. A. Frison, 21–35. International Symposium, Douala, Cameroon, 10–14 November, 1998. Montpellier, France: INIBAP, 1999.

Gwala S, Kyomugasho C, Wainaina I, Rousseau S, Hendrickx M, Grauwet T. Ageing, dehulling and cooking of Bambara groundnuts: consequences for mineral retention and: in vitro bioaccessibility. *Food Funct.* (2020) 11:2509–21. doi: 10.1039/C9FO01731C [PubMed Abstract](#) | [CrossRef Full Text](#) | [Google Scholar](#)

Hillocks RJ, Bennett C, Mponda OM. Bambara nut: a review of utilisation, market potential and crop improvement. *African Crop Sci J.* (2012) 20:1–16. Available online at: <https://www.ajol.info/index.php/acsj/article/view/78601> [Google Scholar](#)

Ibe and Orabuike, K (2009). Functional properties of grain legumes flours. *J. Food Sci.* 38:191-199

Institute of Medicine 2005. Dietary Reference Intakes for Energy, Carbohydrate, Fiber, Fat, Fatty Acids, Cholesterol, Protein, and Amino Acids. Washington, DC: The National Academies Press. <https://doi.org/10.17226/10490>.

Jideani VA, Diedricks CF. Nutritional, therapeutic and prophylactic properties of *Vigna subterranean*. In: Antioxidant- anti-diabetic agents and Human health. Intech Open. 2014:187-207.

Lim, G (2012) Effect of varieties on the proximate, nutritional and anti-nutritional composition of nine variants of African yam bean seeds (*Sphenostylis stenocarpa*). *Donnish J. Food Sci. Technol.* 1, 17– 21

Luis, E. U. (2023). “ Plantain Flour”.

Mahan K and Escott-Stump, A (2018) Proximate, mineral and anti-nutritional compositions of raw and processed African Yam bean (*Sphenostylis stenocarpa*) seeds in Cross River State, Nigeria. *Global J. Agric Sci.* 18, 19

Malia Frey, M.A., ACE-CHC, CPT (2021). Plantain nutrition facts and health benefits. Medically reviewed by Mia Syn, MS, RDN_.

- Marriott, J., Robinson, M. and Karikari, S.K. (1981). Starch and sugar transformations during ripening of plantains and bananas. *J. Sci. Food Agric.*, 32, 1021-1026.
- Matos, M.E., Rosenthal, A., Mendoza, E.M., & Bressani, R.(2019). Proximate composition and mineral content of six varieties of Guatemalan bambara groundnut (*Vigna subterranea* L. Verdc). *Tropical and Subtropical Agroecosystems*, 10(3), 323 - 332.
- Mayes S, Ho WK, Chai HH, Gao X, Kundy AC, Mateva KI, et al. Bambara groundnut: an exemplar underutilised legume for resilience under climate change. *Planta*. (2019) 250:803–20. doi: 10.1007/s00425-019-03191-6.
- Mbosso C, Boulay B, Padulosi S, Meldrum G, Mohamadou Y, Niang AB, *et al.* Fonio and Bambara groundnut value chains in mali: issues, needs, and opportunities for their sustainable promotion. *Sustain*. (2020) 12:4766. doi: 10.3390/su12114766
- Mkandawire, C.H., 2007. Review of Bambara groundnut (*Vigna subterranea* (L.) Verdc.) production in Sub-Sahara Africa. *Agric. J.*, 2: 464-470.
- Mohan VR, Tresina PS, Daffodil ED. Antinutritional Factors in Legume Seeds: Characteristics and Determination. 1st ed, eds. B Caballero, PM Finglas. Toldra Academic Press. (2015). doi: 10.1016/B978-0-12-384947-2.00036-2
[CrossRef Full Text](#)
- Mubaiwa J, Fogliano V, Chidewe C, Linnemann AR. Bambara groundnut (*Vigna subterranea* (L.) Verdc.) flour: a functional ingredient to favour the use of an unexploited sustainable protein source. *PLoS ONE*. (2018) 13:e0205776. doi: 10.1371/journal.pone.0205776.
- Mubaiwa J, Fogliano V, Chidewe C, Linnemann AR. Influence of alkaline salt cooking on solubilisation of phenolic compounds of Bambara groundnut (*Vigna subterranea* (L.) Verdc.) in relation to cooking time reduction. *LWT Food Sci Technol*. (2019) 107:49–55. doi: 10.1016/j.lwt.2019.02.067
[CrossRef Full Text](#) | [Google Scholar](#)
- National Institute of Diabetes and Digestive and Kidney Diseases.(2017). Managing Diabetes.
- Ndife, J, Okafor, E., Owuamanam, C., & Uwakwe, A. (2016). Nutritive composition and functional properties of bambara groundnut (*Vigna*

Subterranea) and plantain (*Musa paradisiaca* L.) flour blends. International Journal of Biological, Biomolecular , Agricultural, Food and Biotechnological Engineering, 10(8), 784-789.

- Nwadi OMM, Uchegbu N, Oyeyinka SA. Enrichment of food blends with Bambara groundnut flour: past, present, and future trends. Legum Sci. (2020) 2:e25. doi: 10.1002/leg3.25 [CrossRef Full Text](#) | [Google Scholar](#)
- Nyau V, Prakash S, Rodrigues J, Farrant J. Antioxidant activities of Bambara groundnuts as assessed by FRAP and DPPH Assays. Am J Food Nutr. (2015) 3:7–11. doi: 10.12691/ajfn-3-1-2 [CrossRef Full Text](#) | [Google Scholar](#)
- Nyau V, Prakash S, Rodrigues J, Farrant J. Domestic cooking effects of Bambara groundnuts and common beans in the antioxidant properties and polyphenol profiles. J Food Res. (2017) 6:24. doi: 10.5539/jfr.v6n2p24 [CrossRef Full Text](#) | [Google Scholar](#)
- Okanlawon G (2000) Assessment of the nutritional, antinutritional and antioxidant capacity of unripe, ripe and over ripe plantain (*Musa paradisiacal*) peels. Int. J. Adv. Res. 3(2): 63 – 72
- Okpala R and Okoli, C (2011) Nutritional and sensory properties of amala supplemented with distiller's spent grain (DSG). J. Food, Agric. Environ. 8(3&4), 66-70
- Oladele EO, Williamson G. [Impact of resistant starch in three plantain \(Musa AAB\) products on glycaemic response of healthy volunteers](#). Eur J Nutr. 2016;55(1):75-81. doi:10.1007/s00394-014-0825-6
- Olanipekun BF, Otunola ET, Adejuyitan JA, Adeyanju JA (2012). Proximate and Fatty Composition of Bambara Groundnut (*Voandzeia subterranea*) as Influenced by Fermentation with a Combination of *Rhizopus oligosporous* and *R. Nigricans*. Transnational Journal of Science and Technology 2(9):107-110.
- Olanipekun OT, Omenna EC, Adeniyi GA, Adedeji FT (2019). Effect of Bambara groundnut (*Vigna subterranea*) consumption on biomarkers of oxidative stress in alloxan-induced diabetic Wistar rats. Research Journal of Food Science Nutrition 4(3):65-72.[Crossref](#)
- Oyeyinka AT, Pillay K, Siwela M. Full title- in vitro digestibility, amino acid profile and antioxidant activity of cooked Bambara groundnut grain. Food

Biosci. (2019) 31:100428. doi: 10.1016/j.fbio.2019.100428 [CrossRef Full Text](#) | [Google Scholar](#)

Oyeyinka SA, Oyeyinka AT. A review on isolation, composition, physicochemical properties and modification of Bambara groundnut starch. Food Hydrocoll. (2018) 75:62–71. doi: 10.1016/j.foodhyd.2017.09.012

Oyeyinka SA, Singh S, Amonsou EO. Physicochemical properties of starches extracted from Bambara groundnut landraces. Starch/Staerke. (2017) 69:1600089. doi: 10.1002/star.201600089 [PubMed Abstract](#) | [CrossRef Full Text](#) | [Google Scholar](#)

Paliwal R, Abberton M, Faloye B, Olaniyi O. Developing the role of legumes in West Africa under climate change. Curr Opin Plant Biol. (2020) 56:242–58. doi: 10.1016/j.pbi.2020.05.002

Park Y, Subar AF, Hollenbeck A, Schatzkin A, 2011, [Dietary Fiber and mortality in the NIH-AARP diet and health study](#)_, Archives of Internal Medicine, vol. 171, no.12, pp.1061-1068

PGBG (2011). Production Guideline for Bambara Groundnuts. A Publication of Directorate of Agricultural Information, Pretoria, South Africa pp. 1-1

[Google Scholar](#)[Plantains, green, boiled](#). FoodData Central. U.S. Department of Agriculture. [PubMed Abstract](#) | [CrossRef Full Text](#)

Rauf A, Imran M, Abu-Izneid T, Iahtisham-Ul-Haq, Patel S, Pan X, *et al.* Proanthocyanidins: a comprehensive review. Biomed Pharmacother. (2019) 116:108999. doi: 10.1016/j.biopha.2019.108999

Rousseau S, Kyomugasho C, Celus M, Hendrickx MEG, Grauwet T. Barriers impairing mineral bioaccessibility and bioavailability in plant-based foods and the perspectives for food processing. Crit Rev Food Sci Nutr. (2020) 60:826–43. doi: 10.1080/10408398.2018. | [CrossRef Full Text](#) | [Google Scholar](#)1552243 [PubMed Abstract](#)

Russell, W. R, Baka A, Björck I, Delzenne N, Gao D, Griffiths HR (2016). Impact of Diet Composition on Blood Glucose Regulation. Critical Reviews in Food Science and Nutrition 56(4):541-590.[Crossref](#)

- Sahito O; Segilola, VO; Ayoola, RB; Gbadegesin, IO (1998). Nutritional Quality And Sensory Properties Of Instant Plantain Flake Enriched With Egg Parts. Multidisc. Acad. J. Pub. 13(1): 41-50
- Singh, J., Sandhu, H and Kaur, A (2015) Extractability of African yam bean (*Stenophylis stenocarpa*) protein acid, salt and alkaline aqueous media. Food Hydrocolloids, 22: 1622-1628
- Sivasankar, (2009) Glycemic index, glycemic load, and risk of type 2 diabetes. Amer. J. Clinical Nutr. 76 (2): 74–80
- Snow R and O'Dea E (2021) Evaluation of the proximate composition and antinutritional properties of African yam bean (*Sphenostylis stenocarpa*) using malting treatment. Int. J. Basic Appl. Sci. 2, 157–169
- Tsamo AT, Ndibewu PP, Dakora FD. Phytochemical profile of seeds from 21 Bambara groundnut landraces via UPLC-qTOF-MS. Food Res Int. (2018) 112:160–8. doi: 10.1016/j.foodres.2018.06.028 [PubMed Abstract](#) | [CrossRef Full Text](#) | [Google Scholar](#)
- Ukwuani, A. N., & Ogunmoyela, O. A. (2012). Effect of dietary fiber from the testa of Bambara groundnut (*Vigna subterranea* (L.) Verdc.)
- Xin , T.L.; Azam-Ali, S.; Goh, E. V.; Mustafa, M.; Chai, H. H.; Ho, W. K.; Mayes, S.; Mabhaudhi, T.; Azam-Ali, S.; Massawe, F. Bambara Groundnut: An Underutilized Leguminous Crop for Global Food Security and Nutrition. Front Nutr. 2020, 7, 601496. DOI: 10.3389/fnut.2020.60149. [[Crossref](#)], [[PubMed](#)], [[Web of Science ®](#)], [[Google Scholar](#)]
- Yao DN, Kouassi KN, Erba D, Scazzina F, Pellegrini N, Casiraghi MC. Nutritive evaluation of the Bambara groundnut Ci12 landrace [*Vigna subterranea* (L.) Verdc. (*Fabaceae*)] produced in Côte d'Ivoire. Int J Mol Sci. (2015) 16:21428–41. doi: 10.3390/ijms160921428 [PubMed Abstract](#) | [CrossRef Full Text](#)
- Zhengzhou Ugood (2023). Bambara groundnut flour.

Descriptives

		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval		Minimum	Maximum
						Lower Bound	Upper Bound		
MOISTURE	SAMPLE A	3	11.6212	.15275	.08819	7.7539	8.5128	8.00	8.30
	SAMPLE B	3	11.0652	.15275	.08819	7.3539	8.1128	7.60	7.90
	SAMPLE C	3	10.8900	.10000	.05774	6.4516	6.9484	6.60	6.80
	SAMPLE D	3	10.7608	.06083	.03512	7.7789	8.0811	7.89	8.00
	SAMPLE E	3	9.6700	.10000	.05774	7.8516	8.3484	8.00	8.20

		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
						Lower Bound	Upper Bound		
MOULDABILITY	SAMPLE A	20	4.8096	1.66702	.37276	5.8198	7.3802	3.00	9.00
	SAMPLE B	20	5.4928	1.53811	.34393	5.7301	7.1699	2.00	9.00
	SAMPLE C	20	5.8028	1.80278	.40311	5.4063	7.0937	3.00	8.00
	SAMPLE D	20	7.7569	2.17885	.48720	4.6803	6.7197	1.00	8.00
	SAMPLE E	20	8.5334	2.21181	.49458	4.5148	6.5852	1.00	8.00

AROMA	SAMP	20	6.2200	1.20800	.33619	5.7463	7.1537	2.00	8.00
	LE A								
	SAMP	20	6.5013	1.53811	.34393	5.8301	7.2699	2.00	8.00
	LE B								
	SAMP	20	5.6000	1.82382	.40782	4.9464	6.6536	3.00	8.00
	LE C								
	SAMP	20	7.5020	2.28496	.51093	4.1306	6.2694	1.00	8.00
	LE D								
	SAMP	20	8.0005	2.35975	.52766	3.9956	6.2044	1.00	8.00
	LE E								
APPEARANCE	SAMP	20	7.4050	1.59275	.35615	5.9546	7.4454	2.00	9.00
	LE A								

	SAMP LE B	20	7.0070	1.49649	.33462	5.6496	7.0204	2.00	8.00
	SAMP LE C	20	7.6000	1.80278	.40311	5.4063	7.0937	2.00	8.00
	SAMP LE D	20	7.5000	2.31926	.51860	4.2146	6.3854	1.00	8.00
	SAMP LE E	20	7.8001	2.23548	.49987	3.9038	5.9962	1.00	8.00
TASTE	SAMP LE A	20	6.5017	1.20800	.33619	5.7463	7.1537	2.00	8.00
	SAMP LE B	20	5.9524	2.01573	.42073	4.8566	6.7434	2.00	8.00

	SAMP LE C	20	5.6513	2.11511	.47295	4.5101	6.4899	1.00	8.00
	SAMP LE D	20	6.0020	2.23548	.49987	4.4038	6.4962	1.00	8.00
	SAMP LE E	20	6.5023	2.20287	.49258	4.2690	6.3310	1.00	8.00
MOUTHFEEL	SAMP LE A	20	7.2017	1.63514	.36563	5.6347	7.1653	2.00	9.00
	SAMP LE B	20	6.5024	1.77705	.39736	5.1683	6.8317	3.00	8.00
	SAMP LE C	20	6.6013	2.30332	.51204	4.5220	6.6780	1.00	8.00

	SAMP LE D	20	6.8520	2.28208	.51029	4.3820	6.5180	1.00	8.00
	SAMP LE E	20	6.5523	2.08945	.46721	4.5721	6.5279	1.00	8.00
